SUSTAINABILITY AT THE CROSSROADS: FORECASTING RARE EARTH MINE SUPPLY THROUGH ECONOMIC AND ENVIRONMENTAL POLICIES FOR A LOW-CARBON ENERGY TRANSITION

Deyi Xu, School of Economics and Management, China University of Geosciences (Wuhan), +86-18971639698, xdy@cug.edu.cn
Yongguang Zhu, School of Economics and Management, China University of Geosciences (Wuhan), zhuyongguang@cug.edu.cn

Overview

Rare earth minerals (REM) have gained significant attention in recent years due to their essential role in driving technological innovation and the development of green energy technologies. Despite the growing scholarly focus on REMs, particularly regarding their importance in modern technologies and green energy systems, there has been limited exploration of how specific economic and environmental policy factors affect REM mine supply dynamics.

Methods

We use an integrated methodological framework, combining Temporal Causal Modelling (TCM) with ARIMA model. This framework enables a comprehensive analysis of both direct and indirect causal interdependencies between REM production and the identified influencing policy drivers, along with forecasting trends. TCM—a specialized technique in SPSS Statistics for time series and panel datasets—is implemented to forecast direct and indirect causal interdependencies as well as REM mine supply projections up to 2040 using root cause and scenario analyses. Finally, we construct eleven independent ARIMA models corresponding to each REM producer to validate projections and provide regional insights, thereby enhancing the reliability and precision of the results.

Results

TCM forecasts that research and development expenditures, clean energy technologies (CEP), climate physical risk, and economic and climate policy uncertainties—along with investment in the clean energy sector—are key drivers of REM production. These factors exert both direct and indirect effects, contributing to a projected increase in REM mine supply to 850 kilotons by 2040 (almost 150% surge). These projections are further verified by eleven independent ARIMA models for each REM producer, which also reveal that China will continue to be the largest contributor to this increase (almost 400 kilotons), followed by Myanmar (50 kilotons), and Australia (18 kilotons) up to 2040. This projection is driven by growth patterns in clean energy technologies (200% increase), economic and climate policy uncertainties, and R&D expenditures (more than 25% of GDP) along with a subsequent reduction in climate physical risks (300% drop). The bidirectional temporal causal interdependencies among REM, R&D, CEP, CPU, CPRI, and EPU suggest that technological, economic, and environmental policies are deeply interconnected.

Conclusions

These interconnected dynamics call for a coordinated, strategic approach that integrates innovation, stable regulatory frameworks, and circular economic practices to ensure a resilient REM supply. Policies promoting clean energy R&D, efficient recycling technologies, and transparent resource governance are crucial for balancing resource availability with environmental sustainability. Addressing these challenges will be essential for supporting the global transition to clean energy and achieving long-term economic and environmental goals while mitigating supply constraints and reducing reliance on primary resource extraction.

References