Research on the Economic Benefits of the Green Port Supply Chain Under the Dual Carbon Goal: Take the Yangtze River Delta Port Cluster as an Example

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Abstract: With the proposal of green development, the dual carbon policy is developing fast. In the context of achieving carbon peak and carbon neutrality and promoting the green transformation and sustainable development of the economy and society, ports, as one of the industries with high pollution and high emissions, have to face a problem of green transformation. The improvement of policies makes it urgent to promote the green process of ports. This report takes a typical port case study in the Yangtze River Delta as the research object, and analyses it qualitatively using economic theories to analyse the impacts of green transformation on the benefits and costs of ports in terms of short-term economic benefits, long-term economic benefits and externality theories respectively. The analysis found that the greening of the port supply chain is costly in the short term, with a negative impact on the growth rate of enterprises. However, from the perspective of long-term economic benefits, along with the continuous improvement of carbon neutral policies, the full implementation of green transformation is positive for enterprises. The greening of the port supply chain is also consistent with positive externalities, with positive impacts on the environment and the lives of the surrounding population.

1 INTRODUCTION

The core policy of ‘Dual carbon’ treats framework as the ‘1+N’ system (Xu,2022). Against the background of accelerating progress towards the clear milestones of carbon peaking by 2030 and carbon neutrality by 2060, the green transformation of the transport sector, as an important component of global carbon emissions, has become a key link in achieving sustainable development (Hao, Chen and Zhang,2022). Ports, as hubs of international trade, occupy a central position in the logistics supply chain. As one of the busiest port clusters in China, the Yangtze River Delta port cluster has a large scale of total carbon emissions and energy consumption. Therefore, promoting the construction of green port supply chain is of essential significance to the low-carbon development of the region and the whole country. At present, domestic and international research on port greening mostly focuses on the application of emission reduction technologies in a single link, and lacks a systematic analysis of the economic benefits of the whole chain of the supply chain. This paper takes the Yangtze River Delta port cluster as the research object. By analysing the internal logic of the green port supply chain between low-carbon technology investment, energy structure optimization and economic efficiency improvement, we aim to reveal the cost-benefit characteristics of port supply chain transformation under the dual-carbon goal. This article tries to provide a theoretical basis and practical path for the port cluster to realize the synergistic development of environmental and economic benefits.

2 ANALYSES OF THE CURRENT SITUATION

The core elements of a green port supply chain cover a wide range of areas such as shipping, port operations, circular economy and knowledge sharing.

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Technology pathways include clean energy, smart management, carbon capture and waste recycling. Tianjin Port is an early developer of green ports. As early as 2008, Tianjin Port incorporated green port construction into the port's construction and development plan, and carried out green planning and construction for the port in three stages from 2008 to 2020. As of 2015, the green coverage rate of Tianjin Port has reached 20%, with a total green area of 7.95 million square meters. As one of the largest port clusters in the world, the green transformation of the Yangtze River Delta port cluster has experienced an evolution from localized pilots to systematic promotion. In 2017, Shanghai officially launched the construction of "Green Port Shore Power Demonstration Area", and the high-voltage shore power systems of Yangshan Port and Wusongkou International Cruise Terminal were put into operation, which can reduce carbon emissions by 2,040 kilograms in a single port call. Promoting the development of green and low-carbon shipping industry is an important goal, and according to the requirements of the Water Transport Bureau of the Ministry of Transportation and Communications, full coverage of standardized shore power facilities at berths of 2,000-ton terminals in Shanghai will be achieved by the end of November 2023. Ningbo Zhoushan Port has put into use liquefied natural gas (LNG) collector trucks since 2010, and the total number of collector trucks reached 700 by the end of 2018. The cumulative number of LNG filling stations has also reached 11, which to a large extent meets the demand for natural gas for port equipment. At present, Ningbo Zhoushan Port is vigorously promoting the construction of green port. Gantry crane "oil to electricity" project has realized the full coverage of Ningbo port area, terminal green lighting coverage rate of more than 63%. LNG (liquefied natural gas) truck scale is the largest in the country's ports, container terminal shore power coverage rate of 60%. The application rate of potential energy recovery technology for large electric machinery has reached over 90%. By the end of 2023, 78 seaport terminal enterprises in the Port of Shanghai had built low-voltage, small-capacity standardized shore power, and more than 90% of SIPG's terminal facilities had been decarbonized. Green ship orders from Shanghai's shipping enterprises have also grown significantly. In 2024, Shanghai's three largest shipbuilders will have delivered 69 ships and received 128 new orders, a year-on-year increase of 19% and 70% respectively (Chen, 2016) (Zhu, 2019).

However, the advancement of greening process will encounter some practical problems while proceeding in an orderly manner. Core ports in the Yangtze River Delta, such as Shanghai Port and Ningbo Zhoushan Port, have realized full coverage of shore power and large-scale application of new energy equipment, but small and medium-sized ports, such as Nantong Port and Jiaxing Port. However, small and medium-sized ports, such as Nantong Port and Jiaxing Port, are limited by capital and technical capacity, the popularization rate of new energy equipment is less than 30%, and the energy consumption of a single container is still higher than the industry average by 15%. From the legal level, green regulation in the specific implementation of the regulatory standards are still inconsistent, the coverage of pollutant receiving facilities is uneven, affecting the cost of corporate compliance as well as the deployment of facilities in various places (Ren,Zhou and Zhu, 2023) (Zhao,Zhang and Zhao, 2025).

3 ANALYSIS OF THE CURRENT SITUATION

3.1 Short-Term Economic Benefits

Under the guidance of the "dual-carbon" strategy, the Yangtze River Delta port cluster has accelerated the construction of green port infrastructure, but this process is usually accompanied by a rising economic burden in the short term. As an example, Yangshan Port, a subsidiary of Shanghai Port Group, has invested more than 20 million yuan in the construction of shore power facilities for ships by 2018 as a green demonstration project, which can satisfy the simultaneous use of shore power by multiple ships. The use of shore power technology by ships at berth is a key technology to reduce environmental pollution in ports. And shore power technology also requires a lot of investment, shore power system using high-voltage inverter technology, need to support the ship and shore interface transformation, but limited by high cost (single set of equipment investment of about 5 million yuan) and electricity price contradiction. Yangshan Port due to administrative belonging to Zhejiang led to electricity prices as high as 1.5 yuan / degree, while the port can only charge 1.06 yuan / degree, a loss of 0.44 yuan per unit of electricity, the economy is seriously inadequate (Yuan,Ma and Wang, 2025). Until 2022, according to the annual report of Shanghai Port Group, the government subsidies related to the shore-based power supply project totalled 152 million yuan,

of which the deferred income portion is dominant. In addition, the State has rewarded 245 projects and about 736 million yuan through three batches of subsidies. In addition to the shore power system, the LNG cold energy recovery station and the automated terminal intelligent control platform, with an initial investment of up to billions of dollars, have brought about significant costs for equipment procurement, technical maintenance and personnel training. For small and medium-sized port enterprises, it is even more enormous cost pressure, these enterprises may be unable to maintain operations and thus launch the market competition. This characteristic of "heavy investment in the first period and low return in the short term" is in line with the typical characteristics of cost-benefit analysis (CBA): in the short term, due to the rigid costs of fixed asset investment and institutional change, the financial pressure on enterprises has risen markedly, and the economic performance has declined in stages (Deng, Chen and Liu, 2025).

3.2 Long-Term Economic Benefits

However, in the long run, the marginal benefits of such green transformation investments are gradually emerging. First of all, the large-scale application of shore power technology in Yangshan Port significantly reduces carbon emissions and fuel consumption expenditure during the port call of ships, which can reduce carbon emissions by more than 20,000 tons per year, and circumvents potential costs for the possible rise of carbon tax in the future, such as the full implementation of the European Union's Carbon Border Adjustment Mechanism (CBAM) in 2026, reflecting the long-term cost-saving advantage (Ministry of Commerce of the People's Republic of China, 2024). Avoiding potential costs reflects the long-term cost-saving advantage. Secondly, the construction of green port enhances the corporate image and customer adhesion, and some European and American high-end shippers explicitly stated that they "preferred low-carbon terminals", which brings "green premium" and more stable transportation cooperation relationship. In addition, the operation efficiency of the fully automated terminal has been increased by 30%, the loading and unloading time of a single vessel has been shortened by 10 hours, and the annual throughput capacity has exceeded 25 million TEUs. In addition to the benefits of green transformation of Yangshan Port, Ningbo Zhoushan Port in the Yangtze River Delta Port Group has introduced new energy container trucks and loading and unloading machinery on a large scale in recent years. According to Ningbo Zhoushan Port Group, the transportation cost per kilometer of electric collector trucks is about 65% of that of diesel trucks, while the maintenance frequency and repair cost of electric forklift trucks have also dropped significantly, reducing short-term operation and maintenance costs.

3.3 Externality Theory

In addition, from the perspective of externality theory, the environmental improvement and health benefits brought by green ports are typical "positive externalities". With the reduction of carbon emissions, the green GDP rate of Shanghai port will increase from 93.71% in 2017 to 96.22% in 2025.

However, since traditional market mechanisms cannot adequately account for these public benefits, it is necessary for the government to internalize the external contribution of enterprises and enhance the economic attractiveness of green port construction through financial subsidies, green bonds, and carbon credit trading. This also explains why in recent years the state has increased its investment in green and low-carbon special funds in core ports such as Yangshan and Ningbo Zhoushan.

4 SUGGESTIONS

4.1 Government Subsidies

One of the key issues that enterprises are concerned about is profit, and the upfront cost of green transformation is also already a considerable burden for large port enterprises, and the burden is even heavier for small and medium-sized enterprises, which further compresses their profits. For enterprises that have carried out shore power transformation, there are some enterprises just to complete the task, the use of shore power interface and the hull of the shore power interface does not match, the significance of the capital invested is limited, and this is the enterprise in order to save the short-term interests of the strategy used. For enterprises that have not carried out green innovation, in response to this problem of high short-term costs of short-term green transformation, the government can implement green transformation subsidies, especially for small and medium-sized enterprises to provide targeted assistance. The launch of green funds and the development of green finance will lay a solid foundation for the green transformation of ports (Li,Zhang and Lin et al, 2019).

4.2 Mutual Assistance Among Enterprises

Mutual assistance among alliances is an important accelerating push to strengthen the development of the industry, just like the shipping alliance 2M, the Ocean Alliance and THE Alliance which are well known to the public, although they are the same shipping enterprises, the direction of the operation they mastered is still different. Shipping as a high-cost industry, the alliance can minimize the waste of resources, focusing on the advantages of enterprises. Therefore, port enterprises can also refer to this initiative. During the period of green transformation, enterprises can also conduct regular green reform seminars to collect and organize successful cases for sharing, so that more enterprises can have information to base on to accelerate the green transformation of port enterprises. In addition, enterprises can also form a green transformation alliance, similar conditions of enterprises can carry out technical interoperability research.

4.3 Sectoral Regulation

In addition to moderate subsidies, the strength of regulation should also be strengthened. For the government, when enterprises carry out shore power transformation, it can make it unified with the hull interface, try to avoid the disadvantages of transformation, but it can not be officially put into use. Secondly, consideration can be given to setting up monitoring points in the vicinity of port enterprises, setting up relevant departments to record and visualize the impact of green transformation on the surrounding environment, and further standardizing the carbon accounting standards of each enterprise.

5 CONCLUSIONS

From the above analysis, we can conclude that although green ports are facing the pressure of "inputs are greater than outputs" in the short term, from the perspective of cost-benefit of the whole life cycle, their long-term economic benefits are highly sustainable, and the multiple dividends of policy, market and society will be gradually realized in the future. In terms of policy, environmental measurement requirements will be further improved, and the regulation of carbon emissions will be further tightened. For the market, carbon trading may become a new wind direction subsequent research can build a multi-dimensional analysis framework: on the one hand, collect energy consumption data, carbon emission reduction inputs and throughput changes in the last five years in major coastal ports and other panel data, use the DEA model to calculate the pure technical efficiency of the green technology inputs and the scale of the efficiency, quantify the investment in new energy equipment, the coverage of the shore power facilities and other variables of the economic efficiency of the marginal contribution. Focus on the carbon accounting method of enterprises. On the other hand, two scenarios of "10% increase in green subsidies" and "20% increase in carbon tax rate" are set up to simulate the decrease in energy consumption per ton of cargo, the incremental carbon trading revenue and the shortening of payback period under different policy combinations to provide quantitative bases for policy formulation and enterprise decision-making. This paper aims to provide a quantitative basis for policy formulation and enterprise decision-making. The purpose of this paper is to provide a planning basis and direction for the green development of enterprises, and there is still a long way to go for the green supply chain transformation of port enterprises, which can be supported by more favourable data after more accurate calculations are made in the future. Greening is not only a direction that the port industry needs to work on, but also a topic that society as a whole is constantly researching in order to achieve the goal of "carbon peak and carbon neutral".

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