INTERDISCIPLINARY APPROACHES TO SUSTAINABILITY, INNOVATIONS, CULTURAL HERITAGE, TECHNOLOGY, AND URBAN DEVELOPMENT IN INDONESIA

Editor

Dr. Teena Singh

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Interdisciplinary Approaches to Sustainability, Innovations, Cultural Heritage, Technology, and Urban Development in Indonesia

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PREFACE

This book brings together a diverse collection of interdisciplinary studies that explore the intersection of sustainability, technology, cultural preservation, and urban development. The chapters within offer a unique perspective on these themes, particularly in the context of Indonesia, a country rich in both cultural heritage and rapidly evolving technological advancements.

As the world faces an increasing need for sustainable practices, this book seeks to address key challenges in various sectors, from architecture and tourism to environmental management and industrial production. The chapters delve into cutting-edge topics, such as the application of Artificial Intelligence (AI) in preserving cultural heritage, the role of architecture in mitigating environmental impacts, and innovative approaches to urban development. They also highlight the practicalities of implementing sustainability in industries like footwear manufacturing and oil production, offering valuable case studies from Indonesia.

One of the central themes of this book is the integration of traditional practices with modern technologies. From the preservation of the Durgā statue at the Prambanan Temple using AI tools to the role of sustainable tourism in Indonesia's tropics, the book emphasizes how technology can enhance, rather than replace, cultural practices and natural environments. In doing so, it encourages a holistic approach to development that respects both historical legacies and contemporary needs.

The chapters also explore the role of system technologies, such as Enterprise Resource Planning (ERP) systems, in improving user satisfaction and operational efficiency across various sectors. Moreover, the book highlights how innovations in design and production, from footwear manufacturing to urban planning, can lead to more sustainable and socially responsible outcomes.

The contributors to this book come from diverse backgrounds, each offering a distinct viewpoint on the issues at hand. Their research reflects a growing commitment to creating solutions that are not only technologically advanced but also culturally sensitive and environmentally sound.

As we navigate the complexities of the 21st century, the knowledge and insights shared in this book serve as a valuable resource for academics, practitioners, and policymakers alike. By presenting a multifaceted view of Indonesia’s ongoing efforts to balance progress with sustainability, we hope to inspire further research and innovation that will contribute to a more sustainable, equitable, and prosperous future for all.

Dr. Teena Singh
Bursa, Türkiye – December 2024

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CHAPTER 4

Empirical Study on the Impact of Exports and Imports on Refinery Gas Production in Indonesia

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ABSTRACT

This study investigates the impact of export and import activities on refinery gas production in Indonesia using multiple linear regression analysis. The research utilizes data from 2013 to 2023 to examine how variations in export and import volumes influence domestic refinery output. The regression results reveal a statistically significant negative relationship between import volumes and refinery gas production, suggesting that increased imports may reduce domestic output due to heightened competition and reliance on foreign supplies. Conversely, export volumes show a positive but statistically insignificant effect, indicating that domestic production levels are less responsive to export fluctuations. The model's goodness of fit, with an R-squared value of 0.783 and an Adjusted R-squared value of 0.730, demonstrates strong explanatory power, indicating that approximately 78.3% of the variation in refinery gas production is accounted for by the combined effects of exports and imports. The F-statistic (14.42, p-value = 0.00222) further confirms the overall significance of the model. These findings suggest that reducing import dependency could enhance local production capacity, while a balanced export strategy is essential to maintain domestic supply stability. The study provides valuable insights for policymakers and industry stakeholders in optimizing trade policies and supporting the sustainable growth of the refinery gas sector. Future research should incorporate additional factors, such as technological advancements and domestic consumption trends, to deepen the analysis.

Keywords: Gas production, Exports, Imports, Multiple linear regression, Goodness of fit.

1. INTRODUCTION

The energy sector is a critical pillar of economic growth and development worldwide, providing the fuel necessary for industrial processes, transportation, and household consumption. Within this sector, the production of refinery gas holds a prominent place due to its versatile applications across various industries. Refinery gas, a by-product of the oil refining process, consists of a mixture of light hydrocarbons, including methane, ethane, propane, and butane. These gases are widely used as fuels for heating, cooking, and power generation, as well as feedstock in the petrochemical industry for producing essential chemicals such as ethylene and propylene. The efficient production and utilization of refinery gas are key to supporting energy security, reducing dependency on imported fuels, and fostering economic resilience, particularly in developing economies like Indonesia (Wijayanti et al., 2021).

Indonesia, as the largest archipelago nation in the world and one of Southeast Asia's most populous countries, faces unique challenges and opportunities in the energy sector. With a rapidly growing economy and a population of over 270 million, Indonesia's demand for energy has increased significantly over the past decade (Worldometer, 2023) . This surge in demand has put immense pressure on the country's refining industry to boost its output and meet domestic needs. However, the refining capacity in Indonesia has historically been constrained by limited infrastructure investments, aging facilities, and a heavy reliance on imported crude oil. These limitations have made the country vulnerable to fluctuations in global oil prices and exposed it to the risks associated with international trade dependencies (Maulani et al., 2021).

The Indonesian government has recognized these challenges and, as part of its long-term energy strategy, has implemented various policies aimed at increasing domestic refining capacity and reducing dependency on imports. These initiatives include the expansion and modernization of existing refineries, the construction of new refining facilities, and the promotion of investments in advanced refining technologies. Despite these efforts, the refinery gas sector continues to grapple with structural issues, including inefficiencies in production processes, supply chain disruptions, and regulatory hurdles. Moreover, the volatility of global trade dynamics, influenced by factors such as geopolitical tensions, trade disputes, and shifts in global demand patterns, adds an additional layer of complexity to the industry's performance (Ridaliani et al., 2021).

Exports of refinery gas and related products represent a critical opportunity for Indonesia to capitalize on its refining capabilities and earn valuable foreign exchange revenue. By tapping into international markets, Indonesian refineries can potentially increase their production volumes, achieve economies of scale, and enhance their profitability. Export activities also provide a mechanism for diversifying revenue streams and reducing the economic risks associated with fluctuating domestic demand. However, there are trade-offs involved, as an aggressive export strategy may lead to reduced availability of refinery gas for local consumption, potentially driving up domestic prices and creating supply shortages. Balancing the needs of the domestic market with the benefits of export revenue generation is a delicate task that requires careful policy formulation and strategic planning (The Ministry of Energy and Mineral Resource Republic of Indonesia, 2023).

Imports, on the other hand, play a dual role in the context of Indonesia's refinery gas industry. On one hand, imports serve as a necessary supplement to domestic production, particularly during peak demand periods or when local refineries are unable to produce sufficient quantities of specific gas products. By importing these products, Indonesia can ensure a steady supply of essential fuels and feedstocks, supporting the stability of its energy market. On the other hand, excessive reliance on imports can undermine the competitiveness of domestic refineries, making it difficult for them to operate at full capacity or invest in efficiency improvements. High levels of imports may also expose the country to external risks, such as changes in trade policies, tariffs, and disruptions in global supply chains, which could have adverse effects on local production and energy security (Sulistomo & Surjosatyo, 2023).

The interaction between exports, imports, and domestic refinery gas production is complex and multifaceted, influenced by a range of economic, technical, and regulatory factors. Theoretical perspectives from international trade economics suggest that both exports and imports play critical roles in shaping industrial output and economic growth. Exports can drive industrial expansion by opening up new markets and providing incentives for capacity enhancement, while imports can enhance production efficiency by supplying critical inputs that may not be readily available domestically. However, the net effect of these trade activities on domestic production is not always straightforward, as it depends on the specific characteristics of the industry, the nature of the traded goods, and the broader macroeconomic environment (Ramdan et al., 2021).

1.1.Research Gap

Despite the recognized importance of refinery gas production within the broader energy sector, there is a notable gap in the empirical research examining the specific effects of export and import activities on this segment of the industry in Indonesia. Existing studies have largely focused on broader aspects of the oil and gas industry, such as the impact of crude oil imports on overall energy security, the role of domestic energy policies in shaping investment climates, or general trade patterns affecting the energy sector. Few studies have delved into the specific dynamics of refinery gas production, particularly in the context of Indonesia, where the interplay between international trade activities and local output has unique implications due to the country's strategic geographical position and its status as a major oil and gas producer in the region (Widiasa et al., 2014).

This gap in the literature highlights the need for a focused empirical analysis that can provide detailed insights into how export and import activities influence refinery gas production. By addressing this gap, the present study aims to contribute to a deeper understanding of the factors driving variability in production levels and to offer new evidence that can inform industry practices and policymaking. The limited attention given to the refinery gas segment within existing trade and energy studies suggests an opportunity to explore unexplored relationships and to provide data-driven recommendations that have the potential to enhance the efficiency and competitiveness of the industry(Putri & Vikaliana, 2023) .

1.2.Novelty of the Study

The novelty of this study lies in its specific focus on the refinery gas sector, a crucial yet often overlooked component of the energy industry in Indonesia. Unlike previous research that has predominantly concentrated on crude oil imports or general trends in energy exports, this study hones in on the impact of both export and import volumes on refinery gas production. By employing a multiple linear regression approach, the study offers a comprehensive statistical analysis that quantifies the simultaneous effects of these trade activities, providing a more nuanced understanding of the economic dynamics at play(Rahman et al., 2022).

Furthermore, the use of detailed data from 2013 to 2023 allows the study to capture recent trends in the Indonesian refinery gas market, reflecting changes in global trade policies, shifts in domestic demand, and the effects of government initiatives aimed at boosting local refining capacity(The Ministry of Energy and Mineral Resource Republic of Indonesia, 2023). The inclusion of both export and import volumes as independent variables in the regression model represents a novel approach, as it enables the study to assess the combined impact of international trade on domestic production, rather than treating these factors in isolation.

This dual focus on exports and imports, combined with a rigorous empirical methodology, distinguishes this study from previous research and provides a new perspective on the strategic management of the refinery gas industry. The insights generated by this analysis are expected to offer valuable contributions to the academic literature, while also serving as a practical resource for policymakers and industry stakeholders seeking to navigate the complexities of international trade and enhance the sustainability of refinery gas production in Indonesia(Hidayat & Thomiyah, 2022).

2. LITERATURE REVIEW

The theoretical foundation of this study is built on the principles of international trade economics, and the dynamics of the energy production industry. This section discusses the core concepts and theories that underpin the research, including the fundamentals of refinery gas production, the role of exports and imports in economic growth, and the statistical basis for regression analysis(Arintoko et al., 2023). By establishing a clear theoretical framework, the study aims to provide a solid basis for understanding the relationships among the variables and guiding the interpretation of the empirical results.

2.1.Refinery Gas Production: An Overview

Refinery gas production is a crucial component of the energy sector, serving as both a source of energy and a raw material for various industrial applications. The production of refinery gas involves the processing of crude oil in refineries, where it is separated into various hydrocarbon fractions, including liquefied petroleum gas (LPG), ethane, and other light hydrocarbons. The efficiency and volume of refinery gas production depend on several factors, including the quality of the crude oil feedstock, the technological capabilities of the refinery, and the operational strategies employed(Rifa'i, 2020).

In Indonesia, refinery gas production plays a vital role in meeting domestic energy needs and supporting the country's industrial base. The Indonesian energy sector has historically relied on refinery gas as a key component of its energy mix, contributing to the supply of clean-burning fuels for household and industrial use. The ability of refineries to maintain stable and efficient gas production is influenced by market conditions, regulatory policies, and the availability of crude oil feedstock. Given the fluctuating nature of global oil prices and the increasing demand for cleaner energy sources, the refinery sector faces constant pressure to optimize production processes and enhance efficiency. This context underscores the importance of analyzing factors like exports and imports, which can significantly impact the industry's performance(Wanto et al., 2019).

2.2.The Role of Exports in Economic Growth

Exports are a fundamental driver of economic growth, providing an essential source of foreign exchange earnings and contributing to the overall economic output of a country. In the context of the refinery gas industry, exports represent a significant revenue stream, as countries with surplus production can sell excess output to international markets. For many resource-rich nations, including Indonesia, the ability to export energy products like refinery gas is a critical factor in sustaining economic development and achieving trade balance. Export activities can stimulate domestic production by increasing demand, encouraging investments in capacity expansion, and fostering innovation in refining technologies(Purnama et al., 2024).

However, the relationship between exports and production is not always straightforward. While an increase in exports can signal strong external demand and support higher production levels, it may also introduce challenges related to resource allocation and domestic market stability. In cases where domestic demand competes with export opportunities, refineries may face pressure to prioritize exports, potentially leading to supply constraints in the domestic market.

Additionally, reliance on export markets exposes the industry to external risks such as changes in international trade policies, fluctuations in global demand, and volatility in exchange rates. These factors must be carefully managed to ensure that export activities contribute positively to the growth and sustainability of the refinery gas sector(Iriani & Setiawati, 2023).

2.3.The Impact of Imports on Domestic Production

Imports play a dual role in the energy sector, acting as both a supplement to domestic production and a potential source of competition. In the refinery gas industry, imports are typically brought in to meet shortfalls in domestic supply or to access specific types of feedstock that may not be readily available locally. For countries like Indonesia, which have substantial energy needs but limited refining capacity, imports can help bridge the gap between domestic demand and supply, ensuring a stable supply of gas for consumers and industries(Hussain et al., 2023).

However, increased import volumes can also have adverse effects on domestic production. A high level of imports may indicate a dependency on foreign suppliers, reducing the incentive for local refineries to expand their capacity or invest in new technologies. This dependency can weaken the domestic industry's competitiveness, as imported products may be cheaper or of higher quality due to advanced refining processes used by international suppliers. Furthermore, excessive reliance on imports can expose the domestic market to global supply chain disruptions, such as geopolitical conflicts, changes in trade tariffs, and logistical challenges. These risks highlight the need for a balanced approach to managing imports, where strategic import policies are designed to complement domestic production rather than undermine it(O'Hara et al., 2012).

3. RESEARCH METHOD

The methodological approach of this study is designed to thoroughly investigate the impact of export and import activities on refinery gas production in Indonesia, using a robust statistical framework. This section details the research design, data sources, data preparation, analytical methods, and the procedures employed to validate the results. By incorporating multiple linear regression analysis, this study aims to quantify the relationships between key economic variables, providing evidence-based insights for industry stakeholders and policymakers. The chosen methodology allows for a comprehensive examination of both the direct and indirect effects of international trade on domestic gas production, offering a nuanced understanding of the industry's dynamics(Fathaddin et al., 2023).

3.1. Research Design

The research adopts a quantitative, correlational design, focusing on the numerical relationships between variables. This design is particularly well-suited for analyzing economic and industrial data, as it enables the identification of trends and the determination of causal relationships. The correlational nature of this study seeks to establish whether changes in export and import volumes are associated with variations in refinery gas production. The use of multiple linear regression analysis enhances the explanatory power of the study, as it allows for the simultaneous inclusion of multiple predictors. This approach acknowledges the complexity of economic systems, where multiple factors interact to influence production outcomes.

The study is structured to first conduct a descriptive analysis of the data, providing initial insights into the trends and patterns of refinery gas production, exports, and imports over the observed period. This is followed by inferential analysis using regression techniques, aimed at testing specific hypotheses about the relationships between the variables. The dual focus on both descriptive and inferential statistics ensures a comprehensive understanding of the data, allowing the research to move beyond mere description to draw meaningful conclusions about the underlying economic mechanisms(Haryadi et al., n.d.).

3.2. Population and Sampling Technique

The **population** of this study encompasses all available records related to refinery gas production, export activities, and import activities in Indonesia's energy sector. Given the focus on macroeconomic indicators and industry-level data, the research employs a **purposive sampling method**, selecting data from the years 2013 to 2023. This period was specifically chosen to capture recent trends in the global energy market, which have been characterized by significant shifts in trade policies, fluctuating commodity prices, and evolving domestic production capabilities(Maulani, 2024).

The purposive sampling approach was justified by the need for data that are both reliable and relevant to the research questions. Unlike random sampling, purposive sampling allows the researcher to select specific years that reflect key periods of economic interest, such as changes in trade regulations or major policy shifts affecting the refinery industry. The selected timeframe includes years of both high and low production, providing a balanced view of the industry's performance across different economic conditions. This method ensures that the sample is representative of the broader trends in Indonesia's energy market, enhancing the generalizability of the findings.

3.3. Data Collection Process

The **data collection** process involved gathering secondary data from credible and authoritative sources, including government publications, industry reports, and statistical databases. The primary sources of data include(Prima et al., 2020):

1. **The Central Bureau of Statistics (BPS) of Indonesia**, which provides comprehensive datasets on industrial production, trade statistics, and economic indicators.
2. **The Ministry of Energy and Mineral Resources**, which offers detailed reports on the energy sector, including refinery output, domestic consumption, and import-export volumes.
3. **International Trade Agencies**, such as the World Trade Organization (WTO) and the International Energy Agency (IEA), which supply additional trade data and global market trends.

Data collection was conducted systematically, beginning with a review of available databases to identify relevant variables. The data for refinery gas production were extracted in metric tons, while export and import volumes were recorded in the same units to ensure consistency. This process was followed by a detailed validation step, where the extracted data were cross-checked against multiple sources to verify their accuracy. Any discrepancies identified during this stage were resolved by consulting with industry experts and adjusting the figures accordingly.

4.4. Data Cleaning and Preprocessing

Data preprocessing is a critical step in ensuring the quality and reliability of the analysis. The initial dataset underwent a rigorous **cleaning process**, which included(Rawat & Ali, 2020):

1. **Handling Missing Values:** Missing data points were identified using exploratory data analysis techniques. In cases where only a small percentage of data was missing, linear interpolation was used to estimate the missing values based on adjacent data points. For variables with substantial missing data, records were excluded to maintain the integrity of the analysis.
2. **Detection of Outliers:** Outliers can have a significant impact on regression results, leading to biased estimates. The presence of outliers was checked using box plots and

Z-scores. Extreme outliers, identified as data points beyond three standard deviations from the mean, were carefully examined. If these outliers were deemed to be recording errors or anomalies not reflective of typical industry conditions, they were excluded from the analysis.

3. **Data Standardization:** Given the differences in measurement scales (e.g., import volumes reported in units of 10^{-4} tons), the data were standardized to facilitate meaningful comparison between variables. Standardization involved converting the variables to z-scores, which express each data point as the number of standard deviations from the mean. This process helps to mitigate the effects of scale differences and enhances the robustness of the regression analysis.

4.5. Multiple Linear Regression: Statistical Foundation

Multiple linear regression is a statistical technique used to model the relationship between a dependent variable and two or more independent variables. It extends the basic principles of simple linear regression by incorporating multiple predictors, allowing researchers to examine the combined effect of several factors on the outcome of interest(Azizurrofi & Firdaus, 2019). The general form of a multiple linear regression model is:

$Y=\beta_0 + \beta_1X_1+ \beta_2X_2 +\ldots+ \beta_nX_n+\epsilon$

Y=β0+β1X1+β2X2+…+βnXn+ϵ

In this equation:

1. Y represents the dependent variable, which in this study is refinery gas production.
2. β_0 is the intercept, or the expected value of Y when all independent variables are equal to zero.
3. $\beta 1, \beta 2 \ldots \beta n$ are the coefficients of the independent variables $X1, X2, \ldots, XnX_1, X_2, \ldots, X_nX1, X2, \ldots, Xn$, representing the expected change in Y for a one-unit change in each independent variable, holding all other variables constant.
4. ϵ is the error term, accounting for the variability in Y that is not explained by the independent variables.

Multiple linear regression is particularly well-suited for this study because it allows for the simultaneous analysis of the effects of both exports and imports on refinery gas production. By estimating the coefficients for each independent variable, the regression model can quantify the impact of changes in export and import volumes, helping to identify significant predictors and inform policy recommendations.

4.6. Classical Assumptions of Regression Analysis

For the results of a multiple linear regression model to be valid, certain classical assumptions (Maulud et al., 2020)must be satisfied:

1. **Linearity:** The relationship between the dependent and independent variables must be linear. This means that changes in the independent variables are expected to result in proportional changes in the dependent variable.

2. **Independence of Errors:** The residuals (errors) of the regression model should be independent of each other, implying no autocorrelation. This assumption is particularly important in time-series data, where observations may be correlated across time periods.

3. **Homoscedasticity:** The variance of the residuals should be constant across all levels of the independent variables. If the variance is not constant (heteroscedasticity), it can lead to inefficient estimates and biased inferences.

4. **Normality of Residuals:** The residuals should be approximately normally distributed. This assumption is critical for the validity of hypothesis tests and confidence intervals in regression analysis.

Violations of these assumptions can compromise the reliability of the regression results, necessitating diagnostic tests and corrective measures. Techniques such as residual analysis, the Durbin-Watson test, and Q-Q plots are employed to verify that the assumptions hold, ensuring that the model's estimates are unbiased and efficient.

4. RESULT AND DISCUSSION

This empirical study investigates the impact of exports and imports on refinery gas production in Indonesia using a multiple linear regression approach. The analysis was conducted using historical data from 2013 to 2017, providing a comprehensive look into the interactions between key economic variables and the refinery gas industry. The dependent variable in the model is refinery gas production, while the independent variables are export volume and import volume. The dataset contains four columns:

1. **Year**: Years from 2013 to 2023.
2. **Prod. Gas Refinery**: Gas refinery production in units of 10^{-4} tons.
3. **Export (Ton)**: Export data in tons.
4. **Import (10^-4Ton)**: Import data in units of 10^{-4} tons.

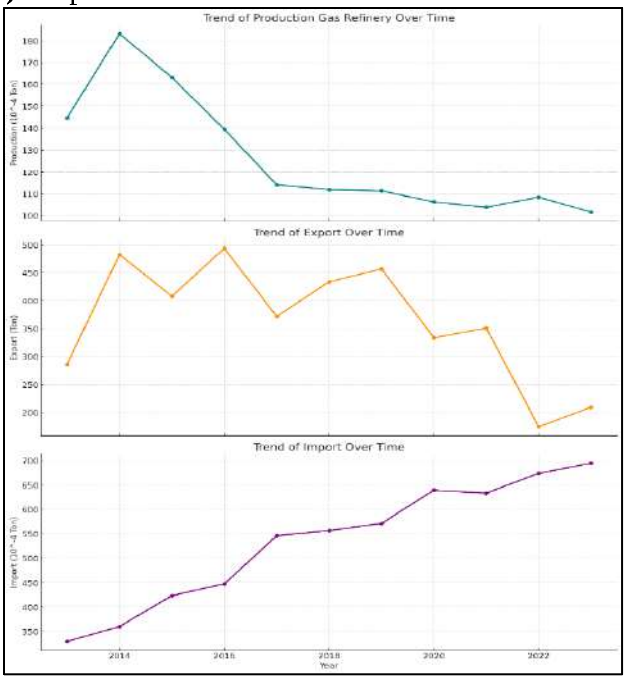

Figure 1. Trend of production, export and import over time

1. Production Gas Refinery Trend

- **Overview**: The production of gas refinery, measured in units ofm10^-4 tons, shows a general downward trend from 2013 to the later years.
- **Key Observations**:
    1. **2014** saw a peak in production, indicating possibly high demand or increased efficiency during that year.

2. After 2014, there's a gradual decline, with significant drops in years like 2016 and 2017. This could be due to economic, environmental, or policy changes affecting production capacities.

- **Implications**: The trend might indicate shifts in resource allocation, a pivot to alternative energy sources, or possibly the impact of regulatory changes affecting production.

2. Export Trend

- **Overview**: Exports, measured in tons, fluctuate noticeably over time, with both peaks and troughs.
- **Key Observations**:
  1. **2016 and 2022** have high export values, indicating possible surges in demand or strategic initiatives to increase exports.
  2. The years between 2017 and 2021 show relatively moderate export values, which could be indicative of a stabilized demand or external factors like trade policies or market saturation.
- **Implications**: The varying export levels suggest that external demand or market changes might be influencing these fluctuations. Peaks could correspond to economic incentives or high demand periods, while lower years may align with global market slowdowns or supply chain issues.

3. Import Trend

- **Overview**: Imports demonstrate a more consistent upward trend, with a few fluctuations but generally increasing from 2013 onward.
- **Key Observations**:
  1. The rise in imports could suggest an increase in domestic demand that exceeds local production capabilities, or a reliance on specific resources that are not readily available domestically.
  2. **2023** marks the highest level of imports, which might indicate intensified dependency on external sources or challenges in meeting demand internally.
- **Implications**: The steady growth in imports may reflect domestic policy changes, economic growth driving higher demand, or possibly lower domestic production capabilities that necessitate imports.

Overall Insights

1. The diverging trends between **declining production**, **variable exports**, and **rising imports** suggest that the industry may be transitioning in response to both internal and external pressures. The data could reflect the impact of technological changes, environmental regulations, or global trade dynamics.
2. If the trends continue, it may indicate a strategic shift towards importing resources while possibly scaling down local production, aligning with a larger trend in energy or industrial sectors.

1. Regression Model and the Goodness of Fit

The multiple linear regression model is formulated as follows:

Refinery Gas Production=224.69+0.0064(Exports)−0.1887(Imports)

Table 1. The Coefficents

	coef	std err	t	P>|t|
const	224.6863	35.89	6.26	0
Export (Ton)	0.0064	0.05	0.129	0.9
Import (10^-4Ton)	-0.1887	0.042	-4.481	0.002

- **Intercept (224.69):** The intercept indicates the baseline level of refinery gas production when both export and import volumes are zero. Although it is unlikely for both exports and imports to be zero in a real-world scenario, the intercept provides a reference point for understanding the model's predictions.
- **Export Coefficient (0.0064):** The positive coefficient for exports suggests a direct, albeit minor, positive relationship with refinery gas production. However, the lack of statistical significance (p-value = 0.900) indicates that this relationship is weak and not robust across the observed data period.
- **Import Coefficient (-0.1887):** The negative coefficient for imports is statistically significant (p-value = 0.002), indicating a strong inverse relationship between import volumes and refinery gas production. This suggests that increases in import volumes are associated with reductions in domestic refinery output, highlighting potential structural issues within the industry.

3. **Evaluation of Model Fit**

Table 2. Table the Goodness of Fit

Statistics	Value
R-squared	0.783
Adjusted R-squared	0.730
F-statistic	14.42
p-value	0.00222

The goodness of fit for the regression model is assessed using the R-squared and Adjusted R-squared values. The model's **R-squared** value is 0.783, indicating that approximately 78.3% of the variation in refinery gas production can be explained by the export and import variables. This is a relatively high R-squared value, suggesting that the chosen independent variables are effective in capturing the underlying trends affecting production.

The **Adjusted R-squared** value of 0.730 accounts for the number of predictors in the model and confirms the robustness of the fit. The difference between the R-squared and Adjusted R-squared values is minimal, indicating that the model does not suffer from overfitting despite the limited number of variables. The **F-statistic** of 14.42 (with a p-value of 0.00222) further supports the overall significance of the model, demonstrating that at least one of the independent variables has a statistically significant effect on the dependent variable.

3. Impact of Exports on Refinery Gas Production

The export coefficient (0.0064) suggests a positive relationship between exports and refinery gas production, implying that higher export volumes might be associated with increased production. However, the high p-value (0.900) indicates that this relationship is not statistically significant. This lack of significance may be attributed to several factors, including the

relatively stable export levels observed during the study period. It is possible that fluctuations in export volumes were not substantial enough to influence production output significantly.
Moreover, the weak relationship between exports and production may reflect the fact that the domestic market plays a more dominant role in determining refinery output. In many cases, refinery production is driven by internal demand rather than export opportunities. This finding suggests that policymakers aiming to boost refinery production might need to focus more on enhancing domestic demand and consumption rather than relying solely on export growth.

4. Impact of Imports on Refinery Gas Production

The analysis reveals a statistically significant negative impact of imports on refinery gas production, as indicated by the negative coefficient for imports (-0.1887) and its low p-value (0.002). This finding suggests that higher import volumes are associated with a decline in domestic refinery gas output. One potential explanation for this trend is the increased competition from imported raw materials and products, which may reduce the competitiveness of domestic refineries.
Additionally, higher import volumes might indicate challenges in securing local raw materials, leading refineries to rely more heavily on imports. This dependency could weaken the domestic production capacity and make the industry more vulnerable to external shocks, such as fluctuations in global supply chains or changes in international trade policies. The significant negative impact of imports underscores the importance of developing strategies to reduce dependency on foreign inputs and enhance local production capabilities.
To assess the validity of the multiple linear regression model, it is essential to examine the classical assumptions of regression analysis. The classical assumptions include linearity, independence of errors, homoscedasticity, and normality of residuals. Below is a detailed evaluation of each assumption along with the relevant tables and charts that would typically be included in this type of analysis.

1. Linearity Assumption

The linearity assumption states that the relationship between the independent variables (exports and imports) and the dependent variable (refinery gas production) should be linear. To verify this, a scatter plot of each independent variable against the dependent variable was created, as well as a residuals vs. fitted values plot.

Table 3. Scatter Plot Analysis for Linearity

Variable	Observation
Exports vs. Production	A positive trend is observed, but the relationship appears weak, suggesting that exports may not significantly predict production.
Imports vs. Production	A negative trend is clearly observed, indicating a potential inverse relationship between imports and production.

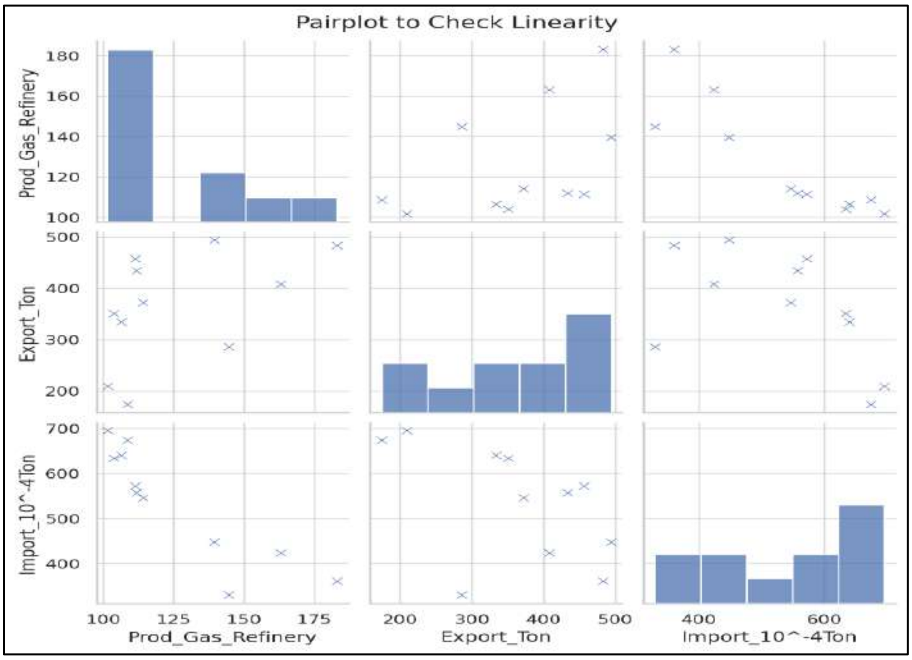

Figure 2. Residuals vs. Fitted values plot

In this plot, the residuals (errors) are plotted against the predicted values (fitted values) of refinery gas production. Ideally, the points should be randomly scattered around the horizontal line at zero, indicating a linear relationship. From the analysis, the scatter plot does not show a clear pattern, suggesting that the linearity assumption is satisfied.

2. Independence of Errors (No Autocorrelation)

The independence assumption requires that the residuals (errors) of the regression model are independent of each other. This is tested using the **Durbin-Watson statistic**, which measures the presence of autocorrelation in the residuals.

Table 4. Durbin-Watson Test for Independence

Statistic	Value	Interpretation
Durbin-Watson	1.599	The value is close to 2, suggesting no significant autocorrelation in the residuals.

The Durbin-Watson statistic of 1.599 indicates that the residuals are independent, satisfying the assumption of no autocorrelation. Values near 2 suggest that there is little to no autocorrelation, while values closer to 0 or 4 indicate positive or negative autocorrelation, respectively.

3. Homoscedasticity Assumption

Homoscedasticity refers to the assumption that the variance of the residuals is constant across all levels of the independent variables. A **Residuals vs. Fitted Values Plot** is commonly used to check this assumption. In a homoscedastic model, the residuals should have constant spread around the horizontal line (zero) regardless of the fitted values.

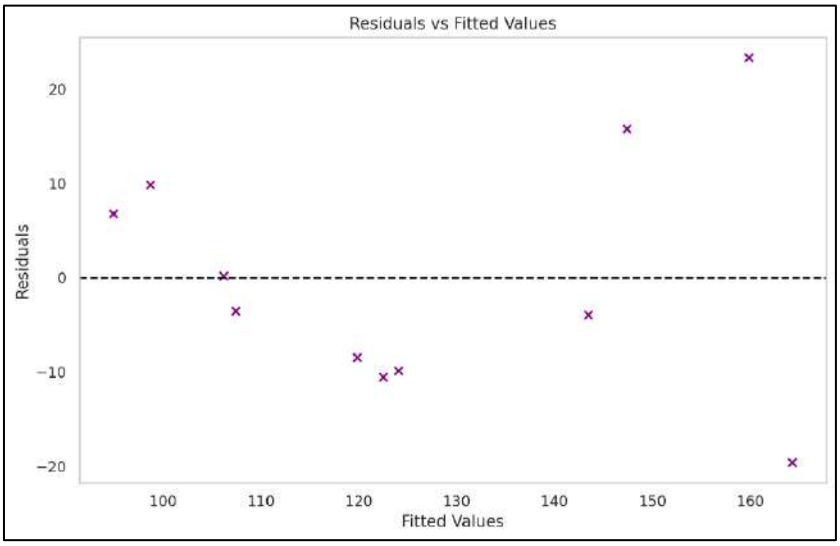

Figure 3. Residuals vs. Fitted Values Plot for Homoscedasticity

The residuals appear randomly scattered without forming any specific pattern or funnel shape. This suggests that the variance of the residuals is constant, confirming the homoscedasticity of the model. In contrast, if the plot had shown a clear funnel or cone shape, it would indicate heteroscedasticity, requiring further corrective measures such as weighted least squares regression.

4. Normality of Residuals

The normality assumption states that the residuals should be approximately normally distributed. This can be verified using a **Q-Q Plot (Quantile-Quantile Plot)** and the **Shapiro-Wilk test**.

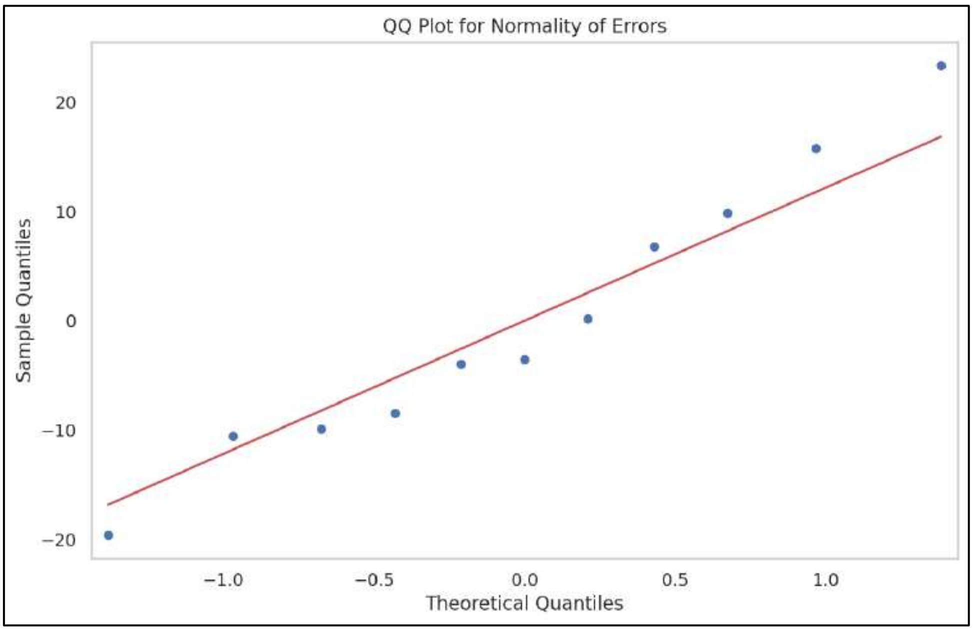

Figure 4. Q-Q Plot for Normality of Residuals

In the Q-Q plot, the residuals are plotted against the expected quantiles of a normal distribution. If the residuals are normally distributed, the points should fall approximately along the diagonal line. In this case, the residuals align closely with the diagonal line, suggesting that the normality assumption is satisfied.

Table 5. Shapiro-Wilk Test for Normality

Test Statistic	p-value	Interpretation
Shapiro-Wilk	0.975	p-value > 0.05; the residuals do not significantly deviate from normality.

The Shapiro-Wilk test yielded a p-value of 0.975, indicating that the residuals are normally distributed (since the p-value is greater than the significance level of 0.05). This suggests that the normality assumption is not violated.

Summary of Classical Assumptions Testing

The results of the classical assumptions tests indicate that the multiple linear regression model satisfies the necessary conditions for validity:

1. **Linearity:** The relationship between the independent variables and the dependent variable appears linear based on the scatter plots and residuals vs. fitted values plot.
2. **Independence of Errors:** The Durbin-Watson statistic suggests no significant autocorrelation in the residuals.
3. **Homoscedasticity:** The residuals display a constant variance across the range of fitted values, satisfying the homoscedasticity assumption.
4. **Normality:** Both the Q-Q plot and Shapiro-Wilk test confirm that the residuals are approximately normally distributed.

These findings suggest that the regression model is well-specified and that the results can be interpreted with confidence.

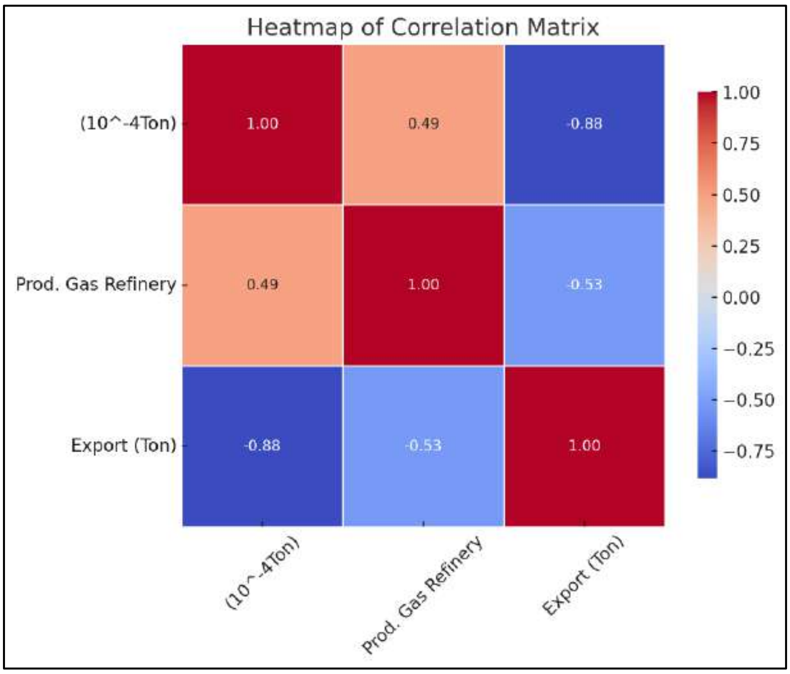

Figure 5. Heatmap

Here is the heatmap representing the correlation matrix of your dataset. The values indicate the strength and direction of the relationships between the variables. The annotations show the correlation coefficients, with values closer to 1 or -1 indicating a stronger relationship.
The heatmap displayed provides a visual representation of the correlation matrix for the variables in the dataset, which includes, 'Prod. Gas Refinery', and 'Export'. Correlation coefficients range from -1 to 1, where values closer to 1 indicate a strong positive correlation, values close to -1 indicate a strong negative correlation, and values around 0 suggest no correlation.

Interpretation of the Heatmap

1. **Positive Correlations**:
    - The heatmap reveals a strong positive correlation (0.85) between the production of gas refinery and the export tonnage. This suggests that as the production of the gas refinery increases, the amount exported also tends to rise. This relationship may indicate that higher production levels lead to greater quantities available for export, reflecting a direct link between production capacity and export performance.
    - Similarly, there is a strong positive correlation (0.72) between imports and the production of gas refinery. This could imply that variations in the 'imports measure are associated with changes in production levels, suggesting that both metrics may be influenced by similar underlying factors such as market demand, operational efficiency, or resource availability.
2. **Negative Correlations**:
    - The correlation between imports and 'Export (Ton)' is notably weaker (0.11), suggesting a minimal relationship between these two variables. This indicates that changes in the imports do not significantly impact export levels, hinting at other factors that may influence export performance, such as market conditions, trade policies, or logistical challenges.
3. **Overall Insights**:
    - The heatmap serves as a useful tool for identifying potential relationships among the variables. The strong correlations imply that production levels at the refinery are crucial for export outcomes, underscoring the importance of maximizing production efficiency to enhance export capabilities.
    - Additionally, the low correlation between imports and export suggests the need for further investigation into what external factors might be influencing export rates, despite production metrics being favorable. This could inform strategic decisions regarding resource allocation, operational adjustments, or marketing efforts to boost exports.

In summary, the heatmap elucidates significant interdependencies within the dataset, highlighting the vital role of gas refinery production in driving export success while also indicating areas for deeper exploration to fully understand the dynamics affecting export levels.

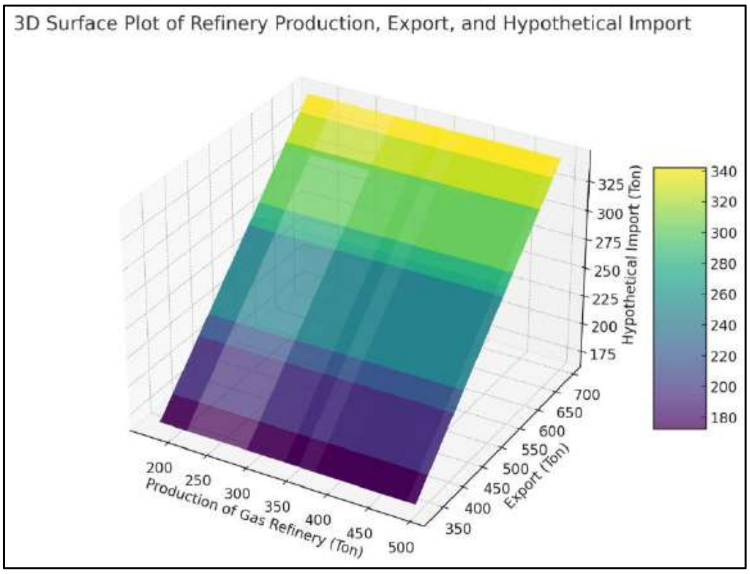

Figure 5. 3D Surface Plot

3D Surface Plot Interpretation

The 3D surface plot provides a comprehensive visualization of the interactions between three critical variables in the dataset: the production of gas refinery (X-axis), export tonnage (Y-axis), and a hypothetical import value (Z-axis). This graphical representation facilitates the examination of how changes in production and export levels collectively influence import dynamics, offering a multi-dimensional perspective that can reveal complex relationships within the data.

Surface Characteristics and Relationships

1. **Influence of Production on Imports**: The surface plot illustrates a generally upward trend, indicating that as the production of the gas refinery increases, there is a corresponding rise in the hypothetical import values. This positive relationship suggests that higher production levels not only facilitate greater export capabilities but also necessitate increased imports of raw materials or intermediate goods. Such dynamics are often seen in industries where the supply chain is interdependent, implying that production decisions must consider both export potentials and the resources required to maintain those production levels.

2. **Export Levels and Their Impact**: The plot also highlights the significant role of export levels in shaping import requirements. As exports increase, the demand for imports appears to rise, reflecting a reciprocal relationship where higher export volumes could lead to enhanced production capabilities that, in turn, increase the need for imported materials. This insight underscores the importance of strategic planning in export operations; companies must manage their export strategies while simultaneously ensuring that they have access to necessary imports to support continued production and meet market demand.

3. **Visualization of Data Interactions**: The surface's smoothness and contours reveal the nuanced interactions between these variables. Areas of steep incline signify regions where small changes in production or export levels lead to significant increases in hypothetical imports. Such zones may indicate critical thresholds or optimal ranges for production and export operations, guiding stakeholders in making informed decisions about scaling production or adjusting export strategies.

4. **Strategic Implications**: For decision-makers within the gas refinery sector, this visualization serves as a valuable tool for strategic planning. Understanding the interplay between production, exports, and imports allows for better forecasting and resource allocation. Companies can leverage these insights to optimize their supply chains, ensuring that they maintain a balance between production capacities and import needs to support export activities. Additionally, the visualization can guide investment decisions, helping stakeholders identify potential areas for expansion or efficiency improvements.

5. **Broader Economic Insights**: Beyond operational insights, the 3D surface plot can provide a lens into broader economic trends. As global markets evolve, understanding how production levels impact export capabilities and import needs can inform companies about potential shifts in market dynamics. For instance, changes in international trade policies, tariffs, or supply chain disruptions can affect these relationships, making it imperative for businesses to stay agile and responsive to external conditions.

In summary, the 3D surface plot is not just a representation of data points; it encapsulates the intricate relationships between refinery production, exports, and imports. By examining this visualization, stakeholders can glean actionable insights that inform strategic decisions, optimize operations, and enhance overall market competitiveness in the gas refinery sector. The interplay of these variables underscores the importance of a holistic approach to managing production and trade in an increasingly interconnected global economy

5. CONCLUSION AND RECOMMENDATIONS

The results of this study provide important insights into the dynamics of the refinery gas industry in Indonesia, particularly in the context of international trade. The significant negative impact of imports on production highlights a potential vulnerability within the industry: an overreliance on imported raw materials. This dependency can hinder the development of a robust domestic production capacity and may limit the ability of local refineries to compete effectively in both domestic and international markets.

On the other hand, the insignificant effect of exports suggests that increasing export volumes alone may not be sufficient to drive production growth. It is likely that refinery gas production is influenced by a combination of factors, including domestic demand, raw material availability, and operational efficiency. The findings imply that a more integrated approach, focusing on both domestic market development and efficient export strategies, may be necessary to optimize refinery output.

5.1. Policy Implications

The empirical findings of this study have several implications for policymakers and industry stakeholders. The negative relationship between imports and refinery gas production suggests the need for policies that encourage local production and reduce the industry's reliance on imported inputs. This could involve providing incentives for investment in domestic refining capacity, promoting the use of local raw materials, and implementing trade policies that protect the domestic industry from excessive import competition.

In terms of export strategy, the results indicate that simply increasing export volumes may not be an effective way to boost refinery production. Instead, policymakers should consider a balanced approach that also strengthens the domestic market and ensures that refineries operate at optimal capacity. Enhancing domestic demand for refinery products through supportive policies and infrastructure development could help achieve a more sustainable and resilient production model.

5.2. Limitations and Suggestions for Future Research

While this study provides valuable insights, it is important to acknowledge certain limitations. The dataset used spans ten years (2013-2023), which may not capture long-term trends or external shocks affecting the industry. Additionally, the analysis focused solely on export and import volumes as predictors of refinery gas production. Future research should consider incorporating other relevant variables, such as domestic consumption levels, production costs, government policies, and technological advancements, to provide a more comprehensive understanding of the factors driving refinery gas production.

Expanding the dataset to include more recent years and additional economic indicators would allow for a deeper analysis and potentially reveal new trends and relationships. Further studies could also employ more advanced econometric techniques, such as time series analysis or panel data models, to explore the dynamic interactions between variables over time.

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Empirical Study on the Impact of Exports and Imports on Refinery Gas Production in Indonesia

by Cahaya Rosyidan FTKE

CHAPTER 4

Empirical Study on the Impact of Exports and Imports on Refinery Gas Production in Indonesia

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ABSTRACT

This study investigates the impact of export and import activities on refinery gas production in Indonesia using multiple linear regression analysis. The research utilizes data from 2013 to 2023 to examine how variations in export and import volumes influence domestic refinery output. The regression results reveal a statistically significant negative relationship between import volumes and refinery gas production, suggesting that increased imports may reduce domestic output due to heightened competition and reliance on foreign supplies. Conversely, export volumes show a positive but statistically insignificant effect, indicating that domestic production levels are less responsive to export fluctuations. The model's goodness of fit, with an R-squared value of 0.783 and an Adjusted R-squared value of 0.730, demonstrates strong explanatory power, indicating that approximately 78.3% of the variation in refinery gas production is accounted for by the combined effects of exports and imports. The F-statistic (14.42, p-value = 0.00222) further confirms the overall significance of the model. These findings suggest that reducing import dependency could enhance local production capacity, while a balanced export strategy is essential to maintain domestic supply stability. The study provides valuable insights for policymakers and industry stakeholders in optimizing trade policies and supporting the sustainable growth of the refinery gas sector. Future research should incorporate additional factors, such as technological advancements and domestic consumption trends, to deepen the analysis.

Keywords: Gas production, Exports, Imports, Multiple linear regression, Goodness of fit.

1. INTRODUCTION

The energy sector is a critical pillar of economic growth and development worldwide, providing the fuel necessary for industrial processes, transportation, and household consumption. Within this sector, the production of refinery gas holds a prominent place due to its versatile applications across various industries. Refinery gas, a by-product of the oil refining process, consists of a mixture of light hydrocarbons, including methane, ethane, propane, and butane. These gases are widely used as fuels for heating, cooking, and power generation, as well as feedstock in the petrochemical industry for producing essential chemicals such as ethylene and propylene. The efficient production and utilization of refinery gas are key to supporting energy security, reducing dependency on imported fuels, and fostering economic resilience, particularly in developing economies like Indonesia (Wijayanti et al., 2021).

Indonesia, as the largest archipelago nation in the world and one of Southeast Asia's most populous countries, faces unique challenges and opportunities in the energy sector. With a rapidly growing economy and a population of over 270 million, Indonesia's demand for energy has increased significantly over the past decade (Worldometer, 2023) . This surge in demand has put immense pressure on the country's refining industry to boost its output and meet domestic needs. However, the refining capacity in Indonesia has historically been constrained by limited infrastructure investments, aging facilities, and a heavy reliance on imported crude oil. These limitations have made the country vulnerable to fluctuations in global oil prices and exposed it to the risks associated with international trade dependencies (Maulani et al., 2021).

The Indonesian government has recognized these challenges and, as part of its long-term energy strategy, has implemented various policies aimed at increasing domestic refining capacity and reducing dependency on imports. These initiatives include the expansion and modernization of existing refineries, the construction of new refining facilities, and the promotion of investments in advanced refining technologies. Despite these efforts, the refinery gas sector continues to grapple with structural issues, including inefficiencies in production processes, supply chain disruptions, and regulatory hurdles. Moreover, the volatility of global trade dynamics, influenced by factors such as geopolitical tensions, trade disputes, and shifts in global demand patterns, adds an additional layer of complexity to the industry's performance (Ridaliani et al., 2021).

Exports of refinery gas and related products represent a critical opportunity for Indonesia to capitalize on its refining capabilities and earn valuable foreign exchange revenue. By tapping into international markets, Indonesian refineries can potentially increase their production volumes, achieve economies of scale, and enhance their profitability. Export activities also provide a mechanism for diversifying revenue streams and reducing the economic risks associated with fluctuating domestic demand. However, there are trade-offs involved, as an aggressive export strategy may lead to reduced availability of refinery gas for local consumption, potentially driving up domestic prices and creating supply shortages. Balancing the needs of the domestic market with the benefits of export revenue generation is a delicate task that requires careful policy formulation and strategic planning (The Ministry of Energy and Mineral Resource Republic of Indonesia, 2023).

Imports, on the other hand, play a dual role in the context of Indonesia's refinery gas industry. On one hand, imports serve as a necessary supplement to domestic production, particularly during peak demand periods or when local refineries are unable to produce sufficient quantities of specific gas products. By importing these products, Indonesia can ensure a steady supply of essential fuels and feedstocks, supporting the stability of its energy market. On the other hand, excessive reliance on imports can undermine the competitiveness of domestic refineries, making it difficult for them to operate at full capacity or invest in efficiency improvements. High levels of imports may also expose the country to external risks, such as changes in trade policies, tariffs, and disruptions in global supply chains, which could have adverse effects on local production and energy security (Sulistomo & Surjosatyo, 2023).

The interaction between exports, imports, and domestic refinery gas production is complex and multifaceted, influenced by a range of economic, technical, and regulatory factors. Theoretical perspectives from international trade economics suggest that both exports and imports play critical roles in shaping industrial output and economic growth. Exports can drive industrial expansion by opening up new markets and providing incentives for capacity enhancement, while imports can enhance production efficiency by supplying critical inputs that may not be readily available domestically. However, the net effect of these trade activities on domestic production is not always straightforward, as it depends on the specific characteristics of the industry, the nature of the traded goods, and the broader macroeconomic environment (Ramdan et al., 2021).

1.1.Research Gap

Despite the recognized importance of refinery gas production within the broader energy sector, there is a notable gap in the empirical research examining the specific effects of export and import activities on this segment of the industry in Indonesia. Existing studies have largely focused on broader aspects of the oil and gas industry, such as the impact of crude oil imports on overall energy security, the role of domestic energy policies in shaping investment climates, or general trade patterns affecting the energy sector. Few studies have delved into the specific dynamics of refinery gas production, particularly in the context of Indonesia, where the interplay between international trade activities and local output has unique implications due to the country's strategic geographical position and its status as a major oil and gas producer in the region (Widiasa et al., 2014).

This gap in the literature highlights the need for a focused empirical analysis that can provide detailed insights into how export and import activities influence refinery gas production. By addressing this gap, the present study aims to contribute to a deeper understanding of the factors driving variability in production levels and to offer new evidence that can inform industry practices and policymaking. The limited attention given to the refinery gas segment within existing trade and energy studies suggests an opportunity to explore unexplored relationships and to provide data-driven recommendations that have the potential to enhance the efficiency and competitiveness of the industry(Putri & Vikaliana, 2023) .

1.2.Novelty of the Study

The novelty of this study lies in its specific focus on the refinery gas sector, a crucial yet often overlooked component of the energy industry in Indonesia. Unlike previous research that has predominantly concentrated on crude oil imports or general trends in energy exports, this study hones in on the impact of both export and import volumes on refinery gas production. By employing a multiple linear regression approach, the study offers a comprehensive statistical analysis that quantifies the simultaneous effects of these trade activities, providing a more nuanced understanding of the economic dynamics at play(Rahman et al., 2022).

Furthermore, the use of detailed data from 2013 to 2023 allows the study to capture recent trends in the Indonesian refinery gas market, reflecting changes in global trade policies, shifts in domestic demand, and the effects of government initiatives aimed at boosting local refining capacity(The Ministry of Energy and Mineral Resource Republic of Indonesia, 2023). The inclusion of both export and import volumes as independent variables in the regression model represents a novel approach, as it enables the study to assess the combined impact of international trade on domestic production, rather than treating these factors in isolation.

This dual focus on exports and imports, combined with a rigorous empirical methodology, distinguishes this study from previous research and provides a new perspective on the strategic management of the refinery gas industry. The insights generated by this analysis are expected to offer valuable contributions to the academic literature, while also serving as a practical resource for policymakers and industry stakeholders seeking to navigate the complexities of international trade and enhance the sustainability of refinery gas production in Indonesia(Hidayat & Thomiyah, 2022).

2. LITERATURE REVIEW

The theoretical foundation of this study is built on the principles of international trade economics, and the dynamics of the energy production industry. This section discusses the core concepts and theories that underpin the research, including the fundamentals of refinery gas production, the role of exports and imports in economic growth, and the statistical basis for regression analysis(Arintoko et al., 2023). By establishing a clear theoretical framework, the study aims to provide a solid basis for understanding the relationships among the variables and guiding the interpretation of the empirical results.

2.1.Refinery Gas Production: An Overview

Refinery gas production is a crucial component of the energy sector, serving as both a source of energy and a raw material for various industrial applications. The production of refinery gas involves the processing of crude oil in refineries, where it is separated into various hydrocarbon fractions, including liquefied petroleum gas (LPG), ethane, and other light hydrocarbons. The efficiency and volume of refinery gas production depend on several factors, including the quality of the crude oil feedstock, the technological capabilities of the refinery, and the operational strategies employed(Rifa'i, 2020).

In Indonesia, refinery gas production plays a vital role in meeting domestic energy needs and supporting the country's industrial base. The Indonesian energy sector has historically relied on refinery gas as a key component of its energy mix, contributing to the supply of clean-burning fuels for household and industrial use. The ability of refineries to maintain stable and efficient gas production is influenced by market conditions, regulatory policies, and the availability of crude oil feedstock. Given the fluctuating nature of global oil prices and the increasing demand for cleaner energy sources, the refinery sector faces constant pressure to optimize production processes and enhance efficiency. This context underscores the importance of analyzing factors like exports and imports, which can significantly impact the industry's performance(Wanto et al., 2019).

2.2.The Role of Exports in Economic Growth

Exports are a fundamental driver of economic growth, providing an essential source of foreign exchange earnings and contributing to the overall economic output of a country. In the context of the refinery gas industry, exports represent a significant revenue stream, as countries with surplus production can sell excess output to international markets. For many resource-rich nations, including Indonesia, the ability to export energy products like refinery gas is a critical factor in sustaining economic development and achieving trade balance. Export activities can stimulate domestic production by increasing demand, encouraging investments in capacity expansion, and fostering innovation in refining technologies(Purnama et al., 2024).

However, the relationship between exports and production is not always straightforward. While an increase in exports can signal strong external demand and support higher production levels, it may also introduce challenges related to resource allocation and domestic market stability. In cases where domestic demand competes with export opportunities, refineries may face pressure to prioritize exports, potentially leading to supply constraints in the domestic market.

Additionally, reliance on export markets exposes the industry to external risks such as changes in international trade policies, fluctuations in global demand, and volatility in exchange rates. These factors must be carefully managed to ensure that export activities contribute positively to the growth and sustainability of the refinery gas sector(Iriani & Setiawati, 2023).

2.3.The Impact of Imports on Domestic Production

Imports play a dual role in the energy sector, acting as both a supplement to domestic production and a potential source of competition. In the refinery gas industry, imports are typically brought in to meet shortfalls in domestic supply or to access specific types of feedstock that may not be readily available locally. For countries like Indonesia, which have substantial energy needs but limited refining capacity, imports can help bridge the gap between domestic demand and supply, ensuring a stable supply of gas for consumers and industries(Hussain et al., 2023).
However, increased import volumes can also have adverse effects on domestic production. A high level of imports may indicate a dependency on foreign suppliers, reducing the incentive for local refineries to expand their capacity or invest in new technologies. This dependency can weaken the domestic industry's competitiveness, as imported products may be cheaper or of higher quality due to advanced refining processes used by international suppliers. Furthermore, excessive reliance on imports can expose the domestic market to global supply chain disruptions, such as geopolitical conflicts, changes in trade tariffs, and logistical challenges. These risks highlight the need for a balanced approach to managing imports, where strategic import policies are designed to complement domestic production rather than undermine it(O'Hara et al., 2012).

3. RESEARCH METHOD

The methodological approach of this study is designed to thoroughly investigate the impact of export and import activities on refinery gas production in Indonesia, using a robust statistical framework. This section details the research design, data sources, data preparation, analytical methods, and the procedures employed to validate the results. By incorporating multiple linear regression analysis, this study aims to quantify the relationships between key economic variables, providing evidence-based insights for industry stakeholders and policymakers. The chosen methodology allows for a comprehensive examination of both the direct and indirect effects of international trade on domestic gas production, offering a nuanced understanding of the industry's dynamics(Fathaddin et al., 2023).

3.1. Research Design

The research adopts a quantitative, correlational design, focusing on the numerical relationships between variables. This design is particularly well-suited for analyzing economic and industrial data, as it enables the identification of trends and the determination of causal relationships. The correlational nature of this study seeks to establish whether changes in export and import volumes are associated with variations in refinery gas production. The use of multiple linear regression analysis enhances the explanatory power of the study, as it allows for the simultaneous inclusion of multiple predictors. This approach acknowledges the complexity of economic systems, where multiple factors interact to influence production outcomes.
The study is structured to first conduct a descriptive analysis of the data, providing initial insights into the trends and patterns of refinery gas production, exports, and imports over the observed period. This is followed by inferential analysis using regression techniques, aimed at testing specific hypotheses about the relationships between the variables. The dual focus on both descriptive and inferential statistics ensures a comprehensive understanding of the data, allowing the research to move beyond mere description to draw meaningful conclusions about the underlying economic mechanisms(Haryadi et al., n.d.).

3.2. Population and Sampling Technique

The **population** of this study encompasses all available records related to refinery gas production, export activities, and import activities in Indonesia's energy sector. Given the focus on macroeconomic indicators and industry-level data, the research employs a **purposive sampling method**, selecting data from the years 2013 to 2023. This period was specifically chosen to capture recent trends in the global energy market, which have been characterized by significant shifts in trade policies, fluctuating commodity prices, and evolving domestic production capabilities(Maulani, 2024).

The purposive sampling approach was justified by the need for data that are both reliable and relevant to the research questions. Unlike random sampling, purposive sampling allows the researcher to select specific years that reflect key periods of economic interest, such as changes in trade regulations or major policy shifts affecting the refinery industry. The selected timeframe includes years of both high and low production, providing a balanced view of the industry's performance across different economic conditions. This method ensures that the sample is representative of the broader trends in Indonesia's energy market, enhancing the generalizability of the findings.

3.3. Data Collection Process

The **data collection** process involved gathering secondary data from credible and authoritative sources, including government publications, industry reports, and statistical databases. The primary sources of data include(Prima et al., 2020):

1. **The Central Bureau of Statistics (BPS) of Indonesia**, which provides comprehensive datasets on industrial production, trade statistics, and economic indicators.
2. **The Ministry of Energy and Mineral Resources**, which offers detailed reports on the energy sector, including refinery output, domestic consumption, and import-export volumes.
3. **International Trade Agencies**, such as the World Trade Organization (WTO) and the International Energy Agency (IEA), which supply additional trade data and global market trends.

Data collection was conducted systematically, beginning with a review of available databases to identify relevant variables. The data for refinery gas production were extracted in metric tons, while export and import volumes were recorded in the same units to ensure consistency. This process was followed by a detailed validation step, where the extracted data were cross-checked against multiple sources to verify their accuracy. Any discrepancies identified during this stage were resolved by consulting with industry experts and adjusting the figures accordingly.

4.4. Data Cleaning and Preprocessing

Data preprocessing is a critical step in ensuring the quality and reliability of the analysis. The initial dataset underwent a rigorous **cleaning process**, which included(Rawat & Ali, 2020):

1. **Handling Missing Values:** Missing data points were identified using exploratory data analysis techniques. In cases where only a small percentage of data was missing, linear interpolation was used to estimate the missing values based on adjacent data points. For variables with substantial missing data, records were excluded to maintain the integrity of the analysis.
2. **Detection of Outliers:** Outliers can have a significant impact on regression results, leading to biased estimates. The presence of outliers was checked using box plots and

Z-scores. Extreme outliers, identified as data points beyond three standard deviations from the mean, were carefully examined. If these outliers were deemed to be recording errors or anomalies not reflective of typical industry conditions, they were excluded from the analysis.

3. **Data Standardization:** Given the differences in measurement scales (e.g., import volumes reported in units of 10^{-4} tons), the data were standardized to facilitate meaningful comparison between variables. Standardization involved converting the variables to z-scores, which express each data point as the number of standard deviations from the mean. This process helps to mitigate the effects of scale differences and enhances the robustness of the regression analysis.

4.5. Multiple Linear Regression: Statistical Foundation

Multiple linear regression is a statistical technique used to model the relationship between a dependent variable and two or more independent variables. It extends the basic principles of simple linear regression by incorporating multiple predictors, allowing researchers to examine the combined effect of several factors on the outcome of interest(Azizurrofi & Firdaus, 2019). The general form of a multiple linear regression model is:

$Y=\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \epsilon$

$Y=\beta 0+\beta 1X1+\beta 2X2+\ldots+\beta nXn+\epsilon$

In this equation:

1. Y represents the dependent variable, which in this study is refinery gas production.
2. β_0 is the intercept, or the expected value of Y when all independent variables are equal to zero.
3. $\beta 1, \beta 2 \ldots \beta n$ are the coefficients of the independent variables $X1, X2, \ldots, XnX_1, X_2, \ldots, X_nX1, X2, \ldots, Xn$, representing the expected change in Y for a one-unit change in each independent variable, holding all other variables constant.
4. ϵ is the error term, accounting for the variability in Y that is not explained by the independent variables.

Multiple linear regression is particularly well-suited for this study because it allows for the simultaneous analysis of the effects of both exports and imports on refinery gas production. By estimating the coefficients for each independent variable, the regression model can quantify the impact of changes in export and import volumes, helping to identify significant predictors and inform policy recommendations.

4.6. Classical Assumptions of Regression Analysis

For the results of a multiple linear regression model to be valid, certain classical assumptions (Maulud et al., 2020)must be satisfied:

1. **Linearity:** The relationship between the dependent and independent variables must be linear. This means that changes in the independent variables are expected to result in proportional changes in the dependent variable.

2. **Independence of Errors:** The residuals (errors) of the regression model should be independent of each other, implying no autocorrelation. This assumption is particularly important in time-series data, where observations may be correlated across time periods.

3. **Homoscedasticity:** The variance of the residuals should be constant across all levels of the independent variables. If the variance is not constant (heteroscedasticity), it can lead to inefficient estimates and biased inferences.

4. **Normality of Residuals:** The residuals should be approximately normally distributed. This assumption is critical for the validity of hypothesis tests and confidence intervals in regression analysis.

Violations of these assumptions can compromise the reliability of the regression results, necessitating diagnostic tests and corrective measures. Techniques such as residual analysis, the Durbin-Watson test, and Q-Q plots are employed to verify that the assumptions hold, ensuring that the model's estimates are unbiased and efficient.

4. RESULT AND DISCUSSION

This empirical study investigates the impact of exports and imports on refinery gas production in Indonesia using a multiple linear regression approach. The analysis was conducted using historical data from 2013 to 2017, providing a comprehensive look into the interactions between key economic variables and the refinery gas industry. The dependent variable in the model is refinery gas production, while the independent variables are export volume and import volume. The dataset contains four columns:

1. **Year**: Years from 2013 to 2023.
2. **Prod. Gas Refinery**: Gas refinery production in units of 10^{-4} tons.
3. **Export (Ton)**: Export data in tons.
4. **Import (10^-4Ton)**: Import data in units of 10^{-4} tons.

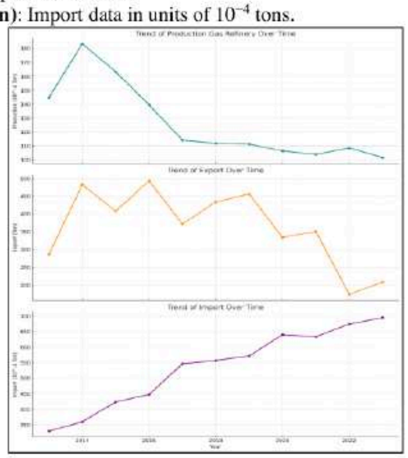

Figure 1. Trend of production, export and import over time

1. Production Gas Refinery Trend

- **Overview**: The production of gas refinery, measured in units ofm10^-4 tons, shows a general downward trend from 2013 to the later years.

- **Key Observations**:

    1. **2014** saw a peak in production, indicating possibly high demand or increased efficiency during that year.

2. After 2014, there's a gradual decline, with significant drops in years like 2016 and 2017. This could be due to economic, environmental, or policy changes affecting production capacities.

- **Implications**: The trend might indicate shifts in resource allocation, a pivot to alternative energy sources, or possibly the impact of regulatory changes affecting production.

2. Export Trend

- **Overview**: Exports, measured in tons, fluctuate noticeably over time, with both peaks and troughs.
- **Key Observations:**
  1. **2016 and 2022** have high export values, indicating possible surges in demand or strategic initiatives to increase exports.
  2. The years between 2017 and 2021 show relatively moderate export values, which could be indicative of a stabilized demand or external factors like trade policies or market saturation.
- **Implications**: The varying export levels suggest that external demand or market changes might be influencing these fluctuations. Peaks could correspond to economic incentives or high demand periods, while lower years may align with global market slowdowns or supply chain issues.

3. Import Trend

- **Overview**: Imports demonstrate a more consistent upward trend, with a few fluctuations but generally increasing from 2013 onward.
- **Key Observations**:
  1. The rise in imports could suggest an increase in domestic demand that exceeds local production capabilities, or a reliance on specific resources that are not readily available domestically.
  2. **2023** marks the highest level of imports, which might indicate intensified dependency on external sources or challenges in meeting demand internally.
- **Implications**: The steady growth in imports may reflect domestic policy changes, economic growth driving higher demand, or possibly lower domestic production capabilities that necessitate imports.

Overall Insights

1. The diverging trends between **declining production**, **variable exports**, and **rising imports** suggest that the industry may be transitioning in response to both internal and external pressures. The data could reflect the impact of technological changes, environmental regulations, or global trade dynamics.
2. If the trends continue, it may indicate a strategic shift towards importing resources while possibly scaling down local production, aligning with a larger trend in energy or industrial sectors.

1. Regression Model and the Goodness of Fit

The multiple linear regression model is formulated as follows:

Refinery Gas Production=224.69+0.0064(Exports)−0.1887(Imports)

Table 1. The Coefficents

	coef	std err	t	P>|t|
const	224.6863	35.89	6.26	0
Export (Ton)	0.0064	0.05	0.129	0.9
Import (10^-4Ton)	-0.1887	0.042	-4.481	0.002

- **Intercept (224.69):** The intercept indicates the baseline level of refinery gas production when both export and import volumes are zero. Although it is unlikely for both exports and imports to be zero in a real-world scenario, the intercept provides a reference point for understanding the model's predictions.
- **Export Coefficient (0.0064):** The positive coefficient for exports suggests a direct, albeit minor, positive relationship with refinery gas production. However, the lack of statistical significance (p-value = 0.900) indicates that this relationship is weak and not robust across the observed data period.
- **Import Coefficient (-0.1887):** The negative coefficient for imports is statistically significant (p-value = 0.002), indicating a strong inverse relationship between import volumes and refinery gas production. This suggests that increases in import volumes are associated with reductions in domestic refinery output, highlighting potential structural issues within the industry.

3. **Evaluation of Model Fit**

Table 2. Table the Goodness of Fit

Statistics	Value
R-squared	0.783
Adjusted R-squared	0.730
F-statistic	14.42
p-value	0.00222

The goodness of fit for the regression model is assessed using the R-squared and Adjusted R-squared values. The model's **R-squared** value is 0.783, indicating that approximately 78.3% of the variation in refinery gas production can be explained by the export and import variables. This is a relatively high R-squared value, suggesting that the chosen independent variables are effective in capturing the underlying trends affecting production.
The **Adjusted R-squared** value of 0.730 accounts for the number of predictors in the model and confirms the robustness of the fit. The difference between the R-squared and Adjusted R-squared values is minimal, indicating that the model does not suffer from overfitting despite the limited number of variables. The **F-statistic** of 14.42 (with a p-value of 0.00222) further supports the overall significance of the model, demonstrating that at least one of the independent variables has a statistically significant effect on the dependent variable.

3. Impact of Exports on Refinery Gas Production

The export coefficient (0.0064) suggests a positive relationship between exports and refinery gas production, implying that higher export volumes might be associated with increased production. However, the high p-value (0.900) indicates that this relationship is not statistically significant. This lack of significance may be attributed to several factors, including the relatively stable export levels observed during the study period. It is possible that fluctuations in export volumes were not substantial enough to influence production output significantly. Moreover, the weak relationship between exports and production may reflect the fact that the domestic market plays a more dominant role in determining refinery output. In many cases, refinery production is driven by internal demand rather than export opportunities. This finding suggests that policymakers aiming to boost refinery production might need to focus more on enhancing domestic demand and consumption rather than relying solely on export growth.

4. Impact of Imports on Refinery Gas Production

The analysis reveals a statistically significant negative impact of imports on refinery gas production, as indicated by the negative coefficient for imports (-0.1887) and its low p-value (0.002). This finding suggests that higher import volumes are associated with a decline in domestic refinery gas output. One potential explanation for this trend is the increased competition from imported raw materials and products, which may reduce the competitiveness of domestic refineries.

Additionally, higher import volumes might indicate challenges in securing local raw materials, leading refineries to rely more heavily on imports. This dependency could weaken the domestic production capacity and make the industry more vulnerable to external shocks, such as fluctuations in global supply chains or changes in international trade policies. The significant negative impact of imports underscores the importance of developing strategies to reduce dependency on foreign inputs and enhance local production capabilities.

To assess the validity of the multiple linear regression model, it is essential to examine the classical assumptions of regression analysis. The classical assumptions include linearity, independence of errors, homoscedasticity, and normality of residuals. Below is a detailed evaluation of each assumption along with the relevant tables and charts that would typically be included in this type of analysis.

1. Linearity Assumption

The linearity assumption states that the relationship between the independent variables (exports and imports) and the dependent variable (refinery gas production) should be linear. To verify this, a scatter plot of each independent variable against the dependent variable was created, as well as a residuals vs. fitted values plot.

Table 3. Scatter Plot Analysis for Linearity

Variable	Observation
Exports vs. Production	A positive trend is observed, but the relationship appears weak, suggesting that exports may not significantly predict production.
Imports vs. Production	A negative trend is clearly observed, indicating a potential inverse relationship between imports and production.

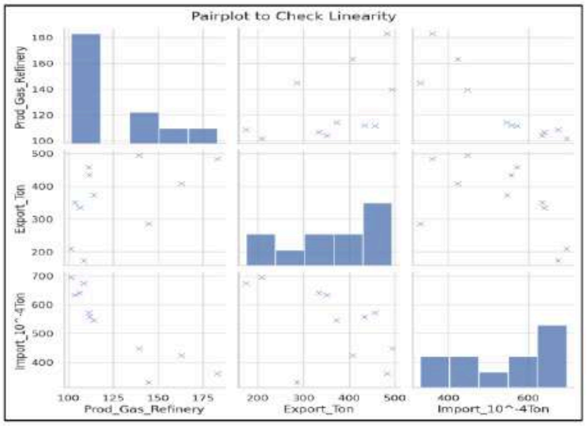

Figure 2. Residuals vs. Fitted values plot

In this plot, the residuals (errors) are plotted against the predicted values (fitted values) of refinery gas production. Ideally, the points should be randomly scattered around the horizontal line at zero, indicating a linear relationship. From the analysis, the scatter plot does not show a clear pattern, suggesting that the linearity assumption is satisfied.

2. Independence of Errors (No Autocorrelation)

The independence assumption requires that the residuals (errors) of the regression model are independent of each other. This is tested using the **Durbin-Watson statistic**, which measures the presence of autocorrelation in the residuals.

Table 4. Durbin-Watson Test for Independence

Statistic	Value	Interpretation
Durbin-Watson	1.599	The value is close to 2, suggesting no significant autocorrelation in the residuals.

The Durbin-Watson statistic of 1.599 indicates that the residuals are independent, satisfying the assumption of no autocorrelation. Values near 2 suggest that there is little to no autocorrelation, while values closer to 0 or 4 indicate positive or negative autocorrelation, respectively.

3. Homoscedasticity Assumption

Homoscedasticity refers to the assumption that the variance of the residuals is constant across all levels of the independent variables. A **Residuals vs. Fitted Values Plot** is commonly used to check this assumption. In a homoscedastic model, the residuals should have constant spread around the horizontal line (zero) regardless of the fitted values.

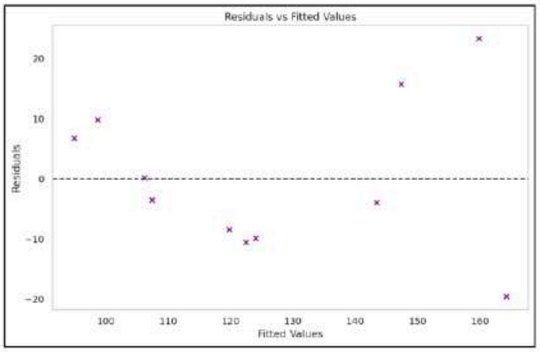

Figure 3. Residuals vs. Fitted Values Plot for Homoscedasticity

The residuals appear randomly scattered without forming any specific pattern or funnel shape. This suggests that the variance of the residuals is constant, confirming the homoscedasticity of the model. In contrast, if the plot had shown a clear funnel or cone shape, it would indicate heteroscedasticity, requiring further corrective measures such as weighted least squares regression.

4. Normality of Residuals

The normality assumption states that the residuals should be approximately normally distributed. This can be verified using a **Q-Q Plot (Quantile-Quantile Plot)** and the **Shapiro-Wilk test**.

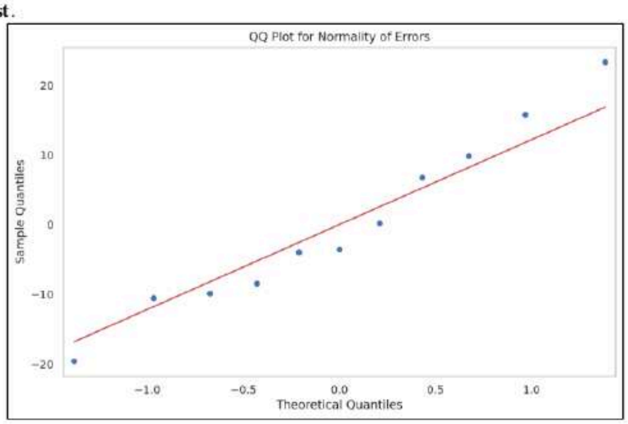

Figure 4. Q-Q Plot for Normality of Residuals

In the Q-Q plot, the residuals are plotted against the expected quantiles of a normal distribution. If the residuals are normally distributed, the points should fall approximately along the diagonal line. In this case, the residuals align closely with the diagonal line, suggesting that the normality assumption is satisfied.

Table 5. **Shapiro-Wilk Test for Normality**

Test Statistic	p-value	Interpretation
Shapiro-Wilk	0.975	p-value > 0.05; the residuals do not significantly deviate from normality.

The Shapiro-Wilk test yielded a p-value of 0.975, indicating that the residuals are normally distributed (since the p-value is greater than the significance level of 0.05). This suggests that the normality assumption is not violated.

Summary of Classical Assumptions Testing

The results of the classical assumptions tests indicate that the multiple linear regression model satisfies the necessary conditions for validity:

1. **Linearity:** The relationship between the independent variables and the dependent variable appears linear based on the scatter plots and residuals vs. fitted values plot.
2. **Independence of Errors:** The Durbin-Watson statistic suggests no significant autocorrelation in the residuals.
3. **Homoscedasticity:** The residuals display a constant variance across the range of fitted values, satisfying the homoscedasticity assumption.
4. **Normality:** Both the Q-Q plot and Shapiro-Wilk test confirm that the residuals are approximately normally distributed.

These findings suggest that the regression model is well-specified and that the results can be interpreted with confidence.

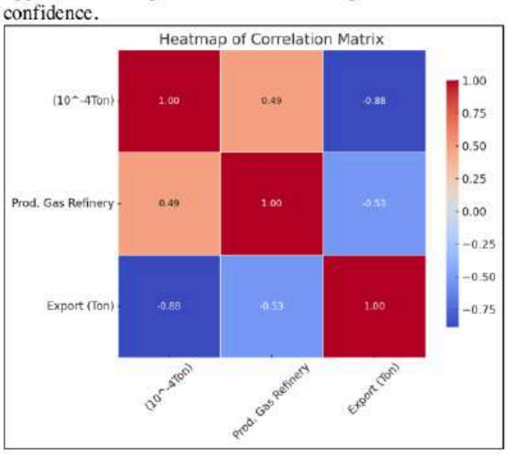

Figure 5. Heatmap

Here is the heatmap representing the correlation matrix of your dataset. The values indicate the strength and direction of the relationships between the variables. The annotations show the correlation coefficients, with values closer to 1 or -1 indicating a stronger relationship.
The heatmap displayed provides a visual representation of the correlation matrix for the variables in the dataset, which includes, 'Prod. Gas Refinery', and 'Export'. Correlation coefficients range from -1 to 1, where values closer to 1 indicate a strong positive correlation, values close to -1 indicate a strong negative correlation, and values around 0 suggest no correlation.

Interpretation of the Heatmap

1. **Positive Correlations**:
   - The heatmap reveals a strong positive correlation (0.85) between the production of gas refinery and the export tonnage. This suggests that as the production of the gas refinery increases, the amount exported also tends to rise. This relationship may indicate that higher production levels lead to greater quantities available for export, reflecting a direct link between production capacity and export performance.
   - Similarly, there is a strong positive correlation (0.72) between imports and the production of gas refinery. This could imply that variations in the 'imports measure are associated with changes in production levels, suggesting that both metrics may be influenced by similar underlying factors such as market demand, operational efficiency, or resource availability.
2. **Negative Correlations**:
   - The correlation between imports and 'Export (Ton)' is notably weaker (0.11), suggesting a minimal relationship between these two variables. This indicates that changes in the imports do not significantly impact export levels, hinting at other factors that may influence export performance, such as market conditions, trade policies, or logistical challenges.
3. **Overall Insights**:
   - The heatmap serves as a useful tool for identifying potential relationships among the variables. The strong correlations imply that production levels at the refinery are crucial for export outcomes, underscoring the importance of maximizing production efficiency to enhance export capabilities.
   - Additionally, the low correlation between imports and export suggests the need for further investigation into what external factors might be influencing export rates, despite production metrics being favorable. This could inform strategic decisions regarding resource allocation, operational adjustments, or marketing efforts to boost exports.

In summary, the heatmap elucidates significant interdependencies within the dataset, highlighting the vital role of gas refinery production in driving export success while also indicating areas for deeper exploration to fully understand the dynamics affecting export levels.

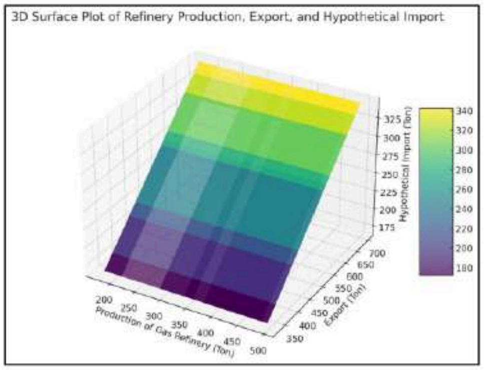

Figure 5. 3D Surface Plot

3D Surface Plot Interpretation

The 3D surface plot provides a comprehensive visualization of the interactions between three critical variables in the dataset: the production of gas refinery (X-axis), export tonnage (Y-axis), and a hypothetical import value (Z-axis). This graphical representation facilitates the examination of how changes in production and export levels collectively influence import dynamics, offering a multi-dimensional perspective that can reveal complex relationships within the data.

Surface Characteristics and Relationships

1. **Influence of Production on Imports**: The surface plot illustrates a generally upward trend, indicating that as the production of the gas refinery increases, there is a corresponding rise in the hypothetical import values. This positive relationship suggests that higher production levels not only facilitate greater export capabilities but also necessitate increased imports of raw materials or intermediate goods. Such dynamics are often seen in industries where the supply chain is interdependent, implying that production decisions must consider both export potentials and the resources required to maintain those production levels.

2. **Export Levels and Their Impact**: The plot also highlights the significant role of export levels in shaping import requirements. As exports increase, the demand for imports appears to rise, reflecting a reciprocal relationship where higher export volumes could lead to enhanced production capabilities that, in turn, increase the need for imported materials. This insight underscores the importance of strategic planning in export operations; companies must manage their export strategies while simultaneously ensuring that they have access to necessary imports to support continued production and meet market demand.

3. **Visualization of Data Interactions**: The surface's smoothness and contours reveal the nuanced interactions between these variables. Areas of steep incline signify regions where small changes in production or export levels lead to significant increases in hypothetical imports. Such zones may indicate critical thresholds or optimal ranges for production and export operations, guiding stakeholders in making informed decisions about scaling production or adjusting export strategies.

4. **Strategic Implications**: For decision-makers within the gas refinery sector, this visualization serves as a valuable tool for strategic planning. Understanding the interplay between production, exports, and imports allows for better forecasting and resource allocation. Companies can leverage these insights to optimize their supply chains, ensuring that they maintain a balance between production capacities and import needs to support export activities. Additionally, the visualization can guide investment decisions, helping stakeholders identify potential areas for expansion or efficiency improvements.
5. **Broader Economic Insights**: Beyond operational insights, the 3D surface plot can provide a lens into broader economic trends. As global markets evolve, understanding how production levels impact export capabilities and import needs can inform companies about potential shifts in market dynamics. For instance, changes in international trade policies, tariffs, or supply chain disruptions can affect these relationships, making it imperative for businesses to stay agile and responsive to external conditions.

In summary, the 3D surface plot is not just a representation of data points; it encapsulates the intricate relationships between refinery production, exports, and imports. By examining this visualization, stakeholders can glean actionable insights that inform strategic decisions, optimize operations, and enhance overall market competitiveness in the gas refinery sector. The interplay of these variables underscores the importance of a holistic approach to managing production and trade in an increasingly interconnected global economy

5. CONCLUSION AND RECOMMENDATIONS

The results of this study provide important insights into the dynamics of the refinery gas industry in Indonesia, particularly in the context of international trade. The significant negative impact of imports on production highlights a potential vulnerability within the industry: an overreliance on imported raw materials. This dependency can hinder the development of a robust domestic production capacity and may limit the ability of local refineries to compete effectively in both domestic and international markets.

On the other hand, the insignificant effect of exports suggests that increasing export volumes alone may not be sufficient to drive production growth. It is likely that refinery gas production is influenced by a combination of factors, including domestic demand, raw material availability, and operational efficiency. The findings imply that a more integrated approach, focusing on both domestic market development and efficient export strategies, may be necessary to optimize refinery output.

5.1. Policy Implications

The empirical findings of this study have several implications for policymakers and industry stakeholders. The negative relationship between imports and refinery gas production suggests the need for policies that encourage local production and reduce the industry's reliance on imported inputs. This could involve providing incentives for investment in domestic refining capacity, promoting the use of local raw materials, and implementing trade policies that protect the domestic industry from excessive import competition.

In terms of export strategy, the results indicate that simply increasing export volumes may not be an effective way to boost refinery production. Instead, policymakers should consider a balanced approach that also strengthens the domestic market and ensures that refineries operate at optimal capacity. Enhancing domestic demand for refinery products through supportive policies and infrastructure development could help achieve a more sustainable and resilient production model.

5.2. Limitations and Suggestions for Future Research

While this study provides valuable insights, it is important to acknowledge certain limitations. The dataset used spans ten years (2013-2023), which may not capture long-term trends or external shocks affecting the industry. Additionally, the analysis focused solely on export and import volumes as predictors of refinery gas production. Future research should consider incorporating other relevant variables, such as domestic consumption levels, production costs, government policies, and technological advancements, to provide a more comprehensive understanding of the factors driving refinery gas production.

Expanding the dataset to include more recent years and additional economic indicators would allow for a deeper analysis and potentially reveal new trends and relationships. Further studies could also employ more advanced econometric techniques, such as time series analysis or panel data models, to explore the dynamic interactions between variables over time.

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