

Exploring on the Identification of Green Transition Risks Based on Big Data-driven Approaches

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Abstract. The green transition is closely intertwined with the rise of sustainable development and green development concepts. Current research on green transition risks primarily focuses on key areas such as energy, finance, trade, and social justice, exhibiting highly interdisciplinary and systemic characteristics. The data requirements for monitoring green transition risks remain unclear. Big data-driven behavioral analysis and situational awareness break away from traditional empirical risk analysis models, bringing fundamental changes to risk situational awareness and analytical paradigms. This paper proposes utilizing AI large models and digital twin technology for the active diagnosis, precise identification, and intelligent policy formulation regarding green transition risks. It further advocates for the active diagnosis of potential risks to achieve accurate identification, promoting a shift in risk analysis from "empirical induction" to "data-driven decision making".

Keywords: Green Transition Risks, Risk Identification, Big Data-driven, Behavioral Diagnosis

1. Introduction

The global green low-carbon transition is an irreversible trend. Existing research and policy practices focus on themes like climate change, carbon markets, and emission accounting. In China, studies emphasize green finance in institutions (e.g., banks) and high-carbon industry upgrades (e.g., energy, manufacturing). However, systematic risk monitoring remains underexplored, as these risks arise from policy/technical shifts and potential systemic impacts on economies, finance, business, and employment.

To address this gap, a comprehensive theoretical framework for green transition risk management is urgently needed. This requires defining the boundaries of green transition risks and distinguishing them from traditional risks, laying a foundation for effective identification, assessment, and mitigation.

Recent advancements in AI and digital twin technologies offer new solutions. AI models can process multi-source data to uncover hidden patterns, while digital twins enable real-time physical system simulations. Integrating these technologies to analyze heterogeneous data could build a data-driven platform for risk prediction, policy design, and enterprise decision-making. Such tools aim to reduce green transition risks and ensure smoother global transitions.

2. Literature review

The management of green transition risks requires real-time monitoring and analysis of complex systems. AI large models demonstrate powerful cross-modal analysis capabilities through domain adaptation, far exceeding traditional methods in processing unstructured data, providing intelligent solutions for the green transition.

2.1. Research on green transition risk

Research on the green transition can be explored from four perspectives: policy tools, technological innovation, historical evolution, and global cooperation. The policy tool perspective focuses on the types, combinations, and practical effectiveness of green transition policies, which can be categorized into different types such as institutional regulations, market incentives, and technical support [1]; The technological innovation perspective emphasizes the utility of technological innovation in the green transition; The historical evolution perspective focuses on the evolutionary process of the green transition. From "cost internalization" to "technological innovation" and then to "system restructuring" emphasizing fairness and sustainability, the green transition exhibits a deepening trend of structural change [2]; The global cooperation perspective reveals that green transition risks have transcended national boundaries and are embedded in the global governance system.

Research on green transition risks can be divided into macro (national), meso (industrial), and micro (enterprise) levels. At the national level, research mainly focuses on key areas such as energy, finance, trade, and social justice, showing highly interdisciplinary and systemic characteristics. Financial risks are concentrated in the volatility and transnational transmission under the financialization of carbon markets, especially as carbon border adjustment mechanisms increase systemic uncertainty in green finance [3]. Green trade barrier risks intensify with the politicization of environmental issues, as developed countries construct green barriers through institutionalized standard export [4]. Social justice risks are reflected in the global green governance order still being dominated by a few developed countries, with structural inequities in carbon rights allocation mechanisms affecting the fair development space for developing countries [5].

2.2. Research on data-driven risk situational awareness

Data-driven is itself a practice-oriented concept, and related research focuses more on the application level rather than conceptual analysis. From the perspective of library risk governance, it is believed that data-driven, compared to "decision-driven", "goal-driven", and "business-driven", primarily takes data as the starting point or perspective [6]. Combining with the field of public security risk governance, citing Techopedia's explanation, big data-driven means that management decisions and processes are determined by data or made based on big data analysis results, rather than relying on intuition or personal experience [7]. Combined with technology embedding theory, the essence of big data-driven lies in changing the processes and methods of government risk governance, providing new solutions to accurately identify and address governance dilemmas, and even requiring the reconstruction of the government governance system [8]. Data-driven refers to the process of taking data as the starting point for specific goals, obtaining information through data mining and utilization, and thereby guiding actions.

In 1988, the concept of Situation Awareness (SA) was first explicitly defined situation awareness as "the perception of elements in the environment within a volume of time and space, the

comprehension of their meaning, and the projection of their status in the near future." He summarized situation awareness into three levels: perception, comprehension, and projection [9].

3. Big data-driven risk identification methods and applications

3.1. Data-driven methodology

Data-driven methods prioritize data as the foundation for decision-making, replacing traditional "experience-based" logic. The Fourth Paradigm of data science emphasizes:

1. Reliance on data collection, processing, and analysis for scientific discovery;
2. Collaborative innovation through open research networks;
3. Community-driven validation of scientific knowledge.
4. Big data processing follows four stages: collection, preprocessing, analysis and visualization.

Decision reliability depends on data quality and integration across stages.

3.2. Big data fusion processing

Traditional risk management methods increasingly reveal their limitations when dealing with the increasingly complex and dynamic green transition risks. Mastering "big data-driven" risk early warning methods can provide a breakthrough response to this. Analysis based on massive data can effectively construct dynamic risk profiles, achieve predictive risk identification and early warning, effectively filling the gaps in the field of data-driven risk management.

However, to achieve "big data-driven" risk early warning, an important prerequisite is data sources and data packages. Currently facing obstacles such as fragmented data sources, data silos, and technical barriers, constructing a trusted data space for the green transition can effectively resolve this issue. Specifically, building a trusted data space for the green transition can not only aggregate massive, diverse spatiotemporal heterogeneous data but also effectively perform data screening, identification, and fusion. Simultaneously, it can establish trust and collaboration mechanisms among participants, resolving difficulties in cross-departmental data sharing.

3.3. Constructing a big data-driven risk prevention and control model

Any systemic risk, before breaking out, inevitably goes through a process from risk accumulation to diffusion and contagion. It is necessary to construct a five-stage closed-loop management system of "Perception-Diagnosis-Decision-Intervention-Iteration" to provide scientific, precise, and intelligent support for risk prevention and control.

1. At the Perception layer, the focus is on being data-driven. Utilizing intelligent sensors, neural systems, the internet, cloud computing, etc., to achieve panoramic situational awareness, and the early capture and deep monitoring of risk factors. Under this premise can multivariate statistical methods, machine learning models, and other analytical frameworks be used to systematically identify, quantitatively assess, and pattern mine potential risk factors, thereby generating scientifically grounded and predictive risk assessment conclusions.

2. At the Intervention layer, emergency risk response teams are the main force for preemptive intervention in green transition risks. As hub nodes, they strongly drive collaborative response mechanisms across administrative regions, functional departments, and professional fields, breaking down "information silos" and "action barriers", ensuring the uniformity of emergency commands, the optimization of resource allocation, and the synchronization of response actions, effectively containing risks.

3. At the Diagnosis layer, through data identification standards and norms, and based on pre-established cross-domain systematic risk indicator systems, risk information is quickly judged, the comprehensive index of systemic risk is calculated, and this state variable is categorized mainly into three risk states: "Low Risk Level", "Medium Risk Level", and "High Risk Level", achieving rapid risk warning and response.

4. At the Decision layer, machine learning is deepened to simulate the cost-benefit ratios of different intervention measures, providing intelligent support for decision-making. Meanwhile, standing or ad-hoc emergency risk response teams need to quickly integrate information, assess the situation, and formulate risk response strategies after a risk event is triggered.

5. At the Iteration layer, it is necessary to promote the continuous evolution of the "digital twin" for risk management, accumulate knowledge graphs from each risk response, continuously input, output, calculate, and analyze various risk indices, strengthen the learning function of the model, and ultimately feed back into real-world decision-making.

4. Analysis

4.1. Green transition behavior and implementation

Before the concept of green transition gradually took shape, the international community mainly focused on environmental governance and climate governance issues. In the 1960s, European countries began to pay attention to environmental pollution problems, attempting to find a balance between economic development and ecological protection, promoting the formation of early environmental protection policies. Subsequently, global environmental governance gradually moved towards institutionalization and systematization. A series of landmark international agreements, such as the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, the Kyoto Protocol in 1997, and the Paris Agreement in 2015, were successively established, constructing a global cooperation framework for addressing climate change.

The green transition is closely related to the rise of sustainable development and green development concepts. In the 1950s and 1960s, environmental pollution problems in Western industrialized countries became increasingly prominent, causing serious environmental damage. Under these circumstances, developed countries began to pursue a transformation of environmental governance models, promoting "clean production". Since the 1980s, driven by the global environmental movement and the trend of sustainable development, the World Bank and major donor countries were forced to restructure the paradigm of international development cooperation, thus initiating the institutional change process of the "green turn". This transition was conceptualized by advocates as "environmental mainstreaming", which involves systematically integrating the core principles of environmental governance into non-environmental policy areas, covering development assistance, trade agreements, financial regulation, etc., requiring actors to embed environmental impact assessments and ecological benefit accounting in goal setting, institutional construction, and project design. As the climate crisis gained priority on the environmental governance agenda, "environmental mainstreaming" gradually evolved into the more action-oriented "green transition" paradigm.

4.2. Analysis and diagnosis of green transition behavior

The green transition inevitably accompanies multiple risks in promoting sustainable development. Risks can be roughly divided into macro (national), meso (industrial), and micro (enterprise) levels.

At the macro level, these risks involve energy, food, financial systems, trade, social equity, and other fields; At the meso level, industry, as an important agent of the green transition, manifests its transition process mainly in the restructuring of the green industrial system and the adjustment of the industrial structure, thereby promoting the industrialized operation of the green economy.

Traditional industries in this process are not only impacted by industrial restructuring and the diffusion of green technology but also limited by resource and environmental constraints. They commonly face challenges such as technological innovation bottlenecks, funding barriers, policy implementation deviations, imperfect market mechanisms, and talent shortages during the transition. In this regard, some scholars propose that technological innovation should be strengthened, policy support optimized, and industrial synergy and cross-border integration promoted to alleviate the transition difficulties of traditional industries and enhance their sustainable competitiveness.

Furthermore, from the perspective of industrial chains, although core enterprises can pull upstream and downstream enterprises towards the green transition through strategic upgrades, practical challenges such as the difficulty in optimizing energy structure and uneven sharing of transition costs still exist.

4.3. Data-driven identification of green transition risks

Facing the new risk situation of the green transition, traditional risk monitoring and prevention methods based on empirical induction seem somewhat inadequate. They not only exhibit systemic incompatibility in risk control models but also lack preemptive risk diagnosis and all-data precise evaluation in specific methods and processes.

Traditional risk monitoring and prevention research is mostly based on the summary of extensive historical risk response experiences or case analyses, subsequently analyzing influencing factors, causative factors, and constructing clear empirical evaluation indicators to monitor risks and make predictions, early warnings, and assessments based on empirical data. The big data-driven technology used in this study is committed to breaking the traditional empirical risk analysis model, bringing fundamental changes to risk situational awareness and analytical paradigms.

1. It is no longer confined to observing within the framework of known risk sources and influencing factors. Instead, it involves in-depth mining and analysis of massive daily behaviors by building multi-source spatiotemporal heterogeneous big data warehouses.

2. The modeling methods have undergone significant evolution, shifting from traditional "empirical models" developed based on existing business logic to "pure data-driven models" that dynamically revise and optimize based on simple physical law rules ("empirical models") using massive data.

3. Accordingly, AI large models and digital twin technology are used for the active diagnosis, precise identification, and intelligent policy formulation regarding green transition risks. Potential risks are actively diagnosed to accurately identify risks, promoting the shift in risk analysis from "empirical induction" to "letting the data speak (Data-Driven)".

The core of the "data-driven" risk monitoring and prevention model lies in long-term training on massive data. The collection and aggregation of "Space-Sky-Ground-Human-Network" multi-source spatiotemporal heterogeneous big data precisely provide key support for constructing a new risk monitoring and prevention method system for green transition risks.

1. Conducting in-depth mining and analysis of the patterns of green transition behaviors of governments, industries, enterprises, and individuals throughout the entire lifecycle of "planning-implementation-operation-optimization" of the green transition. Combined with cross-domain systematic risk systems encompassing social, economic, political, technological, and environmental

factors, real-time diagnosis of potential risks is performed to achieve precise identification and real-time risk warning.

2. Using data-driven big data models for intelligent judgment and decision-making, constructing a closed-loop management system of "Perception-Diagnosis-Intervention-Decision-Iteration" that can cover the entire process of dynamic risk monitoring and early warning, preemptive intervention, rapid response, and experience summarization.

3. On this basis, continuous long-term tracking of data sources is conducted again to obtain risk indicator data, while dynamically training, correcting, and tuning the data models, achieving an intelligent full-chain risk prevention and control support system for the green transition.

5. Conclusion

The green transition has become a key issue for global sustainable development, with related research continuously expanding and deepening from multiple angles. In risk research, various types of systemic risks such as energy security, carbon financial volatility, green trade barriers, and green washing have been identified at different levels including national, industrial, and enterprise, revealing the high uncertainty and structural tensions during the green transition process. However, existing research still focuses mainly on institutional tools, and risk analysis presents a fragmented trend, lacking systematic comprehensive identification and cross-level linkage analysis.

This process promotes the gradual intelligent leap of the risk prevention and control system, and current research focuses on the mutual construction relationship between holistic governance theory and green transition practice. The cross-domain synergy concept advocated by holistic governance can optimize the resource allocation and institutional resilience of green risk prevention and control by breaking down data barriers and fragmented responsibilities, thereby empowering multi-source heterogeneous data-driven dynamic risk perception. On the other hand, after new technologies are embedded into the holistic governance framework, they can promote the formation of a governance closed loop with multi-system linkage in green transition scenarios, ultimately accelerating the construction of a holistic governance system for green transition risk prevention and control, realizing the transformation of risk prevention and control from empirical judgment to intelligent decision-making.

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