

# Study of Shandong Province's 'Dual Circulation' Economy Based on the GTAP Model

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**Abstract:** This paper combined qualitative and quantitative approach to investigating and measuring the quality of Shandong Province's "dual circulation" economy. Building on the qualitative analysis of the economic advantages and limitations of Shandong Province in constructing a new development pattern, a GTAP-DC-SD (GTAP - Dual Circulation - Shan Dong) model with Shandong provincial accounts is further constructed using the method of global value chain decomposition. The paper quantitatively analyzes the development level of various indicators of "dual circulation" in China and Shandong Province. The study finds that indicators of Shandong's "internal circulation" in the domestic cycle are at a relatively high level, but the development of internal circulation within the province is relatively weak. From the perspective of demand-driven economic indicators, China's investment still dominates, leaving some space for the growth of domestic consumption. At the industrial level, the internal demand indicators for Shandong's labor-intensive industries and light and heavy industries are relatively weak. Based on these findings, this paper proposes a strategic path for Shandong Province to construct a high-quality development pattern of "dual circulation"—that is to cultivate a demand-driven economic cycle and build a strong linkage between internal and external circulations. On the supply side, structural reforms with emphasis on industrial innovation capabilities should be advanced; on the demand side, it suggests adjusting the structure of domestic demand to achieve a structural transformation driven by domestic demand. Meanwhile, the paper emphasizes the balance of regional economic development and sustainability, promoting the international circulation with higher-level open economy.

## 1. Introduction

Currently, the world is undergoing an unprecedented transformation. From the global scale, the trend of deglobalization, compounded by the impact of geopolitical conflicts and unilateralism, has caused significant disruptions to global value chains. Internally, China's economy has entered a stage of high-quality development, especially against the backdrop of goals such as carbon emission peak and carbon neutrality. China's economic growth mode and driving forces are facing the imperative for a green and low-carbon transformation. In order to respond to the complex changes in the domestic and international situations, the Central Committee of the Communist Party of China has put forward the strategic deployment of "accelerating the establishment of a new development pattern with the emphasis on internal circulation as well as the mutually reinforcing of internal and external circulation." The "dual circulation" strategy reflects the essence of China's economic transformation, which will lead to a balanced economic cycle toward a new path of globalization[1].

However, China exhibits significant differences among its provinces in terms of resource endowment and development strategies, displaying some distinct characteristics in the integration of each province into the country's "dual circulation" strategy. Shandong Province, as a traditional economic powerhouse, possesses a strong economic development foundation but faces certain constraints in its economic transformation.

This paper starts with the conception of the "dual circulation" and qualitatively analyzes the

foundation and limitations for Shandong Province to follow the new development pattern. Meanwhile, this study built the Global Trade Analysis Project - Dual Circulation- Shan Dong (GTAP-DC-SD) model, which embeds the decomposition method of the global value chain into a global computable general equilibrium model (CGE) and adds Shandong Province's provincial accounts. This paper proposes a quantitative method to measure the "dual circulation" development indicators for the country and province's level. On this basis, the fundamental path of provincial economic integration into the new development pattern is well defined, and relevant policy recommendations are put forward[2].

## **2. The Economic Foundation and Constraints of Shandong's "Dual Circulation" Development**

An economic cycle is composed of production, distribution, exchange, and consumption in both domestic cycles and international cycles. Under the trend of globalization, the international economic cycle has evolved into a value chain system, forming the foundation of the current "external circulation" economy.

Essentially, building a "dual circulation" system involves taking the domestic cycle as the starting point for national economic construction and development. In terms of economic development momentum, there is a need to shift from the traditional "export-investment-driven model" to the "domestic-demand-innovation-driven model." Shandong's "dual circulations" also focus on leading with innovation-driven, high-quality supply to create new demand, establishing dynamic balance between consumption and investment, and promoting interconnectedness between domestic and international markets[3].

From an economic geographical perspective, Shandong as an economic powerhouse in the north plays a crucial role in linking the north, south, east, and west economies to form a balanced nationwide market. As a coastal province, Shandong can leverage its advantages in the marine economy, complementing the inland economy, and act as a hub connecting domestic and international cycles, particularly in the context of the Belt and Road Initiative and the hub for Northeast Asian economic cooperation.

Shandong has significant advantages in agriculture and heavy industry, providing a foundation for nurturing new economic drivers and forming a rational division of labor with economically developed southern provinces. However, compared to economically developed southern provinces, there are still gaps in the development of emerging high-tech industries and sectors of high-end value chain in Shandong. Cultivating new economic driving forces is essential to meet the growing demand for domestic growth in the new situation[4].

Additionally, given the current demand for green transformation, Shandong will play a crucial role in energy reform and environmental protection. As it accelerates the construction of a "low-carbon, high-quality development pilot zone" of energy and power, Shandong strategically positions itself in China's net-zero carbon strategies. It is expected to play a demonstrative role, providing support for forming a high-quality development pattern and sustainable development.

## **3. Quantitative Measurement Method and Results**

The above section provides the inherent logic and measurement basis for quantifying the quality of the new development pattern in Shandong Province. In the current quantitative research on the development of "dual circulation," many scholars have depicted the degree of integration of countries participating in international trade by decomposing the global input-output table (Chen, et al, 2022; Huang and Ni, 2021). Simultaneously, through the analysis of inter-provincial trade, they reflected the level of domestic economic circulation (Zhang, et al, 2022)[5].

This paper takes the core conceptions of "internal demand" in the "dual circulation" as a starting point. It employs the global value chain decomposition method to specify the proportion of domestic demand driving the economy. This measure is used to assess the relative levels of national and provincial circular economies. The paper also analyzes the evolving trends of the dual circulation pattern in China and Shandong Province. In constructing the specific quantitative model, this paper

integrates the provincial account of Shandong Province into the GTAP-DC-SD model, which is based on the Global Computable General Equilibrium (CGE) model with an embedded global value chain module. The paper quantitatively analyzes the "dual circulation" indicators at both the national and provincial levels. The CGE model with embedded global value chain decomposition allows for a more accurate distinction between the decomposition of domestic and international circulation. This includes assessing the impact of increasing the proportion of domestic demand on value-added production in China and Shandong Province or the influence of other countries increasing the ratio of inputting intermediate products and final demand to the national and provincial economies[6].

### 3.1 Building the GTAP-DC-SD model

The integration of global value chain (GVC) index system and the computable general equilibrium (CGE) model can use the input-output data to describe the decomposition of value-added and final goods production at country-sector level. The CGE model presumes that the input-output data is the result of optimal behaviors of various economic sectors under the constraints of existing resources and policies. Based on this assumption, the parameter and elasticity values are estimated and calculated by using a calibration method. Then, the simulations of policy shocks can affect the economywide equilibrium and lead to new balanced input-output data under the constraints of new optimal behavior. The global value chain index system, otherwise, can trace the flow of value-added goods along with global production chains. This method is able to decompose gross exports into its various components, including final products that meet domestic demand, exports of value added, or exports of intermediate products (Koopman et. al., 2014). Therefore, the combination of the CGE model and the GVC index system can provide more accurate description of the decomposition of global value chains by tracing value added embedded in gross trade flows. Such a method fills the technical gap by applying the quantitative models of GVC and the economywide CGE model to analyze trade and economic policy. Therefore, compared to the standardized CGE model, the CGE model with embedded global value chain decomposition can accurately distinguish between the decomposition of domestic and international cycles. It can also assess the role of policy shocks in enhancing both internal and external circulations.

#### 3.1.1 The Structure of Global Value Chain Decomposition Model

Here, we will use a simplified 3-region, 3-sector world input-output table to explain the core components of the global value chain decomposition model and its significance in analyzing the "internal circulation" economy (See Table 1):

Table 1: The Simplified Input-Output Table

			Intermediate Use									Final Demand			Total output
			China			US			Other			China	US	Other	
			Sector1	Sector2	Sector3	Sector1	Sector2	Sector3	Sector1	Sector2	Sector3				
Intermediate Inputs	China	Sector1	11			12			13						
		Sector2													
		Sector3													
	US	Sector1	21			22			23						
		Sector2													
		Sector3													
	Other	Sector1	31			32			33						
		Sector2													
		Sector3													
Value-added															
Total input															

Some scholars intend to use diagonal submatrix 11, 22 and 33 (the domestic input in production)

to explain the internal circulation of a country's industries. However, this method can only be used to observe the input of one sector's production, rather than the country's position in the global value chain and its relationship with upstream and downstream industry chain. For example, although we can observe the domestic intermediate inputs in domestic production from the submatrix 11, the sourcing of upstream value-added is unknown, neither the flow of China's domestic products to downstream consumption, exports for final consumption or intermediate goods for exports.

Actually, the core elements of the decomposition of GVC model has addressed this problem.

First, to avoid replicate counts, the intermediated goods trade is converted to value added as follows (\*\*represents matrix multiplication):

$$VBY = V\_diag ** B ** Y\_diag$$

V\_diag converts the row vector of value-added coefficient of each country and sector into a diagonal matrix. B is the global Leontief inverse matrix. Y\_diag converts the products of final use of column vector into a diagonal matrix.

The conversion of intermediate goods trade relationship into value-added relationship is illustrated in the following simplified input-output table (See Table 2):

Table 2: VBY Structure

		Value Added									
		China			US			Other			
		Sector1	Sector2	Sector3	Sector1	Sector2	Sector3	Sector1	Sector2	Sector3	
Value Added	China	Sector1	11			12			13		
		Sector2									
		Sector3									
	US	Sector1	21			22			23		
		Sector2									
		Sector3									
	Other	Sector1	31			32			33		
		Sector2									
		Sector3									

Take China's sector 1 for example, the row means how China's value-added flows to one country-sector's final goods production along with global industry chains.

Then, we take a look at the four elements of decomposition of VBY, that is  $VBY = VLY\_d + VLY\_f + VLA\_fLY\_d + VLA\_f(BY-LY\_d)$ . The first VLY\_d is calculated as following equation (\*\*represents matrix multiplication):

$$VLY\_d = V\_diag ** L ** Y\_d\_diag$$

V\_diag converts the row vector of value-added coefficient of each country-sector into a diagonal matrix. L is the domestic Leontief inverse matrix. Y\_d\_diag means each country's final goods absorbed in local consumption. It converts row vector into a diagonal matrix. VLY\_d is illustrated as following input-output table (See Table 3):

Table 3: VLY\_d Structure

		Value Added									
		China			US			Other			
		Sector1	Sector2	Sector3	Sector1	Sector2	Sector3	Sector1	Sector2	Sector3	
Value Added	China	Sector1	11								
		Sector2									
		Sector3									
	US	Sector1				22					
		Sector2									
		Sector3									
	Other	Sector1							33		
		Sector2									
		Sector3									

Take China's sector 1 for example, the row means the value added that is domestically produced and consumed in China.

The second element VLY\_f can be calculated as follows (\*\*represents matrix multiplication):

$$VLY\_f = V\_diag ** L ** Y\_f\_diag$$

V\_diag converts the row vector of value-added coefficient of each country-sector into a diagonal matrix. L is the domestic Leontief inverse matrix. Y\_f\_diag is the value-added that is embodied in final product exports. It converts row vector into a diagonal matrix. VLY\_f is illustrated as following input-output table (See Table 4):

Table 4: VLY\_f Structure

			Value Added								
			China			US			Other		
			Sector1	Sector2	Sector3	Sector1	Sector2	Sector3	Sector1	Sector2	Sector3
Value Added	China	Sector1	11								
		Sector2									
		Sector3									
	US	Sector1	22								
		Sector2									
		Sector3									
	Other	Sector1							33		
		Sector2									
		Sector3									

Take China's sector 1 for example, the row means the value added produced in China that is embodied in China's final product exports.

The third element VLA\_fLY\_d is calculated as follows (\*\*represents matrix multiplication):

$$VLA\_fLY\_d = V\_diag ** L ** A\_F ** L ** Y\_d\_diag$$

V\_diag converts the row vector of value-added coefficient of each country-sector into a diagonal matrix. L is the domestic Leontief inverse matrix. A\_F means each country's dependence on importing intermediate goods in global production technical matrixes. Y\_d\_diag means each country's final products that are used in local consumption. It converts column vectors into a diagonal matrix. VLA\_fLY\_d is illustrated as following table (See Table 5):

Table 5: VLA\_fLY\_d Structure

			Value Added								
			China			China			China		
			Sector1	Sector1	Sector1	Sector1	Sector1	Sector1	Sector1	Sector1	Sector1
Value Added	China	Sector1				12			13		
		Sector2									
		Sector3									
	US	Sector1	21						23		
		Sector2									
		Sector3									
	Other	Sector1	31			32					
		Sector2									
		Sector3									

Take China's sector 1 for example, the row means value added produced by China's sector that is used as intermediate goods in production activities for final production outside the source country.

The fourth element VLA\_f(BY-LY\_d) can be calculated as follows:

$$VLA\_f(BY-LY\_d) = V\_diag ** L ** A\_F ** (B ** Y\_diag - L ** Y\_d\_diag)$$

V\_diag converts the row vector of value-added coefficient of each country-sector into a diagonal matrix. L is the domestic Leontief inverse matrix. A\_F means each country's dependence on importing intermediate goods in global production technical matrixes. Y\_d\_diag means each country's final products that are used in local consumption. It converts column vectors into a diagonal matrix. B is the global Leontief inverse matrix. Y\_diag converts column vector of each country's final products into a diagonal matrix. VLA\_f(BY-LY\_d) can be illustrated as following input-output table (See Table 6):

Table 6: VLA\_f(BY-LY\_d) Structure

			Value Added								
			China			China			China		
			Sector1	Sector1	Sector1	Sector1	Sector1	Sector1	Sector1	Sector1	Sector1
Value Added	China	Sector1	11			12			13		
		Sector2									
		Sector3									
	US	Sector1	21			22			23		
		Sector2									
		Sector3									
	Other	Sector1	31			32			33		
		Sector2									
		Sector3									

Take China’s sector 1 for example, the row means the value-added produced in China’s sector 1 that is used as intermediated goods by other countries to produce exports (intermediate or final) for other countries (including re-exports and re-imports).

In order to measure the internal circulation indicators for Shandong Province using the GTAP-DC-SD model, this study employs the macroeconomic data for Shandong Province relative to the national data. The model introduces a provincial account for Shandong Province, while other provinces in China are uniformly designated as "other provinces in China."

Based on the proportion of Shandong Province's GDP to the national GDP according to the *China Statistical Yearbook*, and considering Shandong Province's characteristics as a major industrial manufacturing province, the study utilizes the SplitReg tool developed by the Centre of Policy Studies (CoPS) in Australia. By modifying the regional dimensions in the SplitReg program and using Shandong Province's industrial structure proportion data to create a new dataset (refer to "UserWgt.har" in Figure 1), the GTAP-DC-SD model incorporates two parts, namely "Shandong Province" and "other provinces in China," replacing the traditional model's representation of "China." This approach allows for the depiction of Shandong Province's socio-economic conditions and the dual circulation pattern.

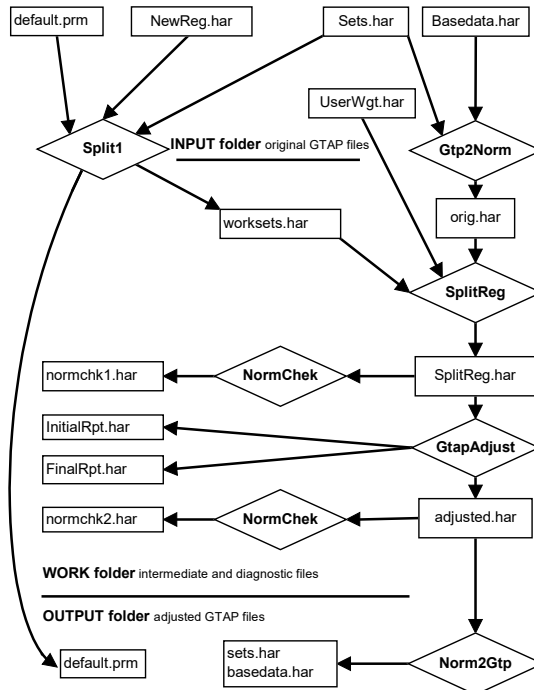


Figure 1 Using SplitReg to Disaggregate the GTAP Database

### 3.2 Analysis of the “Dual Circulation” Indicators

This article starts from the core concept of "dual circulation," using the indicator of the domestic demand-driven Gross Domestic Product (GDP) as the primary indicator for internal circulation at both the national and provincial levels. The overall indicator for China's internal circulation is 0.779, ranking just below the United States (0.814) and Japan (0.8) among major economies. It even

surpasses the European Union and the United Kingdom, indicating a relatively strong level of internal circulation in China. Furthermore, at the provincial level, Shandong Province's performance in domestic circulation exceeds the national average, with an indicator of 0.825, second only to the United States. This suggests that both at the national and provincial levels, local effective demand has played a significant driving role in the economy.

However, the internal circulation indicator within Shandong Province is relatively low, with an index of only 0.547. This implies that Shandong needs to make more effort to enhance the internal circulation system. There is a need to strengthen and improve the provincial industrial chain, supply chain, and value chain (See Figure 2).

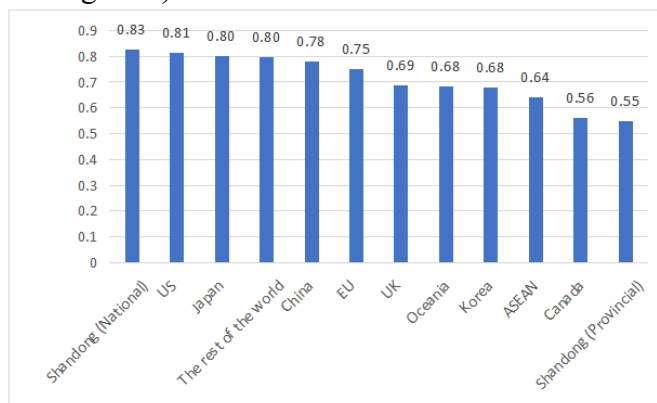


Figure 2 Indicators of Domestic Demand (1 = Completely Domestic Demand-driven)

We further decomposed the indicators of each country/region's domestic demand and found that household consumption consists of a larger proportion in US and Japan's domestic demand than other major economies. Investment, instead, accounts for a key factor of China's domestic demand-driven economic growth. This implies that China's internal circulation is still unbalanced, which requires a transformation from investment to consumption-driven development (See Figure3).

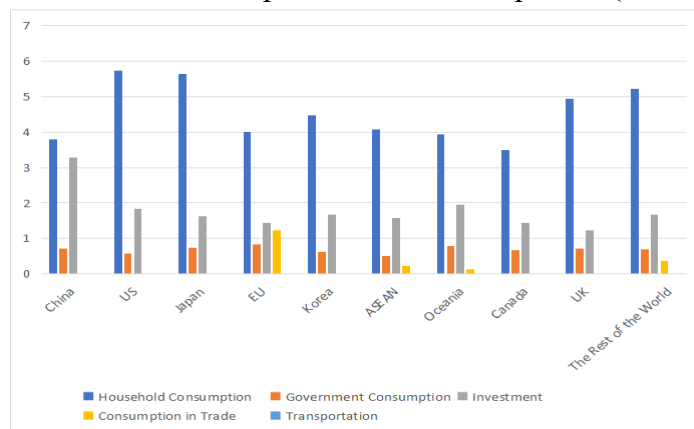


Figure 3 The Decomposition of the Indicators of Domestic Demand

At the industry level, different sectors exhibit heterogeneity in their domestic and international circulations. Based on Shandong's industrial indicators, the textile and apparel industry has the lowest proportion of economic growth driven by domestic demand. This suggests that labor-intensive sectors still rely more on external demand, and the value-added proportion of these sectors is lower. Other manufacturing sectors, including light and heavy industries, also have relatively low internal circulation indicators. As a key area for China's industrial upgrading and one of Shandong Province's key pillar industries, it is essential to fully promote intrinsic growth dynamics of the manufacturing sectors, enhance the role of internal effective demand in driving industrial growth, and further improve the quality of internal circulation through upgrading Shandong's position in the domestic and international industrial chains.

On the other hand, the supply of public resources, including water, electricity, and gas, contributes significantly to domestic market demand, followed by the service sector. Shandong Province's service

sector is gradually increasing its share, with significant growth potential in some industries such as finance, logistics, information services, healthcare, education, and elderly care. Under the impetus of consumption-driven policies, Shandong Province has considerable room for consumption upgrading, further stimulating the diversified development in the service industry. However, the development of an economy primarily driven by internal circulation does not imply a closed system. Shandong Province needs to promote the global flow of factors across various industry sectors at a higher level of openness, facilitating an interaction between internal and external cycles.

From the indicators, we can find that Shandong possesses a significant market size advantage and domestic demand potential in implementing the "dual circulation" strategy. However, compared to developed regions, the level of internal circulation in Shandong Province is relatively weak. This is primarily due to challenges such as insufficient industrial and technological innovation capabilities, regional development imbalances, and relatively inadequate vitality in the private sector. These challenges are reflected in the internal circulation indicators of the provincial industries, particularly the insufficient driving force of domestic demand in the manufacturing sector. To address these issues, it is crucial to prioritize upgrading the real economy as a key aspect of developing the "dual circulation" strategy in Shandong. Simultaneously, efforts should be made to enhance the construction of both intra-provincial and inter-provincial supply chains and value chains.

#### **4. Policy Recommendations**

In light of the current state and future development path of Shandong Province's economy, this article proposes the following specific policy recommendations for the economic transformation of Shandong Province.

##### **4.1 Accelerate Supply-side Structural Reforms and Promote the Transition of Development Momentums**

In the process of promoting supply-side structural reforms, efforts should be focused on optimizing and adjusting the economic structure around the goals of "eliminating outdated production capacity, upgrading traditional industries, and fostering emerging industries." This involves strengthening high-quality supply, expanding effective supply, and improving overall factor productivity in the production field.

In the cultivation of new momentum, Shandong Province should leverage its comparative advantages to create an innovation-driven pattern of high-quality development. In terms of industrial layout, breakthroughs should be made in emerging industries such as light industry, equipment manufacturing, electronic information, logistics, electrical manufacturing, green food, marine products, energy conservation and environmental protection, pharmaceuticals, new materials, and modern agriculture. This will guide investments and innovative talents into emerging industries, drive the development of new business formats, build an innovative economy, and solidify the foundation for supply-side structural reforms.

##### **4.2 Expanding the Effective Demand to Build a Demand-Driven Circular Development Pattern**

While adhering to supply-side structural reforms, it is essential to expand effective demand and enhance the driving role of investment, consumption, and foreign trade in economic growth.

Shandong Province needs to solidify the investment of infrastructure construction while promoting major projects in new infrastructure, urbanization, and new energy. In the long term, Shandong Province should actively explore new investment areas, including the digital economy, energy transformation, advanced manufacturing, and the upgrading of traditional industries.

In the process of economic transformation, domestic consumption demand has surpassed investment demand, becoming the main engine for economic development. In the short term, there is a need to actively promote a system for expanding consumption. Additionally, policies aimed at expanding consumption should be extended to rural consumer groups. In the long term, to solidify the foundation for consumption growth, efforts should be sustained in maintaining employment stability, supporting private and small enterprises, and ensuring employment rates and stable incomes.



Meanwhile, Shandong Province should take into account the trend of population aging across the province. Economic policies should be implemented to strengthen social security, elderly care services, health support, and other aspects to meet the upgrading trend in elderly consumption and effectively expand the consumption demand for elderly care services.

The decreased global economic demand has led to short-term fluctuations in provincial exports. To stabilize the foundation of foreign trade, measures should be made to encourage the expansion of exports to emerging markets along the "Belt and Road" and RCEP countries, and promote the active integration of domestic enterprises into the international value chains. In the long term, it is essential to improve the trade structure and the formation of new trade forms. The Province should vigorously develop green products, enhance the competitiveness of provincial enterprises in green trade, actively explore the construction of a green development system in the free trade zone, and promote high-level international cooperation on green initiatives.

#### **4.3 Elevating the Level of Innovative Development to Construct a High-Level Innovative Province**

Shandong Province must emphasize the role of innovation in economic growth through accelerating self-reliance in science and technology. In terms of the regional innovation system, the province should focus on the needs of regional innovation development around the "one group, two hearts, three circles" plan, establishing the Shandong Peninsula innovation city cluster, creating a distinctive and well-connected source of technological innovation. Meanwhile, the province should enhance the open cooperation system, actively integrating into the global innovation network.

Specifically, Shandong Province should focus on the major demands of economic system construction, strengthen innovation in the development of new-generation information technology, advanced manufacturing, modern transportation technology, new materials technology, biotechnology, and other areas, accelerate breakthroughs in the transformation of old and new driving forces.

#### **4.4 Coordinating Regional Development to Enhance Regional Integration**

To strengthen the regional development strategy, Shandong should fully leverage the synergies of regional economic cooperation, advance the development of new urbanization, and promote green development within the region. First, it is crucial to implement the strategy for ecological protection and high-quality development in the Yellow River Basin. This involves promoting the coordinated development of central cities and urban clusters in the Yellow River region, strengthening regional industrial collaboration and infrastructure connectivity, actively aligning with national major regional development strategies such as the Beijing-Tianjin-Hebei region, the Yangtze River Economic Belt, the Guangdong-Hong Kong-Macao Greater Bay Area, and the Yangtze River Delta integration, to elevate the level of regional development in Shandong Province. Second, there is a need to deepen the development capacity of the three major economic circles: the provincial capital, Jiadong, and Lurou city clusters. Third, the province should accelerate the advancement of new urbanization, promoting the coordinated development of large, medium, and small cities and their surrounding areas.

#### **4.5 Accelerating the Construction of a Green, Low-Carbon, and Circular Economic System to Promote Socioeconomic Green Transformation**

Shandong Province's green development needs to address the shortcomings of low resource utilization, environmental pollution, and the need for optimization of the low-carbon economic structure. From the supply side, firstly, there should be effective efforts to enhance resource utilization efficiency. In terms of industrial energy consumption reform, it is crucial to improve the energy efficiency levels in key sectors such as coal, electricity, steel, and aluminum electrolysis, and promote the development of emerging industries such as renewable energy. Secondly, there is a need to deepen the prevention and control of air, water, and soil environmental pollution to achieve harmonious coexistence between humans and nature. Thirdly, active efforts should be made to advance the construction of ecological corridors such as the Yellow River, Grand Canal, and coastline,

as well as the protection and restoration of key ecological areas within the province. Lastly, there is a need to strengthen green and low-carbon technological innovation activities and green financial innovation, encouraging market entities to participate in the technological innovation system, effectively stimulating the intrinsic motivation for green development, and enhancing the overall green productivity.

## 5. Conclusion

This paper comprehensively investigates the quality of Shandong Province's "dual circulation" economy through both qualitative and quantitative methods, constructing a GTAP-DC-SD model that includes accounts specific to Shandong Province. The study finds that while Shandong has relatively high indicators for "internal circulation" within the domestic cycle, the development of internal circulation within the province itself is comparatively weak. In terms of demand-driven economic indicators, investment continues to dominate in China, leaving room for growth in domestic consumption. At the industry level, the internal demand indicators for labor-intensive industries and both light and heavy industries in Shandong Province are relatively weak. Based on these findings, the paper proposes a strategic path for the development of a high-quality "dual circulation" model in Shandong Province: On one hand, cultivating an economy driven by demand and building strong linkages between internal and external circulations; on the other hand, advancing structural reforms focused on industrial innovation capabilities on the supply side, and adjusting the structure of domestic demand on the demand side to achieve a structural transformation driven by domestic demand. Simultaneously, the paper emphasizes the sustainability of regional economic development and promotes an international circulation within a higher-level open economy.

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