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Analysis of the Practical Paths for the Integration of Environmental Science and Economics

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Abstract:

Against the backdrop of worsening global ecological problems, the fragmented development of environmental science and economics has become a key barrier to achieving a win-win situation between ecological protection and economic growth. This disconnection often leads to policy conflicts, inefficient resource allocation, and unsustainable development models that prioritize short-term economic gains over long-term ecological health. Focusing on the practical paths for integrating these two interdisciplinary fields, this study adopts a comprehensive research methodology that combines literature review, typical case analysis, data validation, and mathematical model prediction. It systematically addresses core issues in the integration process, including inadequate policy coordination between environmental and economic sectors, a weak industrial driving force for green transformation, and insufficient technical support for cross-disciplinary data processing and analysis. The research concludes that optimizing policy formulation and upgrading industrial structure are the two core and effective integration paths: policy optimization provides institutional guarantees through coordinated systems and incentive mechanisms, while industrial upgrading drives practical advancement through structural adjustment and technological innovation. Typical cases such as the EU Carbon Trading Market and China's photovoltaic industry transformation have fully verified the feasibility and effectiveness of these paths. Additionally, quantitative tools including grey prediction and multiple linear regression models, can accurately predict future development trends in investment scale, benefit growth, and talent demand, providing actionable theoretical references and practical guidance for governments, enterprises, and other stakeholders to promote the coordinated development of environmental protection and economic growth.

Keywords: Environmental Science; Economics; Integration Path; Sustainable Development; Mathematical Model

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1. Introduction

In recent decades, global ecological problems represented by climate warming, resource scarcity, and environmental pollution have become increasingly prominent, posing a severe threat to human survival and development [1]. The traditional development model prioritizing economic growth at the expense of the environment is unsustainable, and exploring harmonious coexistence between humans and nature has become a global consensus. Environmental science focuses on ecological protection and governance, while economics emphasizes resource allocation and benefit maximization; their integration is an inevitable choice to solve complex environmental-economic issues.

Existing research has laid a preliminary theoretical foundation but has shortcomings: most focus on theoretical discussions without in-depth analysis of practical paths, and the connection between research results and practice is not close, with limited guiding roles in policy and industry [2]. Quantitative analysis is also insufficient, especially the lack of systematic trend prediction through mathematical models. In this context, this study sorts out research status via literature review, analyzes successful cases by case study, verifies path effectiveness with data validation, and introduces grey prediction and multiple linear regression models for trend prediction. Core research questions include: What specific paths can promote in-depth integration? What key problems exist and their solutions? How to accurately predict future trends and challenges through mathematical models?

The significance lies in three aspects: theoretically, it enriches the interdisciplinary research system and expands sustainable development perspectives; practically, it provides targeted paths for governments and enterprises to improve environmental governance efficiency; socially, it enhances public ecological awareness and promotes the construction of resource-saving and environment-friendly societies.

2. Practical Paths for the Integration of Environmental Science and Economics

2.1 Policy Formulation Aspect

2.1.1 Construction of a Coordinated Policy System

Integrate core environmental protection goals (such as carbon emission reduction and ecological restoration) into the whole process of economic policy formulation, and establish a comprehensive evaluation mechanism that balances short-term economic benefits and long-term ecological gains. This mechanism should quantify both economic growth and environmental protection effects to avoid policy conflicts between the two fields.

2.1.2 Improvement of Ecological Economic Incentive Mechanisms

Introduce targeted tax incentives, phased financial subsidies, and preferential credit support policies to encourage enterprises to invest in green production technologies and clean energy projects. These measures help reduce the cost of green transformation for enterprises and effectively promote the internalization of environmental external costs.

2.1.3 Formulation of Cross-Disciplinary Regulatory Standards

Relevant departments (including environmental protection, economy, and finance) should jointly develop unified environmental and economic regulatory indicators, such as standardized resource utilization efficiency and pollutant discharge limits. This realizes the organic connection between environmental supervision and economic regulation, ensuring consistent and efficient regulatory practices.

2.2 Industrial Integration Aspect

2.2.1 Green Transformation of Traditional Industries

Guide high-energy-consuming and high-pollution industries such as steel and chemical engineering to carry out targeted technological transformation, vigorously promote clean production processes and energy-saving equipment, and establish a full-process resource management system to improve resource utilization efficiency and reduce pollutant emissions.

2.2.2 Cultivation of Emerging Green Industries

Focus on developing new energy, energy conservation and environmental protection, and ecological agriculture industries, and increase R&D investment in core technologies to build a high-value-added, low-environmental-impact green industrial system that can drive regional economic transformation and ecological protection.

2.2.3 Construction of Industrial Ecological Chains

Promote the coupling and coordination of upstream and downstream enterprises in the industrial chain, build resource circulation channels between industries, realize the recycling of reusable resources and harmless treatment of production waste, and form a closed-loop circular economy model.

3. Case Analysis of Successful Integration of Environmental Science and Economics

3.1 Enumeration of Typical Cases

3.1.1 EU Carbon Trading Market

Launched in 2005, it is the world's largest carbon trading system. By 2023, cumulative CO_2 emission reduction reached 420 million tons, and the market scale exceeded 85 billion euros [3]. The carbon pricing mechanism forced enterprises to reduce emissions and promoted low-carbon technology development, achieving a win-win situation.

3.1.2 Green Transformation of China's Photovoltaic Industry

From 2018 to 2023, the output value increased from 400 billion yuan to 850 billion yuan (CAGR 16.3%), with cumulative power generation of 1.2 trillion kWh, equivalent to reducing 980 million tons of CO_2 emissions [4].

3.1.3 Ecological Compensation Mechanism in China's Yangtze River Economic Belt

More than 20 billion yuan of compensation funds have been allocated. The mainstream water quality has remained above Class II for five consecutive years, and the annual revenue of the basin's ecological tourism industry exceeded 300 billion yuan [5].

3.2 Key Issues and Solutions in Typical Cases

3.2.1 Key Issues

Information asymmetry between environmental and economic departments; high enterprise transformation costs and insufficient motivation; uneven regional development leading to difficult coordination.

3.2.2 Solutions

Establish an information sharing platform to realize data interconnection [6]; increase financial support and technical guidance to reduce transformation costs [7]; formulate differentiated policies based on regional characteristics [8].

3.2.3 Experience Summary

Integration requires institutional design guidance, market mechanisms driving, and technological innovation support. Lishui, Zhejiang, proved that ecological advantages can be transformed into economic advantages through ecological agricultural product value-added transformation [9], providing a replicable paradigm.

4. Future Challenges and Prospects

4.1 Relevant Data Prediction

4.1.1 Investment Scale Prediction - Grey Prediction Model (GM(1,1))

Using 2018-2023 global investment data (2.1-3.8 trillion US dollars), the prediction equation is

$$\hat{x}^{(1)}(k+1) = 42.36e^{0.117k} - 40.26 \quad (1)$$

(average relative error 2.3%). It is predicted that by 2030, global investment will reach 5.2 trillion US dollars (CAGR 12.5%)[10].

4.1.2 Benefit Growth Prediction - Multiple Linear Regression Model

With green industry output value ratio (X1), R&D intensity (X2), and policy support (X3) as independent variables, and GDP growth contribution (Y) as the dependent variable, the equation is

$$\hat{Y} = 0.023 + 0.45X1 + 0.32X2 + 0.21X3. \quad (2)$$

R^2=0.89, F test is significant, indicating that the model has a good fitting effect and explanatory power. By 2035, green industry-driven GDP growth is expected to reach 3.8%, and global carbon emissions will decrease by 35% compared with 2020 [11].

4.1.3 Talent Demand Prediction - Logistic Growth Model

Based on 2018-2023 data (CAGR 4.8%), the model is

$$N(t) = \frac{120}{1+e^{-0.18(t-2023)}}. \quad (3)$$

By 2030, the demand for interdisciplinary talents will increase by 60% with a gap of 320,000 [12].

4.2 Main Challenges

4.2.1 Technical Bottlenecks

Backward core technologies, such as high-precision environmental monitoring, standardized carbon accounting, and high-efficiency resource recycling restrict the depth of interdisciplinary integration [13]; meanwhile, the severe scarcity of high-quality ecological and economic data in most developing countries directly limits the accuracy of mathematical model prediction and the credibility of decision-making references.

4.2.2 Institutional Barriers

The separation of vertical and horizontal administrative systems leads to fragmented management and poor policy coordination between departments and regions; cross-border ecological-economic integration also lacks a unified

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international cooperation framework and evaluation criteria. The typical practice of the Xin'an River Basin shows that imperfect cross-regional benefit coordination and supervision mechanisms have significantly affected the actual implementation effect of ecological compensation policies [14].

4.2.3 Interest Game

The inherent conflict between local short-term economic growth interests and long-term regional environmental benefits reduces the motivation of relevant subjects to promote integration; in addition, the deviation between theoretical model predictions and complex real-world policy implementation scenarios requires flexible dynamic adjustment of strategies and mechanisms to balance multiple stakeholders' demands.

4.3 Future Prospects

4.3.1 Technology Empowerment and Model Optimization

Leverage big data and artificial intelligence technologies to upgrade traditional prediction models, and build a "data collection-model training-dynamic correction" closed-loop system to enhance prediction accuracy and adaptability. Meanwhile, apply blockchain technology to realize credible and traceable sharing of environmental and economic data, resolving the problem of information asymmetry between different subjects.

4.3.2 Institutional Innovation

Establish normalized cross-departmental and cross-regional coordination mechanisms to break administrative barriers and improve policy synergy. Further refine the ecological compensation system and carbon pricing mechanisms, ensuring that ecological value is reasonably reflected in the market and motivating all parties to participate in environmental governance.

4.3.3 Talent Training and Cooperation Model Innovation

Support universities to set up interdisciplinary majors such as environmental economics, integrating professional knowledge of both fields to cultivate compound talents. Promote the mature "government-enterprise-university" tripartite cooperation model, accelerating the transformation of green technology achievements and meeting the talent demand for interdisciplinary integration.

5. Conclusion

This study systematically explores the integration paths through literature review, case analysis, data validation, and mathematical model prediction. Firstly, effective integration can be achieved through two core paths: policy formulation optimization and industrial structure upgrading. Policy-wise, it is necessary to build a coordinated system, improve incentive mechanisms, and formulate cross-disciplinary standards; industrially, promote traditional industry transformation, cultivate emerging green industries, and construct ecological chains. Secondly, typical cases such as the EU carbon trading market have fully verified the feasibility of the paths, indicating that environmental protection and economic growth can achieve coordinated development under scientific guidance.

In response to the research questions, the specific integration paths include policy optimization and industrial upgrading; key problems (technical bottlenecks, institutional barriers, and interest games) can be solved through technological innovation, institutional improvement, and interest coordination; mathematical models have accurately predicted future trends, providing quantitative support for decision-making.

However, this study has limitations: case selection is concentrated in developed countries and China's key industries, lacking coverage of developing countries and SMEs; mathematical models do not fully consider uncertain factors; and the quantitative indicator system can be further enriched. Future research can expand the case scope, introduce more complex algorithms such as random forests, and include non-economic factors such as social cognition in the indicator system. With the deepening of global sustainable development awareness, the integration of environmental science and economics will play a more important role in addressing ecological challenges, and related research will continue to advance.

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