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Medium- and long-term sustainable supply approaches and strategies for essential and typical strategic resources in China

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Abstract This paper examines sustainable supply strategies for essential and strategic resources in China, addressing both domestic requirements and global supply uncertainties. In the context of intense global competition for resources and substantial internal demand, China's significant role as a major consumer and global supplier is pivotal in the dynamics of the global supply chain. This study highlights China's dependence on imports for essential resources and the critical need for resilient supply chains to enhance national security and promote environmental sustainability. By referencing international experiences and accounting for China's specific circumstances, this study proposes strategic initiatives, including updating the strategic resource catalog, imposing export controls on key minerals, promoting resource conservation, and enhancing global cooperation. These strategies aim to reduce external dependencies and support global resource sustainability. The proposed framework can help policymakers ensure long-term resource security and manage resources more effectively in complex global landscapes.

Keywords resources, sustainable supply, supply chain, security, stability

1 Introduction

Essential and strategic resources serve as the material basis for residents' livelihoods, national defense construction, economic development, and the shift toward green and low-carbon practices. Essential resources include vital commodities such as water, coal, and agricultural products that are necessary for daily life and economic activities. In contrast, strategic resources, including rare earth elements, cobalt, and lithium, play crucial roles in high-tech industries, renewable energy technologies, and national security applications. There are important overlaps between these resource categories. For instance, while coal is primarily considered a fundamental resource due to its extensive use in power generation, it also holds strategic value due to its critical role in the energy supply, impacting both national security and economic stability. The significance of these resources lies in their widespread influence on the economy and society, as well as their strategic position in global technological and economic security.

First, essential and strategic resources serve as a firm foundation for promoting social security and stability. They are essential for human survival, economic development, industrial production, social stability, and national defense (Randive and Jawadand, 2019). For example, the energy supply profoundly affects people's quality of life (Vanegas Cantarero, 2020), and increased energy costs could result in millions falling into extreme poverty (Guan et al., 2023).

Second, essential and strategic resources are vital for attaining economic prosperity and development. China's economic recovery and growth heavily rely on the stable supply of these resources. As the world's largest manufacturing nation, these resources are the lifeblood of critical

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industries (Guo and You, 2023), particularly in meeting the high production demands of traditional manufacturing sectors.

Third, guaranteeing the provision of essential and strategic resources is an essential prerequisite for achieving high-quality development. As China strives toward its goals of “Carbon Peak and Carbon Neutrality,” it not only requires a stable supply of fossil energy but also must rapidly increase the supply of crucial mineral resources necessary for the development of green technologies (Calvo and Valero, 2022). For example, rare-earth elements and gold are essential for wind energy technology (Kim et al., 2015); metals such as copper are necessary for solar energy technology (Davidsson and Höök, 2017); metals are used in electric vehicles (Steinbuks et al., 2017); and metals such as lithium and cobalt are crucial for fuel cells (Grandell et al., 2016).

With the increasing significance of sustainable resource management worldwide, China has become increasingly critical due to its significant reserves of rare-earth elements and other critical minerals. With some of the world's largest reserves, China plays a pivotal role not only as a global supplier but also as a major consumer of these resources. This dual role presents distinct challenges and opportunities that are central to understanding and developing sustainable supply strategies.

China is currently undergoing a critical period of economic recovery and structural transformation, with the demand for essential and strategic resources remaining high (Zhang and Shi, 2023). Despite its abundant resources, China's reliance on resource imports has exposed vulnerabilities in its supply chain, highlighting the importance of enhancing resource security and self-sufficiency. For instance, in 2022, China's imports of cobalt and nickel reached \$1.4 billion and \$4.5 billion, respectively, accounting for 73.7% and 84.9% of the global total import value. This emphasizes China's significant dependence on external sources for critical materials.

In response to these challenges, the Chinese government has implemented strategic policy initiatives to bolster national security and enhance resource self-sufficiency. Recent measures include the implementation of export controls on minerals such as gallium and germanium, as well as the requirement for export licenses for graphite products. These measures demonstrate China's strategic approach to safeguarding its supply chain security in the face of global political and economic fluctuations.

The focus on these issues within the Chinese context is motivated by the need to address the vulnerabilities of China's supply chains amidst global political and economic fluctuations. Furthermore, this study aims to explore strategic measures that can effectively utilize China's resource endowments, thereby reducing external dependencies and promoting economic and environmental sustainability.

2 Main challenges in ensuring the medium- and long-term sustainable supply of China's essential and strategic resources

In the medium and long-term, China will continue to maintain its position as the world's largest producer and consumer of grain and energy, as well as the largest importer and consumer of strategic mineral resources. This will result in a continued high demand for essential strategic resources. Additionally, profound adjustments in the global political and economic landscape, intensified geopolitical conflicts, and escalating power rivalries among nations have increased risks. Therefore, ensuring a sustainable supply of China's essential and strategic resources in the medium- and long-term remains a significant challenge.

First, China is highly dependent on imports for essential and strategic resources. Although it is the world's largest consumer of these resources, there are still some resources for which self-sufficiency has not been achieved. With rapid economic development and a growing population, the demand for resources continues to rise, leading to a heavy reliance on imports for their supply. A notable example is the metal industry, which has faced substantial challenges in terms of the metal supply in recent years. This has resulted in increased vulnerability of the industry's energy consumption due to import dependence (Sun et al., 2023). In 2022, China's imports of iron, tin, cobalt, and nickel were \$128.1 billion, \$20.4 billion, \$1.4 billion, and \$4.5 billion, respectively, accounting for 79.5%, 97.6%, 73.7%, and 84.9%, respectively, of the global total import value.

Furthermore, the rapid changes in the international landscape and domestic demand for high-quality development have exposed inadequacies in the existing strategic mineral resources catalog. Introduced in 2016, this catalog includes 24 minerals and aims to streamline the management of critical resources and enhance strategic reserves. However, its limitations have become evident as it struggles to reflect the latest global trends in resource governance or the evolving strategic needs of China. Economic transformations have spurred the rise of new industries and technologies that require minerals not previously considered critical. This misalignment highlights the necessity of updating the catalog to include new basic and strategic minerals that are crucial for the current and future technological and economic landscape. Consequently, it is essential to revise and expand the strategic mineral resources catalog to ensure it aligns with the latest trends in global resource governance and meets the national strategic needs more effectively.

Moreover, despite China's significant mineral resource endowment, which ranks third globally, the country still faces high import dependence and significant supply risks (Reichl and Schatz, 2022). For instance, in 2021, out of

the 20 minerals consumed in China, 6 had an import dependence exceeding 50%, with the import quantities of strategic critical minerals such as petroleum, uranium, iron, chromium, copper, nickel, cobalt, and lithium metals exceeding 70% of domestic consumption.

Second, the instability of international supply chains is increasing. As the global political and economic landscapes evolve, supply chains for essential and strategic resources are facing increasingly severe challenges. Geopolitical conflicts, alterations in trade policies, and political instability in producing nations can all result in disruptions to supply chains or substantial fluctuations in resource prices. Some countries may utilize restrictions or bans on the export of certain resources as a political tool, directly impacting the global flow and price stability of resources (Sun et al., 2022). For instance, in recent years, the United States has entered into agreements such as the Energy Resource Governance Initiative and the “Mineral Security Partnership” with numerous nations to ensure resource availability while intensifying global competition for resource control, posing a significant threat to the stability of China’s strategic mineral supply chain.

Additionally, the financialization of global resource markets has exacerbated price volatility, with fluctuations in futures markets rapidly impacting the physical market and amplifying uncertainty in supply chains. In contrast, China’s commodity futures market started relatively late. Despite its rapid development, the market is still immature and lacks substantial influence over the pricing of resource products (Wang et al., 2022; Yang et al., 2021). For example, China’s crude oil futures market began trading in 2018, which is much later than the US market, which commenced in 1983. Moreover, although China is the world’s largest consumer of natural gas, its natural gas futures market has not yet begun to trade. This situation indicates that despite being a leading consumer of many strategic resources globally, China primarily assumes a follower role in global resource pricing mechanisms (Dai et al., 2022; Yao and Zhang, 2024).

Finally, the security of the supply chain for essential and typical strategic resources needs to be improved. China’s supply chain faces several challenges, including high concentration, excessive length, lack of diversification, and absence of coordination mechanisms. For instance, many of China’s overseas sources for essential and key strategic resources are relatively limited in number. According to the United Nations Commodity Trade Database (UN Comtrade), in 2022, China’s imports of several strategic resources exhibited high dependence on specific countries such as Russia, Australia, and the Democratic Republic of the Congo. This dependency makes the supply chain notably vulnerable to international political and economic fluctuations.

Additionally, China’s strategic resource supply chains are highly concentrated in specific regions or enterprises,

leading to significant disparities between different areas and companies. The challenges encountered by these regions or enterprises can have a profound impact on the entire supply chain. Moreover, the lengthy process involved in resource extraction, processing, and final sale includes multiple intermediary stages, which results in higher transaction costs and the potential for information asymmetry. These factors ultimately detract from the efficiency and quality of the supply chain.

Furthermore, control over core technologies and resources within the supply chain is dominated by only a few enterprises or regions and lacks diversification. This concentration increases the vulnerability and fragility of supply chains.

Finally, there is a lack of effective coordination mechanisms between different links of the supply chain and between upstream and downstream enterprises. This leads to information and data silos, hindering the overall development and innovation capacity of the supply chain.

3 International experiences and lessons for China

International experiences offer valuable insights into addressing the challenges of sustainable resource supply. This section explores relevant strategies and practices from developed countries and analyzes their applicability to China’s unique context.

First, the updating of critical mineral lists to reflect strategic development priorities is important. Countries develop these lists using distinctive screening models and methods based on selected indicators. While the models, methods, and indicators may vary, they rely on relatively stable assessment mechanisms. For instance, the United States, Australia, Russia, the European Union, the UK, and Japan have listed 35, 24, 43, 27, 40, and 31 critical minerals, respectively, utilizing their unique models and methods. The US prioritizes factors such as supply risk, production growth, and market dynamics, considering aspects such as production concentration, net import dependence, and byproducts. Australia focuses on the geological endowment and supply situation. Russia considers national economic needs, development conditions, reserves, and geological prospects for mineral raw materials. The European Union assesses minerals based on supply risk, economic importance, and environmental risk, categorizing a mineral as critical if it meets all three specified thresholds.

Accordingly, the lists of critical minerals undergo dynamic updates. For example, the US Department of Energy launched the “Critical Minerals Strategy” in 2012, and the US Department of Commerce issued the “Federal Strategy to Ensure a Reliable Supply of Critical Minerals” in 2019. The European Union initially published its list of critical raw materials in 2010 and

revised it in 2017. Russia revises its list of critical minerals approximately every five years.

This strategy helps to address the challenges of resource supply volatility and external dependencies mentioned in Section 3. By maintaining an up-to-date critical mineral list, China can better manage supply risks and align with strategic development priorities. China can also adopt similar dynamic updating mechanisms for its critical mineral list, taking into account its unique economic, geological, and industrial conditions. This strategy will enhance the country's ability to predict and mitigate resource supply risks, resulting in a more resilient and responsive resource management system.

Second, it is important to enhance international cooperation to establish leadership in the global resource industry. Through international cooperation, clear and effective global mining governance rules have been established. Leading developed countries have taken the lead in various international cooperative initiatives. For instance, in 2018, the United States and Japan issued a joint statement to coinvest in liquefied natural gas infrastructure projects. Furthermore, in August 2019, they signed a memorandum to expand energy sector collaboration in sub-Saharan Africa. In June 2019, the United States launched the Energy Resource Governance Initiative, which facilitates the sharing of mining expertise and experiences with different countries to enhance their capabilities in exploring and developing minerals such as lithium, copper, and cobalt, as well as managing the mining industry. This initiative supports the establishment of a resilient supply chain for critical minerals. Additionally, in 2022, the United States, together with key global partners, including European and Asian nations, established the Mineral Security Partnership. This initiative focuses on securing the supply of critical minerals essential for clean energy and advanced technologies.

This strategy helps to address the challenges of external dependency and resource supply chain security mentioned in Section 2. By strengthening international cooperation, China can establish more stable and diversified resource supply channels, reducing its dependence on single sources. China can adopt these international cooperation models to build long-term partnerships with resource-rich countries, ensuring a stable supply of critical minerals. In advancing its Belt and Road Initiative, China has already begun to establish cooperative relationships with multiple resource-rich countries, which is particularly important for enhancing the stability of the global resource supply chain. This will enhance China's voice and influence on global resource governance while improving the efficiency and stability of domestic resource management. By adopting this approach, China can more effectively predict and mitigate resource supply risks, ensuring the security and resilience of the resource supply chain.

Finally, it is crucial to enhance domestic resource

extraction to reduce reliance on foreign resources. Various countries have implemented effective strategies to promote domestic resource development, diminish dependence on imports, and strengthen local supply capabilities.

(1) To encourage increased local resource extraction, countries employ incentives such as tax breaks. For instance, in 2019, the Russian government significantly reduced the rare earth mining tax from 8% to 4.8%, which sparked enthusiasm among enterprises for rare earth development (Cherepovitsyn and Solovyova, 2022). Similarly, in August 2022, the United States passed the "Inflation Reduction Act," which provides up to \$7,500 in tax credits for every new energy vehicle purchased by US households. However, this benefit is exclusive to vehicles that utilize critical minerals that are mined, processed, or recycled in North America or its allied countries, as well as battery components produced within the same regions.

(2) Furthermore, financial support plays a crucial role in facilitating domestic resource extraction. For example, the German government offers unconditional financial loan guarantees to mining companies, thereby mitigating financing risks for their international projects. Moreover, it provides investment guarantees to support direct investments by German companies in developing nations and emerging economies. Additionally, targeted mineral exploration loans are available to alleviate financing challenges for enterprises, thereby promoting development and invigorating the market.

(3) Countries are actively advancing their resource extraction technologies to enhance their domestic capabilities. An illustrative example is the US Department of Defense's agreement with Lynas, an Australian company, in June 2022. The \$120 million agreement aims to establish the first heavy rare earth refining and separation production line in the United States. This initiative is intended to strengthen the United States' capacity for rare earth refining and processing while ensuring a steady supply of rare earth products.

Several countries, including the United States, Germany, and Finland, have established specialized institutions dedicated to mining engineering, geology, earth sciences, and related disciplines. The objective of these institutions is to cultivate a skilled workforce proficient in modern mining technologies that integrate advanced high-tech methods with traditional practices. Furthermore, specialized research departments and projects are being established to address critical industry challenges, with substantial research funding allocated to maintaining leadership in specific areas.

In September 2020, the European Commission submitted the "Critical Raw Materials Resilience: Charting a Path to a Safer and More Sustainable Future" report to the European Council and Parliament. The report proposed ten actions to ensure the supply of critical minerals, with

actions 5 through 8 concentrating on enhancing Europe's production and supply capabilities. These actions entail supporting domestic mineral extraction and processing projects, enhancing expertise and skills in development, implementing earth exploration and remote sensing monitoring projects, and carrying out research and innovation initiatives to minimize environmental impact.

This strategic approach effectively addresses the challenges posed by external dependency and resource supply chain security, as discussed in Section 2. By bolstering domestic resource extraction, China can mitigate its reliance on foreign resources and enhance the stability and security of its domestic resource supply. China can draw upon international experiences and employ incentives such as tax benefits and financial support to motivate domestic enterprises and strengthen the research and application of resource extraction technologies. For instance, China can adopt approaches utilized by the United States and Germany, which advocate for policy incentives and financial support to increase the domestic extraction and processing capacities of critical minerals such as rare earth elements, cobalt, and lithium. Furthermore, by increasing investments in domestic geological exploration to discover and develop new mineral resources, China cannot only curtail its dependence on external markets but also actively participate in global resource governance.

By analyzing and incorporating the successful experiences of developed countries in strategic resource planning, international resource cooperation, and domestic resource development, China can effectively address the challenges of external dependency and resource supply chain security mentioned in Section 2. However, it is essential to adjust and optimize these international experiences to suit China's specific conditions. Section 4 will provide detailed countermeasures and suggestions to further implement these experiences and strategies, ensuring a sustainable and secure resource supply for China in the future.

4 Approaches and strategies for China's medium and long-term sustainable supply of essential and strategic resources

In the face of numerous environmental and security challenges, such as global climate change, geopolitical conflicts, and increasing international competition, the uncertainty and instability of the global political economy are on the rise. This exacerbates the risk of disruptions in China's supply chains for essential and strategic resources. To ensure the medium- and long-term sustainable supply of these resources, it is crucial to establish stable and secure supply chains. The stability of the supply chain not only impacts the entire lifecycle of resource products, from production to consumption but

also directly affects the control and availability of resources (Villena and Gioia, 2020). Reducing external dependence on critical strategic resources and enhancing resilience through strategic layout optimization and risk management are key ways to strengthen China's supply chain resilience and increase global influence.

First, it is necessary to update the list of essential and strategic resources to address the issues of supply chain instability and external dependency risks mentioned in Section 2. Continuously updating the list of critical minerals will enable China to better manage supply risks and align with strategic development priorities. China's economic development has transitioned from a phase of high-speed growth to one of high-quality development. Resource consumption is now characterized not only by a large overall volume, diverse varieties, and wide-ranging applications, but also by the fact that different types of resources are entering a period of rapid transformation characterized by mutual growth and decline, as well as successive progress. Therefore, it is necessary to establish and regularly update a list of essential and strategic resources that aligns with China's national conditions and the evolving international landscape. This will lay the groundwork for enhancing the country's resource security and its ability to participate in global resource governance. Considering the supply risks of strategic mineral resources, their importance to the national economy and defense security, and their indispensability to strategic emerging industries, a methodology for evaluating China's strategic mineral resources is proposed. This system will help determine and dynamically update the catalog of fundamental and strategic resources in China, improve the country's ability to predict and mitigate resource supply risks, and ensure a more resilient and responsive resource management system.

Second, it is important to enhance self-sufficiency to reduce dependence on essential and strategic resources from external sources. China has already implemented various measures to expand the supply of these resources, such as making breakthroughs in mineral exploration, reforming the mining rights system, and improving technical standards for resource utilization. These efforts have yielded significant results, including the discovery of new mineral deposits and increased efficiency in resource extraction. However, to further reduce external dependence and enhance the security of the supply chain, additional measures are still necessary.

(1) One such measure is to intensify domestic exploration of scarce resources to enhance supply capacity and international competitiveness. This can be achieved by streamlining relevant policies and approval procedures to encourage domestic exploration and extraction of critical scarce resources. Continuous efforts should be made to explore China's scarce strategic minerals, with a focus on increasing technological support and strengthening technological capabilities in the mining, processing, and

smelting of these minerals. This will help to maintain a competitive advantage.

(2) Emphasis should be placed on the development of breakthrough core technologies for resource extraction, particularly in the field of intelligent mineral exploration. It is crucial to innovate predictive theories for mineral exploration and develop advanced exploration technologies and equipment. Special attention should be given to mineral exploration in new areas characterized by high altitudes, deep incisions, and shallow coverages, as this will significantly enhance exploration efficiency.

(3) Efforts should be made to advance the development and utilization of resource exploitation technologies. This includes the development of efficient selection, smelting, and comprehensive utilization technologies for large-scale mineral resources and coexistent ores. These technologies should be specifically applied in regions such as Panxi, Baotou, and Aba Tibetan and Qiang Autonomous Prefecture. Key technologies, such as precise selection, green and low-carbon smelting and separation, recycling and utilization of materials, and large-scale balanced application of high-purity rare earth elements, should be prioritized for development.

(4) The promotion of resource substitution and the construction of a national reserve system should be prioritized. Extensive research should be conducted on alternative technologies for scarce mineral resources, such as aluminum replacing copper, magnesium replacing aluminum, and sodium-magnesium-vanadium replacing lithium. In addition, a comprehensive national reserve system should be established to increase storage capacity and strengthen distribution, transfer, and comprehensive support functions. It is important to increase emergency reserves for scarce resources, optimize the layout of energy reserve facilities, and improve coordination mechanisms to ensure the supply of coal, electricity, oil, and gas. Furthermore, a reserve system that covers the entire chain, from mining to smelting, materials, equipment manufacturing, and recycling, should be built. The oil and gas reserve system should be given priority, with an equal level of importance as exploration and development investments.

Third, there is a need to actively strengthen resource diplomacy to enhance the global competitiveness of essential and strategic resources and to address the supply chain instability and external dependency risks mentioned in Section 2. By reinforcing resource diplomacy and promoting the development of resource futures markets, China aims to increase its global control and influence over the supply chain of essential and strategic resources. This is essential for ensuring the smooth operation of the supply chain, particularly in extreme circumstances, and for guaranteeing a secure and stable supply of essential and strategic resources.

(1) Deepen resource cooperation and promote the

construction of a global community for essential and strategic resources. China has successfully established intergovernmental energy cooperation mechanisms with more than 90 countries and regions. It has collaborated with more than 30 international organizations and multi-lateral mechanisms in the energy sector and has undertaken significant projects, such as oil and gas cooperation zones in Central Asia-Russia, the Middle East, Africa, the Americas, and the Asia-Pacific region. Through notable platforms such as the China International Mining Conference and the China-ASEAN Mining Cooperation Forum, China has deepened its international cooperation in mineral resources. These efforts have yielded substantial results, consolidating China's position and influence in the global resource supply chain.

Moving forward, China should continue collaborating with resource-rich nations, including Chile, Brazil, Peru, Indonesia, the Philippines, South Africa, the Democratic Republic of the Congo, Russia, and Middle Eastern countries. Moreover, China should extend its invitations to resource-rich western nations, such as Canada and Australia, to engage in and foster secure and mutually advantageous supply mechanisms for critical minerals. By pursuing such collaborations, China can avoid being isolated from the international supply chain and instead foster a closely interconnected community for resource security.

(2) Participate in the construction of global industrial and supply chains for essential and strategic resources. Setting up a novel international cooperative framework embedded within the global value chain can enable control over core technologies and value-added links. By relying on its abundant raw material advantages in terms of essential and strategic resources, China can actively participate in the development of global industrial chains. This involvement includes continuous enhancement and transformation of these chains, as well as advancements in the technical proficiency of related industries.

By promoting China's essential and strategic resource supply chains as vital components of global circulation, the aim is to ensure the safety and stability of the world's supply chains. This entails identifying and resolving bottlenecks and obstacles, reestablishing disrupted links, and fortifying the supply chain's resilience against risks. Enhancing control and influence within the global industrial chain is crucial to gaining pricing power for resources and establishing the security and stability of the essential and strategic resource supply chain.

(3) Participate in the global governance of essential and strategic resource supply chains. The governance structure of these supply chains should be strengthened by actively participating in international conferences and joining strategic resource security organizations. China should assume a key role in formulating global resource security governance rules, promote the establishment of a mutually beneficial resource allocation governance system, and

shift from being a recipient to being a creator of resource governance rules. Foster the stable development of resource supply chains, drive the reform of the global resource supply chain security governance mechanism, and establish a comprehensive security governance system.

(4) Improve the trading mechanism for essential and strategic resources to strengthen China's pricing power. Launch and further enhance the regulatory system for futures markets in China, enhance the global openness of these markets, expand trading channels, and increase the pool of investors in China's strategic resource futures market. China's influence in the international futures market has gradually increased, a mature international futures trading market has been established, China's futures trading market has transformed into an international pricing center, and international pricing power regarding strategic resources has been enhanced.

Fourth, the sustainable use of essential and strategic resources should be improved through green transformation to directly address the challenges of low resource utilization efficiency and environmental impacts mentioned in Section 2. A resource–product–circular utilization pathway aimed at boosting resource utilization efficiency on the consumption side, exploring alternative resources, and developing a recycling economy on the production side should be established to enhance sustainable resource utilization and alleviate pressure on resource supply.

The green transition of the resource industry should be promoted to increase the level of green development and address the issues of an unsound industrial structure and low technological level mentioned in Section 2. Stricter criteria for entry into the green industry sector should be implemented to encourage the establishment of green mines and green resource-based industries and to guide enterprises toward supporting the resources required for new energy, new materials, and new-generation information technology.

To address the environmental pressures discussed in Section 2, it is crucial to implement a corporate carbon emission management account system and manage corporate carbon emissions in accordance with international standards. Collaboration with downstream smelting and transportation enterprises is key to collectively reducing carbon emission intensity across the entire value chain. This collaborative effort not only tackles carbon emissions, but also raises the overall environmental standards of the supply chain.

In terms of production, there should be a vigorous push toward the development of a circular economy, enabling the recycling and reuse of resources to combat the issues of resource waste and inadequate recycling highlighted in Section 2. The goal is to achieve sustainable resource utilization that supports the continual supply of essential and strategic resources. China must enhance its secondary

resource recycling system and optimize relevant policies. By establishing an information-oriented resource recycling management platform, it becomes possible to increase the levels of secondary utilization of steel, nonferrous metals, precious metals, and rare metals.

Finally, the construction of an information support system should be strengthened to strengthen risk prevention and control capabilities to address the challenges of supply chain instability and external dependence mentioned in Section 2. Risk awareness must be heightened, and the ability to predict and prevent risks must be improved. To ensure resource supply during critical moments, China should enhance its ability to guarantee resource reserves. Leveraging the advantages of information technology and digital economics and utilizing multisource heterogeneous dynamic big data and various artificial intelligence techniques, a risk monitoring and response system capable of adapting to global changes can be constructed. Ultimately, this system will fortify the security of supply chains for essential and strategic resources.

On the one hand, it is necessary to establish an information-sharing platform and supply chain management system to enhance production and supply analysis capabilities. China should strengthen its ability to collect and analyze relevant data pertaining to essential and strategic resources and establish a comprehensive database. It is crucial to employ techniques such as data mining and artificial intelligence algorithms to analyze both macro- and micro-risk factors that affect the security of essential and strategic resources within multisource heterogeneous big data, ultimately identifying production and supply information as well as trends.

On the other hand, it is essential to establish an essential and strategic resource risk monitoring system to enhance the ability to perceive, warn, and address risks. China should integrate multidimensional data, including industrial policies, market mechanisms, and domestic and international environments, to form a comprehensive strategic resource warning mechanism. This mechanism will enable rapid and accurate identification and prediction of potential risks, ultimately strengthening the security of China's strategic resource supply chain. Additionally, an information platform should be created to improve transparency, reliability, and efficiency in managing risks. Risk disposal plans should be developed based on thorough risk assessments to ensure that swift and effective measures can be implemented to minimize the effects of risks.

5 Conclusions

To maintain the stable operation of the economy and society by continuously supplying essential and strategic materials, it is crucial to ensure the long-term sustainable

supply of these resources. This paper has explored the challenges faced by China in terms of the sustainable supply of essential and typical strategic resources, taking into consideration the unique characteristics of China's resource endowment and the current international environment, and has proposed corresponding approaches and strategies.

Given the high dependence on external sources, intense competition, and uncertainty in the international supply chain, it is crucial to enhance the security of China's resource supply. This paper recommends the following five measures to ensure sustainable resource supply in the mid- to long-term: (1) regularly updating the list of essential and strategic resources; (2) increasing self-sufficiency to reduce dependence on external sources of essential and strategic resources; (3) strengthening resource diplomacy to enhance the global competitiveness of essential and strategic resources; (4) promoting the sustainable utilization of essential and strategic resources through green transitions; and (5) improving the development of an information support system to enhance capabilities in risk prevention and control. These strategies aim to secure a stable and sustainable supply of critical resources, supporting the resilience and growth of China's economy and society.

Competing Interests The authors declare that they have no competing interests.

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