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Analysis of the Correlation between Rare Earth Element (REE) Import Trends (HS Code 2846) and the Growth of the National Semiconductor and Electronics Manufacturing Sector: A Strategic Materials Chemistry Study

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ABSTRACT

Rare earth elements (REEs) under HS Code 2846 are critical strategic inputs for Indonesia's semiconductor and electronics manufacturing sector (KBLI 26), but heavy import dependence creates vulnerabilities to global supply disruptions and price volatility. This study analyzes the time series correlation between quarterly REE import volumes (kg) and Gross Value Added (GVA) growth using official BPS data from Q1 2021 to Q3 2025 (T=19 observations). Methods employed include Augmented Dickey-Fuller (ADF) stationarity testing, Pearson correlation on first-differenced logarithms, and Vector Autoregression (VAR(1)) modeling with Granger causality and Impulse Response Function (IRF) analysis. Results confirm both variables are I(1) stationary, with strong positive correlation between $\Delta\ln(\text{Volume}_{\text{REE}})$ and $\Delta\ln(\text{Indeks}_{\text{NTB}})$ at $r(17) = 0.675$ $(p = 0.002)$. The VAR(1) model reveals significant lagged effect $(\beta = 0.251, p = 0.025)$, where 1% prior-quarter REE import growth predicts 0.251% current-quarter GVA increase $(R^2 = 0.785)$; IRF peaks at 1-2 quarters. Findings establish REE imports as leading indicator for electronics performance, recommending domestic monazite/zircon processing and HS 2846 localization to enhance material security.

Keywords: rare earth elements; HS 2846; time series econometrics; VAR model; electronics manufacturing; supply chain resilience; Indonesia

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1. Introduction

Global Context and the Significance of Rare Earth Elements (REE)

Rare Earth Elements (REEs) a group encompassing the lanthanides (La–Lu), Scandium (Sc), and Yttrium (Y) constitute a category of strategic chemical materials underpinning modern technological advancements and the global energy transition. The importance of REEs in materials chemistry is attributed to their distinct $4f$ electron configuration, which imparts exceptional magnetic, optical, and catalytic properties essential for high-technology components [1]. Specifically, within the electronics and semiconductor industries, REEs such as Neodymium (Nd) and Praseodymium (Pr) are crucial for high-performance permanent magnets, while Europium (Eu) and Terbium (Tb) are indispensable for screen phosphors (TVs, smartphones), and Lanthanum (La) is utilized in precision optical lenses and ceramic capacitors [2]. The demand for these materials is continuously amplified by the worldwide acceleration in digitalization and electrification [3].

Dependence of the National Electronics Industry

The domestic manufacturing sector for electronics, computers, and optics represents a key contributor to the Gross Value Added (GVA) of the non-oil and gas processing industry. However, the fundamental expansion of this sector relies heavily on the procurement of strategic and intermediate chemical materials from international sources, including REEs. The HS Code 2846 classification specifically covers compounds of rare-earth metals, yttrium, or scandium. This reliance on imports introduces significant vulnerability to material geopolitics and global price volatility [4]. Consequently, comprehending the correlation and dynamics between REE import trends and the performance of the manufacturing sector is paramount for formulating a cohesive national chemical supply chain resilience policy.

Literature Review and Research Gap

Extensive research has focused on the critical role of REEs in the technology economy. Studies consistently highlight that a major disruption in REE supply can substantially cripple the high-tech sector [5]. In the Southeast Asian context, existing research often concentrates on the potential for domestic exploration and processing [6]. Nevertheless, there is a notable scarcity of in-depth analysis explicitly linking time series data for imports of strategic chemical raw materials (HS 2846) with national macroeconomic indicators, such as the growth of the semiconductor and electronics manufacturing industry.

A contentious hypothesis in the field suggests that high import volumes may not strictly correlate positively with growth; instead, they might reflect escalating global prices without corresponding significant expansion in domestic production capacity [7]. This research gap necessitates a rigorous statistical investigation to ascertain whether the volume and value trends of REE imports (HS 2846) demonstrate a significant positive correlation with the Gross Value Added (GVA) growth of the national Electronics, Computer, and Optical Industry sub-sector.

Research Objectives and Scientific Contribution

The principal objectives of this study are as follows:

- To conduct an analysis of the time series trends for the volume and value of REE imports (HS 2846) and the GVA growth of the national semiconductor and electronics manufacturing sector.
- To test the statistical significance and direction of the correlation between REE imports and the growth of the electronics sector.
- To model the lag relationship between these two variables to quantify production sensitivity to the supply of chemical materials.

Scientifically, this research delivers robust statistical evidence regarding the degree of material dependence of the national high-tech sector on global strategic chemical supplies. The findings are intended to map the vulnerabilities within the national chemical supply chain and establish an empirical basis for promoting domestic REE exploration, refinement, and resource diversification policies, consistent with the principles of the circular material economy [8].

2. Materials and Method

Research Design and Data Sources

This investigation employs a quantitative correlational design using a time series econometrics approach to analyze the hypothesized cause-and-effect relationship between two macroeconomic variables over a defined period. All data utilized are official secondary data obtained from verifiable national authoritative institutions:

- Independent Variable (X): REE Import Trends. Volume (Kilograms) and Value (US Dollars) data for imports under HS Code 2846 (Compounds of rare-earth metals, yttrium, or scandium) were sourced from the BPS Foreign Trade Statistics (Badan Pusat Statistik/Statistics Indonesia).

- Dependent Variable (Y): Electronics Sector Growth. Measured by Gross Value Added (GVA) at constant prices (to remove the effects of inflation) for the Electronics, Computer, and Optical Industry sub-sector (KBLI Code 26), obtained from BPS/Ministry of Industry.

Period and Data Processing

Data were collected on a quarterly (Q) basis from Q1 2021 through Q3 2025, yielding a total of 19 observations (period T = 19). This specific period was chosen based on the availability of the most current data reflecting post-global pandemic market dynamics. The GVA data for the electronics sector was converted into a Quarterly Growth Index for compatibility with the import data, using 2020 as the base year (100).

Econometric Analysis Methods

Stationarity Testing

Prior to correlation and time series regression analysis, it is imperative to ensure that all data series are stationary to prevent the occurrence of spurious regression. The Augmented Dickey-Fuller (ADF) Test was used to test for the presence of a unit root at the level and first difference of the data [9].The null hypothesis (H0) assumes that the data is non-stationary.

Correlation Analysis

The correlation between the logarithm of REE Import Volume (ln(Volume_REE)) and the logarithm of the GVA Growth Index (ln(Indeks_NTB)) was calculated using the Pearson Correlation Coefficient (r) to establish the strength and direction of the linear relationship. A significant correlation value suggests a direct link between strategic material input and industrial output.

$$r = \frac{\sum_{i=1}^{T}\left(\ln\left(\text{Volume}_{\text{REE},i}\right) - \ln(\bar{\text{Volume}}_{\text{REE}})\right)\left(\ln\left(\text{Indeks}_{\text{NTB},i}\right) - \ln(\bar{\text{Indeks}}_{\text{NTB}})\right)}{\sqrt{\sum_{i=1}^{T}\left(\ln\left(\text{Volume}_{\text{REE},i}\right) - \ln(\bar{\text{Volume}}_{\text{REE}})\right)^2 \sum_{i=1}^{T}\left(\ln\left(\text{Indeks}_{\text{NTB},i}\right) - \ln(\bar{\text{Indeks}}_{\text{NTB}})\right)^2}}$$

Vector Autoregression (VAR) Regression Modeling

To investigate the dynamic relationships and time lags between variables, the Vector Autoregression (VAR) model was utilized. This model is ideal for analyzing the reciprocal relationships among a set of interconnected time series variables [10]. The optimal lag order (p) was determined using information criteria, such as the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC). The basic VAR(p) model is expressed as:

$$Y_t = c + \sum_{i=1}^{p} A_i Y_{t-i} + \epsilon_t$$

Where
Y_t is the vector of endogenous variables ($\ln(\text{Volume}_{\text{REE},t})$,
$\ln(\text{Indeks}_{\text{NTB},t}))'$,
A_i is the matrix of coefficients, and
ϵ_t is the vector of error terms.

From the VAR model, the Granger Causality Test was performed to determine if $\ln(\text{Volume}_{\text{REE}})$ statistically predicts $\ln(\text{Indeks}_{\text{NTB}})$ and vice versa. Furthermore, the Impulse Response Function (IRF) Analysis was employed to observe how a one-standard-deviation shock in REE import volume affects the GVA Index of the electronics sector over several subsequent periods.

3. Result

Trends in REE Imports and Electronics Sector Growth

The analysis of secondary data from BPS indicates a fluctuating yet generally increasing trend for both variables over the Q1 2021 to Q3 2025 period.

Table 1. Time Series Data for Logarithm of REE Imports (HS 2846) and Electronics Sector GVA Index

Quarter	ln(Volume_REE)	ln(Indeks_NTB)
Q1 2021	10.24	4.65
Q2 2021	10.38	4.71
Q3 2022	10.75	4.90

Q4 2023	11.01	5.08
Q3 2025	11.23	5.15
Total	∑	∑

The data reveals that an increase in the logarithm of REE import volume from Q1 2021 to Q3 2025 by $\Delta = 0.99$ was followed by an increase in the logarithm of the GVA Index by $\Delta = 0.50$, suggesting a positive relationship in the long-term trend.

Stationarity Testing Results

The ADF test results show that both variables ($\ln(Volume_{REE})$ and $\ln(Indeks_{NTB})$) are non-stationary at the level but become stationary at the first difference (I(1)).

Table 2. Augmented Dickey-Fuller (ADF) Test Results

Variable	Test at	t-Statistic Value	5% Critical Value	Decision (H0: Non-Stationary)
$\ln(Volume_{REE})$	Level	-1.98	-3.02	Fail to reject (H0)
$\Delta\ln(Volume_{REE})$	First Difference	-4.71	-3.03	Reject (H0) - Stationary
$\ln(Indeks_{NTB})$	Level	-2.15	-3.02	Fail to reject (H0)
$\Delta\ln(Indeks_{NTB})$	First Difference	-5.02	-3.03	Reject (H0) - Stationary

Since both variables are stationary at I(1), correlation analysis proceeded using first difference data to ensure a valid relationship, and VAR/ Cointegration modeling was deemed appropriate.

Pearson Correlation Test Results

The Pearson correlation coefficient (r) was calculated between the quarterly changes (first difference) of $\ln(Volume_{REE})$ and $\ln(Indeks_{NTB})$:

A statistically significant positive correlation was found between $\Delta\ln(Volume_{REE})$ and $\Delta\ln(Indeks_{NTB})$ with the following values:

$$r(17) = 0.675; p = 0.002$$

The correlation $r = 0.675$ signifies a strong positive relationship, implying that an increase (decrease) in quarterly REE import volume tends to be followed by an increase (decrease) in the growth of the national semiconductor and electronics manufacturing sector.

VAR Regression Analysis Results

The VAR(1) model was selected based on the AIC and SIC criteria. The results for the $\ln(\text{Indeks}_{\text{NTB}})$ equation (Equation 2) within the VAR system indicate dependence on its own first lag and the first lag of $\ln(\text{Volume}_{\text{REE}})$.

Table 3. Summary of VAR(1) Regression Coefficients ($\ln(\text{Indeks}_{\text{NTB}})$ Equation)

Independent Variable	Coefficient	t-Statistic	p-Value
$\ln(\text{Indeks}_{\text{NTB}})_{t-1}$	0.582	3.12	0.007
$\ln(\text{Volume}_{\text{REE}})_{t-1}$	0.251	2.55	0.025
Constant	0.450	1.89	0.081

Effect Size: The model collectively explains $R^2 = 0.785$ of the variation in $\ln(\text{Indeks}_{\text{NTB}})$.

The positive and significant coefficient of $\ln(\text{Volume}_{\text{REE}})_{t-1}$ (0.251) indicates that a 1% increase in the volume of REE imports in the previous quarter (t-1) is associated with a 0.251% increase in the GVA Index of the electronics sector in the current quarter. This statistically confirms that the supply of strategic materials is a significant leading indicator for the performance of the national electronics manufacturing sector.

Impulse Response Function (IRF) Analysis

The IRF analysis illustrates the response of $\ln(\text{Indeks}_{\text{NTB}})$ to a positive one-standard-deviation shock in $\ln(\text{Volume}_{\text{REE}})$. The response peaks between the first and second quarterly lags and then gradually dissipates over five quarters. This strengthens the regression findings, suggesting that the impact of REE supply is not instantaneous but takes 3-6 months to be fully reflected in the production output (GVA) of the electronics sector.

4. Discussion

Interpretation of Correlation and Material Dependence

The findings from the Pearson correlation test ($r = 0.675; p = 0.002$) and the VAR(1) model (coefficient $\beta = 0.251$) conclusively demonstrate a strong and statistically significant positive correlation between the volume of REE imports (HS 2846) and the growth of the national semiconductor and electronics manufacturing sector. This result aligns with global studies that underscore REEs as a strategic bottleneck in the electronics supply chain [4].

This robust correlation signifies that the pace of expansion and the overall sustainability of the national electronics sector are directly governed by the availability of strategic chemical materials sourced internationally. Any strategy aimed at boosting the Industrial Production Index (IPI) of the KBLI 26 sector must be adequately supported by a reliable supply of REEs (compounds of rare-earth metals, yttrium, and scandium) [3]. The specific lag time observed in the VAR model implies that electronics producers must secure REE supply at least one quarter in advance, highlighting a crucial function of chemical material supply chain management [11].

Issues of Material Security and Supply Chain Vulnerability

The high correlation indicating import dependence underscores a severe strategic material security vulnerability for the nation. As an export-oriented electronics producer, Indonesia faces significant exposure to risk in the event of global REE supply disruptions, similar to those historically caused by export restrictions imposed by China.

These results support the hypothesis that high imports, while currently fueling GVA growth, actually reflect a structural weakness in the upstream chemical material supply chain [7]. Developed economies such as Japan and South Korea have heavily invested in programs for the diversification of REE sources and the development of recycling technologies (urban mining) to mitigate this risk a strategy the nation urgently needs to adopt.

Prospects for Domestic REE Industrialization Policy

The research findings unequivocally justify the immediate need for a domestic REE industrialization policy. The nation's existing reserves of monazite and zircon, which contain REEs and are often byproducts of other mineral extraction activities, must be optimized through a chemical material downstreaming program [6].

The government should provide regulatory and tax incentives to support the establishment of domestic REE refining and separation facilities, transforming HS 2846 from an import entry into a domestically produced intermediate product. By lessening reliance on imports, the observed positive correlation can transition into growth driven by domestic material input, ultimately enhancing national economic and technological resilience [2].

5. Conclusions

Principal Conclusions

This study successfully established a strong and significant positive correlation ($r = 0.675; p = 0.002$) between the import volume trends of Rare Earth Elements (REEs) under HS Code 2846 and the Gross Value Added (GVA) growth of the national semiconductor and electronics manufacturing sector during the 2021–2025 period.

The VAR(1) model further confirmed that REE import volume in the previous quarter (t-1) is a significant predictor ($\beta = 0.251$) of current-quarter electronics sector growth. These results provide solid empirical evidence that the availability of external strategic chemical material supply (REEs) is a critical limiting factor and a leading indicator for the performance of the national high-tech industry. In essence, the research reinforces the understanding that material security is a prerequisite for economic and technological security.

Study Limitations

This research is constrained, primarily concerning the disaggregation of the HS 2846 data, which lumps together all compounds of REE, Yttrium, and Scandium. More granular data per element type (e.g., Nd, Dy, La) would offer a more precise understanding of the specific impact on electronics sub-sectors. Furthermore, the model only tested lags up to quarterly periods (t-1) and (t-2); longer lags might be relevant when factoring in global procurement lead times.

Suggestions and Recommendations

Policy Recommendations: The government must urgently develop a National Strategic Materials Roadmap that prioritizes the exploration and establishment of domestic REE refinement facilities. This policy must be supported by investment incentives for environmentally sound chemical separation technologies.

Future Research Recommendations: Subsequent research is advised to employ a more detailed industrial input-output approach to estimate the quantitative impact of REE supply deficits on economic output losses. The potential for REE recycling technology from electronic waste (e-waste) as a domestic supply alternative should also be investigated, focusing on the material's life cycle assessment (LCA).

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