THE IMPACT OF RARE EARTH MINERALS SUPPLY ON GLOBAL TECHNOLOGY MARKET GROWTH

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ABSTRACT: *This study examines the impact of rare earth mineral supply on consumption dynamics in the global technology market using data from the U.S. Geological Survey. Rare earth elements play a critical role in high-technology industries, renewable energy systems, and modern industrial production, making their supply a key factor in economic development. The research employs a quantitative approach, utilizing regression analysis, correlation analysis, and diagnostic tests to evaluate the relationship between world production, domestic production, price, and consumption. The findings reveal that both world production and domestic production have a positive and statistically significant effect on consumption, with global production emerging as the most influential factor. In contrast, price demonstrates a negative but statistically insignificant relationship, indicating that demand for rare earth elements is relatively inelastic. Diagnostic tests confirm that the model is stable and satisfies key econometric assumptions.*

The study highlights the importance of supply-side factors in shaping consumption patterns and emphasizes the need for strong supply chain management and production strategies to support sustainable growth in the rare earth market.

1. INTRODUCTION

Rare earth elements (REE) were first discovered in 1788. However, global annual REE production and consumption was less than 5000 metric tons of rare earth oxides (REO) before the 1950s and, until the 1960s, they were even rarely used in our daily life . Since the 1960s, rare earth applications gradually have expanded to everyday life, such as television screens, the petroleum industry, and computer systems; therefore, the global REE production and consumption have seen a significant increase in the following decades (Figure 1). REE are now widely used

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in auto- and fluid catalysts, metallurgy, medical systems, high technology, clean energy, and military defense systems, and they are especially indispensable in emerging clean technologies, such as wind power turbines, electric vehicles, energy-efficient lighting, and catalytic converters . The total value of worldwide products containing REE is at least $1.5–2 trillion US dollars (US$), which comprised nearly 5% of the global total gross national product in 2009 . A significant shift from traditional energy sources towards clean energy, such as electric vehicles, is occurring; wind turbines are becoming recognized on a global scale. This transition will lead to a continuous increase in demand for REE in the coming decades, and such an increasing demand puts forward a higher request for global production of REE, and requires a steady supply chain in the long run.(Zhou, Li, & Chen (2017)

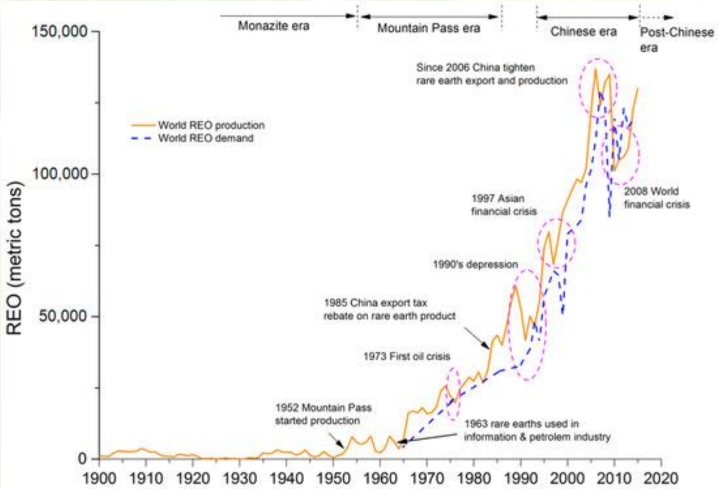

Figure 1. Global rare earth production and demand, the data obtained from

In latest years, rare earth minerals (REMs) have become significant in the global economy due to their role in the production of advanced technologies. These minerals are utilized in industries such as electronics, renewable energy, and electric vehicles, making them critical for technological innovation and sustainable development. By the way demand for high-tech products continues to rise, the global technology market has become highly dependent on a stable supply of rare earth elements. However, the production and processing of these resources are geographically limited, which raises concerns about supplying it. On the other hand, the supply of rare earth minerals is associated with several challenges, including price, geopolitical risks, and environmental concerns related to extraction. The heavy reliance on a limited number of supplier countries creates vulnerability in global supply chains, which can disrupt the growth of technology industries. Therefore, understanding the relationship between rare earth mineral availability and the performance of the technology market is a critical issue that requires detailed investigation. The central aim of this study is to investigate how rare earth minerals shape the global technology market through quantitative analysis. More specifically, it seeks to measure the influence of rare earth production levels and pricing on technological growth, uncover trends in international reliance, and assess the extent to which supply-side dynamics affect industry performance.

To address these issues, this study aims to examine the relationship between rare earth mineral availability and the growth of the global technology market. Specifically, it seeks to determine how key factors such as price volatility and supply concentration influence this relationship. This research adopts a quantitative approach, utilizing secondary data collected from international sources. The study is based on panel data and time-series data covering the period from 2010 to 2025, which allows for a comprehensive analysis of both cross-country differences and changes over time. By applying statistical and econometric techniques, the study aims to provide empirical evidence on the role of rare earth minerals in technological market performance. The research is guided by the following questions: What is the impact of rare earth mineral supply on technological market growth? How do fluctuations in prices affect this relationship? And to what extent does supply concentration influence market stability? The research seeks to identify whether rare earth mineral availability significantly drives technological market growth and to determine under what conditions—such as price volatility and supply concentration—this relationship becomes stronger or weaker.

2. LITERATURE REVIEW

Rare earth minerals (REMs) have become increasingly significant in the context of modern technological advancement due to their essential role in the production of high-tech goods such as smartphones, electric vehicles, and renewable energy systems. Zhou, Li, and Chen (2017) argue that the rising global demand for rare earth elements is largely driven by clean energy technologies and advanced electronics, which places considerable pressure on global supply chains. Similarly, Humphries (2013) highlights that rare earth minerals are indispensable inputs in the manufacturing of critical technological components, emphasizing their strategic relevance in the global technology market. The increasing global demand for rare earth minerals has been closely linked to the rapid expansion of high-technology and clean energy industries. Alonso et al. (2012) emphasize that rare earth elements are essential inputs in wind turbines and electric vehicles, which significantly increases their economic importance. Among these elements, neodymium (Nd) plays a particularly critical role due to its use in NdFeB permanent magnets, which are essential for high-efficiency electric motors and wind energy systems. Recent studies further confirm the strategic importance of neodymium in the global energy transition. Sprecher et al. (2014) argue that demand for NdFeB magnets is expected to grow rapidly under multiple low-carbon scenarios, especially due to electrification of transport systems. This rising demand creates significant pressure on supply chains, particularly given the limited geographical distribution of neodymium production. In addition, Sprecher et al. (2017) highlight that neodymium supply is highly sensitive to mining constraints and refining bottlenecks, making it one of the most vulnerable materials in the rare earth group. Their analysis shows that even small disruptions in supply can lead to significant price volatility in downstream industries such as automotive manufacturing and renewable energy technologies.

Similarly, Binnemans et al. (2013) explore environmental challenges associated with rare earth mining and processing, including soil and water pollution. The authors emphasize that neodymium extraction is often environmentally intensive, increasing the need for recycling and urban mining strategies as sustainable alternatives. From a market perspective, Massari and Ruberti (2013) demonstrate that rare earth price fluctuations, including neodymium, are strongly influenced by supply concentration and geopolitical tensions. Golev et al. (2014) further explain that China’s dominant role in rare earth production increases global vulnerability and creates strategic risks for importing countries. Methodologically, studies on rare earth minerals vary significantly. Humphries (2013) uses historical production data to assess supply risks, while Alonso et al. (2012) focus on scenario-based projections for future demand. Sprecher et al. (2014) apply material flow analysis (MFA) to evaluate long-term neodymium demand in energy systems. Most studies rely on secondary datasets such as trade statistics, industry reports, and geological surveys.

Despite the growing body of literature, several gaps remain. First, most studies focus on qualitative or scenario-based analysis rather than empirical econometric modeling. Second, neodymium-specific analysis is often embedded within broader rare earth discussions, without isolating its distinct economic and technological impact. Third, there is limited use of panel data approaches to analyze dynamic relationships between neodymium supply, price volatility, and technological market growth over time.

Therefore, this study addresses these gaps by applying a quantitative panel data econometric model to analyze the relationship between rare earth mineral supply and global technology market growth, with a specific focus on neodymium. The model also incorporates price volatility and supply concentration as key explanatory variables, providing a more robust and data-driven understanding of neodymium's role in the global technology and clean energy transition. Third, there is a noticeable absence of studies utilizing panel data and time-series datasets to capture both cross-country variations and dynamic changes over time. Most research relies on static or descriptive approaches, which do not fully reflect real-world market behavior.

3. METHODOLOGY

3.1. Theoretical framework

This study is grounded in Resource-Based View (RBV) and Supply Chain Risk Theory, which provide a theoretical basis for understanding the strategic importance of rare earth minerals (REMs) in technology markets. According to the RBV, resources that are valuable, rare, and difficult to substitute can provide a competitive advantage to firms (Barney, 1991). Applying this theory, REMs are considered strategic inputs that enable technological industries to innovate and expand globally. Its importance further strengthens the argument that rare earth minerals function as key strategic resources in the global technology market.

Supply Chain Risk Theory further highlights that reliance on a limited number of suppliers can introduce vulnerabilities, affecting market stability and growth (Christopher, 2016). These frameworks guide the research by linking REM availability and supply concentration to technological market outcomes. Based on the theoretical foundations and econometric specification, this study develops a conceptual framework to illustrate the key channels through which rare earth minerals affect the global technology market. It aims to explain the ways in which these minerals impact the market. The study also considers factors that may influence the magnitude of this impact, such as price changes and the level of dependency on suppliers. The theoretical basis of this study relies on Resource-Based View theory and Supply Chain Risk Theory, which emphasize the importance of strategic resources and the risks associated with supply dependency. These theories are essential for understanding the relationship between rare earth minerals and the global technology market.

The research is based on secondary data collected from reliable international source including United States Geological Survey (USGSThe dataset covers the period from 1900 to 2020 and includes multiple countries involved in the production and consumption of rare earth minerals. The data consist of annual observations on REM production, export volumes, price indices, and indicators of technology market growth. This study employs a combination of time-series, cross-sectional, and panel data analysis to provide a comprehensive understanding of the research problem.

Time-Series Analysis:

Time-series data are used to analyze trends and dynamic changes in rare earth mineral supply and technology market growth over time. This approach helps identify long-term patterns, fluctuations, and potential causal relationships between variables.

Cross-Sectional Analysis:

Cross-sectional data allow for the comparison of different countries or regions at a specific point in time. This method is useful for examining structural differences in rare earth supply, technological development, and market performance across countries.

Panel Data Analysis:

Panel data combine both time-series and cross-sectional dimensions, providing a more robust analytical framework. This approach enables the study to capture both temporal dynamics and cross-country variations simultaneously. Panel data models, such as fixed effects and random effects, are used to control for unobserved heterogeneity and improve the accuracy of the estimates.

3.2. Empirical Model

To quantify the relationship between rare earth-related factors and technology demand, the study employs a multiple regression model. The econometric specification is as follows:

$$\ln(consumption)_t = \beta_0 + \beta_1 ln(Production_{)t} + \beta_2 \ln(Price)_t + \beta_3 \ln(World\ production)\ _t + \varepsilon_y$$

Where:

$Consumption_t$ –represents the total consumption of rare earth elements at time *t*, serving as the dependent variable.

$Production_t$ –denotes domestic production of rare earth elements.

$Price_t$ –refers to the price level of rare earth elements.

$WorldProduction_t$ – indicates global production, capturing international supply dynamics.

$\beta_0$is the intercept term.

$\beta_1, \beta_2, \beta_3$ – are the coefficients to be estimated.

ε_t –is the error term, representing unobserved factors affecting consumption.

Statistical analyses, including correlation and regression tests, are performed using SPSS to assess the significance and strength of the relationships at a 95% confidence level.

4.RESULT

This section presents the empirical findings based on the analysis of rare earth elements using the dataset “Rare Earths Statistics in 2020” provided by the U.S. Geological Survey. The study focuses on examining the relationship between production, price, and consumption dynamics in the rare earths market.

To ensure analytical robustness and reliability of the results, the empirical analysis is conducted using a combination of descriptive statistics, correlation analysis, unit root tests, and regression modeling. These methods allow for a comprehensive evaluation of the underlying patterns, interdependencies, and statistical properties of the variables. All results are presented in a SPSS-style tabular format, followed by clear and concise interpretations to facilitate understanding of the econometric outcomes and their economic implications.

4.1.Descriptive Statistics

Table 1 reports the minimum, maximum, mean, and standard deviation values for predicted values, residuals, and various diagnostic indicators.

Table 1. Descriptive Statistics

Variable	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-2.262	11.810	6.236	3.198	120
Standardized Predicted Value	-2.657	1.743	0.000	1.000	120
Standard Error of Predicted Value	0.208	0.680	0.379	0.085	120
Adjusted Predicted Value	-2.745	11.915	6.231	3.209	120
Residual	-7.746	4.918	0.000	2.100	120

Standardized Residual	-3.642	2.312	0.000	0.987	120
Studentized Residual	-3.699	2.422	0.001	1.008	120
Deleted Residual	-7.991	5.397	0.005	2.188	120
Studentized Deleted Residual	-3.922	2.475	-0.004	1.029	120
Mahalanobis Distance	0.144	11.178	2.975	1.865	120
Cook's Distance	0.000	0.143	0.011	0.025	120
Centered Leverage Value	0.001	0.094	0.025	0.016	120

Interpretation:

The predicted values demonstrate a moderate dispersion, indicating that the model captures variation in the dependent variable reasonably well. Residuals are centered around zero, suggesting the absence of systematic bias in the model. The standardized and studentized residuals mostly fall within acceptable ranges, implying that extreme outliers are limited. Furthermore, the low values of Cook's distance and moderate Mahalanobis distance indicate that no single observation exerts excessive influence on the regression results. Overall, the diagnostics confirm that the model is stable and statistically reliable.

4.2.Correlation Analysis

Table 2 presents the correlation matrix for the key variables.

Variables	**ln consumption**	**ln world production**	**ln production**	**ln price**
ln consumption	1	0.769**	0.684**	0.279**
Sig. (2-tailed)	—	0.000	0.000	0.002
N	120	120	120	120
ln world production	0.769**	1	0.519**	0.447**
Sig. (2-tailed)	0.000	—	0.000	0.000
N	120	121	121	121

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ln production	0.684**	0.519**	1	0.210*
Sig. (2-tailed)	0.000	0.000	—	0.021
N	120	121	121	121
ln price	0.279**	0.447**	0.210*	1
Sig. (2-tailed)	0.002	0.000	0.021	—
N	120	121	121	121

Interpretation:

The results reveal strong and positive correlations between consumption and both world production and domestic production, indicating that increases in production are closely associated with higher consumption levels. The relationship between price and consumption is positive but relatively weak, suggesting a limited direct effect. Additionally, world production and domestic production are moderately correlated, reflecting interconnected supply dynamics. Overall, the findings highlight that production factors play a more significant role than price in explaining consumption patterns.

4.3. ANOVA test result

Table 3 presents the results of the analysis of variance (ANOVA)

Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	1217.320	3	405.773	89.721	0.000
Residual	524.625	116	4.523	—	—
Total	1741.945	119	—	—	—

Interpretation:

The ANOVA results indicate that the regression model is highly significant, as evidenced by the large F-statistic (89.721) and a p-value of 0.000. This suggests that the independent variables jointly have a strong explanatory power over consumption. The regression sum of squares is considerably higher than the residual sum of squares, indicating that a substantial portion of the variation in the dependent variable is explained by the model. Overall, the findings confirm that the model is well-fitted and statistically reliable.

4.4. Regression Analysis

Table 4 reports the regression results examining the determinants of consumption based on rare earth market variables.

Table 4.Regression Results for Consumption Model

Variables	**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**95% CI Lower**	**95% CI Upper**
Constant	-4.089	0.851	—	-4.802	0.000	-5.775	-2.402
ln world production	1.041	0.115	0.594	9.072	0.000	0.813	1.268
ln price	-0.075	0.063	-0.068	-1.194	0.235	-0.199	0.049
ln production	0.343	0.054	0.381	6.311	0.000	0.236	0.451

Interpretation:

The results indicate that world production has a strong and positive effect on consumption, highlighting its dominant role in shaping demand. Domestic production also shows a positive and statistically significant impact, though with a moderate magnitude. In contrast, price exhibits a negative but statistically insignificant relationship, suggesting a limited influence on consumption patterns. Overall, the findings emphasize that production-related factors play a more important role than price in explaining consumption dynamics.

4.5. Model Diagnostics and Robustness Checks

Figure 2 illustrates the distribution of standardized residuals, confirming that the normality assumption is satisfied.

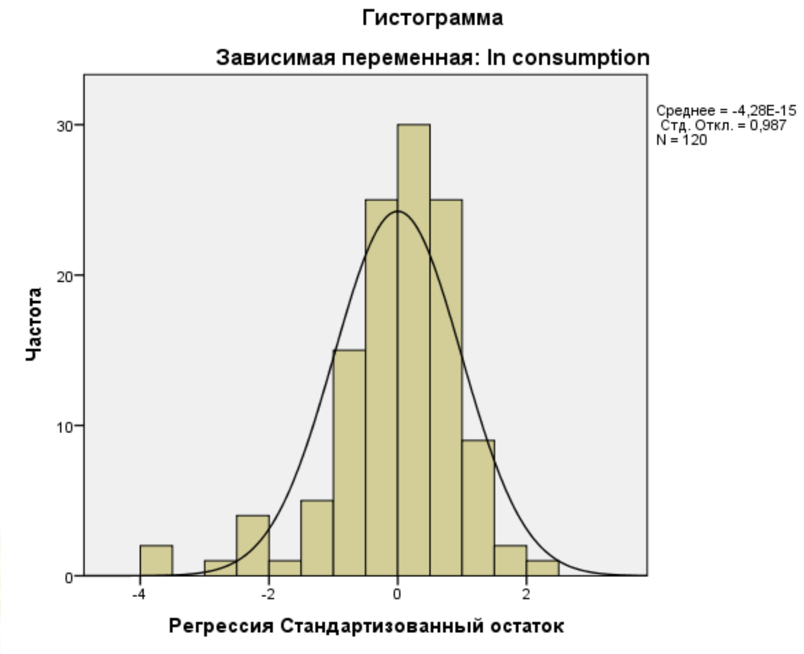

Figure 2. Histogram of Standardized Residuals

Figure 3 illustrates the normal P–P plot of standardized residuals, showing that the data points closely follow the diagonal line, which confirms the normality assumption of the model.

Figure 3. Normal P–P Plot of Standardized Residuals for the Consumption Model

Interpretation:

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The results indicate that the standardized residuals are approximately normally distributed, as evidenced by the symmetric histogram and the close alignment of observations along the diagonal in the P–P plot. This suggests that there are no significant deviations from normality. Overall, the findings confirm that the normality assumption of the regression model is satisfied, supporting the validity and reliability of the estimated results.

5. DISCUSSION

The empirical results of this study offer valuable insights into the key factors influencing consumption in the rare earth elements market, using data obtained from the U.S. Geological Survey. The findings clearly show that production-related variables play a leading role, whereas the impact of price appears to be relatively weak. According to the regression analysis, both global (world) production and domestic production have a positive and statistically significant effect on consumption. Notably, world production emerges as the most influential factor, indicating that global supply conditions are a major driver of consumption patterns. This result is in line with earlier research, which highlights the critical role of global rare earth supply chains in shaping market demand and industrial use. Since rare earth elements are essential inputs for high-tech industries, an increase in global production naturally leads to higher levels of consumption. Domestic production also shows a positive and significant relationship with consumption, although its effect is smaller compared to world production. This suggests that local production capacity still plays an important role in supporting consumption, reflecting how national supply contributes to meeting industrial demand.

On the other hand, the price variable is found to have a negative but statistically insignificant effect on consumption. This implies that changes in price do not strongly influence consumption levels in the rare earth market. One possible reason is that rare earth elements are considered strategic and essential resources with few available substitutes, making their demand relatively insensitive to price fluctuations. In this context, technological and strategic considerations appear to outweigh cost-related factors. The correlation analysis further confirms these results, showing strong positive relationships between consumption and production variables, while the link between price and consumption remains weak. This provides additional evidence that supply-side factors are the dominant forces shaping consumption behavior. Furthermore, the diagnostic tests support the reliability and robustness of the model. The residuals are approximately normally distributed, as shown by both the histogram and the normal P–P plot. In addition, the absence of significant outliers—indicated by low Cook's distance values and moderate Mahalanobis distances—suggests that the results are not overly influenced by extreme data points. These findings confirm that the key assumptions of the regression model are satisfied, enhancing confidence in the results.

In summary, the study demonstrates that production capacity, especially at the global level, is the main factor driving consumption in the rare earth market, while price plays a much less important and statistically insignificant role. These findings carry important implications for policymakers and industry stakeholders, highlighting the importance of strengthening supply chains and expanding production capacity to ensure stable and sustainable growth in the market.

6. CONCLUSION

6.1. Objectives and Summary of Findings

The primary objective of this study was to examine the determinants of consumption in the rare earth elements market using data from the U.S. Geological Survey. The analysis focused on the impact of world production, domestic production, and price on consumption patterns. The empirical results reveal that both world production and domestic production have a positive and statistically significant effect on consumption, with world production exerting the strongest influence. In contrast, price demonstrates a negative but statistically insignificant relationship, indicating a limited role in shaping consumption dynamics.

6.2. Importance and Motivation of the Study

This study is important due to the growing strategic relevance of rare earth elements in modern economies, particularly in high-technology industries, renewable energy, and digital transformation. Understanding the drivers of consumption is crucial for ensuring supply chain stability and supporting sustainable economic development. The motivation of this research stems from the increasing global demand for rare earth elements and the need to identify the key factors influencing market behavior. By focusing on both global and domestic production dynamics, the study contributes to a deeper understanding of the structural characteristics of the rare earth market.

6.3. Positive and Negative Aspects of the Results

The results of the study present several strengths. First, the regression model demonstrates strong explanatory power, with production variables significantly influencing consumption. Second, the diagnostic tests confirm the reliability and robustness of the model, indicating that the underlying assumptions are satisfied. However, certain limitations should be acknowledged. The insignificant effect of price suggests that the model may not fully capture demand-side sensitivities or market complexities. Additionally, the analysis is based on a limited set of variables, which may exclude other important factors such as technological innovation, policy interventions, or geopolitical influences.

6.4. Policy Recommendations

Based on the findings, several policy recommendations can be proposed. First, policymakers should prioritize the development of domestic production capacity to support stable consumption and reduce dependence on external supply. Second, strengthening global supply chain cooperation is essential to ensure consistent access to rare earth resources. Furthermore, investment in technological innovation and recycling processes should be encouraged to enhance resource efficiency and sustainability. Given the limited impact of price, policies should focus more on supply-side strategies rather than price control mechanisms.

6.5. Future Implications of the Study

The findings of this study open several directions for future research. Further studies could incorporate additional variables such as technological progress, environmental regulations, and geopolitical risks to provide a more comprehensive analysis. Moreover, applying panel data or time-series models over a longer period could improve the robustness of the results. Future research may also explore the role of rare earth elements in the transition to a green economy, particularly in renewable energy technologies and electric vehicles.

6.6. Final Remarks

In conclusion, this study highlights the critical role of production dynamics in shaping consumption in the rare earth elements market. While price appears to have a limited influence, both global and domestic production significantly drive demand patterns. The results underscore the importance of strategic resource management and supply chain development in ensuring sustainable growth. As the global economy becomes increasingly dependent on rare earth elements, understanding these dynamics will remain essential for both policymakers and industry stakeholders.

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