Analysis on the effect of industrial structure upgrading on the level of double cycle development

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Abstract. The new development pattern of double cycle is the strategic axis of China's economic development, and it is of great significance to clarify the impact mechanism of industrial structure upgrading on the double cycle in constructing the new development pattern. In this paper, the provincial level of double cycle development is measured, and the panel regression model is used to analyze the impact of industrial structure upgrading on double cycle. It is found that there is regional imbalance in the level of double-cycle development of China's economy, and the higher level of domestic circular development is the higher level of international circular development. The dual-cycle performance shows that the developed areas in the southeast coast and the backward areas in the northwest have obvious spatial accumulation characteristics, and the dual-cycle development level in the eastern coastal area grows faster than that in the western region. The upgrading of industrial structure has significantly improved the level of dual-cycle development in China, and scientific and technological innovation, as a regulating variable, has an incentive effect on the relationship between industrial structure upgrading and domestic and international dual-cycle development. Heterogeneity analysis found that the promotion effect of accelerating industrial structure upgrading on the double cycle in the eastern region is greater than that in the western region, and the promotion effect of industrial structure upgrading on the double cycle in the "13th Five-Year Plan" period is stronger than that in the "12th Five-Year Plan" period.

Keywords: Industrial structure upgrading; Scientific and technological innovation; Double cycle development level.

1   Introduction

After China joined WTO in 2001, the export-oriented development strategy dominated the whole economic development process and promoted the rapid economic development. However, the world today is undergoing profound changes unseen in a century. Profound changes have taken place in China's internal and external environment, and the driving role of the international cycle in China's economic development has been significantly weakened. On the one hand, the global outbreak and spread of COVID-

19 and the wave of "anti-globalization" have strengthened the fragmentation and re-gionalization of the trading system, and the global economy is facing the risk of recession. On the other hand, various cyclical, structural and institutional problems that have accumulated in the course of our country's long-term development are intertwined, which hinders the unimpeded development of the domestic economic cycle. On August 24, 2020, at the forum of experts in economic and social fields, national leaders further emphasized that "adhere to the supply-side structural reform, focus on the strategic basis of expanding domestic demand, and make production, distribution, circulation and consumption and other links more dependent on the domestic market, that is, the main body of the domestic cycle"[1].As the supply side of products, industrial production is the starting point and basis of circulation, which determines the level and structure of distribution, circulation and consumption. One of the important forms of supply-side upgrading is the optimization and upgrading of industrial structure, and the continuous upgrading of industrial structure is an important basis for smooth domestic circulation. The continuous optimization of industrial structure can not only change the production mode, accelerate the production speed, but also improve the utilization rate of resources, which is bound to have an important impact on the new development pattern of double cycle. Therefore, it is of great theoretical and practical significance to explore the impact of industrial structure upgrading on the new development pattern of double cycle.

2   Literature Review

Existing studies have extensively discussed the internal logic, strategic connotation, theoretical mechanism, implementation path and policy system of the double-cycle new development pattern[2-5]. The new development pattern of "double cycle" is an important strategic choice made based on the changes in the international environment and the characteristics of China's new development stage. With a complete industrial system, broad market and abundant human capital[6], China has a good foundation for building a new development pattern of "double cycle", but there are still some gambling points[7], which hinder the smooth implementation of the new development pattern. From the perspective of domestic economic cycle, our industrial structure is unreasonable, and there is a structural contradiction between supply and demand[8]. With the continuous development of economy, the income level of residents has correspondingly increased, and the consumption demand has shifted from quantity to quality, and from physical consumption to service consumption[8]. Many products produced can no longer meet the consumption needs of the people, resulting in serious overcapacity, idle means of production[7-8] and insufficient supply of high-end products[9]. From the perspective of international economic cycle, China's production stage is in the middle and downstream links of the global value chain, the supply system is of low quality, the high-end supply is insufficient, the key core technologies are highly dependent on the external market, and the economic development is easily controlled by others, resulting in the smooth national economic cycle[10]. The key to solve this problem is to deepen the supply-side structural reform, accelerate the upgrading of industrial structure, improve the added

value of products, meet the consumer demand of residents, expand domestic demand, give play to China's super-large market advantage, and drive the rapid development of the "double cycle" new development pattern with industrial structure upgrading[7].In the relevant studies on industrial structure upgrading, scholars agree that industrial structure upgrading plays a significant role in promoting economic growth. For example, Zhou Hui found through empirical analysis that industrial structure upgrading will promote economic growth[11].

In the few existing studies, scholars have analyzed the relationship between the upgrading of industrial structure and the new development pattern of "double cycle" from different dimensions, but the deficiency is that these studies only explain the importance of the upgrading of industrial structure to improve the level of economic double cycle development in the theoretical level, without empirical support. Based on this, this paper uses the entropy method to measure the inter-provincial dual-cycle development level in China, and attempts to demonstrate the impact of industrial structure upgrading on the domestic and international dual-cycle development level by using panel regression model and the moderating effect of scientific and technological progress on the relationship between industrial structure upgrading and domestic and international dual-cycle development level.

3   Mechanism analysis and research hypothesis

3.1   Influence mechanism of industrial structure upgrading

The upgrading of industrial structure mainly refers to the evolution of the industry from low added value, low technology level, low processing depth, and low scale economy to high added value, technical level, high processing depth, and high scale economy[12]. As a country with the most complete industrial categories in the world[13], China's industrial structure upgrading and optimization will have an impact on the domestic and international double cycle mainly in the following three aspects.

3.1.1 Industrial structure upgrading promotes domestic and international circular development by improving supply quality

The upgrading of industrial structure makes the production adjustment among various industries, the coordination and cooperation among various industrial departments, the rationalization of production organization and the optimal allocation of production factors improve the production efficiency, and at the same time, improve the supply quality of products and services, and improve the development level of domestic and international double cycle. On the one hand, the production of high-quality products and services has reduced the supply of low-end products in the market, alleviated the problem of overcapacity, and increased the supply of high-end products to meet the increasingly diversified consumer demand. Improved the supply system's adaptability to domestic demand, made full use of the supersize market advantage, and unimpeded the domestic economic cycle. On the other hand, the improvement of the supply quality of products and services has changed the division of labor in the international industrial

chain, supply chain and value chain, which has gradually transformed the downstream link of the industrial chain into the upstream link. Exports of high value-added products and services not only increase industrial profits, but also meet the international market's demand for product and service quality. Demand stimulates supply, supply creates demand, the balance of supply and demand promotes the smooth implementation of the "double cycle" new development pattern, promotes the high quality of economic development.

3.1.2 Industrial structure upgrading promotes domestic and international circular development by increasing employment opportunities

Industrial structure upgrading can increase employment opportunities[14]. Compared with the primary and secondary industries dominated by labor-intensive industries, the employment absorption capacity of the service industry is much higher than that of the agricultural and industrial sectors, and the employment created by one unit of added value of the tertiary industry is about 1.5-2 times that of the secondary industry[15]. For example, the Internet industry such as Douyin, Kuaishou and e-commerce, which have risen rapidly in recent years, and the service industry represented by takeaway and express delivery, have provided more job opportunities in the process of their rapid development. From urban to rural areas, most residents can participate in the social division of labor through this new form of employment mode, which increases residents' income while improving social and economic efficiency, greatly improves residents' sense of security and happiness, and stimulates the upgrading of residents' consumption structure. Therefore, upgrading the industrial structure can increase employment opportunities and unblock the domestic economic cycle.

3.1.3 Industrial structure upgrading promotes domestic and international circular development through the formation of a modern industrial chain

From the perspective of domestic big cycle, although our country has a relatively perfect industrial system, the industrial modernization level is low, the supply quality is poor, and the unbalanced regional development leads to industrial clusters in different regions cannot cooperate well. The upgrading of industrial structure and the modernization of industrial chain are conducive to improving the supply quality of products and services, optimizing the allocation of resources, enabling all regions to make full use of their comparative advantages to maximize economic benefits in the domestic industrial chain, thus narrowing the poverty gap in all regions, increasing social income, and providing a strong guarantee for the smooth circulation of the domestic great cycle in all regions. From the perspective of international circulation, the uncertainty of international environment increases the risk of our participation in the international division of labor. With the upgrading of the industrial structure, the improvement of the modernization level of the industrial chain will help enhance China's competitive advantage in international division of labor and cooperation, promote the development of China's supply chain and value chain in the upstream of the global supply chain and value chain, improve the competitiveness of China's products and services in the international mar-

ket, and ensure the core position of China's industrial chain in the international industrial chain. It can resist the uncertain risks of the anti-globalization in the international environment and raise the competitive advantage of our country in the international cycle.

In conclusion, the upgrading of industrial structure plays a positive role in improving the level of domestic and international dual-cycle development through the three mechanisms of improving supply quality, increasing employment opportunities and forming a modern industrial chain. Therefore, the following hypothesis is proposed in this paper.

Hypothesis A1: There is a positive correlation between the upgrading of industrial structure and the new development pattern of "double cycle".

3.2   Regulatory mechanisms for scientific and technological innovation

Technological innovation is the fundamental driving force to promote the upgrading of industrial structure. Technological innovation improves industrial production efficiency, attracts more resources and factors into related industries, and promotes rapid industrial development. In order to upgrade the industrial structure and accelerate the formation of a new development pattern in which the domestic big cycle plays the main role and both domestic and international cycles reinforce each other, we need to vigorously promote scientific and technological innovation, accelerate the research on key core technologies, achieve breakthroughs in the research and development of key technologies and replace key products with domestic ones, and reduce the dependence of core technologies on external markets. We will move from low-value-added midstream to high-value-added upstream R&D, design and core parts production, and establish an independent and controllable industrial chain and a highly sophisticated value chain. Based on this, this paper discusses the regulating effect of scientific and technological progress on the relationship between the upgrading of industrial structure and the new dual-cycle development pattern based on the support degree of local government's scientific and technological innovation, the quality of scientific research achievements and the market transformation of scientific research achievements.

3.2.1 The moderating effect of government support for scientific and technological innovation on the relationship between industrial structure upgrading and the new double-cycle development pattern

The government's use of financial means to moderately support enterprises' scientific research activities will have a positive impact on the upgrading of industrial structure, and then improve the level of domestic and international dual-cycle development. With the government's financial subsidies, enterprises can timely update technical equipment when solving the problem of lack of advanced technology encountered in the process of industrial upgrading, attract more scientific research talents, reduce the cost and risk of enterprise innovation, attract more entrepreneurs who are afraid of high risks to join the team to conquer core technologies, promote the improvement of innovation level, and promote the optimization and upgrading of industrial structure. We will accelerate efforts to raise the level of dual-cycle development. However, with the

investment of government funds, the level of scientific research and technology in China has reached a certain height, and the gap with the international frontier technology level has been narrowing, foreign enterprises have increased the protection of frontier technology and even blocked, and the difficulty of technology research and development in China has gradually increased. At this time, enterprises that are over-funded by the government lack the awareness of independent innovation, reducing the confidence to overcome technical difficulties, and the technical level is slowly improved. Therefore, the government's excessive financial subsidies will inhibit the improvement of the level of science and technology, slow down the upgrading of industrial structure, and thus hinder the domestic and international dual-cycle development. Therefore, this paper proposes the following hypothesis:

Hypothesis B1: In the early stage of technology research and development, government financial subsidies for science and technology positively adjust the positive correlation between the upgrading of industrial structure and the new dual-cycle development pattern.

Hypothesis B2: In the late stage of technology research and development, government financial subsidies for science and technology negatively regulate the positive correlation between the upgrading of industrial structure and the new double-cycle development pattern.

3.2.2 The moderating effect of high-quality scientific research achievements on the relationship between industrial structure upgrading and the new development pattern of double cycle

Increasing investment in scientific research, improving the quality of scientific research achievements, and solving the problem of "stuck neck" of core technologies through independent innovation from the level of technological innovation can fundamentally promote the upgrading of industrial structure and effectively improve the level of double-cycle economic development at home and abroad. High-quality scientific research results with innovation, application and economy (high value) can rapidly increase the supply of China's high-end and key core technologies, narrow the gap between the international scientific research level, reduce the dependence on foreign technology imports in key fields, break the high-tech export barriers of first-mover countries, and achieve higher achievements in high-tech fields such as big data, cloud computing, and 5G. Enhance China's international competitive advantage, and enhance China's position in the global industrial chain, supply chain and value chain. Therefore, this paper proposes the following hypothesis:

Hypothesis C1: High-quality scientific research results positively moderate the positive correlation between the upgrading of industrial structure and the new dual-cycle development pattern.

3.2.3 The regulating effect of the transformation of scientific and technological achievements on the relationship between the upgrading of industrial structure and the new double-cycle development pattern

The transformation of scientific and technological achievements is the "last mile" of the whole process of scientific and technological innovation activities, and the success of the transformation of scientific and technological achievements largely determines the success or failure of scientific and technological innovation activities. Improve the conversion rate of scientific research achievements, apply the thinking concept of scientific and technological innovation to the product production process, meet the demand for technological innovation in enterprise production, and then meet the market demand, expand domestic demand, and promote the high-quality development of double cycle economy. On the one hand, the transformation of high-quality research results into productivity can significantly improve technical efficiency and thus total factor productivity, optimize resource allocation, promote the development of high-tech industries, adjust the supply structure, and thus accelerate the upgrading of industrial structure. On the other hand, improving the conversion rate of scientific and technological achievements can effectively alleviate the problem of overcapacity and unbalanced regional development. To sum up, improving the conversion rate of scientific research results can speed up the production of high-quality new products, so that high-quality scientific research and innovation results in the production of economic and social value. Therefore, this paper proposes the following hypothesis:

Hypothesis D1: The transformation of scientific and technological achievements positively moderates the positive correlation between the upgrading of industrial structure and the new dual-cycle development pattern.

4   Research design

4.1   Construction of evaluation system

4.1.1 Explained variables

Performance of the double-cycle new development pattern (Y): This paper draws on Li Rongjie et al. 's performance evaluation system construction method for the double-cycle new development pattern, and on the basis of a profound analysis of the core significance and profound connotation of the double-cycle new development pattern, constructs an evaluation system from two aspects of domestic and international circulation (Table 1). Among them, the measurement of consumption structure refers to the research of Xia et al., and takes the proportion of per capita consumption expenditure and total per capita consumption expenditure of transportation and communication, education, culture and entertainment, and medical care among the three types of developmental consumption as the measurement index.

Table 1. Performance evaluation index system of new development pattern of double cycle

First level index	Second level index	Three level index	Interpretation of Indicators
Great domestic circulation	supply side	Quality of supply	Excellent product quality rate
		Efficiency of supply	New product sales revenue/total revenue of industrial enterprises above designated size
	Measurement of consumption	Consumption level	Per capita consumption expenditure
		Consumption structure	Comfortable consumption expenditure/total consumption expenditure per capita
		Consumption upgrading	Contribution rate of consumption
	Domestic balance	Balance of consumption and investment	Final consumption expenditure/total fixed assets
		Income distribution relation	Per capita disposable income
	Domestic trade	Development of logistics industry	Freight volume
			Transportation, storage and postal industry added value
		Commodity circulation	Total retail sales of consumer goods
International circulation	Foreign trade	Foreign trade structure	Degree of dependence upon foreign trade
		Quantity of foreign trade	Total volume of trade
	Introduce foreign capital and investments abroad	Introduction of foreign capital	Foreign direct investment
		Investments abroad	Outward foreign direct investment

4.1.2 Explanatory variables

The core explanatory variable industrial structure upgrading is measured by the industrial structure upgrading (TS) and rationalization (TL) index. In view of the fact that the growth rate of the tertiary industry is faster than that of the secondary industry in the process of "economic service", this paper measures the degree of industrial structure upgrading by the ratio between the added value of the tertiary industry and the added value of the secondary industry. The rationalization of industrial structure is to make full use of domestic resources and the benefits of international division of labor, the coordinated development of various sectors of the national economy, so that the factors of production get the best combination. Based on Gan Chunhui's practice, this paper takes Theil index as the metric index [16].

4.1.3 Adjust variables

In terms of the regulating effect of scientific and technological innovation, Zhang Xiangyu's practice is referred to and supplemented to some extent. From the three dimensions of government scientific and technological subsidies, technological content of patented inventions and transformation of scientific and technological achievements, the financial expenditure of government subsidies on science and technology (one billion), the number of authorized invention patents (thousands) and the turnover of technology market (one billion) are taken as the measurement indicators respectively.

4.2   Sources of data

Based on the principle of data integrity and availability, this paper takes 30 provinces as the research object during 2010-2020 to conduct an empirical study on the impact of industrial structure upgrading on the new dual-cycle development pattern. The data comes from China Statistical Yearbook, China Science and Technology Statistical Yearbook, China Industrial Statistical Yearbook, China High-tech Industry Statistical Yearbook, provincial and municipal Statistical Yearbook and National Bureau of Statistics for 2011-2021. Some missing data were filled by linear interpolation and mean filling method.

5   Analysis of the level and characteristics of domestic and international double cycle development

Since the development strategy of expanding domestic demand was put forward in 2008, the development situation of domestic and international double cycle of Chinese economy and the impact of industrial structure upgrading on double cycle have been studied. According to the performance evaluation index system of new development pattern of double cycle, the entropy method has been used to estimate the development level of double cycle of Chinese economy during 2010-2020 (Table 2). On the whole, there is regional imbalance in the level of dual-cycle economic development, and the eastern region is obviously stronger than the western region. The top five regions in terms of dual-cycle economic development are all eastern regions, among which Guangdong Province, Beijing and Jiangsu Province rank the top three with 0.3618, 0.2877 and 0.2687 respectively. The western region with relatively backward economic development is not optimistic about the double-cycle economic development. The difference between Qinghai Province, which has the worst development, and Guangdong Province, which ranks the first, is 0.3263. From the perspective of global spatial autocorrelation, the domestic and international dual-cycle development levels show obvious spatial accumulation characteristics in the developed areas along the southeast coast and the backward areas in the northwest (Figure 1). That is, the areas with high dual-cycle development level mainly accumulate in the coastal areas, such as Guangdong Province, Beijing, Jiangsu Province, Shanghai, Zhejiang Province and Shandong Province. The regions with low level of dual-cycle economic development mainly accumulate in northwest inland areas, such as Qinghai Province, Gansu Province, Ningxia Hui

Autonomous Region and Xinjiang Uygur Autonomous Region. In 2010, there was not a big gap between the east and the central and western regions in the double-cycle development level of Chinese economy. After ten years of development, by 2020, the double-cycle development level of eastern coastal areas will grow rapidly, while the growth rate of western areas will be slow, especially Guangdong Province and Beijing's double-cycle economic development level will grow by leaps and bounds. The previous better development of Jiangsu, Zhejiang and other provinces are slightly inferior. The main reason is that the economic foundation of the eastern coastal areas is strong, the income level of residents is much higher than that of the western inland areas, and the per capita consumption expenditure on culture, entertainment, education, health care, transportation and communication greatly promotes the development of the double economic cycle [17]. However, the inland northwest region has a weak economic foundation, a single industrial structure and a backward level of technological innovation, leading to a serious problem of low-end overcapacity and high-end insufficient supply of products and services. The economic double cycle development is not driven by the eastern region obviously, and the speed of economic double cycle development is relatively slow[18-20].

Table 2. Performance of regional dual-cycle new development pattern in China from 2010 to 2020

| Rank	Area	Double cycle development level	Rank	Area	Double cycle development level	Rank	Area	Double cycle development level
1	Guang-dong	0.3618	11	Fujian	0.1208	21	Shanxi	0.0701
2	Beijing	0.2877	12	Hunan	0.1184	22	Jilin	0.0646
3	Jiangsu	0.2687	13	Hebei	0.1153	23	Hei-longjiang	0.0629
4	Shanghai	0.2563	14	Hubei	0.1063	24	Hainan	0.0616
5	Zhejiang	0.2269	15	Sichuan	0.1022	25	Yunnan	0.0610
6	Shandong	0.2087	16	Chong-qing	0.0950	26	Xinjiang Uygur	0.0589
7	Tianjin	0.1396	17	Jiangxi	0.0878	27	Guizhou	0.0574
8	Liaoning	0.1317	18	Inner Mongolia	0.0815	28	Ningxia Hui	0.0485
9	Henan	0.1260	19	Shaanxi	0.0745	29	Gansu	0.0446
10	Anhui	0.1229	20	Guangxi	0.0716	30	Qinghai	0.0355
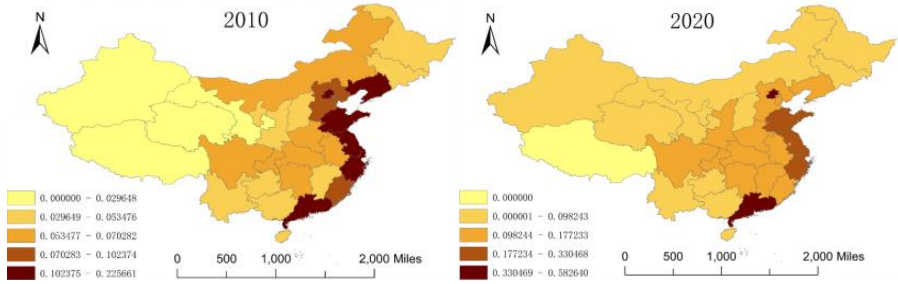
Fig. 1. Domestic and international double cycle development in 2010 and 2020

6   Empirical analysis

6.1   Main effect test

The main effect regression results were analyzed (Table 3). Firstly, the industrial structure upgrading and rationalization variables are added to the model for regression analysis, and then the product term of the two independent variables is added to the model for regression analysis. According to model 1, the coefficient of industrial structure upgrading is positive (&=5.470), and is significant at the level of 0.01, indicating that there is a positive correlation between the degree of adjustment and transformation of industrial structure from low level to high level and the level of domestic and international double cycle development. According to model 2, the coefficient of industrial structure rationalization is positive (&=8.892), and is significant at the level of 0.01, indicating that there is a positive correlation between the strengthening of coordination ability and the improvement of correlation level between industries and the level of domestic and international dual-cycle development. According to model 3, the coefficient of the product term of industrial structure upgrading and rationalization is positive (&=9.680), and is significant at the level of 0.01, indicating that there is a positive correlation between the interaction between industrial structure upgrading and rationalization and the domestic and international double cycle development level. In summary, assuming A1 is verified, there is a positive correlation between the upgrading of industrial structure and the new development pattern of "double cycle".

Table 3. Main effect regression results

Variable	Double cycle development level		
	(1)	(2)	(3)
TS	5.470***		
	(0.990)		
TL		8.892***	
		(2.761)	
TS×TL			9.680***
			(1.534)
_cons	-100.147***	-56.656	-91.764**

	(37.682)	(38.451)	(36.841)
id	Yes	Yes	Yes
year	Yes	Yes	Yes
r2_a	0.630	0.605	0.641
F	37.821	34.265	39.469
N	330.000	330.000	330.000

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

6.2   Adjustment effect test

In Table 4, it can be seen from model 4 that the coefficient between the primary item of government financial subsidies and the advanced interaction item of industrial structure is positive (&=4.616) and is significant at the level of 0.01, while the coefficient between the secondary item of government financial subsidies and the advanced interaction item of industrial structure is negative (&=-4.418) and is significant at the level of 0.01. It shows that government financial subsidies first positively adjust the positive correlation between the upgrading of industrial structure and domestic and international economic circulation, and then negatively adjust the relationship. According to Model 5, government financial subsidies first positively adjust the positive correlation between industrial structure rationalization and domestic and international economic circulation, and then negatively adjust it. In summary, hypothesis B1 and hypothesis B2 are verified. In the early stage of technology research and development, government financial subsidies positively adjusted the positive correlation between industrial structure upgrading and double-cycle new development pattern, and in the later stage of technology research and development, government financial subsidies negatively adjusted the positive correlation between industrial structure upgrading and double-cycle new development pattern. According to model 6, the coefficient of interaction between the quality of scientific research achievements and the upgrading of industrial structure is positive (&=1.281), and is significant at the level of 0.01. As can be seen from model 7, the coefficient of the interaction term between the quality of scientific research achievements and the rationalization of industrial structure is positive (&=1.514), and is significant at the level of 0.01. Assuming C1 is verified, high-quality scientific research achievements positively regulate the positive correlation between the upgrading of industrial structure and the new dual-cycle development pattern. According to model 8, the coefficient of the interaction term between the transformation of scientific research achievements and the upgrading of industrial structure is positive (&=0.849), and is significant at the level of 0.01. As can be seen from model 9, the coefficient of the interaction term between the transformation of scientific research achievements and the rationalization of industrial structure is positive (&=0.495), and is significant at the level of 0.01. Assuming D1 is verified, the transformation of scientific and technological achievements positively regulates the positive correlation between the upgrading of industrial structure and the new dual-cycle development pattern.

Table 4. Regression results of adjustment effect

Variable	Double cycle development level					
	(4)	(5)	(6)	(7)	(8)	(9)
TS	2.541***		2.436***		2.235***	
	(0.590)		(0.644)		(0.698)	
TL		13.404***		7.772***		4.499*
		(3.091)		(2.309)		(2.347)
T_Sub	0.216***	0.464***				
	(0.038)	(0.080)				
T_Sub2	-0.001***	-0.005***				
	(0.000)	(0.001)				
TS×T_Sub	4.616***					
	(0.248)					
TS×T_Sub2	-4.418***					
	(0.567)					
TL×T_Sub		4.494***				
		(1.178)				
TL×T_Sub2		-5.694***				
		(2.023)				
Grant			0.149***	0.499***		
			(0.032)	(0.042)		
TS×Grant			1.281***			
			(0.083)			
TL×Grant				1.514***		
				(0.284)		
Volume					0.004	0.048***
					(0.005)	(0.004)
TS×Volume					0.849***	
					(0.068)	
TS×Volume						0.495***
						(0.186)
id	Yes	Yes	Yes	Yes	Yes	Yes
year	Yes	Yes	Yes	Yes	Yes	Yes
r2_a	0.879	0.651	0.853	0.735	0.828	0.725
F	122.380	33.124	108.290	53.179	90.876	50.743
N	330.000	330.000	330.000	330.000	330.000	330.000

6.3   Robustness test

In order to further verify the reliability of the empirical analysis structure, the ratio of new product sales revenue and total income of industrial enterprises above designated size is used to measure the supply efficiency, the ratio of developmental consumption

to total consumption is used to measure the consumption structure, the consumption contribution rate is used to measure the consumption upgrading, and the cargo transportation volume is used to measure the development of the logistics industry. The ratio between the main business income of high-tech products and the main business income of industrial enterprises above designated size is used to measure the supply efficiency. The Engel coefficient is used to measure the consumption structure, the sales volume of e-commerce is used to measure the consumption upgrade, and the road mileage is used to measure the development of the logistics industry. Instead of the previous dependent variable, the robustness test is conducted.

6.3.1 Robustness test of the main effect

In Table 5, the upgrading of industrial structure and rationalization of industrial structure significantly promote the domestic and international double cycle; The coefficient of the interaction term of industrial structure upgrading and rationalization is positive and significant (&=8.689, $p < 0.01$), and hypothesis A1 is verified. In summary, the robustness test results of the main effect are consistent with the above results.

Table 5. Main effect regression results (robustness test)

Variable	Double cycle development level		
	(10)	(11)	(12)
TS	5.379***		
	(0.964)		
TL		7.812***	
		(2.699)	
TS×TL			8.689***
			(1.510)

6.3.2 Robustness test of the moderating effect

In the analysis of models 13 and 14 in Table 6, it can be seen that hypothesis B1 and B2 are verified, and the robustness test structure of the regulatory effect of government financial subsidies is consistent with the previous test results. By analyzing models 15 and 16, it can be seen that hypothesis C1 is verified, and the robustness test structure of the quality regulation effect of scientific research achievements is consistent with the above test results. According to models 17 and 18, hypothesis D1 is verified, and the robustness test structure of the regulating effect of the transformation of scientific achievements is consistent with the above test results.

Through the above tests, it can be seen that the robustness test results of the main effect are completely consistent with those mentioned above. In the robustness test of the moderating effect, all the other results were consistent except that the significance level of D1 ($p<0.05$) was different from the previous one ($p< 0.01$), indicating that this study had good robustness.

Table 6. Regression results of adjustment effect (robustness test)

variable	Double cycle development level					
	(13)	(14)	(15)	(16)	(17)	(18)
TS	2.751***		2.492***		2.345***	
	(0.583)		(0.656)		(0.693)	
TL		11.893***		6.800***		3.499
		(3.029)		(2.328)		(2.245)
T_Sub	0.159***	0.434***				
	(0.037)	(0.079)				
T_Sub2	-0.001**	-0.005***				
	(0.000)	(0.001)				
TS×T_Sub	4.065***					
	(0.245)					
TS×T_Sub2	-2.822***					
	(0.560)					
TL×T_Sub		4.510***				
		(1.154)				
TL×T_Sub2		-6.008***				
		(1.982)				
Grant			0.119***	0.455***		
			(0.033)	(0.042)		
TS×Grant			1.243***			
			(0.085)			
TL×Grant				1.386***		
				(0.286)		
Volume					0.011**	0.049***
					(0.005)	(0.004)
TS×Volume					0.729***	
					(0.068)	
TS×Volume						0.366**
						(0.178)

7   Heterogeneity analysis

In order to ensure the accuracy of the empirical analysis, this paper analyzes the heterogeneity of the research samples from two dimensions of region and time, and the detailed results are shown in Table 7.

According to the difference of spatial and geographical location of different cities, it is divided into eastern and central and western regions. A comparative analysis of the regression results of model 19 and model 20 shows that the regression model coefficient of the eastern region is significantly greater than that of the central and western regions, indicating that accelerating the upgrading of industrial structure has a greater promoting

effect on the domestic and international double cycle in the eastern region, and the promoting effect is more than three times that of the western region. The "Twelfth Five-Year Plan" mentioned that this period is the transition period from the middle to the late industrialization of China, and it is also a key period to promote the optimization and upgrading of China's industrial structure and realize the transformation of economic development mode; In the "13th Five-Year Plan" period, China has increased its attention to the upgrading of industrial structure. A comparative analysis of model 21 and model 22 in Table 7 shows that the coefficients of the interaction between the upgrading and rationalization of industrial structure are positive and significant, and the coefficients and significance level in the "13th Five-Year Plan" period are significantly greater than that in the "12th Five-Year Plan" period. During the "12th Five-Year Plan" period, due to the imperfect infrastructure and policies and the low level of scientific and technological innovation, the promotion effect of industrial structure upgrading on the double cycle is not large and not significant enough, but as time goes by, The continuous improvement of the state's attention to the upgrading of industrial structure, the progress of independent scientific and technological innovation, and the rapid improvement of policies and infrastructure have accelerated the process of upgrading China's industrial structure, fully demonstrating the significant promotion role of industrial structure upgrading on the domestic and international double cycle.

Table 7. Regression results of heterogeneity analysis

variable	Regional heterogeneity		Heterogeneity of time	
	(19)	(20)	(21)	(22)
	east	Midwest	The 12th Five-Year Plan	The 13th Five-Year Plan
TS×TL	12.917***	4.159***	5.325**	12.103***
	(3.329)	(1.025)	(2.174)	(1.909)
r2_a	0.629	0.758	0.265	0.290
F	14.332	42.767	9.274	9.990
N	121.000	209.000	150.000	150.000

8   Conclusion

The level of double-cycle development of China's economy is characterized by regional imbalance, the eastern region is obviously stronger than the western region, and the level of domestic circular development is higher, the level of international circular development is also higher. Promoting the upgrading of industrial structure has a significant promoting effect on improving the level of domestic and international double-cycle development in China, and the promotion effect on the eastern region is stronger than that of the western region. As a regulating variable, scientific and technological innovation has played a significant incentive role in the relationship between industrial structure upgrading and domestic and international double cycle. Government financial subsidies, the quality of scientific research results and the conversion rate of scientific

research results in the early stage of technology research and development will play a significant incentive role in the positive correlation between the upgrading of industrial structure and the level of dual-cycle development. However, the government cannot provide long-term financial support to technology research and development enterprises, and excessive financial subsidies will negatively adjust the positive correlation between the former two.

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