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The Effect of Coal Production, Domestic Market Obligation, Selling Price, Coal Reserves, and Mining Investment on Indonesia's Coal Export Realization

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Abstract: As the world's second-largest coal exporter, Indonesia faces complex dynamics in managing its coal export realizations amid domestic policy obligations and market fluctuations. This phenomenon is increasingly significant given coal's strategic role as a major source of state revenue and its position as a primary energy supplier to Asian emerging markets, particularly China and India. This study aims to analyze the determinants affecting Indonesia's coal export realizations. The research employs a quantitative approach using quarterly time-series data from 2014 to 2023, comprising 40 observations. The analytical methods utilized are the Vector Error Correction Model (VECM) to examine both short-term dynamics and long-term equilibrium relationships among variables. The independent variables examined include coal production volume, domestic market obligation (DMO), selling price, coal reserves, and mineral and coal sector investment, with coal export realization as the dependent variable. The findings reveal that simultaneously, all independent variables significantly influence coal export realizations. Partially, coal production, selling price, coal reserves, and investment demonstrate significant positive effects on export realizations. Conversely, domestic market obligation shows a significant negative effect on Indonesia's coal export realizations, indicating that mandatory domestic supply requirements constrain export volumes.

Keywords: coal export realization, coal production, domestic market obligation, selling price, coal reserves, investment, VECM, ECM.

INTRODUCTION

Indonesia plays a vital role in global coal trade as the world's second-largest exporter after Australia. The Ministry of Energy and Mineral Resources (Kementerian ESDM., 2023) recorded that Indonesia's coal production reached 694 million tons in 2022, with the majority destined for export markets. Its strategic geographical position makes Indonesia the main supplier for Asian countries such as China, India, Japan, and South Korea (IEA., 2023). The dependence of these countries on Indonesian coal creates complex demand dynamics and significantly impacts national export realizations (Sugiyono, A., Wahid, L. M. A., 2022)

Indonesia's coal export realization has shown fluctuating trends over the past decade, influenced by various external and internal factors. (Statistik, 2023) reported that coal export values experienced a significant increase in 2021-2022 alongside post-pandemic economic recovery, but had previously contracted due to the global economic slowdown. This volatility creates uncertainty in state revenue planning and mining sector investment (Putra, F. P., & Kusuma, 2023). These fluctuations underscore the need for a comprehensive understanding of the determinants affecting Indonesia's coal export realization.

National coal production has a close correlation with export realization, given that most production is allocated for international markets. The Directorate General of Mineral and Coal (Direktorat Jenderal Mineral dan Batubara, 2023) noted that production capacity continues to increase alongside the expansion of major mines in Kalimantan and Sumatra. However, production limitation policies outlined in the National Energy General Plan (RUEN) aim to maintain reserve sustainability (Wibowo, D. A., & Hidayat, 2022). Balancing production optimization for exports with resource conservation presents a distinct challenge for stakeholders.

The Domestic Market Obligation (DMO) policy, which requires mining companies to allocate at least 25% of production for domestic needs, is a significant factor affecting export realization. Minister of Energy and Mineral Resources Regulation No. 139 of 2021 regulates this obligation with special prices for public electricity, maximum US$ 70 per ton (Kementerian ESDM., 2021). This policy has generated pros and cons among business actors as it is considered to reduce volume available for exports and potentially decrease company revenues (Prasetyo, A. D., Fauzi, A., & Juanda, 2023). On the other hand, DMO aims to ensure national energy security and supply availability for domestic power plants.

While the coal mining sector remains a primary pillar of the national economic structure, a significant empirical gap exists, underscoring the urgency of this study. Empirically, there is a clear contradiction between the implementation of the Domestic Market Obligation (DMO) policy and export realization targets. On one hand, regulations mandate producers to allocate 25% of total production for domestic needs, which theoretically should restrict export capacity. However, in reality, Indonesian coal export volumes have continued to show a significant upward trend, even reaching record highs despite tightening DMO regulations and global price fluctuations. This anomaly suggests that the effectiveness of the DMO policy as an export control instrument has not been fully tested empirically, particularly concerning production capacity that continues to be pushed to meet international market demands.

In addition to this empirical gap, this research is also driven by a theoretical gap concerning the impact of natural resource dependence on economic growth. In macroeconomic literature, there is an ongoing debate between the Resource-Based Theory, which supports growth through commodity exports (export-led growth), and the Resource Curse theory, which warns that excessive reliance on mineral extraction can hinder economic diversification and long-term GDP sustainability. Previous research findings remain inconsistent; some studies suggest that domestic allocation policies strengthen economic resilience, while others view them as market distortions that diminish global competitiveness. This study aims to bridge these theoretical gaps by re-examining the causal relationship between production, DMO policy, and export realization on the Gross Domestic Product (GDP) of the mineral and coal sector in Indonesia over the last decade.

International coal selling prices experienced extreme volatility in the 2014-2023 period, influenced by energy policies of destination countries, geopolitical conditions, and global energy transition. The World Bank (World Bank, 2023) noted that the coal reference price (HBA) reached its lowest point in 2015-2016, then surged sharply post-Russia's invasion of Ukraine which disrupted European energy supplies. Selling price becomes a crucial determinant as it directly affects export profitability and company decisions to increase

shipping volumes abroad (Sari, N. K., & Nugroho, 2022). Price fluctuations also impact state revenues through royalties and export taxes.

Indonesia's coal reserves are estimated at 38.84 billion tons with a reserve-to-production (R/C) ratio of approximately 65 years at current production levels (ESDM, 2023). Reserve sustainability issues are a serious concern given the high rate of exploitation to meet export demand. Research by (Handayani, T., & Suwarno, 2023) emphasizes the importance of prudent reserve management to maintain Indonesia's position as a reliable long-term exporter. Exploration of new reserves through upstream investment is key to maintaining export volumes in the future.

Investment in the mineral and coal sector forms the foundation for sustainable production and exports. (BKPM, 2023) recorded that mining sector investment realization reached Rp 89.3 trillion in 2022, an increase compared to previous years. This investment covers not only exploration and extraction but also development of supporting infrastructure such as special ports and processing facilities (Kurniawan, R., Sugiyanto, F., & Prasetyo, 2022). However, regulatory uncertainty and tax policies often become obstacles to new investment needed to maintain production capacity.

The empirical reality of Indonesia's coal export sector reveals complex dynamics and multifaceted challenges. As the world's second-largest coal exporter, Indonesia currently faces significant fluctuations in export realizations, with volumes varying considerably from year to year due to volatile international prices, shifting global demand, and domestic policy constraints. Data from the Ministry of Energy and Mineral Resources (Kementerian ESDM., 2023) indicates that while coal production has consistently increased, reaching 694 million tons in 2022, export realizations have not always followed a linear upward trend. The implementation of the Domestic Market Obligation (DMO) policy since 2018 has created tension between domestic energy security needs and export-oriented business interests, with mining companies often struggling to balance the mandatory 25% domestic allocation against more profitable international sales (Prasetyo, A. D., Fauzi, A., & Juanda, 2023). Furthermore, investment in the mineral and coal sector has shown uneven growth patterns, hampered by regulatory uncertainty and global pressure for energy transition, while coal reserves continue to be exploited at rates that raise concerns about long-term sustainability. The current reality also shows that the contribution of coal exports to GDP, non-tax state revenues, and labor absorption, although substantial, remains vulnerable to external shocks such as the COVID-19 pandemic, geopolitical conflicts, and the accelerating global shift toward renewable energy sources (Putra, F. P., & Kusuma, 2023).

The ideal condition for Indonesia's coal export sector envisions a balanced, sustainable, and optimally managed system that maximizes national economic benefits while ensuring resource longevity and environmental responsibility. Ideally, coal production should be maintained at sustainable levels that align with reserve conservation principles, ensuring that Indonesia can continue to benefit from its coal resources for decades to come rather than experiencing rapid depletion (Handayani, T., & Suwarno, 2023). The Domestic Market Obligation policy should function as an effective instrument that guarantees domestic energy security without creating excessive burden on exporters, ideally calibrated at an optimal level that meets national electricity needs while allowing sufficient volume for profitable international trade. Coal selling prices should reflect fair market values that provide adequate returns for producers and optimal state revenues through royalties and taxes, while remaining competitive in the international market. Investment in the mineral and coal sector should flow consistently into both extraction activities and downstream processing facilities, creating added value domestically and reducing dependence on raw coal exports (Kurniawan, R., Sugiyanto, F., & Prasetyo, 2022). Furthermore, coal reserves should be managed with a long-term perspective, incorporating comprehensive geological surveys and strategic extraction planning.

In this ideal scenario, export realizations would demonstrate stable growth patterns, providing predictable contributions to the national economy, state budget, and employment creation, while gradually transitioning toward a more diversified and value-added mineral and coal industry that aligns with global sustainability trends.

A substantial gap exists between the current reality and the ideal condition of Indonesia's coal export sector, necessitating comprehensive research and policy intervention. While the ideal envisions stable and predictable export realizations, the current reality shows high volatility influenced by uncontrollable external factors such as international price fluctuations and global economic conditions (Bank Indonesia, 2023). The DMO policy, intended as a balanced instrument for domestic and international interests, in practice creates significant friction with export performance, as evidenced by the negative correlation between DMO obligations and export volumes found in preliminary studies (Prasetyo et al., 2023). Investment flows remain suboptimal compared to the sector's potential, constrained by regulatory inconsistencies and the growing global divestment movement from fossil fuels, falling short of the ideal level needed for sustainable sector development and infrastructure modernization. Reserve management currently prioritizes short-term export earnings over long-term sustainability, with extraction rates that may compromise future generations' ability to benefit from this non-renewable resource (ESDM, 2023).

Despite the strategic importance of coal exports to Indonesia's economy, previous studies have revealed significant research gaps in comprehensively analyzing the determinants of coal export realization. Several studies have examined individual factors affecting coal exports, such as production volume (Sugiyono, A., Wahid, L. M. A., 2022) and international price fluctuations (Sari & Nugroho, 2022), but these investigations remain fragmented and fail to integrate the complex interplay between multiple determinants simultaneously. Research specifically addressing the Domestic Market Obligation (DMO) policy remains limited, with Prasetyo et al. (2023) noting that most studies focus on the policy's impact on domestic electricity generation rather than its direct effect on export volumes. Furthermore, while Handayani and Suwarno (2023) have explored coal reserve sustainability, their analysis does not extend to how reserve levels influence export realization decisions by mining companies. Investment in the mineral and coal sector has been examined by Kurniawan et al. (2022) in the context of regional economic growth, yet its direct relationship with export performance remains underexplored. Methodologically, previous studies have predominantly employed static panel data regression or simple time-series analysis, with limited application of dynamic models such as Vector Error Correction Model (VECM) that can capture both short-term dynamics and long-term equilibrium relationships among variables (Putra & Kusuma, 2023). Additionally, most existing research examines the determinants of coal exports in isolation without extending the analysis to the broader implications for Gross Domestic Product, non-tax state revenues, and labor absorption, creating a disconnect between export analysis and national economic outcomes (Rahman, A., & Fitriani, 2023). This study addresses these gaps by comprehensively analyzing the simultaneous and partial effects of coal production, DMO, selling price, coal reserves, and investment on coal export realization using VECM and ECM approaches with quarterly data from 2014-2023, while also examining the implications of export realizations on key macroeconomic indicators.

Literature Review

International Trade Theory

The theoretical foundation of export realization analysis is rooted in classical and modern international trade theories. Ricardo's (1817) theory of comparative advantage explains that countries engage in international trade by specializing in producing goods where they have relative efficiency. Indonesia's position as a major coal exporter reflects its comparative

advantage in coal resources, characterized by abundant reserves, favorable geological conditions, and relatively lower production costs compared to many other countries (Salvatore, 2020)

The Heckscher-Ohlin theorem further elaborates that countries export commodities that intensively utilize their abundant factors of production. Indonesia's coal exports exemplify this principle, as the country possesses abundant coal resources and utilizes labor-intensive mining techniques, making coal a natural export commodity (Krugman, P. R., Obstfeld, M., & Melitz, 2021). Modern trade theory, particularly the gravity model of trade, emphasizes that bilateral trade flows are determined by economic size and geographical distance, explaining why Indonesia's coal exports are predominantly directed toward geographically proximate Asian markets such as China, India, Japan, and South Korea (Tietenberg, T., & Lewis, 2018)

Supply and Demand Theory

The supply and demand framework provides essential theoretical underpinnings for understanding export realization determinants. According to Marshall's (1890) principles of economics, the quantity of goods exported is determined by the interaction of supply-side factors (production capacity, domestic obligations, reserves) and demand-side factors (international prices, foreign demand). In the context of coal exports, supply is influenced by production capabilities, regulatory constraints such as DMO, and available reserves, while demand is primarily driven by international prices and the energy needs of importing countries (Mankiw, 2022)

The theory of export supply suggests that producers allocate output between domestic and international markets based on relative prices and profitability, with higher international prices incentivizing greater export volumes (Goldstein, M., & Khan, 2018). This theoretical perspective directly informs the analysis of how coal selling prices influence export realizations, as mining companies respond to price signals in their allocation decisions between domestic and export markets.

Resource Economics Theory

Resource economics theory, particularly the Hotelling (1931) model of non-renewable resource extraction, provides crucial insights into coal reserve management and export decisions. The model posits that owners of non-renewable resources will extract and sell their resources at rates that maximize the present value of future profits, considering both current prices and expected future price appreciation. In the Indonesian coal context, this theory explains how reserve levels influence production and export decisions, with companies balancing current export earnings against the option value of preserving reserves for future extraction (Hartwick, J. M., & Olewiler, 2018).

The theory of optimal resource depletion suggests that countries with abundant resources face intertemporal trade-offs between current consumption (through exports) and future availability, highlighting the importance of sustainable reserve management (Tietenberg, T., & Lewis, 2018). This theoretical foundation is particularly relevant for understanding how coal reserve levels affect export realizations and the long-term sustainability of Indonesia's coal export sector.

Coal Production and Export Realization

The relationship between coal production and export realization has been extensively examined in empirical literature. Production volume represents the fundamental supply-side constraint on export capacity, as exports cannot exceed available production after accounting for domestic consumption and stock changes. (Sugiyono, A., Wahid, L. M. A., 2022) analyzed Indonesia's coal production trends and found a strong positive correlation between production

increases and export volumes, with elasticity estimates suggesting that a 1% increase in production leads to approximately 0.85% increase in exports, ceteris paribus. Their study, utilizing time-series data from 2000-2020, highlighted that production growth has been driven by expanding mining areas in Kalimantan and Sumatra, technological improvements, and foreign investment in the sector.

Internationally, research by (Zakaria, M., & Jun, 2022) examined coal production and export dynamics in major coal-producing countries including Australia, Indonesia, and Russia. Their panel data analysis revealed that production capacity significantly determines export performance, but the relationship is moderated by infrastructure quality, particularly port facilities and transportation networks. In the Indonesian context, (Wibowo, D. A., & Hidayat, 2022) noted that production constraints, including regulatory caps and environmental permitting issues, have occasionally limited export growth despite strong international demand. They emphasized that production planning must balance export opportunities with domestic energy security requirements and environmental sustainability concerns.

Domestic Market Obligation (DMO) Policy

The Domestic Market Obligation (DMO) policy represents a unique regulatory intervention in Indonesia's coal sector that has attracted significant scholarly attention. (Prasetyo, A. D., Fauzi, A., & Juanda, 2023) conducted a comprehensive analysis of the DMO policy's impact on coal export performance using panel data regression across Indonesian coal mining companies from 2015-2021. Their findings revealed that the mandatory 25% domestic allocation significantly reduces export volumes, with an estimated elasticity of -0.32, indicating that a 10% increase in DMO requirements decreases export volumes by approximately 3.2%. The study also highlighted heterogeneous effects across company sizes, with smaller miners experiencing greater proportional export reductions due to limited flexibility in production adjustment.

The policy's origins and objectives were examined by (Sari, N. K., & Nugroho, 2022), who traced the evolution of DMO regulations from initial implementation in 2009 through subsequent revisions in 2018 and 2021. Their analysis positioned the DMO within Indonesia's broader energy security framework, emphasizing the policy's role in ensuring affordable coal supply for domestic power generation, particularly for state-owned electricity company PLN. However, they also documented industry concerns regarding the price cap mechanism, which requires DMO coal to be sold at a maximum of US$ 70 per ton, significantly below international market prices that frequently exceeded US$ 150 per ton during the 2021-2022 price surge.

International comparative research by (Zhang, Y., & Liu, 2022) examined similar domestic market obligation policies in other resource-exporting countries, including India's coal linkage policy and China's domestic supply requirements. Their cross-country analysis concluded that while such policies effectively secure domestic energy supplies, they create efficiency losses and may discourage investment in export-oriented production capacity. The Indonesian experience with DMO, they noted, provides valuable lessons for other resource-rich developing countries seeking to balance domestic needs with export earnings.

Coal Selling Price Dynamics

The influence of coal selling prices on export realization has been extensively studied, given the central role of price signals in market allocation decisions. (Sari, N. K., & Nugroho, 2022) investigated the relationship between international coal prices and Indonesia's export volumes using cointegration and error correction models with monthly data from 2010-2020. Their findings demonstrated a significant long-run equilibrium relationship between prices and exports, with short-term adjustments occurring within 2-3 quarters following price changes.

The price elasticity of export supply was estimated at 0.45 in the short run and 0.78 in the long run, indicating that exporters respond substantially to price incentives but with some temporal lag due to production and shipping constraints.

Global coal price dynamics were analyzed by the International Energy Agency (IEA., 2023), which documented extreme price volatility in recent years, including the price collapse during 2015-2016 (reaching below US$ 50 per ton) and the unprecedented surge during 2021-2022 (exceeding US$ 400 per ton for certain grades). This volatility, according to their analysis, reflects complex interactions between supply-side factors (production disruptions, investment cycles), demand-side factors (economic growth, weather patterns, policy changes in importing countries), and geopolitical events (trade disputes, the Russia-Ukraine conflict).

Putra and Kusuma (2023) specifically examined how price volatility affects Indonesian coal export performance, employing GARCH models to capture price uncertainty effects. Their results indicated that price volatility itself negatively affects export volumes, as uncertainty discourages long-term contracting and complicates production planning. They recommended that exporters diversify market destinations and contract types (spot versus long-term) to mitigate price risk exposure. The study also highlighted the importance of price information transmission along the supply chain, with mining companies, traders, and government agencies all requiring accurate price forecasts for effective decision-making.

Coal Reserves and Export Sustainability

Coal reserves represent the fundamental resource base underlying Indonesia's export capacity, and their relationship with export realizations has been examined from both economic and sustainability perspectives. Handayani and Suwarno (2023) analyzed Indonesia's coal reserve dynamics, estimating proven reserves at 38.84 billion tons with additional indicated and inferred resources extending the resource base substantially. Their reserve-production ratio analysis indicated approximately 65 years of production at current levels, though they cautioned that this figure varies significantly across coal quality grades and geographical locations. Higher-quality thermal and coking coal reserves, they noted, have shorter depletion horizons, raising concerns about future export composition.

The sustainability of coal exports given reserve constraints was explored by Rahman and Fitriani (2023) using input-output analysis and resource depletion modeling. Their simulations suggested that maintaining current export growth rates would accelerate reserve depletion, potentially exhausting economically recoverable reserves within 40-50 years. They recommended gradual export diversification and investment in downstream processing to maximize value addition from remaining reserves. The study also examined regional implications, noting that reserve depletion would disproportionately affect coal-dependent regions such as East Kalimantan and South Sumatra, requiring proactive economic diversification strategies.

International perspectives on reserve management were provided by the World Bank (2023) in its Commodity Markets Outlook, which emphasized that resource-rich developing countries face particular challenges in managing non-renewable resources for sustainable development. The report highlighted the "resource curse" phenomenon, where resource abundance sometimes leads to poor economic outcomes due to price volatility, Dutch disease effects, and governance challenges. For Indonesia's coal sector, the report recommended strengthening resource governance frameworks, improving reserve estimation methodologies, and integrating resource depletion considerations into fiscal planning through sovereign wealth funds or similar mechanisms.

Investment in Mineral and Coal Sector

Investment flows to the mineral and coal sector constitute a critical determinant of production capacity and, consequently, export realization potential. Kurniawan, Sugiyanto, and Prasetyo (2022) comprehensively analyzed investment patterns in Indonesia's mining sector from 2010-2020, documenting substantial fluctuations in both domestic and foreign direct investment. Their panel data analysis of mining companies revealed that investment responds positively to coal prices (elasticity 0.65), regulatory stability, and infrastructure quality, while being negatively affected by policy uncertainty and tax complexity. The study highlighted that investment lags significantly affect production capacity, with exploration investment requiring 3-5 years to translate into increased production, and mine development requiring even longer timeframes.

The relationship between investment and export performance was specifically examined by (Lestari, D., & Haryanto, 2022) in the context of East Kalimantan's coal industry. Using firm-level data and Granger causality tests, they found bidirectional causality between investment and exports: investment expands production capacity enabling greater exports, while export revenues provide the internal funding for further investment. This virtuous cycle, however, can be disrupted by external shocks or policy changes that reduce either investment incentives or export profitability. Their study emphasized the importance of maintaining a conducive investment climate to sustain export growth.

Regulatory aspects of mining investment were analyzed by the Directorate General of Mineral and Coal (2023), which documented the evolution of investment regulations from the 2009 Mining Law through subsequent amendments. Key developments included the divestment requirements for foreign investors, domestic processing obligations, and contract renegotiation periods that created investment uncertainty during transition periods. The report noted that investment recovery following regulatory stabilization demonstrates the sector's fundamental attractiveness but also its sensitivity to policy signals.

International investment trends in coal mining were examined by the International Energy Agency (IEA, 2022) in its World Energy Investment report, which documented declining investment in coal mining globally due to energy transition pressures, despite strong short-term demand and prices. This global trend creates both challenges and opportunities for Indonesia: reduced investment elsewhere may tighten global supply, benefiting existing Indonesian producers, but also signals longer-term structural decline that must be incorporated into national planning. The report emphasized that investment decisions must now account not only for market fundamentals but also for transition risks associated with climate policies and technological change.

Hypothesis

Hypothesis 1: The Effect of Coal Production on Coal Export Realization

Coal production is hypothesized to have a significant positive effect on the realization of coal exports in Indonesia. This hypothesis is grounded in supply-side economics, where production volume represents the fundamental constraint on export capacity, as exports cannot exceed available production after accounting for domestic consumption and stock changes (Mankiw, 2021). Empirical evidence from Sugiyono, Wahid, and Adiarso (2022) demonstrated a strong positive correlation between production increases and export volumes in Indonesia, with elasticity estimates suggesting that a 1% increase in production leads to approximately 0.85% increase in exports.

Similarly, Zakaria and Jun (2021) in their cross-country panel data analysis of major coal-producing countries including Australia, Indonesia, and Russia, found that production capacity significantly determines export performance. Wibowo and Hidayat (2022) further confirmed that production expansion through new mining areas in Kalimantan and Sumatra

has been a primary driver of Indonesia's export growth. Therefore, based on theoretical foundations and empirical evidence, this study hypothesizes that higher coal production levels enable greater export volumes, establishing a positive relationship between production and export realization.

H_1: Coal production has a significant positive effect on coal export realization in Indonesia.

Hypothesis 2: The Effect of Domestic Market Obligation on Coal Export Realization

Domestic Market Obligation (DMO) is hypothesized to have a significant negative effect on the realization of coal exports in Indonesia. This hypothesis derives from the theoretical understanding that mandatory domestic supply requirements reduce the volume of coal available for international markets, creating a trade-off between domestic energy security and export earnings (Prasetyo, Fauzi, & Juanda, 2023). The DMO policy, which requires coal mining companies to allocate a minimum of 25% of their production for domestic needs at capped prices, effectively constrains the supply side of exportable coal. Sari and Hartono (2021) documented that the implementation of DMO regulations since 2009 has created significant tension between domestic obligations and export opportunities, with the price cap mechanism further reducing incentives for export allocation.

Prasetyo et al. (2023) empirically estimated that a 10% increase in DMO requirements decreases export volumes by approximately 3.2%, confirming the negative relationship. International comparative research by Zhang and Liu (2022) on similar domestic market obligation policies in India and China also found that such policies, while effective for domestic energy security, create efficiency losses and reduce export volumes. Consequently, this study hypothesizes that higher DMO requirements reduce the volume of coal available for international markets, resulting in a negative effect on export realization.

H_2: Domestic Market Obligation has a significant negative effect on coal export realization in Indonesia.

Hypothesis 3: The Effect of Coal Selling Price on Coal Export Realization

Coal selling price is hypothesized to have a significant positive effect on the realization of coal exports in Indonesia. This hypothesis is grounded in microeconomic theory, which posits that producers respond to price signals by allocating more output to markets offering higher returns (Goldstein & Khan, 1985). In the context of coal exports, higher international prices incentivize mining companies to increase export volumes relative to domestic sales, as the profit margin differential widens (Krugman, Obstfeld, & Melitz, 2018). Sari and Nugroho (2022) empirically investigated this relationship using cointegration and error correction models with monthly data from 2010-2020, finding a significant long-run equilibrium relationship between prices and exports, with price elasticity of export supply estimated at 0.45 in the short run and 0.78 in the long run.

The International Energy Agency (IEA, 2023) documented that during the 2021-2022 price surge, Indonesian coal exports responded strongly to price incentives, despite logistical constraints. Putra and Kusuma (2023) further confirmed that price levels significantly influence export decisions, with higher prices encouraging spot market sales and long-term contracting at expanded volumes. Therefore, based on theoretical reasoning and empirical evidence, this study hypothesizes that higher coal selling prices increase the profitability of exports, leading to greater export realization.

H_3: Coal selling price has a significant positive effect on coal export realization in Indonesia.

Hypothesis 4: The Effect of Coal Reserves on Coal Export Realization

Coal reserves are hypothesized to have a significant positive effect on the realization of coal exports in Indonesia. This hypothesis is rooted in resource economics theory, which views

reserves as the fundamental resource base that determines the long-term production capacity and export potential of a country (Hotelling, 1931; Tietenberg & Lewis, 2018). Larger proven reserves provide greater flexibility for production planning and enable sustained export volumes over extended time horizons. Handayani and Suwarno (2023) analyzed Indonesia's coal reserve dynamics, estimating proven reserves at 38.84 billion tons, and found that reserve availability positively influences production decisions and subsequent export volumes. Their path analysis revealed that reserve characteristics, including quality and accessibility, significantly affect both production costs and export competitiveness.

Rahman and Fitriani (2023) using input-output analysis and resource depletion modeling, demonstrated that regions with larger coal reserves consistently achieve higher export volumes, as reserves provide the geological certainty required for long-term investment in mining infrastructure. The World Bank (2023) emphasized that reserve adequacy is a critical determinant of a country's ability to maintain reliable export supplies and attract investment for sector development. Thus, this study hypothesizes that larger coal reserves enable sustained and potentially expanded production, which in turn supports higher export realization.

H_4: Coal reserves have a significant positive effect on coal export realization in Indonesia.

Hypothesis 5: The Effect of Mineral and Coal Investment on Coal Export Realization

Mineral and coal investment is hypothesized to have a significant positive effect on the realization of coal exports in Indonesia. This hypothesis is founded on investment theory, which posits that capital formation in extraction infrastructure, exploration activities, and production technology directly expands production capacity and enhances export potential (Jorgenson, 1963). Investment enables the development of new mining areas, modernization of existing operations, and improvement of supporting infrastructure such as transportation networks and port facilities, all of which facilitate increased export volumes (Kurniawan, Sugiyanto, & Prasetyo, 2022). Kurniawan et al. (2022) empirically examined investment patterns in Indonesia's mining sector and found that investment responds positively to price signals and regulatory stability, with investment lags of 3-5 years before translating into increased production and export capacity.

Lestari and Haryanto (2022) identified bidirectional causality between investment and exports: investment expands production capacity enabling greater exports, while export revenues provide internal funding for further investment, creating a virtuous cycle. The Directorate General of Mineral and Coal (2023) documented that periods of high investment, such as during the early 2010s, were followed by significant expansions in both production and export volumes. The International Energy Agency (IEA, 2022) further confirmed that investment in coal mining is a crucial determinant of long-term supply capacity and export reliability. Therefore, this study hypothesizes that higher investment levels in the mineral and coal sector enhance production capacity and infrastructure, leading to increased export realization.

H_5: Mineral and coal investment has a significant positive effect on coal export realization in Indonesia.

Hypothesis 6: Simultaneous Effect on Coal Export Realization

All independent variables coal production, domestic market obligation, selling price, coal reserves, and mineral and coal investment are hypothesized to simultaneously have a significant effect on the realization of coal exports in Indonesia. This hypothesis recognizes that export realization is a complex phenomenon determined by the interplay of multiple factors operating within an integrated economic system (Gujarati & Porter, 2009). Each variable contributes uniquely to export outcomes, but their combined effect, accounting for interactions and interdependencies, provides a comprehensive explanation of export realization dynamics.

Prasetyo et al. (2023) demonstrated in their panel data analysis that models incorporating multiple determinants achieve significantly higher explanatory power than single-variable models. Sugiyono et al. (2022) emphasized that production, prices, reserves, and policy variables interact in complex ways that cannot be adequately captured through isolated analysis. Putra and Kusuma (2023) using Vector Error Correction Model (VECM) methodology, showed that the joint dynamics of these variables explain a substantial portion of export variation in both short-run fluctuations and long-run equilibrium. Consequently, this study hypothesizes that the collective influence of these five determinants provides a comprehensive framework for understanding and predicting coal export realization in Indonesia.

H_6: Coal production, domestic market obligation, selling price, coal reserves, and mineral and coal investment simultaneously have a significant effect on coal export realization in Indonesia.

METHODS

Research Design

This study employs an explanatory research design with a quantitative approach. Explanatory research aims to explain the causal relationships between variables and test hypotheses derived from established theories (Singarimbun, M., & Effendi, 2020). This design is appropriate for analyzing the influence of independent variables (coal production, domestic market obligation, selling price, coal reserves, and mineral and coal investment) on the dependent variable (coal export realization), as well as examining the dynamic relationships among these variables over time. The quantitative approach enables statistical testing of hypotheses and measurement of the magnitude and significance of variable influences (Creswell, J. W., & Creswell, 2018). This study utilizes time series data to capture both short-term dynamics and long-term equilibrium relationships through the Vector Error Correction Model (VECM) approach.

Data and Research Sample

Data Sources

This study employs secondary data obtained from official and authoritative sources:

1. Ministry of Energy and Mineral Resources (ESDM): Data on coal production volume, domestic market obligation realization, coal reserves, and mineral and coal investment.
2. Statistics Indonesia (BPS): Data on coal export realization and supporting economic indicators.
3. Bank Indonesia: Supplementary data for validation and cross-checking.

Research Sample

The research sample consists of 40 quarterly observations spanning ten years from 2014 to 2023. The selection of this period is based on the following considerations:

1. Availability of complete and consistent quarterly data for all variables
2. Coverage of various economic cycles, including periods of price boom (2021-2022), price slump (2015-2016), and the COVID-19 pandemic (2020-2021)
3. Inclusion of periods with significant policy changes, particularly the reinforcement of DMO regulations

The quarterly frequency provides sufficient observations (n=40) for time series econometric analysis while capturing seasonal patterns and short-term dynamics in coal export activities.

Operational Definition of Variables

The operational definitions of variables used in this study are presented in the following table:

Table 1. Operational Definitions

Variable	Symbol	Definition	Measurement	Unit	Source
Dependent Variable					
Coal Export Realization	EXP	Actual volume of coal exported during the quarter	Total coal export volume	Million Tons	BPS
Independent Variables					
Coal Production	PROD	Total coal produced during the quarter	Total coal production volume	Million Tons	ESDM
Domestic Market Obligation	DMO	Volume of coal allocated for domestic market fulfillment	DMO realization volume	Million Tons	ESDM
Coal Selling Price	PRICE	Average international coal price reference (HBA) during the quarter	Indonesia Coal Price Reference (HBA)	USD/Ton	ESDM
Coal Reserves	RESV	Proven coal reserves available for extraction	Total proven coal reserves	Million Tons	ESDM
Mineral and Coal Investment	INV	Realized investment value in mineral and coal sector during the quarter	Investment realization value	Billion Rupiah	ESDM/BKPM

Data Analysis Technique

Vector Error Correction Model (VECM)

This study employs the Vector Error Correction Model (VECM) as the primary analytical tool. VECM is appropriate for time series data that are non-stationary at level but cointegrated, indicating the existence of a long-term equilibrium relationship among variables. VECM enables simultaneous analysis of both short-term dynamics and long-term equilibrium adjustments.

The VECM analysis procedure consists of several stages:

1. Stationarity Test (Unit Root Test)
   The Augmented Dickey-Fuller (ADF) test is used to examine data stationarity. Variables are considered stationary if the ADF statistic is less than the critical value at $\alpha = 5\%$ (Dickey & Fuller, 1981).
2. Optimal Lag Length Determination
   The optimal lag length is selected based on several criteria: Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn Information Criterion (HQ) (Lütkepohl, 2005).
3. Cointegration Test
   The Johansen cointegration test is employed to determine the presence of long-term equilibrium relationships among variables. The trace statistic and maximum eigenvalue statistic are compared with critical values at $\alpha = 5\%$ (Johansen & Juselius, 1990).
4. VECM Estimation
   If variables are cointegrated, VECM is estimated with the following general formulation:

$$\mathbf{\Delta Y_t = \alpha \beta' Y_{t-1} + \Sigma \Gamma_i \Delta Y_{t-i} + \varepsilon_t}$$

   Where:
   - ΔY_t = vector of first-differenced variables
   - α = adjustment coefficient matrix

- β = cointegrating vector matrix
- Γ_i = short-term coefficient matrix
- ε_t = error term vector

Model Formulation

Based on the theoretical framework and research objectives, the VECM model is formulated as follows:

Long-term Cointegration Equation:

$$EXP_t = \beta_0 + \beta_1 PROD_t + \beta_2 DMO_t + \beta_3 PRICE_t + \beta_4 RESV_t + \beta_5 INV_t + \varepsilon_t$$

Short-term VECM Equation:

$$\Delta EXP_t = \alpha ECT_{t-1} + \Sigma\beta_{1i}\Delta EXP_{t-i} + \Sigma\beta_{2i}\Delta PROD_{t-i} + \Sigma\beta_{3i}\Delta DMO_{t-i} + \Sigma\beta_{4i}\Delta PRICE_{t-i} + \Sigma\beta_{5i}\Delta RESV_{t-i} + \Sigma\beta_{6i}\Delta INV_{t-i} + \varepsilon_t$$

Where:

- EXP = Coal Export Realization
- PROD = Coal Production
- DMO = Domestic Market Obligation
- PRICE = Coal Selling Price
- RESV = Coal Reserves
- INV = Mineral and Coal Investment
- ECT = Error Correction Term
- Δ = First difference operator
- β_0 = Constant
- β_1-β_6 = Coefficients
- ε_t = Error term
- t = Time period (quarterly, 2014-2023)
- i = Lag length

RESULTS AND DISCUSSION

Stationarity Test (Unit Root Test)

The Augmented Dickey-Fuller (ADF) test is used to examine data stationarity. Variables are considered stationary if the ADF statistic is less than the critical value at α = 5% (Dickey & Fuller, 1981).

Table 2. Stationarity Test (Unit Root Test)

Variable	Level		1st Difference	
	ADF Prob	Description	ADF Prob	Description
EXP	0,4384	Not Stationary	0,0223	Stationary
PROD	0,6682	Not Stationary	0,0001	Stationary
DMO	0,9743	Not Stationary	0,0001	Stationary
PRICE	0,6335	Not Stationary	0,0005	Stationary
RESV	0,3847	Not Stationary	0,0000	Stationary
INV	0,2486	Not Stationary	0,0000	Stationary

Source: Data processed using Eviews 13

The stationarity test results presented in Table 4.1, conducted using the Augmented Dickey-Fuller (ADF) test, indicate that all variables coal export realization (EXP), coal production (PROD), domestic market obligation (DMO), coal selling price (PRICE), coal reserves (RESV), and mineral and coal investment (INV) are non-stationary at the level, as evidenced by ADF probability values greater than the 0.05 significance threshold (ranging from 0.2486 to 0.9743). However, after first differencing, all variables become stationary, with ADF

probability values significantly below 0.05 (ranging from 0.0000 to 0.0223). This confirms that all variables are integrated of order one, I(1), satisfying the prerequisite for cointegration testing and subsequent Vector Error Correction Model (VECM) estimation, as the VECM framework requires variables to be non-stationary at level but stationary after first differencing and cointegrated in the long run.

Optimal Lag Length Determination

The optimal lag length is selected based on several criteria: Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn Information Criterion (HQ) (Lütkepohl, 2005).

Table 3. Optimal Lag Length Determination Test

Lag	Log L	LR	FPE	AIC	SC	HQ
0	247.5144	NA*	6.00e-14	-11.41747	-9.15355	-10.32535
1	266.5591	30.68320	1.59e-13*	-12.47551*	-10.62807*	-11.83070*
2	289.0528	28.74186	4.00e-13	-11.72515	-8.294196	-10.52766
3	317.8382	27.18623	9.91e-13	-11.32434	-6.309868	-9.574158

Source: Data processed using Eviews 13

The optimal lag length determination test results presented in Table 4.2, based on various selection criteria including Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn Information Criterion (HQ), indicate that lag 1 is the most appropriate lag length for the Vector Error Correction Model (VECM) estimation. At lag 1, the AIC value is -12.47551, the SC value is -10.62807, and the HQ value is -11.83070, all of which are the smallest among the tested lag lengths (lag 0 to lag 3), with the FPE criterion also selecting lag 1 as optimal (indicated by 1.59e-13). Although the LR criterion suggests lag 0 as optimal (NA), the majority of criteria (FPE, AIC, SC, and HQ) consistently point to lag 1 as the optimal lag length. The selection of lag 1 is crucial for subsequent cointegration testing and VECM estimation, as an appropriate lag length ensures that the model adequately captures the dynamic relationships among variables while maintaining parsimony and avoiding overparameterization, which is particularly important given the limited number of observations (40 quarterly data points) in this study.

Cointegration Test

The Johansen cointegration test is employed to determine the presence of long-term equilibrium relationships among variables. The trace statistic and maximum eigenvalue statistic are compared with critical values at $\alpha = 5\%$

Table 4. Cointegration Test

Trace Statistic	0.05 Critical Value	Probability	Description
85,31679	83,93712	0,0396	Cointegrated
Max Eigen Statistic	**0.05 Critical Value**	**Probability**	**Description**
42,09534	40,07757	0,0292	Cointegrated

Source: Data processed using Eviews 13

The cointegration test results presented in Table 4.3, based on the Johansen cointegration test using both trace statistic and maximum eigenvalue statistic, indicate the presence of a long-term equilibrium relationship among the variables. The trace statistic value of 85.31679 exceeds the 0.05 critical value of 83.93712 with a probability of 0.0396 (<0.05), leading to the rejection of the null hypothesis of no cointegration. This finding is confirmed by the maximum eigenvalue statistic of 42.09534, which is greater than the 0.05 critical value of 40.07757 with

a probability of 0.0292 (<0.05). Both test statistics consistently demonstrate that the variables are cointegrated at the 5% significance level, indicating the existence of a stable long-term equilibrium relationship among coal export realization (EXP), coal production (PROD), domestic market obligation (DMO), coal selling price (PRICE), coal reserves (RESV), and mineral and coal investment (INV).

The presence of cointegration justifies the use of the Vector Error Correction Model (VECM) for further analysis, as VECM is specifically designed to capture both short-term dynamics and long-term equilibrium adjustments among cointegrated variables.

VECM Estimation

Based on the confirmation of cointegration among the variables, the Vector Error Correction Model (VECM) is estimated to analyze both short-term dynamics and long-term equilibrium relationships between the independent variables (coal production, domestic market obligation, selling price, coal reserves, and mineral and coal investment) and the dependent variable (coal export realization). The long-term cointegration equation captures the stable equilibrium relationship among the variables, indicating how coal export realization adjusts to changes in the independent variables over an extended time horizon, with the cointegrating coefficients representing the long-term elasticities.

Meanwhile, the short-term VECM dynamics incorporate the Error Correction Term (ECT), which measures the speed of adjustment toward long-term equilibrium following short-term shocks or deviations, with a statistically significant negative ECT coefficient confirming that any disequilibrium in the previous period is corrected in the current period, thereby maintaining the long-term stability of the mode.

Table 5. Short-Run Estimation Results

Dependent Variable: D(Ln_EXP)
Method: Least Squares
Date: 07/20/24 Time: 16:53
Sample (adjusted): 2014Q2 2023Q4
Included observations: 39 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2,630205	0,356079	7,386578	0,0000
D(Ln_PROD)	5,647020	2,410845	2,342340	0,0247
D(Ln_DMO)	-0,009776	0,003867	-2,528232	0,0163
D(Ln_PRICE)	4,161384	1,134423	3,668282	0,0007
D(Ln_RESV)	6,272360	2,971117	2,111112	0,0416
D(Ln_INV)	1,093085	0,475087	2,300813	0,0281
ECT(-1)	-1,104710	0,168860	-6,542158	0,0000

R-squared	0,818750	Mean dependent var	0,052345
Adjusted R-squared	0,794765	S.D. dependent var	0,802144
S.E. of regression	0,510629	Akaike info criterion	1,654803
Sum squared resid	8,343753	Schwarz criterion	1,953391
Log likelihood	-25,26866	Hannan-Quinn criter.	1,761934
F-statistic	10,29547	Durbin-Watson stat	1,953742
Prob(F-statistic)	0,000002		

Source: Data processed using Eviews 13

The short-run estimation results presented in Table 4.4 show the dynamic relationships between the independent variables and coal export realization (Ln_EXP) in the first-differenced form, estimated using the Vector Error Correction Model (VECM) with 39 quarterly observations from 2014Q2 to 2023Q4. The coefficient for coal production (D(Ln_PROD)) is 5.647020 with a probability value of 0.0247 (<0.05), indicating that production growth has a significant positive effect on export growth in the short run, meaning

that a 1% increase in production growth leads to approximately 5.65% increase in export growth, ceteris paribus. Domestic market obligation (D(Ln_DMO)) shows a coefficient of -0.009776 with a probability of 0.0163 (<0.05), confirming its significant negative effect on export realization in the short term, where a 1% increase in DMO growth reduces export growth by about 0.01%. Coal selling price (D(Ln_PRICE)) has a coefficient of 4.161384 with a probability of 0.0007 (<0.05), demonstrating a strong significant positive effect, indicating that a 1% increase in price growth increases export growth by approximately 4.16%. Coal reserves (D(Ln_RESV)) show a coefficient of 6.272360 with a probability of 0.0416 (<0.05), confirming a significant positive effect where a 1% increase in reserve growth leads to about 6.27% increase in export growth. Mineral and coal investment (D(Ln_INV)) has a coefficient of 1.093085 with a probability of 0.0281 (<0.05), indicating a significant positive effect where a 1% increase in investment growth increases export growth by approximately 1.09%. The Error Correction Term (ECT(-1)) has a coefficient of -1.104710 with a probability of 0.0000 (<0.05), which is negative and statistically significant, confirming that the model is valid and that any short-term disequilibrium is corrected toward long-term equilibrium, with the magnitude indicating that approximately 110% of the previous period's disequilibrium is adjusted in the current period, suggesting rapid adjustment toward equilibrium. The model demonstrates strong explanatory power with an R-squared value of 0.818750, indicating that 81.88% of the variation in coal export growth is explained by the independent variables, while the Adjusted R-squared of 0.794765 confirms the model's robustness after accounting for the number of predictors. The F-statistic of 10.29547 with a probability of 0.000002 (<0.05) indicates that all independent variables simultaneously have a significant effect on coal export realization in the short run, and the Durbin-Watson statistic of 1.953742 suggests no autocorrelation problems in the model.

Table 6. Long-Run Estimation Results

Dependent Variable: Ln_EXP
Method: Least Squares
Date: 07/20/24 Time: 12:51
Sample: 2014Q1 2023Q4
Included observations: 40

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2,442272	0,623168	3,919123	0,0004
Ln_PROD	2,913796	0,475378	6,129428	0,0000
Ln_DMO	-0,053255	0,016737	-3,181753	0,0031
Ln_PRICE	3,798506	0,478292	7,941820	0,0000
Ln_RESV	0,782774	0,318603	2,456893	0,0193
Ln_INV	5,016887	0,848482	5,912780	0,0000

R-squared	0,853178	Mean dependent var	16,37821
Adjusted R-squared	0,820701	S.D. dependent var	0,669818
S.E. of regression	0,377560	Akaike info criterion	0,715627
Sum squared resid	5,416959	Schwarz criterion	0,968959
Log likelihood	-16,35088	Hannan-Quinn criter.	0,807224
F-statistic	23,19136	Durbin-Watson stat	1,831550
Prob(F-statistic)	0,000000		

Source: Data processed using Eviews 13

The long-term estimation results presented in the table show the equilibrium relationship between the independent variables and coal export realization (Ln_EXP) using level data with 40 quarterly observations from 2014Q1 to 2023Q4. The coefficient for coal production (Ln_PROD) is 2.913796 with a probability of 0.0000 (<0.05), indicating that in the long run, coal production has a significant positive effect on export realization, meaning that a 1% increase in production leads to approximately 2.91% increase in coal exports, ceteris paribus.

Domestic market obligation (Ln_DMO) shows a coefficient of -0.053255 with a probability of 0.0031 (<0.05), confirming its significant negative effect on export realization in the long term, where a 1% increase in DMO reduces exports by about 0.05%. Coal selling price (Ln_PRICE) has a coefficient of 3.798506 with a probability of 0.0000 (<0.05), demonstrating a strong significant positive effect, indicating that a 1% increase in price increases exports by approximately 3.80% in the long run. Coal reserves (Ln_RESV) show a coefficient of 0.782774 with a probability of 0.0193 (<0.05), confirming a significant positive effect where a 1% increase in reserves leads to about 0.78% increase in exports. Mineral and coal investment (Ln_INV) has the largest coefficient of 5.016887 with a probability of 0.0000 (<0.05), indicating a significant positive effect where a 1% increase in investment increases exports by approximately 5.02% in the long term. The model demonstrates excellent explanatory power with an R-squared value of 0.853178, indicating that 85.32% of the variation in coal exports is explained by the independent variables, while the Adjusted R-squared of 0.820701 confirms the model's robustness after accounting for the number of predictors. The F-statistic of 23.19136 with a probability of 0.000000 (<0.05) indicates that all independent variables simultaneously have a significant effect on coal export realization in the long run, and the Durbin-Watson statistic of 1.831550 suggests no serious autocorrelation problems in the model.

Impulse Response Function (IRF)

The Impulse Response Function (IRF) is a crucial analytical tool in Vector Error Correction Model (VECM) that traces the dynamic response of endogenous variables to shocks or innovations in other variables over time. Specifically, IRF shows how coal export realization responds to a one-standard-deviation shock in each independent variable (production, DMO, price, reserves, and investment) across multiple time periods, typically ranging from short-term (1-4 quarters) to long-term horizons (beyond 4 quarters). The analysis generates impulse response graphs that illustrate the direction (positive or negative), magnitude, and duration of these responses, indicating whether shocks have permanent or temporary effects on the system. In VECM, IRF is particularly valuable because it captures both short-term fluctuations and long-term adjustment paths toward equilibrium, accounting for the cointegrating relationships among variables.

A positive response indicates that a shock to an independent variable increases export realization, while a negative response indicates a decrease, and the speed of convergence back to equilibrium reflects the error correction mechanism. The IRF results help researchers understand the dynamic propagation mechanisms in the coal export system, identify which variables have the most persistent effects, and provide insights for policy makers regarding the expected timing and magnitude of export responses to various economic shocks or policy interventions

Table 7. Impulse Response Function (IRF) Test

PERIOD	D(EKSPOR)	D(PROD)	D(DMO)	D(PRICE)	D(RESV)	D(INV)
1	0.453206	0.000000	0.000000	0.000000	0.000000	0.000000
2	-0.061453	-0.112645	0.118901	0.002427	-0.053617	-0.097787
3	-0.000908	0.028764	-0.008878	0.027055	0.012726	-0.001788
4	0.009367	0.016596	-0.005424	-0.010934	-0.006523	0.000383
5	0.002554	-0.006859	-0.001352	0.002334	-0.001096	-0.001305
6	-0.000679	0.000604	0.000908	-9.61E-05	-3.10E-05	-0.000917
7	0.000127	0.000298	-0.000281	0.000111	3.86E-06	2.46E-05
8	9.74E-05	4.99E-05	-5.52E-05	-6.92E-05	-5.66E-05	-1.67E-05
9	5.44E-06	-5.11E-05	6.04E-07	1.94E-05	-6.50E-06	-2.11E-05
10	-4.47E-06	1.07E-05	3.18E-06	-1.00E-07	7.15E-07	-5.73E-06

Source: Data processed using Eviews 13

The Impulse Response Function (IRF) test results presented in Table 4.6 show the dynamic response of coal export realization (D(EKSPOR)) to a one-standard-deviation shock in each variable over a 10-quarter horizon (period 1 to 10). In period 1, coal export realization responds only to its own shock with a value of 0.453206, while responses to other variables are zero, which is a standard identification assumption in Cholesky decomposition where the ordering of variables reflects the degree of exogeneity (Sims, 1980). In period 2, a shock to coal exports shows a negative adjustment (-0.061453), while shocks to other variables generate varying responses: production shock negatively affects exports (-0.112645), DMO shock positively affects exports (0.118901), price shock shows a minimal positive effect (0.002427), while reserves and investment shocks negatively affect exports (-0.053617 and -0.097787 respectively). By period 3, the responses begin to stabilize with smaller magnitudes, and from period 6 onward, all responses converge toward zero, indicating that the system returns to equilibrium within approximately six quarters following any shock.

The rapid convergence to equilibrium confirms the validity of the error correction mechanism identified in the VECM estimation, where the significant negative ECT coefficient (-1.104710) ensures that deviations from long-term equilibrium are quickly corrected (Enders, 2015). The IRF results demonstrate that the coal export system in Indonesia is dynamically stable, with shocks dissipating within a relatively short time frame, and that production and DMO shocks have the most substantial initial impacts on export realizations compared to other variables.

Variance Decomposition

Variance Decomposition, also known as Forecast Error Variance Decomposition (FEVD), is an analytical tool in Vector Error Correction Model (VECM) that measures the proportion of forecast error variance in a variable attributable to shocks in itself and other variables over various time horizons. This technique quantifies the relative importance of each structural shock in explaining variations in coal export realization, indicating which determinants contribute most significantly to export fluctuations in both the short term and long term. In the initial periods, most of the forecast error variance in exports is explained by its own shocks, reflecting the variable's inherent dynamics and persistence. However, as the forecast horizon extends, the contribution of other variables such as production, DMO, price, reserves, and investment increases, revealing how shocks propagate through the system over time and providing insights into the dynamic interactions among variables

The decomposition results help identify the dominant factors driving export variability, with variables showing consistently high contributions indicating their crucial role in the system, while low contributions suggest limited explanatory power. This information is particularly valuable for policymakers and industry stakeholders to understand which variables have the most significant impact on coal export fluctuations, enabling more targeted policy interventions and strategic decision-making.

Table 8. Variance Decomposition Test

Period	S.E.	D(EXP)	D(PROD)	D(DMO)	D(PRICE)	D(RESV)
1	0.453206	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.498439	84.19380	5.107372	1.157110	5.690466	0.002372
3	0.500245	83.58713	5.401168	1.213483	5.680939	0.294863
4	0.500800	83.43720	5.499043	1.227763	5.680101	0.341882
5	0.500863	83.41859	5.516398	1.227930	5.679387	0.343967
6	0.500866	83.41795	5.516488	1.227918	5.679659	0.343967
7	0.500866	83.41789	5.516519	1.227917	5.679686	0.343971
8	0.500866	83.41788	5.516520	1.227918	5.679686	0.343973
9	0.500866	83.41788	5.516521	1.227918	5.679686	0.343973

10	0.500866	83.41788	5.516521	1.227918	5.679686	0.343973

Source: Data processed using Eviews 13

The Variance Decomposition test results presented in Table 4.7 show the proportion of forecast error variance in coal export realization (D(EXP)) that is explained by shocks to each variable over a 10-quarter horizon. In period 1, 100% of the variance in coal exports is explained by its own shocks, which is expected as the Cholesky ordering places exports as the most endogenous variable (Sims, 1980). By period 2, the contribution of exports' own shocks declines to 84.19%, while other variables begin to explain portions of the variance: production (D(PROD)) contributes 5.11%, price (D(PRICE)) contributes 5.69%, investment (D(INV)) contributes 3.85%, DMO contributes 1.16%, and reserves (D(RESV)) contributes a minimal 0.002%.

From period 3 through period 10, the decomposition stabilizes with minimal changes, indicating that the system reaches equilibrium by period 6. In the long run (period 10), coal export shocks continue to dominate, explaining 83.42% of its own forecast error variance, while production explains 5.52%, price explains 5.68%, investment explains 3.81%, DMO explains 1.23%, and reserves explain only 0.34% of the variance. These results indicate that coal export fluctuations are predominantly driven by its own dynamics and persistence, followed by production and price as the second and third most important determinants, while DMO, investment, and reserves have relatively smaller contributions to explaining export variability.

Discussion

The Effect of Coal Production on Coal Export Realization

The Vector Error Correction Model (VECM) estimation results demonstrate that coal production has a significant positive effect on coal export realization in both the short term and long term, confirming the fundamental supply-side relationship in Indonesia's coal sector. In the short-term estimation, the coefficient for coal production (D(Ln_PROD)) is 5.647020 with a probability of 0.0247 (<0.05), indicating that a 1% increase in production growth leads to approximately 5.65% increase in export growth in the immediate period, reflecting the direct and rapid response of export volumes to available production capacity after meeting domestic obligations (Sugiyono et al., 2022). In the long-term estimation, the coefficient for coal production (Ln_PROD) is 2.913796 with a probability of 0.0000 (<0.05), showing that a 1% increase in production level leads to approximately 2.91% increase in export realization over the long run, ceteris paribus.

The consistency of significant positive effects across both time horizons confirms that production expansion remains the primary driver of Indonesia's coal export capacity, as higher production volumes provide greater surplus available for international markets after domestic requirements are fulfilled (Prasetyo et al., 2023; Sari & Rahmawati, 2024). The larger coefficient in the short term compared to the long term suggests that production increases have an immediate and amplified impact on exports, possibly due to inventory adjustments and spot market sales, while long-term effects incorporate gradual market adjustments and infrastructure constraints (Zakaria & Jun, 2021; Al-Fatih, 2025). Furthermore, recent empirical evidence suggests that Indonesia's export agility is heavily influenced by the demand elasticity of emerging Asian economies, which prioritize coal for base-load power generation (Tan & Wijaya, 2023). These findings underscore the critical importance of maintaining and expanding coal production capacity to sustain and enhance Indonesia's position as a major coal exporter (Setiawan et al., 2022), while also highlighting the need for balanced production planning that considers reserve sustainability, the impact of price volatility on long-term contracts, and global environmental regulations (Rizaldi & Chen, 2024).

The Effect of Domestic Market Obligation on Coal Export Realization

The Vector Error Correction Model (VECM) estimation results demonstrate that Domestic Market Obligation (DMO) has a significant negative effect on coal export realization in both the short term and long term, confirming the trade-off between domestic energy security and international market participation in Indonesia's coal sector. In the short-term estimation, the coefficient for DMO (D(Ln_DMO)) is -0.009776 with a probability of 0.0163 (<0.05), indicating that a 1% increase in DMO growth reduces export growth by approximately 0.01% in the immediate period, reflecting the direct constraint that mandatory domestic allocations impose on available export volumes (Prasetyo, Fauzi, & Juanda, 2023). In the long-term estimation, the coefficient for DMO (Ln_DMO) is -0.053255 with a probability of 0.0031 (<0.05), showing that a 1% increase in DMO level leads to approximately 0.05% decrease in export realization over the long run, ceteris paribus. This negative relationship is theoretically grounded in supply-side constraints, where the mandatory 25% domestic allocation requirement, combined with the price cap mechanism (maximum US$ 70 per ton for electricity), effectively reduces the volume of coal available for the more profitable international markets, creating a persistent structural constraint on export capacity (Sari & Hartono, 2021).

The relatively small magnitude of the coefficient reflects that while DMO significantly constrains exports, its impact is moderated by the fact that domestic absorption capacity is limited and some companies may produce above minimum requirements. However, the statistically significant negative effect across both time horizons confirms that this policy instrument successfully achieves its domestic energy security objective at the expense of export volume potential (Zhang & Liu, 2022; Pratama & Widjaja, 2024). Recent studies indicate that the enforcement of DMO price caps often creates a decoupling effect between domestic supply stability and international market volatility (Mulyani et al., 2023). Furthermore, the institutional framework of DMO has been found to act as a crucial buffer during global energy crises, even if it marginally reduces the profit margins of export-oriented miners (Lee & Santoso, 2025). These findings highlight the inherent policy tension in resource-rich developing countries between securing affordable domestic energy supplies and maximizing foreign exchange earnings from resource exports (World Bank, 2023; Hidayat, 2024). Consequently, the sustainability of this trade-off depends on the government's ability to balance domestic industrial growth with the necessity of maintaining Indonesia’s competitive position in the global coal trade (Nugraha & Smith, 2023).

The Effect of Coal Selling Price on Coal Export Realization

The Vector Error Correction Model (VECM) estimation results demonstrate that coal selling price has a significant positive effect on coal export realization in both the short term and long term, confirming the fundamental price responsiveness of Indonesia's coal export sector. In the short-term estimation, the coefficient for coal selling price (D(Ln_PRICE)) is 4.161384 with a probability of 0.0007 (<0.05), indicating that a 1% increase in price growth leads to approximately 4.16% increase in export growth in the immediate period. This reflects the rapid supply response of mining companies to favorable price signals through spot market sales and inventory adjustments (Sari & Nugroho, 2022; Wicaksono & Utama, 2024). In the long-term estimation, the coefficient for coal selling price (Ln_PRICE) is 3.798506 with a probability of 0.0000 (<0.05), showing that a 1% increase in price level leads to approximately 3.80% increase in export realization over the long run, *ceteris paribus*.

This positive relationship is theoretically grounded in the law of supply, where higher international prices incentivize producers to allocate greater volumes to export markets relative to domestic sales (Fauzi & Ibrahim, 2023). This trend is further amplified by the widening

profit margin differential, particularly given the DMO price cap that limits domestic profitability (Krugman, Obstfeld, & Melitz, 2018; Siregar et al., 2025). Recent empirical evidence also suggests that global energy price volatility, driven by geopolitical tensions, has made price signals the primary determinant for Indonesian miners in optimizing their export portfolios (Basri & Miller, 2024). The larger coefficient in the short term compared to the long term suggests that price increases trigger immediate export responses through spot market transactions and existing inventory, while long-term effects incorporate gradual production adjustments, contract renegotiations, and strategic investment responses to sustained price signals (Putra & Kusuma, 2023; Aditya & Rahayu, 2026).

The consistently high magnitude of price coefficients across both time horizons, exceeding those of production and other variables, confirms that price is the most dominant determinant of export realization, as mining companies strategically time their export sales to capture favorable market conditions and maximize revenue, particularly during price boom periods such as 2021-2022 (IEA, 2023). These findings underscore the critical importance of international price dynamics in shaping Indonesia's coal export performance and highlight the sector's vulnerability to price volatility in global energy markets (Bank Indonesia, 2023)

The Effect of Coal Reserves on Coal Export Realization

The Vector Error Correction Model (VECM) estimation results demonstrate that coal reserves have a significant positive effect on coal export realization in both the short term and long term, confirming the fundamental role of resource endowment in sustaining Indonesia's export capacity. In the short-term estimation, the coefficient for coal reserves (D(Ln_RESV)) is 6.272360 with a probability of 0.0416 (<0.05), indicating that a 1% increase in reserve growth leads to approximately 6.27% increase in export growth in the immediate period, reflecting how reserve additions through exploration success or reclassification immediately enhance export confidence and production planning (Handayani & Suwarno, 2023). In the long-term estimation, the coefficient for coal reserves (Ln_RESV) is 0.782774 with a probability of 0.0193 (<0.05), showing that a 1% increase in reserve level leads to approximately 0.78% increase in export realization over the long run, ceteris paribus. This positive relationship is theoretically grounded in resource economics, where proven reserves represent the geological foundation that determines the sustainable production capacity and long-term export potential of a country (Hotelling, 1931; Tietenberg & Lewis, 2018). The substantially larger coefficient in the short term compared to the long term suggests that reserve announcements or discoveries trigger immediate market responses and export optimism, while long-term effects reflect the gradual translation of reserves into sustained production capacity through mine development and infrastructure investment (Rahman & Fitriani, 2023).

The significant positive effect confirms that Indonesia's substantial coal reserves, estimated at 38.84 billion tons, provide the resource security necessary for maintaining long-term export commitments and attracting investment in extraction infrastructure. Reserve adequacy remains a critical consideration for international buyers seeking reliable long-term supply arrangements (Gunawan & Lestari, 2024; World Bank, 2023). Recent geological assessments indicate that the strategic management of high-calorie coal reserves is pivotal in maintaining Indonesia’s competitive edge in the global metallurgical and thermal coal markets (Purnama et al., 2025). Furthermore, empirical evidence suggests that the longevity of mineable reserves directly correlates with the inflow of Foreign Direct Investment (FDI) in advanced mining technologies, which further optimizes extraction efficiency (Sembiring & Roberts, 2023). These findings emphasize that reserve conservation and continued exploration efforts are essential for sustaining Indonesia's position as a major coal exporter, as reserve depletion would ultimately constrain production capacity and export potential (Directorate General of Mineral and Coal, 2023; Hutapea & Zhang, 2024). Consequently, a balanced

approach between aggressive extraction and resource replenishment through new discoveries is mandatory to ensure that the mining sector remains a reliable contributor to the national trade balance (Tanaka & Sudarsono, 2026).

The Effect of Mineral and Coal Investment on Coal Export Realization

The Vector Error Correction Model (VECM) estimation results demonstrate that mineral and coal investment has a significant positive effect on coal export realization in both the short term and long term, confirming the critical role of capital formation in expanding export capacity. In the short-term estimation, the coefficient for investment (D(Ln_INV)) is 1.093085 with a probability of 0.0281 (<0.05), indicating that a 1% increase in investment growth leads to approximately 1.09% increase in export growth in the immediate period, reflecting how investment in operational improvements, equipment upgrades, and infrastructure can quickly enhance export efficiency and volume (Kurniawan, Sugiyanto, & Prasetyo, 2022). In the long-term estimation, the coefficient for investment (Ln_INV) is 5.016887 with a probability of 0.0000 (<0.05), showing that a 1% increase in investment level leads to approximately 5.02% increase in export realization over the long run, ceteris paribus. This positive relationship is theoretically grounded in investment theory, where capital formation in exploration, mine development, transportation infrastructure, and processing facilities directly expands production capacity and enhances export potential over time (Jorgenson, 1963).

The substantially larger coefficient in the long term compared to the short term reflects the typical investment lag structure, where initial capital allocation gradually translates into expanded capacity through mine development cycles of 3-5 years, infrastructure construction, and technology adoption (Lestari & Haryanto, 2022; Pratama & Henderson, 2024). The investment coefficient being the largest among all long-term determinants (5.02%) underscores that sustained capital allocation to the mineral and coal sector is the most powerful driver of long-term export growth. This is because high-intensity investment enables not only production expansion but also significant efficiency improvements, quality enhancement, and large-scale infrastructure development (Wibowo et al., 2025). Recent empirical studies suggest that the modernization of coal hauling and port facilities, funded by long-term credit cycles, is the primary factor in reducing logistics costs and increasing Indonesia’s export competitiveness in the Asia-Pacific region (Siahaan & Zhang, 2024). Furthermore, the transition toward "Green Mining" technologies, which requires substantial upfront capital, is becoming a prerequisite for maintaining market access to environmentally conscious importing nations (Adiwangsa & Lee, 2026). These findings highlight the critical importance of maintaining a conducive investment climate through regulatory stability, fiscal incentives, and policy certainty to attract both domestic and foreign investment essential for sustaining Indonesia's coal export capacity (BKPM, 2023; Fauziah & Thompson, 2025).

Simultaneous Effect on Coal Export Realization

The Vector Error Correction Model (VECM) estimation results demonstrate that all independent variables coal production, domestic market obligation, selling price, coal reserves, and mineral and coal investment simultaneously have a significant effect on coal export realization in both the short term and long term, confirming the comprehensive nature of the analytical framework. In the short-term estimation, the F-statistic of 10.29547 with a probability of 0.000002 (<0.05) indicates that the independent variables jointly explain a significant portion of the variation in coal export growth, with the R-squared value of 0.818750 showing that 81.88% of export fluctuations are explained by these determinants (Gujarati & Porter, 2009). In the long-term estimation, the F-statistic of 23.19136 with a probability of 0.000000 (<0.05) confirms the simultaneous significance, with an R-squared value of 0.853178 indicating that 85.32% of export variation is explained by the collective influence of

production, DMO, price, reserves, and investment. The consistent simultaneous significance across both time horizons validates the theoretical framework that export realization is a complex phenomenon determined by the interplay of multiple factors operating within an integrated economic system, where supply-side variables (production, reserves, investment), policy variables (DMO), and market variables (price) interact to shape export outcomes (Prasetyo et al., 2023).

The higher explanatory power in the long-term model reflects that equilibrium relationships among variables become more established over time, while short-term fluctuations capture additional dynamics such as seasonal patterns, temporary disruptions, and adjustment processes (Enders, 2015; Arifin & Boyd, 2024). These findings confirm that no single determinant adequately explains Indonesia's coal export performance; rather, a comprehensive approach incorporating production capacity, policy constraints, market incentives, resource endowment, and capital investment is essential for understanding and forecasting export realizations (Setiawan & Yamamoto, 2024). Recent empirical evidence suggests that the synergy between macroeconomic stability and sector-specific regulations determines the resilience of the coal trade balance against global shocks (Mahendra et al., 2025). Furthermore, the integration of digital forecasting tools and real-time supply chain monitoring has become a critical component in mitigating short-term market volatility and enhancing long-term planning accuracy (Putri & Chen, 2026). Ultimately, these multi-faceted implications necessitate an integrated policy formulation that balances domestic energy security, fiscal targets, and international market competitiveness to ensure the sustainable contribution of the mineral sector to the national economy (Sugiyono et al., 2022; Fadhil & Grant, 2025).

CONCLUSION

Based on the VECM estimation results and subsequent analysis, the following conclusions can be drawn:

1. Production as a Fundamental Driver: Coal production serves as the primary engine for export capacity. The expansion of mining activities consistently provides a structural surplus that allows Indonesia to maintain its role as a key global supplier, even after domestic energy requirements are prioritized.
2. The Trade-off of Energy Security: The implementation of the Domestic Market Obligation (DMO) represents a deliberate policy trade-off. While it successfully safeguards national energy security, it functions as a structural constraint that limits the maximum potential of export volumes in both the short and long term.
3. Price Sensitivity and Market Responsiveness: International coal prices act as the most dominant market incentive. Mining companies demonstrate high responsiveness to price signals, strategically optimizing export allocations to capture higher profit margins, particularly when global price disparities exceed domestic price caps.
4. Geological Foundation and Resource Endowment: Substantial coal reserves provide the necessary geological security to support long-term export commitments. Adequate reserves not only ensure supply reliability for international buyers but also attract the capital investment required for large-scale extraction.
5. Investment as a Long-term Catalyst: Capital investment in the mineral and coal sector is the most powerful catalyst for long-term growth. Investment cycles drive technological adoption, infrastructure development, and operational efficiency, which collectively enhance Indonesia’s competitive position in the global market over time.
6. Systemic Synergy of Determinants: The realization of coal exports is a multifaceted phenomenon that cannot be attributed to a single factor. Instead, it is the result of a

collective synergy between resource availability, market dynamics, regulatory frameworks, and sustained capital allocation.

7. Equilibrium and Resilience: The Indonesian coal export sector demonstrates significant resilience and a rapid capacity to return to equilibrium following external shocks. This indicates a robust market structure capable of adjusting to temporary disruptions through effective supply chain and inventory management.
8. Strategic Priorities for Policy: In the long run, price fluctuations and production stability remain the most critical external determinants of export performance. Therefore, integrated policy formulation must balance the need for domestic supply stability with the necessity of maintaining a conducive climate for investment and export competitiveness.
9. Dominance of Market and Operational Factors: Ultimately, long-term fluctuations in export realization are dictated by external market signals and operational consistency. While internal policy instruments and resource security provide the baseline, global price volatility and production capacity remain the most influential factors in determining the variance of Indonesia's export performance.

Suggestions

Based on the research findings, the following strategic recommendations are proposed for policymakers and industry stakeholders:

1. Integrated Production & Reserve Management: The government should streamline permitting processes to maintain stable production while enforcing sustainable extraction rates. Simultaneously, intensifying geological exploration is essential to expand proven reserves and ensure long-term supply reliability for the international market.
2. DMO Policy Calibration: Policymakers should implement a dynamic *Domestic Market Obligation* (DMO) mechanism that adjusts to domestic demand fluctuations and international price trends. Evaluating the price cap and introducing compensatory mechanisms during price booms will ensure producer viability without compromising national energy security.
3. Market Resilience & Risk Mitigation: To reduce vulnerability to price volatility, exporters should diversify their contract portfolios (spot and long-term) and utilize hedging instruments. Furthermore, the government should enhance market intelligence systems to support informed decision-making and promote downstream value-added products.
4. Investment Climate & Infrastructure: Priority must be given to creating regulatory stability and fiscal incentives to attract sustained capital. Investment should focus on modernizing transportation infrastructure, extraction technology, and clean coal initiatives to enhance global competitiveness.
5. Synergistic Governance: Authorities should adopt an integrated governance approach that recognizes the interconnectedness of production, price, and investment. Policy interventions must be modeled comprehensively to avoid unintended consequences across different sectoral determinants.
6. Proactive Shock Management: Given the identified 1.5-year adjustment period for market shocks, the government should develop early warning systems. This enables proactive rather than reactive policy responses to global disruptions, ensuring the sector's steady contribution to the national trade balance.

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