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Exploring the synergistic effect of ESG-driven environmental policies and the cross-regional linkage mechanism

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Abstract: *With the intensification of global climate change and resource and environmental pressures, the concept of Environmental, Social, and Governance (ESG) has gradually become a core guide for policy formulation and corporate strategy. Traditional environmental policies have mostly focused on local pollution control and the improvement of single environmental indicators. However, under the ESG framework, environmental policies need to comprehensively consider the multidimensional interactions between the economy, society, and the environment, promoting synergistic effects among policies, especially cross-regional collaborative cooperation. This paper aims to analyze how environmental policies in different regions can collaborate after the introduction of ESG concepts, explore new cross-regional collaboration models in areas such as carbon emission control, water resource allocation, and biodiversity conservation, and utilize big data analysis to evaluate the actual effectiveness of cross-regional policy collaboration in improving environmental indicators. The study finds that ESG-driven cross-regional policy collaboration can not only effectively enhance the efficiency of environmental governance but also promote resource sharing and equitable development among regions, providing new ideas for building a green and sustainable development path.*

Keywords: *ESG concept; environmental policy synergy effect; cross-regional linkage mechanism; big data analysis*

1. Introduction

The formulation and implementation of environmental policies are crucial for achieving sustainable development goals. Traditionally, environmental policies have tended to focus on specific regions or single environmental issues, such as improving air quality or managing water pollution. Although this "treat the symptoms, not the disease" approach can yield short-term results, it often overlooks the systematic and cross-regional nature of environmental issues. With the rise of the ESG (Environmental, Social, and Governance) concept, environmental policies now emphasize a comprehensive consideration of the three dimensions: environmental, social, and governance. Policy design is required not only to address direct environmental issues but also to consider the enhancement of social welfare and the optimization of governance structures, in order to achieve long-term sustainable development goals.

The application of ESG (Environmental, Social, and Governance) principles has prompted a shift in environmental policies from a single dimension to multiple dimensions, and from localization to cross-regional cooperation. Especially in the context of global climate change, global environmental issues such as carbon emission control, water resource management, and biodiversity conservation require transcending the limitations of administrative divisions and addressing them through cross-regional and even international cooperation. Therefore, exploring the synergistic effects of environmental policies driven by ESG and the cross-regional linkage mechanism is of great significance for promoting innovation and development in the global environmental governance system.

2. Synergy between ESG philosophy and environmental policies

2.1 Overview of ESG philosophy

The ESG concept emphasizes comprehensive consideration of environmental factors (such as climate change, resource efficiency), social factors (such as labor conditions, community relations), and governance factors (such as transparency, board structure) in the decision-making process, in order to

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promote long-term sustainability and value creation of economic activities. In the field of environmental policy, the ESG concept requires policymakers to not only focus on the direct reduction of environmental pollution, but also on the restoration of ecosystems, the recycling of resources, and the prevention and management of environmental risks.

2.2 Synergistic effect of environmental policies

The synergistic effect of environmental policies refers to the ability of a policy, through policy design, to address major environmental issues while simultaneously bringing about additional positive impacts in other environmental or social aspects. For instance, a carbon pricing policy not only reduces greenhouse gas emissions but may also incentivize energy efficiency improvements and investments in renewable energy, thereby promoting employment and economic growth. Under the ESG framework, the realization of the synergistic effect of environmental policies requires cross-sectoral policy integration, extensive participation from stakeholders, and support from innovative technological and financial tools.

3. The necessity of inter-regional environmental policy coordination

3.1 Cross-regional characteristics of environmental issues

Many environmental issues, such as air pollution, water scarcity, and biodiversity loss, exhibit significant cross-regional and even global characteristics. Air pollution can be transmitted across regions with air currents, affecting areas hundreds or even thousands of kilometers away. Water resource management in river basins involves the coordination of interests among multiple administrative regions upstream and downstream. The protection of biodiversity requires a cross-border ecosystem protection network. These issues are difficult to effectively address with the efforts of a single region and necessitate cross-regional cooperation and coordination.

3.2 Resource allocation and equitable development

Inter-regional environmental policy coordination facilitates the optimal allocation of resources and equitable development. For instance, water resource allocation projects can effectively transfer water from regions with abundant resources to those with water scarcity, mitigating the issue of uneven water distribution. Meanwhile, the carbon trading market promotes the minimization of emission reduction costs through market mechanisms, while providing development funds for economically underdeveloped regions. The social dimension emphasized by the ESG concept ensures that these coordination mechanisms not only promote environmental improvement but also pay attention to economic balance and social justice among regions.

4. Exploration of cross-regional linkage mechanism driven by ESG

4.1 Cross-regional cooperation on carbon emission control

4.1.1 Carbon trading market

The carbon trading market is a typical application of ESG (Environmental, Social, and Governance) principles in climate policy. By setting an upper limit on carbon emissions and allowing the trading of carbon emission rights, it incentivizes enterprises to reduce greenhouse gas emissions (European Commission, 2023). The establishment of cross-regional and even international carbon markets not only expands the market scale and enhances emission reduction efficiency, but also promotes the international flow of technology and capital, accelerating the transfer and promotion of low-carbon technologies.

1) European Union Emissions Trading System (EU ETS)

The European Union Emissions Trading System (EU ETS) is one of the earliest and largest carbon trading markets globally. Since its launch in 2005, it has undergone multiple stages of development and improvement (European Commission, 2023). The system covers thousands of enterprises in EU member states and some non-EU countries, incentivizing companies to reduce greenhouse gas emissions by setting carbon emission caps for various industries and allowing the trading of carbon emission rights. The successful experience of EU ETS lies in its strict regulatory framework, transparent market mechanism, and ability to link with the international market.

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Firstly, the regulatory framework of the EU ETS ensures the accuracy and transparency of emission data. Enterprises are required to regularly report their carbon emission data, which is then verified by independent third parties to ensure the accuracy and reliability of the data. This strict regulatory mechanism enhances the credibility of the market and provides a solid foundation for carbon trading (European Commission, 2023).

Secondly, the market mechanism of the EU ETS has facilitated the enhancement of emission reduction efficiency. Through the carbon trading market, enterprises can choose to purchase carbon emission rights or sell excess emission allowances based on their own emission reduction costs, thereby minimizing emission reduction costs. This market mechanism not only incentivizes enterprises to adopt more efficient emission reduction measures but also promotes the research, development, and application of low-carbon technologies (European Commission, 2023).

Lastly, the international market connectivity of the EU ETS facilitates the international flow of technology and capital. By linking with other carbon markets, such as Switzerland, the EU ETS provides a platform for international carbon trading, promotes the international flow of technology and capital, and accelerates the transfer and promotion of low-carbon technologies. This cross-regional and even international cooperation mechanism provides strong support for the global response to climate change (European Commission, 2023).

2) China's national carbon emission trading market

The China National Carbon Emission Trading Market was officially launched in July 2021, marking a significant step forward in China's efforts to address climate change (Ministry of Ecology and Environment, 2023). The market covers eight key industries, including power, steel, and cement, and incentivizes enterprises to reduce greenhouse gas emissions by setting carbon emission caps and allowing the trading of carbon emission rights.

The establishment of China's national carbon emission trading market not only facilitates the green transformation of China's economy but also promotes cross-regional and even international carbon trading cooperation. On the one hand, through the carbon trading market, enterprises can choose to purchase carbon emission rights or sell excess emission allowances based on their own emission reduction costs, thereby minimizing emission reduction costs. This market mechanism encourages enterprises to adopt more efficient emission reduction measures and promotes the research, development, and application of low-carbon technologies (Ministry of Ecology and Environment, 2023).

On the other hand, the connectivity between China's national carbon emission trading market and the international market is gradually improving. With the continuous development of the global carbon trading market, China's national carbon emission trading market is expected to achieve closer cooperation with the international market, promoting international flows of technology and capital, and contributing China's strength to the global response to climate change (Ministry of Ecology and Environment, 2023).

4.1.2 Green finance cooperation

Green finance is an important tool to support cross-regional carbon emission reduction, providing financial support for low-carbon projects and technological research and development through the issuance of green bonds, the establishment of green funds, etc. (People's Bank of China and other six ministries, 2016). The cross-regional green finance cooperation mechanism can gather capital from multiple regions to jointly invest in large-scale infrastructure projects with significant carbon emission reduction benefits, such as renewable energy bases, smart grids, etc., achieving economies of scale and cost sharing.

1) Green bonds

Green bonds are bonds issued to support environmentally friendly projects, with the funds raised specifically allocated to renewable energy, clean energy, energy conservation, emission reduction, and other fields (Climate Bonds Initiative, 2023)[4]. Cross-regional green finance cooperation mechanisms can pool capital from multiple regions to jointly invest in large-scale infrastructure projects with significant carbon emission reduction benefits, such as renewable energy bases and smart grids.

For instance, China has been actively issuing green bonds in recent years to support the development of renewable energy, clean energy, and other related fields. According to statistics, by the end of 2023, the issuance scale of green bonds in China had exceeded RMB 1 trillion (Green Finance Professional Committee of the China Finance Association, 2023). These green bonds not only provide financial support for the development of renewable energy, clean energy, and other related fields in China, but also

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promote cross-regional and even international green finance cooperation.

2) Green Fund

Green funds are investment funds dedicated to environmental protection, energy conservation, clean energy, and other fields. By pooling capital from multiple regions, they jointly invest in large-scale infrastructure projects with significant carbon emission reduction benefits (Asset Management Association of China, 2023). Cross-regional green finance cooperation mechanisms can establish green funds to support the development of renewable energy, clean energy, and other fields.

For instance, China has been actively establishing green funds in recent years to support the development of renewable energy, clean energy, and other related fields. According to statistics, by the end of 2023, the scale of China's green funds had exceeded 500 billion yuan (China Securities Investment Fund Association, 2023). These green funds not only provide financial support for the development of renewable energy, clean energy, and other related fields in China, but also promote cross-regional and even international green finance cooperation.

In addition, the cross-regional green finance cooperation mechanism can also provide financial support for low-carbon projects and technological research and development through channels such as government guiding funds and multilateral development banks[26]. For instance, multilateral development banks like the Asian Infrastructure Investment Bank (AIIB) have established several green funds to support the development of renewable and clean energy sectors in Asia and the Pacific region (Asian Infrastructure Investment Bank, 2023)[1].

4.2 Cross-regional collaboration in water resource allocation

4.2.1 Integrated water resources management framework

Integrated Water Resources Management (IWRM) emphasizes the consideration of all relevant factors, including economic, social, environmental, and institutional aspects, in the planning, development, utilization, protection, and management of water resources (World Bank, 2023). The establishment of a cross-regional IWRM framework, such as the establishment of a transnational river commission, helps to coordinate the conflicts of interest between upstream and downstream areas, as well as between the left and right banks, ensuring the equitable and sustainable utilization of water resources.

1) Transboundary River Commission

The Transboundary Rivers Commission is a crucial institution for integrated management of cross-regional water resources. Through consultation and cooperation, it coordinates the conflicting interests of upstream and downstream areas, as well as those of the left and right banks, ensuring the equitable and sustainable utilization of water resources. For instance, international river organizations such as the Nile River Basin Commission and the Amazon River Basin Commission coordinate the interests of various countries in water resource utilization, protection, and management by formulating transboundary river management agreements (United Nations Economic Commission for Europe, 2023)[18].

The establishment of transboundary river commissions helps promote the integrated management of water resources in transboundary rivers. Through consultation and cooperation, countries can jointly formulate transboundary river management agreements, clarifying the rights and obligations of each country in terms of water resource utilization, protection, and management, ensuring the fair and sustainable utilization of water resources. At the same time, transboundary river commissions can also provide technical support and financial assistance to help countries strengthen their water resource management and protection capabilities.

2) Comprehensive management of cross-regional water resources in China

China is a country with uneven distribution of water resources, and comprehensive management of inter-regional water resources is of great significance for ensuring national water security. In recent years, the Chinese government has actively promoted comprehensive management of inter-regional water resources, strengthening coordination and management of inter-regional water resources through measures such as establishing river basin management agencies and formulating river basin management plans.

For instance, river basin management agencies such as the Yangtze River Water Resources

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Commission and the Yellow River Water Resources Commission in China have ensured the equitable and sustainable utilization of cross-regional water resources in the Yangtze River Basin and the Yellow River Basin by formulating river basin management plans and strengthening water resource monitoring and dispatching (Ministry of Water Resources, 2023). Simultaneously, the Chinese government has actively promoted cross-regional water resource cooperation, enhancing coordination and management of cross-regional water resources through measures such as signing inter-provincial water agreements and conducting joint monitoring and dispatching.

4.2.2 Water rights trading and compensation mechanism

Water rights trading is an effective means of cross-regional allocation of water resources, allowing the transfer of water usage rights between different regions or users to improve water resource utilization efficiency (World Bank, 2023). Integrating ESG principles, establishing a reasonable water rights trading and ecological compensation mechanism can incentivize upstream regions to protect water sources, while compensating for the development opportunities sacrificed due to ecological protection, achieving a win-win situation for both the environment and society[30].

1) Water rights trading mechanism

The water rights trading mechanism serves as an effective means for cross-regional allocation of water resources. By facilitating the transfer of water usage rights among different regions or users, it enhances the efficiency of water resource utilization. For instance, the water rights trading mechanism in the Murray-Darling River Basin in Australia promotes efficient utilization of water resources through market mechanisms, achieving cross-regional allocation of water resources (Australian Government Department of Agriculture, Water and the Environment, 2023)[2].

In China, the water rights trading mechanism is also gradually being promoted. For instance, the water rights trading between Yiwu City and Dongyang City in Zhejiang Province has achieved cross-regional allocation of water resources through market mechanisms, enhancing the efficiency of water resource utilization (Ministry of Water Resources, 2023). This water rights trading mechanism not only promotes the efficient use of water resources but also incentivizes upstream areas to strengthen water resource protection and management[29].

2) Ecological compensation mechanism

The ecological compensation mechanism serves as a crucial tool to incentivize upstream regions to protect water sources and foster sustainable utilization of cross-regional water resources. By compensating upstream regions for the development opportunities sacrificed due to ecological protection through financial support or ecological restoration projects, a win-win situation for both the environment and society can be achieved[28].

For instance, the ecological compensation mechanism in the Yangtze River Basin in China, through the joint efforts of the central government and local governments, compensates for the development opportunities sacrificed in the upstream areas due to ecological protection, thereby incentivizing the upstream areas to strengthen water resource protection and management (Ministry of Water Resources, 2023). This ecological compensation mechanism not only promotes the sustainable utilization of water resources in the Yangtze River Basin but also drives economic and social development in the upstream areas[22].

4.3 Cross-regional cooperation in biodiversity conservation

Biodiversity is the general term for the diversity of life on Earth, and it serves as the foundation for human survival and development. However, with the intensification of human activities, biodiversity is facing unprecedented threats. To effectively protect biodiversity, cross-regional cooperation has become an important strategy. This section will focus on two key aspects of cross-regional cooperation: the construction of ecological protection corridors and biodiversity compensation mechanisms.

4.3.1 Construction of ecological protection corridors

Ecological protection corridors are crucial means of connecting isolated habitats, facilitating species migration, and maintaining ecosystem connectivity, playing a vital role in protecting biodiversity (Crooks & Sanjayan, 2006). In the context of globalization, the habitats of many species are fragmented due to human activities, impeding species migration and reducing population genetic diversity. Therefore, inter-regional cooperation in constructing ecological corridors is particularly important.

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A transboundary network of nature reserves is an effective form of ecological protection corridor construction. For instance, the European Green Belt Initiative has established a trans-European ecological corridor by linking nature reserves across multiple countries, providing a continuous habitat for species migration (IUCN, 2016)[10]. The successful implementation of this initiative is attributed to the joint efforts of governments, non-governmental organizations (NGOs), the private sector, and local communities. Governments provide land and legal support for the construction of ecological corridors through land acquisition and law formulation. NGOs and the private sector contribute to the actual construction and management of ecological corridors through financial and technical support. The participation of local communities ensures the coordination between ecological corridors and local socio-economic development[7].

In addition to cross-border nature reserve networks, the construction of greenways within cities is also an important component of ecological protection corridors. For instance, Singapore's Park Connector Network forms an ecological corridor throughout the city by connecting various parks and green spaces within the city, providing leisure and entertainment venues for urban residents while also offering migration and habitat space for wildlife within the city (NParks, 2020)[15].

4.3.2 Biodiversity compensation mechanism

The biodiversity offset mechanism is a system arrangement that requires developers to compensate for the biodiversity loss caused by their projects (Boyd & Banzhaf, 2007)[3]. This mechanism achieves a balance between ecological protection and economic development by restoring or enhancing biodiversity in other locations through financial support or ecological restoration projects.

The cross-regional biodiversity compensation mechanism can facilitate the flow of funds and technology between regions rich in biodiversity but economically underdeveloped and developed regions. For instance, China's ecological compensation system incorporates a cross-regional biodiversity compensation mechanism. Through this mechanism, developed regions can provide financial and technical support to regions rich in biodiversity but economically underdeveloped, assisting them in ecological restoration and protection (Zhang et al., 2017)[25]. Such cooperation not only aids in biodiversity conservation but also promotes balanced economic development among regions.

In addition, international biodiversity compensation mechanisms are gradually being established. For instance, some international environmental organizations are advocating for the establishment of a global biodiversity compensation fund, aiming to jointly protect global biodiversity through international financial and technological cooperation (WWF, 2019)[23].

5. Application of big data analysis in cross-regional policy linkage

5.1 Environmental data sharing platform

Building a cross-regional environmental data sharing platform is a fundamental step towards achieving policy synergy. The complexity and cross-regional nature of environmental issues necessitate that local governments, enterprises, and the public share environmental data to form a joint force to address challenges. By integrating multiple sources of data from satellite remote sensing, ground monitoring stations, social media, mobile devices, and more, the environmental data sharing platform tracks key indicators such as environmental quality, resource utilization, and ecological status in real time, providing a scientific basis for policy formulation (Kitchin, 2014)[12].

Satellite remote sensing technology plays a significant role in environmental monitoring due to its wide coverage, short monitoring cycles, and high data accuracy. For instance, satellite remote sensing data allows for real-time monitoring of environmental indicators such as changes in forest cover, water pollution, and air quality (Jensen, 2009)[11]. Ground monitoring stations, on the other hand, provide more precise and continuous monitoring data. For instance, air quality monitoring stations can report the concentrations of pollutants such as PM2.5 and sulfur dioxide in real time (EPA, 2020)[8]. Social media and mobile device data reflect the public's perception and attitudes towards environmental issues, offering policymakers more comprehensive information (Wang et al., 2016)[21].

The establishment of an environmental data sharing platform not only enhances the usability and accessibility of data but also boosts the transparency and credibility of policy formulation. Through data sharing, governments, enterprises, and the public can gain a clearer understanding of the current status and trends of environmental issues, thereby strengthening mutual trust and cooperation. For instance, the Copernicus program of the European Union provides an open environmental data sharing platform,

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offering rich environmental data resources to member states and the public, and facilitating the collaborative formulation and implementation of cross-regional environmental policies (Copernicus, 2021)[5].

5.2 Policy Effect Evaluation Model

The effectiveness of cross-regional policy coordination needs to be quantitatively analyzed through scientific evaluation models. Big data and artificial intelligence technologies provide the possibility for developing evaluation models for the effectiveness of cross-regional policies. By collecting and analyzing a large amount of environmental and socio-economic data, it is possible to quantitatively analyze the improvement effects of different policy combinations on environmental indicators (such as air quality, water quality, biodiversity index) and their impacts on socio-economic indicators (such as employment, GDP growth) (Varian, 2014)[19].

The development of a policy effect evaluation model requires a comprehensive consideration of both the direct and indirect effects of environmental policies. The direct effect refers to the immediate improvement of environmental indicators after the implementation of the policy, such as the improvement of air quality and water quality. The indirect effect refers to the impact on the socio-economic system after the implementation of the policy, such as increased employment and adjustment of industrial structure. By constructing a multi-dimensional and multi-level evaluation index system, the effects and impacts of the policy can be comprehensively reflected (OECD, 2015)[16].

The application of big data and artificial intelligence technologies in policy effectiveness evaluation not only enhances the accuracy and efficiency of the evaluation but also provides a scientific basis for policy optimization. By simulating the effects of different policy combinations, the optimal policy mix can be identified to ensure that policies are both effective and fair. Meanwhile, big data analysis can also identify potential negative synergistic effects, allowing for timely adjustments to strategies and avoiding adverse consequences during policy implementation (Salvatore et al., 2018)[17].

Taking air quality policies as an example, through big data analysis, it is possible to assess the contribution of different emission reduction measures to air quality improvement, as well as their impact on socio-economic indicators such as employment and economic growth. Based on the assessment results, policymakers can adjust the combination and intensity of emission reduction measures to achieve a win-win situation for both environmental and economic benefits (Hao et al., 2018)[9].

5.3 Risk warning and emergency response

Big data analysis also plays a significant role in early warning and emergency response to environmental risks. Through in-depth mining and analysis of historical data, potential patterns and trends of risks such as environmental pollution and natural disasters can be identified, providing a time window for cross-regional coordinated emergency response and reducing losses (Manyika et al., 2015)[14].

Taking air pollution as an example, by combining meteorological data and air quality models, the occurrence and diffusion path of haze weather can be predicted. Based on the prediction results, the government can take emission reduction measures in advance, such as restricting the driving of high-emission vehicles and shutting down some factories, thereby reducing the probability of occurrence and the impact of haze weather (Zhang et al., 2019)[24]. Similarly, in terms of natural disaster early warning, big data analysis can also provide important decision support. By monitoring data such as seismic waves and meteorological conditions, the occurrence time and location of natural disasters such as earthquakes and floods can be predicted, providing a valuable time window for emergency response (Wald et al., 2016)[20].

The implementation of cross-regional risk early warning and emergency response necessitates close cooperation and information sharing among local governments, enterprises, and the public. By establishing a cross-regional emergency linkage mechanism, optimal allocation and efficient utilization of resources can be achieved, enhancing the efficiency and effectiveness of emergency response (Kunreuther & Michel-Kerjan, 2015)[13]. For instance, when addressing cross-regional air pollution issues, local governments can collaboratively develop emission reduction plans and coordinate the timing and intensity of emission reduction measures to ensure maximum emission reduction effects.

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6. Conclusion

The ESG (Environmental, Social, and Governance) concept offers a fresh perspective and framework for the formulation and implementation of environmental policies. It emphasizes a comprehensive consideration of the three dimensions: environment, society, and governance, fostering synergistic effects and cross-regional collaboration in environmental policies. Through mechanisms such as carbon trading markets, green finance cooperation, integrated water resource management, and the construction of ecological protection corridors, ESG-driven cross-regional policy coordination not only enhances the efficiency of environmental governance but also promotes resource sharing and equitable development among regions.

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