

# The Formation Path and Action Mechanism of High-quality Green Port-adjacent Industrial Cluster in Zhanjiang City

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## Abstract

The port-adjacent industrial cluster is an important cornerstone and a powerful driving force for the economic development of port-adjacent. This paper elucidates the primary issues within the industrial cluster by conducting an in-depth analysis of the current agglomeration status and the composition of the industrial chain in the port-adjacent industries of Zhanjiang city. Guided by the core principles of green and sustainable development, this paper designs a scientifically rational development pathway for the green port-adjacent industrial cluster in Zhanjiang city and delves into its underlying mechanisms. Based on this, targeted policy recommendations are proposed. This paper aims to provide valuable insights for the formation and development of port-adjacent industrial cluster in Zhanjiang city.

## Keywords

Zhanjiang city, Green and low carbon, Port-adjacent industry, Industrial cluster, Formation pathway, Action mechanism.

## 1. Introduction

The port-adjacent industry serves as a crucial engine for the economic development of maritime cities. Leveraging its unique geographical location and resource advantages, it facilitates deep integration between maritime cities and both domestic and international markets, thereby enhancing the economic strength of these cities (Cao, 2012). The port-adjacent industrial cluster enhances the resilience of the agglomerated industries and boosts the economic and comprehensive competitiveness of maritime cities by concentrating related industries, integrating resources, and constructing a complete industrial chain, thereby creating a powerful agglomeration effect.

With the deepening development of the global economy, port-adjacent industrial cluster has increasingly highlighted its significance in global trade, investment, and regional development, garnering widespread attention from scholars. Numerous scholars have extensively explored various aspects of port-adjacent industrial cluster, including cluster performance (Cheng, 2020; Shao et al., 2018; Branco et al., 2018), knowledge and innovation (Franco et al., 2020), collaborative development (Mortensen et al., 2023; Zhang, 2020), as well as risk control and management (Cao & Ham, 2019; Jia & Xiao, 2013). However, these findings primarily focus on research conducted within port-adjacent industries that have already achieved cluster scale, with limited exploration into the initial cluster formation pathways of port-adjacent industries. Due to variations in regional economic development levels and disparities in port and marine resource endowments, there are significant differences in the development level, structure, and industrial chains of port-adjacent industries across different regions. Consequently, existing recommendations for the development of port-adjacent industrial clusters often fail to align with the specific needs of individual regions. Furthermore, within the context of global climate governance, green and low-carbon development has emerged as a critical issue for the

development of port-adjacent industrial clusters across various regions both presently and in the future (Qiao, 2023). Consequently, in the process of promoting the formation of regional port-adjacent industrial cluster, it is imperative to thoroughly consider regional characteristics and adhere to the principles of green and low-carbon development, thereby designing a feasible pathway for the establishment of green industrial cluster.

Zhanjiang city is located at the southernmost tip of mainland China, at the junction of Guangdong, Guangxi, and Hainan provinces. It is surrounded by the sea on three sides, with a coastline stretching 2,023.6 kilometers. The city boasts unique marine resources and port conditions, making it a veritable major maritime city. In recent years, the marine economy has experienced vigorous development. Taking advantage of this momentum, Zhanjiang city has fully leveraged its marine resource advantages to vigorously develop port-adjacent industries. Currently, it has established a series of leading industries such as petrochemicals, steel, and energy. The distinctive characteristics of port-adjacent industries are gradually becoming more pronounced. However, issues such as a relatively singular industrial structure, low agglomeration, short and weak industrial chains, and insufficient technological innovation capabilities have emerged, indicating that the industrial cluster has not yet fully formed. In April 2024, to further promote the development of the marine economy and accelerate the construction of a strong marine city, the municipal government formulated the "Zhanjiang city Development Plan for a Characteristic Modern Marine City." The plan prioritizes the development of green port-adjacent industries as its foremost task, aiming to establish a world-class green port-adjacent industrial cluster. It sets a phased target of achieving initial formation of a green port-adjacent industrial cluster by 2030, marking a critical breakthrough stage. Therefore, to accelerate the high-quality formation of Zhanjiang's green port-adjacent industrial cluster, it is essential to integrate the characteristics of Zhanjiang's port-adjacent industrial agglomeration and the current status of its industrial chain. This involves designing the formation pathway and exploring the mechanism of action for the green port-adjacent industrial cluster. Additionally, it is crucial to optimize the guiding policies for cluster formation to promote the clustering, greening, and high-end development of Zhanjiang's port-adjacent industrial agglomeration, thereby achieving high-quality development of Zhanjiang's marine economy.

In summary, the existing research on the formation of green port-adjacent industrial cluster in Zhanjiang city lacks pertinence, which makes the effectiveness of countermeasures and suggestions weak. This paper aims to clarify the main issues hindering the formation of industrial cluster by analyzing the current status of port-adjacent industrial agglomeration and the industrial chain in Zhanjiang city. Guided by the principles of green and sustainable development, it designs a rational pathway for the formation of green port-adjacent industrial cluster and explores its underlying mechanism. Furthermore, targeted policy recommendations are proposed to provide decision-making references for promoting the high-quality development of green port-adjacent industrial cluster in Zhanjiang city.

## **2. The port-adjacent industrial agglomeration in Zhanjiang city and the present situation of its industrial chain**

### **2.1. Analysis on the characteristics of port-adjacent industrial agglomeration**

Through on-site investigations of the port-adjacent industrial landscape in Zhanjiang city and an analysis of government-disclosed data, this paper elucidates the current agglomeration characteristics of port-adjacent industries from four perspectives: the scale of agglomeration, the enterprise composition, the industrial sectors, and the spatial distribution.

(1) The scale of the agglomeration

Zhanjiang city has planned and constructed a large-scale industrial agglomeration zone adjacent to the port, covering approximately 620 square kilometers. Currently, the primary areas where enterprises have settled are the Donghai Island area and the Fenyong area. The Donghai Island area serves as the primary core zone for port-adjacent industries in Zhanjiang city, with flagship projects such as the Zhongke Refinery Petrochemical Company Limited and BASF, each valued at tens of billions yuan, leading the development. To date, the region has successfully attracted over 60 major projects, with a cumulative investment totaling approximately 196 billion yuan. From a financial perspective, the area has already achieved a significant scale of development. However, field investigations reveal that there are approximately 40 enterprises of the targeted industrial type, yet the overall land use ratio is less than 50%. The Fenyong area, with a planned area of 46 square kilometers, has attracted over 40 enterprises of the targeted industrial type, with a total investment exceeding 9 billion yuan. However, field investigations indicate that the land use ratio is less than 20%.

#### (2) The enterprise composition

The Donghai Island area currently comprises three large-scale enterprises, namely China Baowu Steel Group, Zhongke Refinery Petrochemical Company Limited, and BASF, along with medium-sized and small enterprises such as Runtai Heavy Industry and Huadeli Electric. Additionally, local small and medium-sized enterprises from Zhanjiang, including Hengxiang Electromechanical and Hongrun Renewable Resources Recycling, contribute to the industrial landscape. The total number of sizable enterprises in the region is approximately 40. The enterprises in the Fenyong area are primarily small and medium-sized, including Guangdong Fenyong Heavy Steel Structure, Guangdong Nanguo Pharmaceutical, Guangdong Dongdao New Energy, Guangdong Nengsheng Biotechnology, among others, with a total of over 40 companies.

#### (3) In the industrial sector

At present, Zhanjiang port-adjacent industries are mainly based on China Baowu Steel project, forming a petrochemical industrial chains in the Donghai Island area with Zhongke Refinery Petrochemical integration project and BASF integration project base as the double leaders, relying on large oil refining, large ethylene and large aromatic hydrocarbons, and forming an automobile industry ecological chain with automobile research and development, vehicle manufacturing and logistics trade, as well as some industries such as agricultural and seafood processing and ASEAN characteristic products processing in the Fenyong area.

#### (4) In terms of spatial layout

The port-adjacent industries in Zhanjiang city are centered on the Donghai Island area, with the Fenyong area and Wushi area serving as interconnected nodes, creating a tripartite synergistic effect. Currently, the Donghai Island area adopts a spatial layout for its functional zones primarily along the coastal axis of the petrochemical industrial park to the north. This layout includes the BASF integrated project zone, the Zhongke Refinery Petrochemical integration project zone, the midstream and downstream petrochemical production and port logistics zone, the olefin raw materials and supporting production zone, and the fine chemicals and new materials production zone, among others. The Fenyong area is divided into three zones, south, middle and north, each of which is about 15 square kilometers, and is in charge of automobile-related industries, modern service industries, logistics and product processing. In addition, the Wushi area is planned to be green energy industry zone.

On the basis of the above-mentioned port-based industrial zone, the enterprise composition and spatial layout of the Donghai Island area are basically in line with the plan and seem reasonable, but the overall industrial field is still in the primary stage of agglomeration, and the supporting and extended industrial types are still lacking. The business types of enterprises in Fenyong area are complex and the correlation is low. Although it is divided into three zones in geographical space, the types of enterprises in each zone are very different, which leads to the

inconspicuous agglomeration effect. Overall, the port-adjacent industries in Zhanjiang city currently exhibit some characteristics as a small scale of agglomeration, diverse ranges of enterprise business type with weak interconnection, insufficient number of enterprises, and an agglomeration effect that has yet to materialize.

## 2.2. Analysis on the present situation of industrial chain

Based on the characteristics of industrial agglomeration in section 2.1, this section further analyzes the overall industrial chain of Zhanjiang port-adjacent from four aspects: supply chain, enterprise chain, value chain and spatial chain.

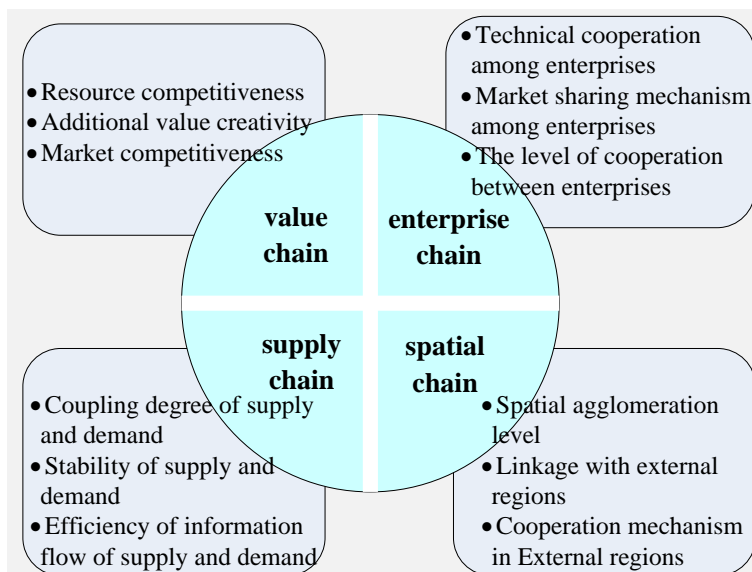


Figure 1: Four-dimensional analysis of industrial chain

### (1) The supply chain

It is the foundation of industrial chain. It refers to the series of processes through which raw materials, components, and other goods are transformed into finished products and delivered to the end consumers via a sequence of buying and selling node enterprises, driven by the relationship between supply and demand. At present, some enterprises in Zhanjiang port-adjacent industrial cluster do have a certain supply-demand relationship in product association. For instance, Zhongke Refinery Petrochemical primarily produces petroleum products such as kerosene and gasoline, as well as ethylene. And BASF's main products include engineering plastics and thermoplastic polyurethane, with ethylene being one of its key raw materials, indicating a linkage between their products and raw materials. Additionally, China Baowu Steel Group manufactures automotive sheets and steel products, which can supply relevant raw materials for new energy vehicles and electronic appliance manufacturers in the Fenyong area; supporting logistics distribution is provided by Zhanjiang Chengtong Logistics. However, as both Zhongke Refinery Petrochemical and BASF had established stable supply and demand channels prior to their collaboration, no actual supply-demand relationship was formed between them. The upstream and downstream supply chain effects extended by Zhongke Refinery Petrochemical and China Baowu Steel Group within the port-adjacent industrial cluster in Zhanjiang have initially emerged. However, the degree of coupling, stability, and efficiency of information flow remain low.

### (2) The enterprise chain

It is a specific manifestation of the industrial chain, referring to a sequence of node enterprises that are involved in the production of raw materials, components, and other related products, forming a chain of nodes. In the current port-adjacent industrial cluster in Zhanjiang, the limited

number of enterprises and the low degree of inter-firm connectivity have resulted in short industrial chains, insufficient sharing of market information, limited collaboration among enterprises, and a generally low level of mutual cooperation.

### (3) The value chain

It serves as the foundational driver for the evolution of both the supply-demand chain and the enterprise chain. And it represents a sequentially connected chain of all value-adding activities involved in the process from the procurement of raw materials to the formation of the final product and its delivery to the consumer. The port-adjacent industrial cluster in Zhanjiang is primarily focused on the green petrochemical industry chain, green automotive manufacturing, and new energy. The cluster has attracted world-leading green petrochemical giants such as BASF and Zhongke Refinery Petrochemical, which significantly enhance the resource competitiveness, value-added creation potential, and overall market competitiveness of the industrial cluster. However, at present, the degree of connection between the actual enterprises in Zhanjiang port-adjacent industrial cluster is not high, and many enterprises are upstream and downstream external enterprises, which makes the actual value chain short and fails to show the due value creation effect, resulting in the average market competitiveness and low value-added products between nodes.

### (4) The spatial chain

It is the spatial layout of node enterprises in industrial chain. In the current port-adjacent industrial cluster in Zhanjiang city, the spatial agglomeration level of steel-related enterprises in the Donghai Island area is relatively high. For instance, near the China Baowu Steel project base, small-scale related enterprises such as Zhanjiang Weida Pile and Zhanjiang Hengxiang Electromechanical have already gathered. However, the spatial agglomeration level of petrochemical-related enterprises is relatively poor, and a significant scale has yet to be formed. This also results in weaker regional linkages with external areas, such as the Greater Bay Area and the Hainan Free Trade Zone. The Fenyong area has attracted a diverse range of small and medium-sized enterprises across various industries, exhibiting a relatively high level of spatial agglomeration. However, the inter-firm linkages within the area are weak, resulting in insufficient agglomeration effects. Consequently, the ability of the area to establish strong inter-regional connections and synergies is also limited.

Overall, the port-adjacent industrial cluster in Zhanjiang is currently in a relatively weak state across the supply-demand chain, enterprise chain, value chain, and spatial chain, indicating an initial stage of development. In the supply-demand chain, there are partially mismatched supply and demand among potentially linkable enterprises, while the existing connected supply-demand industries are relatively small in scale, resulting in moderate coupling and stability between enterprises and industries; In the enterprise chain, although there is a diversity of industrial types among enterprises, the interconnections are weak, and the total number of enterprises in target industries is insufficient, leading to limited collaboration and low levels of cooperation among enterprises; In the value chain, the industrial clusters exhibit short and limited value chains, with a high dependence on external sources, resulting in low value creation. In the spatial chain, while some industries demonstrate good spatial distribution and clustering, the overall scale is insufficient or the interconnections are weak, leading to limited internal spatial chain effects and weak external linkages.

## 2.3. Main existing problems

According to the above-mentioned characteristics and the present situation of industrial chain, we can find that the main problems of Zhanjiang port-adjacent industrial cluster are as follows:

(1) There are insufficient enterprises in the target industry. At present, the number of enterprises in the target industry in the port-adjacent cluster built by Zhanjiang is insufficient.

Firstly, there is a quantitative insufficiency. Although Zhanjiang city possesses favorable port conditions and relatively well-established infrastructure, it still exhibits deficiencies in attracting and aggregating upstream and downstream enterprises in industrial chains such as petrochemicals, steel, and food. This has resulted in a sparse enterprise network within the industrial cluster, making it difficult to form tightly-knit industrial chains and efficient industrial synergies. Furthermore, there is a notable issue of quality disparity within the cluster. The enterprises in the cluster exhibit significant variations in terms of scale, technological capabilities, and innovation capacity. This heterogeneity hinders the formation of strong market competitiveness and brand influence for the industrial cluster, thereby constraining its overall development potential and growth prospects.

(2) There is a low correlation between enterprises. This phenomenon is primarily manifested in the insufficient collaboration between upstream and downstream enterprises within the industrial chain, the lack of effective mechanisms for collaborative innovation, and the inadequacy of resource sharing and information exchange. Currently, in the port-adjacent industrial cluster zone of Zhanjiang, the majority of enterprises operate independently, with a low proportion of firms establishing long-term and stable cooperative relationships with upstream and downstream partners. There is a notable lack of awareness regarding collaborative development among these enterprises. In particular, enterprises within the port-adjacent industrial cluster generally exhibit insufficient collaborative innovation. Additionally, there is a notable lack of resource sharing and information exchange among these firms. In the port-adjacent industrial cluster of Zhanjiang city, enterprises exhibit significant deficiencies in the sharing of logistics, energy, and technological resources. For instance, Zhanjiang Port, as a shared resource, is not fully utilized, with the current utilization rate by local enterprises standing at approximately 40%, which is considerably lower than that of other major port cities in China (e.g., the local utilization rate of Ningbo Port exceeds 60%). Furthermore, the development of information exchange platforms among enterprises lags behind, resulting in a lack of effective communication mechanisms. This has led to widespread resource wastage and redundant construction.

(3) The value-added in the industrial value chain is relatively low. The port-adjacent industrial cluster in Zhanjiang city is predominantly characterized by traditional industries such as petrochemicals and steel. However, these industries are largely concentrated in the stages of raw material processing and primary product manufacturing, with insufficient extension into higher value-added segments such as research and development, design, brand management, and advanced manufacturing. Therefore, the overall added value of the steel, petrochemical, and other industrial chains within the port-adjacent industrial cluster in Zhanjiang is currently relatively low, with insufficient development of high-value-added sectors such as fine chemicals and new materials. Taking Baowu Steel as an example, despite its relatively large scale, the majority of its products consist of ordinary steel, with high-end special steel accounting for only about 20% of the total output. Furthermore, the current technological innovation capabilities of enterprises within the port-adjacent industrial cluster in Zhanjiang are relatively weak. This has resulted in the industrial cluster struggling to break free from the low value-added development model, thereby constraining industrial upgrading and the enhancement of competitiveness.

(4) The industrial chain suffers from shortages and is imperfect. Currently, the petrochemical, steel, and other industrial chains adjacent to the port in Zhanjiang are not yet fully developed, and a comprehensive industrial ecosystem has not been established. In the petrochemical industry, its sector primarily focuses on crude oil processing and the production of basic chemical products. However, there is a notable absence in the downstream high-value-added segments such as fine chemicals and new materials. Additionally, the upstream critical segments, including high-end catalysts and specialty chemicals, heavily rely on external

supplies, indicating a need for enhanced local production and R&D capabilities. In the steel industry, there is a similar challenge of supply chain shortages. Currently, the number of downstream deep-processing enterprises in the steel industry in Zhanjiang city is limited, with fewer than 50 companies, and their output value accounts for only 10% of the total industry. In summary, the issue of incomplete target industrial chains within the port-adjacent industrial cluster in Zhanjiang is notably prominent, a common challenge faced by numerous industrial clusters in China during their initial stages of development.

(5) The green degree of industrial clusters is relatively low. The port-adjacent industry in Zhanjiang is predominantly centered on high-energy-consumption sectors such as petrochemicals and steel, resulting in persistently high energy intensity levels. Despite the adoption of advanced production processes by some enterprises, such as Baowu steel, the level of energy consumption remains relatively high, and the proportion of green energy usage is comparatively low. Meanwhile, the agglomeration of primary product industries within the port-adjacent industrial cluster has led to prominent issues of wastewater and waste gas pollution emissions, accounting for over 50% of the total industrial emissions in the city. However, the insufficient capacity for green technology innovation among related enterprises has resulted in a relatively low level of green and low-carbon development in the Zhanjiang port-adjacent industrial cluster.

To sum up, Zhanjiang Port-adjacent industrial cluster still faces some challenges and problems in the process of developing into a complete industrial cluster, mainly as follows: firstly, the number and quality of target industry enterprises are insufficient, making it difficult to form a tightly integrated industrial chain and achieve efficient collaboration. Secondly, the degree of inter-firm connectivity is relatively low, resulting in deficiencies in resource sharing and information exchange. Thirdly, the value-added in the industrial value chain is relatively low, and the development of high value-added segments is insufficient. Fourthly, the industrial chain suffers from shortages and inadequacies, failing to establish a comprehensive industrial ecosystem. Fifthly, the green performance of industrial clusters is relatively low, characterized by high energy consumption intensity and significant pollution emission issues. These issues have hindered the formation of a green port-adjacent industrial cluster in Zhanjiang city, necessitating the implementation of effective measures to promote the development of a high-quality, low-carbon, and comprehensive port-adjacent industrial cluster.

### **3. Path design and action mechanism analysis of high-quality green port-adjacent industrial cluster in Zhanjiang city**

In light of the primary issue concerning the incomplete formation of the port-adjacent industrial cluster in Zhanjiang, this paper, guided by the principles of green and sustainable development, proposes a well-structured pathway for the establishment of a green port-adjacent industrial cluster. Furthermore, it delves into the underlying mechanisms that facilitate its effectiveness.

Based on systems theory, this paper constructs a design approach for the formation path of Zhanjiang's green port-oriented industrial cluster, guided by the principle of "green and low-carbon development", founded on "trade policy + platform", and aimed at the industrial cluster's objectives of "supplementing the chain → extending the chain → strengthening the chain". For details, refer to Figure 2. Specifically, the formation pathway encompasses five key nodes: green and low-carbon development concept, trade policies and platforms, chain complementation, chain extension, and chain strengthening.

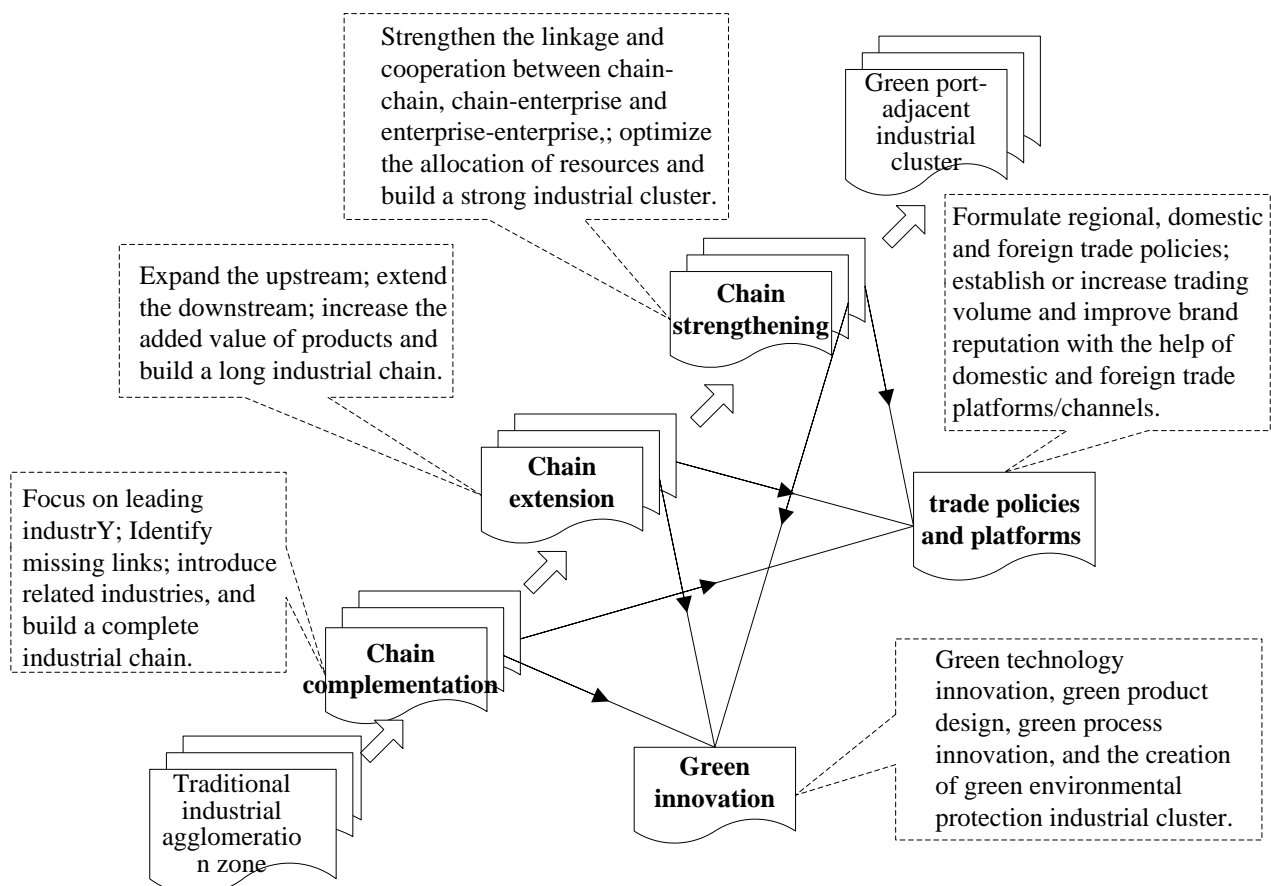


Figure 2: Path design of Zhanjiang green port-adjacent industrial cluster formation

In Figure 2, the existing port-adjacent industrial agglomeration zone in Zhanjiang can achieve the formation of a green port-adjacent industrial cluster through a step-by-step approach of supplementing, extending, and strengthening the industrial chain, based on the foundations of green innovation, trade policies, and platforms. Adhering to the principles of green and low-carbon development, the enterprise cluster within the Zhanjiang port-adjacent industrial zone can foster the creation of an environmentally friendly industrial community by advancing green technology innovation, optimizing green product design, and implementing green process innovation, thereby achieving sustainable development. In terms of trade policies and platforms, the Zhanjiang government and enterprises can formulate trade policies targeting regional, domestic, and international markets. Additionally, they can establish or leverage domestic and international trade platforms and channels to increase transaction volumes and enhance the brand reputation of port-adjacent industrial agglomeration enterprises in Zhanjiang. In parallel, initiating from "chain complementation" as the foundation, the approach centers on the core industries, accurately identifies gaps within the industrial chain, integrates related ancillary industries, and establishes a fully integrated industrial chain. Secondly, by "chain extension" to expand upstream and extend downstream, the added value of products is enhanced, creating a vertically extended long industrial chain. Finally, with "chain strengthening" as the core, the synergy within the industrial chain, between chains, and among enterprises is reinforced, optimizing resource allocation and constructing a highly efficient and competitive industrial cluster system, thereby promoting high-quality development of the industry.

From a systematic point of view, the five major path points have comprehensively optimized the loose industrial structure of the original traditional industrial agglomeration, and formed a strong, competitive and complete industrial chain cluster. The action position (see Figure 3 for details) and action mechanism of each path point in system optimization are as follows.

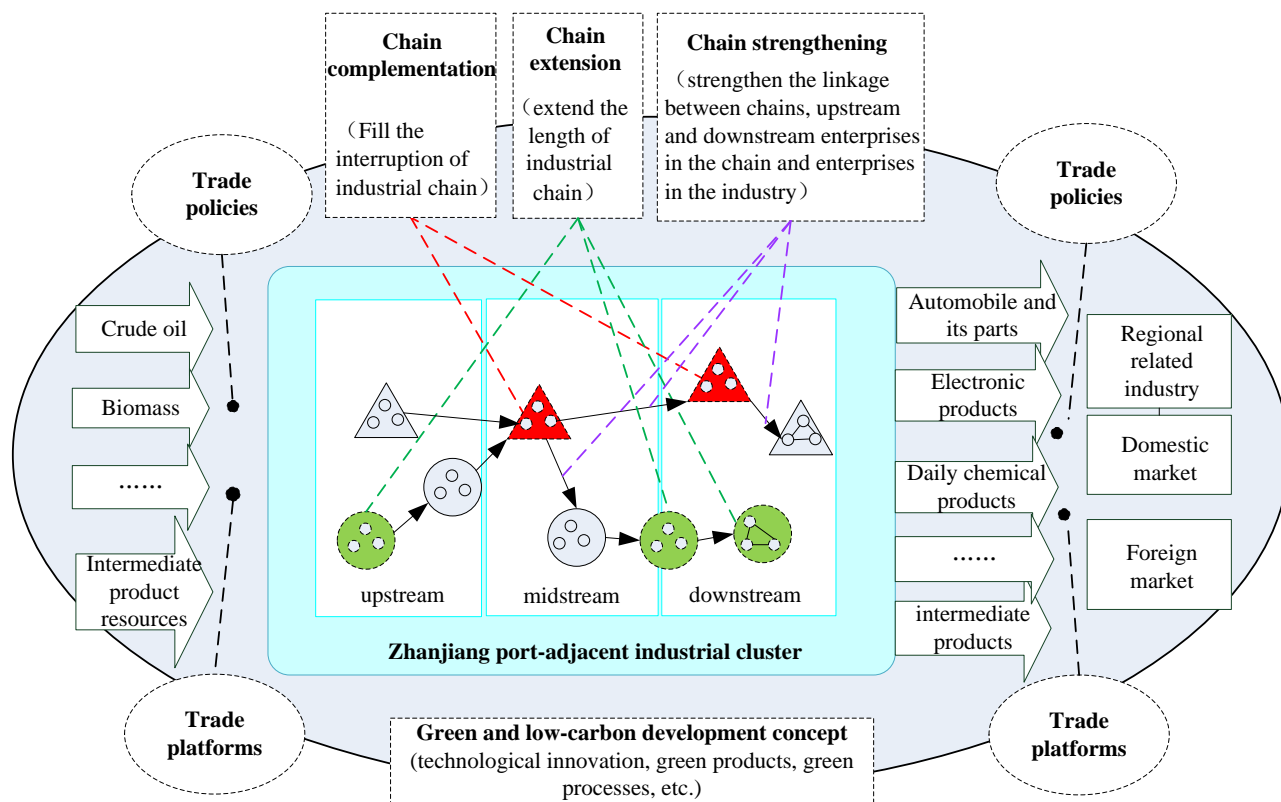


Figure 3: Analysis framework of action mechanism of forming path under system theory

(1) Green and low-carbon development concept

Green and low-carbon development concept, as the basic concept of Zhanjiang’s green port-facing industrial cluster formation, has been refined into all aspects of the formation of the path system. It can point out the direction for the planning of industrial cluster, urge Zhanjiang government or enterprises to give priority to resource-saving and environment-friendly projects in industrial layout and resource utilization, and promote the traditional industries with high energy consumption and high pollution to transform into low carbon. Secondly, the concept of green and low carbon encourages enterprises to adopt clean energy and energy-saving technologies through policy guidance and market mechanism, so as to reduce carbon emissions and improve the efficiency of resource utilization, thereby enhancing the sustainable competitiveness of industrial cluster. At the same time, relying on the advantages of Zhanjiang Port, we will develop green logistics and circular economy, promote the cooperation between upstream and downstream of the industrial chain near the port, and form a low-carbon closed loop. The concept of green and low carbon is helpful to enhance the brand image of Zhanjiang port-adjacent zone, attract more green investment and technical cooperation, and inject innovation power into industrial cluster.

(2) Trade policies and platforms

Trade policies and platforms are the important support of Zhanjiang port-adjacent industry's external trade, which are at the front and rear ends of the formation path system, and provide efficient and convenient trading mechanisms and channels for the supply of raw materials such as crude oil and biomass in the upstream of industrial cluster, as well as the output of industrial clusters such as parts, electronic products and intermediate products. Perfect trade policies and platforms will help to reduce transaction costs, improve logistics efficiency and optimize the allocation of resources, thus enhancing the competitiveness of Zhanjiang port-adjacent industrial cluster. At the same time, they can attract more domestic and foreign enterprises to

participate in the industrial chain division, promote technological innovation and industrial upgrading, and inject vitality into the sustainable development of Zhanjiang port-adjacent industrial cluster. A good trade policy and platform will help improve the level of regional opening up, promote international trade cooperation and create favorable conditions for Zhanjiang port-adjacent industrial cluster to integrate into the global value chain.

### (3) Chain complementation

Chain supplementation is one of the pivotal components in the formation of Zhanjiang's green port-adjacent industrial cluster and constitutes the current primary imperative. There is an urgent need to fill the existing gaps in Zhanjiang's targeted port-adjacent industrial chain. For the Zhanjiang port-adjacent industrial cluster zone, which is still in the nascent stage of industrial agglomeration, implementing chain complementation initiatives proves critical to addressing missing links within petrochemical and steel industrial chain. This strategic approach facilitates the formation of comprehensive industrial chains through vertical integration, enabling tight operational coupling and high-efficiency synergies across supply networks, production systems, and value-added processing segments. Through supply chain complementation, the port-adjacent industrial cluster in Zhanjiang will further enhance the resilience and competitiveness of its industrial chains, accelerate the maturation and development of industrial agglomerations, and establish a solid foundation for high-quality economic growth in the region.

### (4) Chain extension

Chain extension is a critical operation following chain complementation, positioned at the front and rear ends of the target industrial chain within the formation pathway system. It primarily addresses the truncated industrial chain in the port-adjacent industrial cluster of Zhanjiang by integrating upstream supplier resources and expanding downstream deep-processing sectors, such as fine chemicals, advanced materials R&D, and high-end equipment manufacturing. Industrial chain extension can effectively elongate industrial chain and enhance its added value. This initiative contributes to increasing the value of the industrial chain, promoting the sound development of the industrial cluster, while improving resource utilization efficiency and industrial competitiveness. Through chain extension, the Zhanjiang port-adjacent industrial cluster zone will further achieve vertical extension and horizontal expansion of the industrial chain, injecting sustained growth momentum into the regional economy.

### (5) chain strengthening

Chain strengthening represents a strategic optimization and upgrading of port-adjacent target industrial chain in Zhanjiang, building upon foundational efforts of chain supplementation and chain extension. This concept permeates all phases of industrial chain formation pathway systems, aiming to enhance overall efficiency through intensified inter-enterprise collaboration and systematic integration of resources, technological capabilities, and innovation advantages across the value chain. Chain strengthening is to enhance the resilience, flexibility, and agility of supply chains, thereby reinforcing the risk resilience of the industrial chain. This enables them to efficiently respond to fluctuations in market demand and swiftly adapt to uncertainties in external environments. The Zhanjiang port-adjacent industrial agglomeration zone will establish a more robust, efficient, and sustainable industrial chain system through industrial chain consolidation and reinforcement, thereby enhancing the global market competitiveness of its supply chain ecosystem.

#### 4. Policy suggestions on promoting the formation of Zhanjiang green port-adjacent industrial cluster

The construction of Zhanjiang's green port-adjacent industrial cluster requires the formulation and implementation of multi-departmental policies, as well as the participation and support of various stakeholders. According to the design of the formation path of Zhanjiang green port-adjacent industrial cluster mentioned above, combined with the current situation and existing problems of industrial agglomeration, this paper puts forward the following series of policy suggestions to promote the formation of Zhanjiang green port-adjacent industrial cluster.

(1) Establish the concept of green sustainable development and introduce green and low-carbon development initiatives along with incentive policies

The concept of green sustainable development emphasizes the harmonious integration of economic growth and environmental protection, aiming to achieve long-term healthy economic development by reducing environmental pollution and maintaining ecological balance. The Zhanjiang municipal government departments can guide enterprises within the port-adjacent industrial cluster to adopt green and sustainable development practices by formulating green and low-carbon development policies. Specifically, the Zhanjiang Development and Reform Bureau can take the lead, in collaboration with relevant departments such as the Zhanjiang Ecological Environment Bureau and the Zhanjiang Industry and Information Technology Bureau, to establish and improve a carbon emission trading mechanism for key energy-consuming enterprises, high-emission enterprises, and green technology innovation enterprises within industrial clusters. They should formulate green and low-carbon industry support policies, promote the optimization and upgrading of the industrial structure, and facilitate the application and innovation of green technologies, thereby achieving a win-win situation for both economic and ecological benefits.

(2) By leveraging various trade platforms, refine the trade promotion policy system and facilitate effective trade between the supply and sales ends of the industrial chain

By leveraging global and regional trade platforms, complemented by a comprehensive trade promotion policy system, the supply and output of port-adjacent industries in Zhanjiang can be effectively accelerated. For the port-adjacent industrial cluster zone in Zhanjiang, the Zhanjiang Municipal Bureau of Commerce could take the lead, jointly with the Zhanjiang Municipal Development and Reform Bureau, the Zhanjiang Municipal Bureau of Industry and Information Technology, the Zhanjiang Municipal Transportation Bureau, and the Zhanjiang Municipal Finance Bureau, to formulate and issue specialized trade support policies. These policies may include tax incentives, logistics subsidies, export credit insurance support, etc., aimed at reducing the trade costs for enterprises; establish a Trade Development Special Fund to support enterprises in participating in international exhibitions and engaging in cross-border e-commerce; leveraging partnerships with renowned domestic and international e-commerce platforms, supply chain platforms, and exhibition platforms, we aim to establish an integrated online and offline trade promotion platform. This platform will provide enterprises with services such as supply-demand matching, market expansion, and brand promotion.

(3) Create a favorable business environment to attract and introduce target industrial enterprises for chain complementation and extension initiatives

Creating a favorable business environment is crucial for attracting and introducing target industrial enterprises in the chain supplementation and chain extension initiatives. This will help strengthen the weak links in Zhanjiang's port-adjacent industrial cluster, expand the upstream and downstream of the industrial chain, and enhance the integrity and connectivity of the industrial chain. In the port-adjacent industrial cluster zone of Zhanjiang, with a focus on the chain complementation and extension initiatives, targeted enterprises (including leading

enterprises, specialized and sophisticated SMEs, and key players in the industrial chain) in sectors such as high-end equipment manufacturing, green petrochemicals, new energy, modern logistics, and marine economy are being prioritized. The Zhanjiang Investment Promotion Bureau, in collaboration with the Zhanjiang Development and Reform Bureau, Zhanjiang Industry and Information Technology Bureau, Zhanjiang Natural Resources Bureau, Zhanjiang Taxation Bureau, and Zhanjiang Market Supervision Administration, has jointly developed and implemented mechanisms such as "one-stop online services" and "tolerating deficiencies in acceptance" to streamline the processes of business establishment and project approval; establish a "green channel" to provide efficient and convenient government services for key industrial enterprises; prioritize land use requirements for target industrial projects, offer tax reductions, land use incentives, and fixed asset investment subsidies to eligible enterprises; formulate specialized talent policies to attract high-level professionals and technical teams; and improve living such as education, healthcare, and housing. Meanwhile, through international exhibitions, thematic promotion events, and other formats, Zhanjiang's port-adjacent industrial advantages are being promoted, enabling precise investment attraction in the industrial chain and drawing high-quality enterprises to establish their presence.

(4) Deepen the empowerment of digital intelligence, encourage enterprises to intensify their technological innovation efforts, and enhance the value creation capacity of the industrial chain. Deepening the empowerment of digital intelligence and encouraging enterprises to intensify their technological innovation efforts can effectively enhance the intelligence and automation levels across various segments of the industrial chain. This strengthens the value creation capacity of the industrial chain and propels the Zhanjiang port-adjacent industrial cluster towards a high-end, efficient, and high-quality development trajectory. For manufacturing enterprises, technology-based enterprises, digital transformation service providers, and upstream and downstream enterprises in the industrial chain within the port-adjacent industrial zone, especially high-tech enterprises, specialized and sophisticated "little giant" enterprises, and digital transformation pilot enterprises, the Zhanjiang Science and Technology Bureau can take the lead, jointly with the Zhanjiang Bureau of Industry and Information Technology, Zhanjiang Development and Reform Bureau, Zhanjiang Finance Bureau, and Zhanjiang Human Resources and Social Security Bureau, to promote the construction of new digital infrastructure such as 5G networks, industrial internet, and big data centers; establish special funds to support enterprises in implementing intelligent transformation, building digital workshops and smart factories, and promoting the application of industrial internet platforms; encourage enterprises to collaborate with universities and research institutions to jointly establish technological innovation alliances and R&D centers.

(5) Establish an industrial chain information exchange platform, improve information communication channels between enterprises, and promote in-depth collaboration among businesses

The establishment of an industrial chain information exchange platform can enhance the communication channels between enterprises, accelerate information sharing and technical exchanges, and promote in-depth cooperation and innovative collaboration among enterprises. This plays a crucial role in the formation of the port-adjacent industrial cluster in Zhanjiang. In the port-adjacent industrial cluster area of Zhanjiang, targeting manufacturing enterprises, logistics enterprises, trade enterprises, technology-based enterprises, and related enterprises in the upstream and downstream of the industrial chain, especially leading enterprises, small and medium-sized enterprises, and core enterprises in the supply chain, the Zhanjiang Municipal Bureau of Industry and Information Technology can take the lead, collaborating with the Zhanjiang Municipal Bureau of Commerce, the Zhanjiang Municipal Bureau of Science and Technology, the Zhanjiang Municipal Market Supervision Administration, and the Zhanjiang

Municipal Government Service Data Administration, to take some measures, such as promoting the establishment of a digital platform integrating functions such as enterprise supply-demand matching, technical exchange, and resource sharing; regularly organizing industrial chain matchmaking events, industry forums, and technical seminars to provide enterprises with face-to-face communication opportunities, to promoting precise matching between supply and demand; encouraging enterprises to open non-core data and establish data-sharing incentive mechanisms to facilitate information interconnection across the industrial chain; establishing and improving data security management mechanisms to ensure the safety and compliance of enterprise information during the sharing process.

(6) Construct fundamental shared facilities, deepen the integration of industrial chain resources, and enhance the overall operational efficiency and profitability of the industrial chain

The construction of shared infrastructure facilities, the deepening of resource integration across the upstream and downstream sectors of the industrial chain, and the optimization of resource allocation can enhance the overall operational efficiency and profitability of the Zhanjiang port-adjacent industrial chain, laying a solid foundation for the formation of the Zhanjiang port-adjacent industrial cluster. For manufacturing enterprises, logistics companies, technology-based firms, and related upstream and downstream enterprises in the industrial chain within the port-adjacent industrial area of Zhanjiang, particularly small and medium-sized enterprises and core supply chain enterprises, the Zhanjiang Development and Reform Bureau, in collaboration with the Zhanjiang Bureau of Industry and Information Technology, the Zhanjiang Bureau of Natural Resources, the Zhanjiang Bureau of Transportation, and the Zhanjiang Bureau of Finance, can jointly take some measures, such as planning and constructing standardized factory buildings, shared warehouses, logistics hubs, and other infrastructure to provide enterprises with low-cost, high-efficiency sharing spaces and services; establishing an industrial chain resource integration platform to promote the sharing and optimal allocation of resources such as raw materials, equipment, technology, and talent, thereby reducing operational costs for enterprises; construct public service facilities such as inspection and testing centers, technology R&D centers, and talent training bases to provide enterprises with technical support and service guarantees; granting policy support such as rental subsidies and tax incentives to lower the entry threshold for participation to the enterprises that utilize shared facilities and participate in resource integration; and adopting the big data, internet of things technologies to enable intelligent management of shared facilities, resource utilization and operational efficiency.

## 5. Conclusion

The foundation and driving force of port-adjacent economies lie in the development of their industrial clusters. This article provides a comprehensive overview of the current state of industrial agglomeration in the port-adjacent zone of Zhanjiang city, revealing the distinctive characteristics of its steel and chemical industry cluster. It further analyzes, from the perspective of the industrial chain, issues related to upstream and downstream linkages, connectivity, and the completeness of the industrial chain within the agglomeration zone. Research findings indicate that the Zhanjiang port-adjacent industrial cluster exhibits deficiencies in several critical areas, including the number of enterprises within the target industries, the degree of inter-firm connectivity, the value-added of industrial chains, and the completeness of the industrial chain. These shortcomings hinder the formation of a robust industrial cluster in the Zhanjiang port-adjacent region.

Based on the perspective of systems theory, this paper constructs the formation pathway of the green port-adjacent industrial cluster in Zhanjiang city, clarifies the role and mechanism of each

pathway point within the system, and provides theoretical support for the green development of Zhanjiang's port-adjacent industry. Based on this, this paper proposes a series of targeted policy recommendations aimed at promoting the formation of a high-quality green port-adjacent industrial cluster in Zhanjiang.

Specifically, it is recommended to establish a green and sustainable development philosophy, launch initiatives and incentive policies for green and low-carbon development, leverage various trade platforms to refine the trade promotion policy system, and facilitate effective trade at both the supply and sales ends of the industrial chain, create a favorable business environment to attract and introduce target industrial enterprises for chain complementation and chain extension plans; deepen the empowerment of digital intelligence, encourage enterprises to increase their efforts in technological innovation, and enhance the value creation capability of the industrial chain; establish an information exchange platform for the industrial chain, improve communication channels between enterprises, and promote in-depth cooperation among enterprises; build shared infrastructure, deepen the integration of industrial chain resources, and improve the overall operational efficiency and profitability of the industrial chain.

The research presented in this paper aims to provide valuable insights for the green development of port-adjacent industry in Zhanjiang city, thereby contributing to the high-quality economic growth of the region.

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