



Regional Integration and the Dual Carbon Goals

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Abstract. Carbon emissions and the resulting climate issues have garnered global attention. The impact of regional integration on carbon emission efficiency holds significant academic and policy implications. Through literature analysis and a case study of China's Yangtze River Delta region, this paper explores the influence of regional integration on carbon emission efficiency. The study finds that regional integration significantly enhances carbon emission efficiency by optimizing resource allocation, promoting technological innovation, and establishing a unified carbon market. In the Yangtze River Delta, regional integration not only drives economic growth but also reduces carbon emission intensity through cross-regional resource integration and carbon trading markets. Based on the findings, this paper recommends expanding the scope of regional integration and strengthening its linkage with technological innovation to support the achievement of the "dual carbon" goals.

Keywords: carbon emissions; integration; efficiency

1 Introduction

Carbon emissions and the resulting climate issues have become a global focus. As the world's largest carbon emitter, China proposed the "dual carbon" goals at the 75th United Nations General Assembly on September 22, 2020, aiming to achieve carbon peaking by 2030 and carbon neutrality by 2060 (Guo et al., 2022)[1]. As economic development pattern changes from investment driven to innovation driven, regional integration will be a major trend in China's economic growth. Regional integration facilitates the cross-regional flow of goods and factors, optimizes resource allocation, and enhances economic efficiency. It also provides a potential pathway for improving carbon emission efficiency to achieve the "dual carbon" vision on schedule (Xu, 2023)[2].

To explore how regional integration enhances carbon emission efficiency, this paper first reviews relevant literature, covering three aspects: the green transformation of industrial sectors, how regional integration reduces carbon emissions, and carbon market integration. Building on this literature, the study analyzes the current state of regional integration and carbon emission efficiency in China's Yangtze River Delta, incorporating real-world case studies from industrial enterprises. The findings reveal that in-

creased regional integration in the Yangtze River Delta helps enterprises optimize resource allocation and improve the efficiency of carbon trading markets, thereby enhancing carbon emission efficiency.

Based on the above findings, this paper proposes the following policy recommendations. First, enhance the level of regional integration, which facilitates enterprises in efficiently utilizing comparative advantages across regions, improving production efficiency, and thereby increasing carbon emission efficiency. Second, strengthen the development of a unified carbon trading market. A standardized carbon market can better meet the carbon emission allowance demands of industrial enterprises, provide economic incentives for environmentally friendly firms to reduce emissions, and enhance corporate motivation for decarbonization.

The rest of this paper is structured as follows. Section 2 summarizes the relevant literature. Section 3 provides a case study of Yangtze River Delta in China. Section 4 concludes.

2 Literature Review

There is extensive literature on regional integration and carbon emissions. This paper reviews the literature from three perspectives: the green transformation of industrial sectors, how regional integration reduces carbon emissions, and carbon market integration.

2.1 Factors Influencing the Green Transformation of Industrial Sectors.

The industrial sector is the primary source of carbon emissions, and efforts to reduce carbon emissions should therefore focus on this sector. The green transformation of industry is influenced by three main factors: resource factors, policy factors, and innovation factors (Li, 2023)[3]. First, from a resource perspective, improving the efficiency of resource allocation can alter the existing input structure of production factors without increasing their scale, thereby enhancing green productivity. Conversely, resource misallocation often leads to distorted price signals, resulting in excessive energy consumption and declining productivity for enterprises. The resulting high energy consumption and emissions encourage firms to adopt traditional high-input, high-emission production methods, which hinder industrial green transformation (Yang et al., 2018)[4].

Second, from a policy perspective, existing literature has found an inverted U-shaped relationship between government environmental regulations and corporate green productivity (Sun and Liu, 2021; Yuan and Bu, 2022)[5,6]. This is because excessively stringent environmental requirements increase operational costs for enterprises, crowding out their investments in research and development of green production technologies, which may ultimately impede improvements in green productivity.

Finally, from an innovation perspective, technological progress is the core driver of corporate energy conservation and emission reduction. Technological innovation plays a crucial role in enhancing resource utilization efficiency, reducing pollution emissions,

and promoting regional green economic development, thereby facilitating industrial green transformation (Guo et al., 2017)[7].

2.2 Regional Integration Can Reduce Carbon Emissions

Improving carbon emission efficiency means that reduces carbon emissions without decreasing economic output, or increases economic output without raising carbon emissions. Since regional integration optimizes the allocation of factor resources and improves economic efficiency, it facilitates higher economic output per unit of carbon emissions. Wang and Yuan (2022)[8], based on spatial panel data from 37 cities in the Yangtze River Delta region from 2010 to 2020, empirically found that both regional integration and manufacturing supply chain efficiency exhibit significant spatial autocorrelation. Therefore, regional integration can enhance economic efficiency by improving supply chain efficiency.

Zhang et al. (2023)[9], using data from Chinese prefecture-level cities, found that regional integration significantly drives economic growth in cities along the Yangtze River Economic Belt. The mechanism lies in the fact that regional integration indirectly promotes urban economic growth through capital flows and financial development as intermediaries. More directly, regional integration provides firms with more opportunities to choose partners with relatively lower opportunity costs. The profit-maximizing motive also encourages firms to focus more on their areas of expertise, leading to technological and managerial specialization—key sources of productivity growth. Thus, regional integration fosters productivity development at the micro-level of firms and improves regional carbon emission efficiency.

Regional integration strengthens inter-regional industrial division and collaboration, enhances cooperative efficiency, and creates industrial differentiation, avoiding redundant construction and resource waste caused by industrial homogeneity. This effectively improves economic efficiency and carbon emission efficiency at the industry level (Xu, 2023)[2]. Regional integration also tightens economic linkages between regions. Beyond driving industrial upgrading and green innovation technology advancements, it promotes policy formulation for urban green development and regional coordinated development, effectively reducing urban carbon emission intensity (Yan and Sun, 2022)[10].

Some scholars have examined the spatial spillover effects of regional integration policies on energy conservation and emission reduction. Chen and Wu (2021)[11], based on panel data from prefecture-level cities in the Yangtze River Delta urban agglomeration, investigated the impact of regional integration on industrial green development efficiency. They elaborated on the mechanisms through which regional integration affects industrial green development efficiency, including factor flows, industrial upgrading, technological innovation, and pollution control. The study concluded that regional integration hinders local industrial green development efficiency but has a positive spatial spillover effect on the green development of surrounding regions.

2.3 Carbon Market Integration

In 2011, China established carbon trading markets in Beijing, Tianjin and Hebei respectively. In 2017, China established a unified national carbon market. The establishment of a nationwide unified carbon market is conducive to utilizing regional advantages to achieve energy conservation and emission reduction. The integration of carbon markets in Beijing-Tianjin-Hebei region can build a fundamental platform connecting energy-saving and environmental protection industries with financial investment markets across the three regions, making full use of Beijing's financial investment and technological innovation resources to provide important support for Tianjin and Hebei in cultivating emerging pillar industries of energy conservation and environmental protection, and promoting the transformation and upgrading of traditional industries. The construction of a unified carbon market helps break the funding bottleneck for low-carbon development. From the perspective of industrial structure, Beijing is mainly dominated by tertiary industry; Tianjin, as an old industrial base, relies on secondary and tertiary industries with a considerable number of high-energy-consumption enterprises; while Hebei is dominated by secondary industry with a strong bias towards steel enterprises. The production capacity that Hebei and Tianjin need to eliminate to improve air quality requires corresponding financial compensation and support. By establishing an integrated carbon market in Beijing-Tianjin-Hebei region, the voluntary emission reductions generated by Hebei and Tianjin can all be traded in the regional carbon market to obtain partial funds, which can be used for ecological environment protection. Regions contributing to improving regional air quality can obtain corresponding cost compensation through market mechanisms, changing the uncertainty of relying solely on administrative compensation and rewards, thus significantly reducing financial constraints and stimulating the enthusiasm of relevant regions. This is also conducive to the cost-benefit transformation of corporate emission reduction and promotes low-carbon technology transfer (Feng, 2016)[12].

The efficiency of carbon markets also directly depends on the establishment of a unified market. Zhang and Fan (2022)[13] empirically found that the development of carbon markets generates carbon emission reduction effects by driving low-carbon technological innovation and forcing industrial structure upgrades. However, market segmentation negatively impacts carbon emission reduction efficiency. In practice, under a unified national carbon market, to strengthen the binding force of emission reduction targets, the quota allocation method should be optimized by gradually increasing the auction proportion with reference to the EU experience, while reducing the total quota annually based on the "dual carbon" progress goals. Additionally, market access for entities such as banks, institutional investors, and asset management institutions should be permitted to stimulate market vitality (Li et al., 2024)[14].

3 Case Study

3.1 Yangtze River Delta Integration

The Yangtze River Delta integration is a regional development initiative designed and planned by China since 2010, encompassing Shanghai, Zhejiang Province, Jiangsu Province, and Anhui Province. In the first quarter of 2025, the YRD accounted for 25% of China's economy, making it the most economically dynamic region in the country. The YRD integration primarily focuses on nine key areas:

- Cross-regional collaboration in scientific and technological innovation
- Joint development of world-class industrial clusters in the YRD
- Accelerating the improvement of integrated development institutions and mechanisms
- Enhancing regional market integration
- Promoting high-level coordinated openness in the YRD
- Strengthening joint ecological and environmental protection
- Exploring the construction of a modern Chinese civilization
- Expanding the scope and depth of intercity cooperation
- Enhancing safety and development capabilities

The National Bureau of Statistics of China has compiled the Yangtze River Delta Regional Development Index, as shown in Figure 1, which includes six indicators: collaborative innovation, joint green development, exemplary leadership, coordinated progress, shared livelihood benefits, and open cooperation for mutual benefit. The Yangtze River Delta Development Index demonstrates that the region has achieved steady progress in recent years.

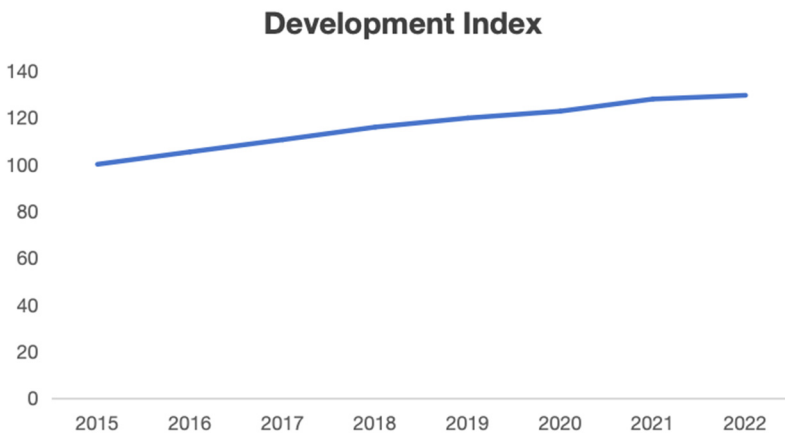


Fig. 1. Development Index of Yangtze River Delta

3.2 Carbon Emission Efficiency of Yangtze River Delta

According to Fig.2, which shows data from the Statistical Monitoring Office for Yangtze River Delta Integration Development under the National Bureau of Statistics, the green index of the Yangtze River Delta has shown a significant upward trend in recent years. The calculation indicators for the green index include six metrics: average PM2.5 concentration, emissions of major industrial air pollutants, surface water pollution levels, emissions of major industrial water pollutants, land use area per unit of regional GDP, and the proportion of renewable energy in total energy consumption.

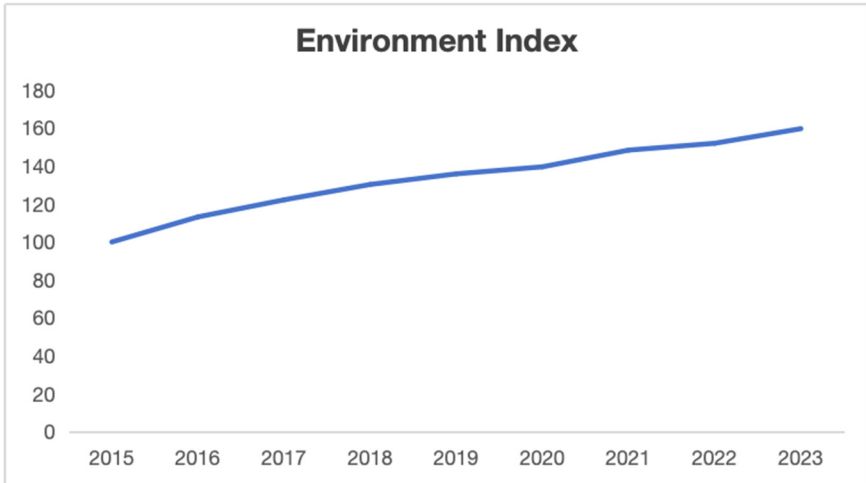


Fig. 2. Environment Index of Yangtze River Delta

As the most economically dynamic and open region in China, the Yangtze River Delta has a high total regional carbon emission volume. According to the Yangtze River Delta Urban Carbon Emissions Report, the region's carbon emissions reached 1.8 billion tons in 2012 and have since fluctuated at a high level between 1.8 and 1.9 billion tons. Notably, despite sustained economic growth in the region from 2012 to 2019, carbon emissions remained stable at this high range, indicating significant improvements in the Yangtze River Delta's carbon emission efficiency.

In terms of carbon intensity (emissions per unit of GDP), the Yangtze River Delta's level is approximately two-thirds of the national average, while its per capita emissions are about nine-tenths of the national average. Sector-wise, three industries—energy production, industry & construction, and transportation—account for 90% of the Yangtze River Delta's total carbon emissions.

The trends in interprovincial carbon emissions show significant divergence. From 2010 to 2019, Jiangsu and Anhui provinces experienced continuous growth in carbon emissions, with Anhui's emissions increasing by 43.3% and Jiangsu's by 20.8%. In contrast, Shanghai and Zhejiang essentially entered a plateau phase of carbon peaking, with Zhejiang's emissions rising slightly by 3.4%, while Shanghai's emissions declined slowly by 6.2%. When correlating urban GDP growth rates with carbon emission

growth rates, it was found that nine cities—including Shanghai and Hangzhou—achieved economic growth alongside reduced carbon emissions. Notably, five cities (Taizhou, Xuancheng, Huaian, Ningbo, and Nanjing) demonstrated GDP growth rates over ten times higher than their carbon emission growth rates.

3.3 Regional Integration and Carbon Emission Efficiency

The integration of the Yangtze River Delta region has enhanced resource allocation efficiency, thereby improving carbon emission efficiency. A case in point is Chint Group, a leading new energy enterprise in the Yangtze River Delta region, which has leveraged the comparative advantages of different cities to achieve rapid development. The company strategically located its smart electrical equipment manufacturing base in Wenzhou, Zhejiang, capitalizing on the city's convenient transportation and well-established upstream and downstream industrial chains. Its photovoltaic cell factory was established in Jiaxing to facilitate collaboration with Shanghai's new energy vehicle industry, while its R&D centers were set up in Shanghai and Hangzhou to access local high-caliber talent and research resources. The deepening regional integration of the Yangtze River Delta has enabled enterprises like Chint to optimize cross-regional resource allocation. This approach reduces land and transportation costs, leverages mature industrial chains across localities, and avoids redundant construction—all of which enhance operational efficiency and, consequently, carbon emission efficiency.

The unified carbon trading market in the Yangtze River Delta has enhanced carbon emission efficiency. In 2024, Tianlun Nano Dyeing and Finishing Co., Ltd. in Jiaxing City engaged in a cross-provincial carbon transaction with Suzhou Wangyuan Photovoltaic New Energy Co., Ltd. in Suzhou Industrial Park, trading 500 tons of carbon emission reductions to obtain a "carbon neutrality" certificate for overseas expansion. This marked the first inter-provincial carbon trade following the integration of the Yangtze River Delta carbon market. Carbon trading not only meets the emission reduction needs of demand-side enterprises but also generates substantial returns for new energy companies, creating a mutually beneficial arrangement for both parties. The existence of a carbon trading market further incentivizes new energy firms to improve their technologies and actively reduce emissions, thereby boosting the overall carbon efficiency of the economy. The establishment of the Yangtze River Delta's unified carbon trading market addresses regional imbalances in carbon supply and demand. It provides more options for companies with emission reduction needs and encourages broader participation in carbon trading, fostering a more efficient and sustainable regional carbon market.

4 Conclusion

This study employs a combination of literature review and case analysis to demonstrate that the deepening integration of the Yangtze River Delta facilitates rational resource allocation for enterprises and enhances the consistency of carbon trading markets, thereby improving carbon emission efficiency. Consequently, regional integration

proves essential for boosting carbon emission efficiency. Building on these findings, the paper recommends advancing regional integration and establishing a unified carbon trading market. Specifically, the following measures should be prioritized:

Further dismantle administrative barriers between markets to facilitate the cross-regional flow of resources and products, while streamlining the movement of talent and capital—thereby enhancing carbon emission efficiency. An integrated market enables comprehensive monitoring of corporate carbon emissions, strengthening oversight of corporate emissions.

Refine the carbon trading market by leveraging green finance, emissions trading mechanisms, and industrial policies to incentivize enterprises to adopt energy-saving technology.

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