Analysis of the Impact of Saudi Arabia's Diversification on the US Dollar's Value And International Trade Patterns

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Abstract

This study examined the impact of Saudi Arabia's economic diversification efforts on the value of the US Dollar (USD) and international trade patterns over the period 2002-2021. Utilizing a comprehensive dataset of non-oil exports, USD exchange rates, and trade denominated in non-USD currencies, we apply various machine learning models—Gradient Boosting Regression, Support Vector Regression, and Random Forest Regression—to analyze trends and forecast future patterns. Our findings indicated a significant increase in non-oil exports, reflecting the success of diversification strategies. Exchange rate analysis shows relative stability of the Saudi Riyal (SAR) against the USD, supporting a stable economic environment. Additionally, the data reveals a gradual shift towards trade denominated in multiple currencies, reducing reliance on the USD. The study provides critical insights for policymakers on sustaining economic growth and stability through continued diversification and strategic financial policies. Recommendations for future research and policy implications are discussed, emphasizing the importance of ongoing support for non-oil sectors, exchange rate stability, and trade currency diversification.

Keywords: Economic Diversification, Non-Oil Exports, Exchange Rates, Saudi Arabia, Machine Learning, Trade Pattern

1. Introduction

Saudi Arabia has long been recognized as one of the world's leading oil producers, heavily reliant on oil revenues to drive its economy. However, in recent years, the Kingdom has embarked on an ambitious journey to diversify its economy away from oil dependency, primarily through its Vision 2030 initiative. Launched in 2016, Vision 2030 aims to transform various sectors, including tourism, entertainment, and manufacturing, to build a more sustainable and resilient economic model (Saudi Vision 2030, 2016).

A key strategy in this diversification effort has been to increase non-oil exports. The data presented in Table 1 illustrates the steady growth in Saudi Arabia's non-oil exports from 145,817 million SAR in 2002 to 885,924 million SAR in 2021. This growth reflects the Kingdom's success in expanding its export base beyond oil, thereby reducing its vulnerability to fluctuations in global oil prices.

The US dollar has long been the dominant currency in international trade and finance. Its status as the world's primary reserve currency means it is widely used for global transactions, commodity pricing, and foreign exchange reserves held by central banks (International Monetary Fund, 2020). This dominance stems from the Bretton Woods Agreement of 1944, which established the USD as the cornerstone of the international monetary system, pegging other currencies to the dollar, which was convertible to gold.

Over the decades, the dollar's preeminence has been reinforced by the economic strength of the United States, its deep and liquid financial markets, and its perceived stability. Consequently, many international contracts, especially in the oil industry, have traditionally been denominated in USD, contributing to its persistent demand and stability (Eichengreen, 2011).

Studying the impact of Saudi Arabia's economic diversification on the value of the USD and international trade patterns is of significant importance for several reasons. Saudi Arabia is a key player in the global energy market, and its shift towards a more diversified economy could have far-reaching implications for global trade dynamics. Understanding how these changes influence the value of the USD provides insights into broader economic trends, given the dollar's central role in the global financial system.

Moreover, the move towards non-USD denominated trade, as evidenced by the increasing percentage of Saudi Arabia's trade conducted in other currencies (Table 3), indicates a potential shift in global trade practices. This trend could impact the demand for the USD and, by extension, its value and stability. Analyzing these dynamics can help policymakers, economists, and businesses better understand and navigate the evolving international economic landscape.

The primary research question guiding this study is: How has Saudi Arabia's economic diversification impacted the value of the US dollar and international trade patterns over the past two decades? This question is crucial in understanding the broader implications of Saudi Arabia's strategic shift from an oil-dependent economy to a more diversified one, particularly in the context of its relationship with the US dollar, which has traditionally played a pivotal role in global trade and finance.

To address this research question, the study focuses on the following objectives:

- Analyzing trends in Saudi Arabia's non-oil exports from 2002 to 2021.

- Examining the exchange rate movements between the Saudi Riyal (SAR) and the US Dollar (USD) over the same period.

- Evaluating the extent of Saudi Arabia's trade denominated in currencies other than the USD.

- Assessing the correlation between Saudi Arabia's economic diversification and the value of the USD.

- Forecasting future trends in non-oil exports and exchange rates using time series and machine learning models.

- Comparing the effectiveness of different analytical approaches in understanding the impact of Saudi Arabia's diversification on the USD and international trade.

2. Literature

Review of Key Concepts

Economic Diversification

Economic diversification is the process of reducing reliance on a single sector or resource in favor of a broader economic base. For resource-dependent economies like Saudi Arabia, this often means shifting from oil dependency to developing sectors such as tourism, manufacturing, and technology. Diversification helps mitigate the volatility associated with resource-based revenues and promotes sustainable economic growth. Saudi Arabia's Vision 2030 initiative epitomizes this strategy, focusing on creating a resilient economy through investments in infrastructure, education, and regulatory reforms to enhance non-oil sectors (Albassam, 2015; Saudi Vision 2030, 2016).

Role of the US Dollar in Global Trade

The US Dollar (USD) has long been the dominant currency in global trade, serving as the primary reserve currency since the Bretton Woods Agreement of 1944. Its widespread use is attributed to the stability of the US economy, the depth of its financial markets, and the convenience of trading in a universally accepted currency. The dollar facilitates global transactions, commodity pricing, and reserve holdings, offering lower transaction costs and reduced exchange rate risks (Eichengreen, 2011). However, the increasing trend of trade diversification, such as Saudi Arabia's gradual shift towards non-USD trade, challenges this dominance, potentially reshaping global trade practices (Chinn & Frankel, 2007).

Exchange Rates and Trade Patterns

Exchange rates significantly influence international trade dynamics. A stable exchange rate regime, like Saudi Arabia's peg of the Saudi Riyal (SAR) to the USD, ensures predictability, which fosters investor confidence and facilitates smooth international transactions. However, fluctuations in exchange rates can impact the competitiveness of exports and the cost of imports. In recent years, Saudi Arabia's diversification efforts have included expanding trade conducted in currencies other than the USD, indicating a deliberate effort to minimize exchange rate risks and reduce dependency on a single currency for international transactions (Bahmani-Oskooee & Ratha, 2004).

These concepts provide the foundational framework for understanding the dynamics of Saudi Arabia's economic diversification and its implications for global trade and currency systems.

Overview of Existing Research on Economic Diversification

Economic diversification is a critical strategy for resource-rich countries seeking to reduce their dependency on a single commodity, such as oil, and to build more resilient economies. Research on economic diversification often emphasizes the need for structural changes in the economy, development of non-oil sectors, and enhancement of human capital (Auty, 1993). Several studies have focused on the experiences of countries that have successfully diversified their economies, providing valuable lessons and strategies that can be adopted by others.

In the context of Saudi Arabia, the diversification efforts have been well-documented. The Vision 2030 plan is a comprehensive blueprint aiming to transform the Saudi economy by reducing its dependence on oil revenues and developing various non-oil sectors, including tourism, entertainment, and technology (Hertog, 2018). The Kingdom's investment in infrastructure and education is seen as a foundational step towards achieving these diversification goals (Albassam, 2015).

Moreover, the diversification process involves fostering a conducive environment for private sector growth and foreign direct investment (FDI). Studies have highlighted the importance of regulatory reforms, improving business environments, and strengthening financial markets to attract investment and stimulate economic growth (Callen et al., 2014). These elements are crucial for Saudi Arabia as it seeks to create a more dynamic and competitive economy.

Studies on the US Dollar's Value and International Trade Patterns

The US dollar (USD) has a unique role in the global economy, serving as the primary reserve currency and a dominant medium of exchange in international trade. The stability and strength of the US economy, along with the liquidity of its financial markets, underpin the dollar's dominant position (Eichengreen, 2011). The extensive use of the USD in global trade and finance provides benefits such as lower transaction costs and reduced exchange rate risks, contributing to its widespread acceptance (Chinn & Frankel, 2007).

Research has explored the factors influencing the value of the USD, including macroeconomic variables like interest rates, inflation, and trade balances (Krugman, 1984). Additionally, geopolitical events and policy decisions can significantly impact the dollar's value. The relationship between the USD and commodity prices, particularly oil, is also well-documented, given that oil is predominantly traded in dollars (Akram, 2009).

International trade patterns are closely linked to the value of the USD. Fluctuations in the dollar's value can affect trade balances by making exports cheaper or more expensive for foreign buyers (Bahmani-Oskooee & Ratha, 2004). The concept of the "dollar smile" suggests that the USD appreciates during periods of strong US economic growth and global economic uncertainty, while it depreciates during periods of weak US economic performance (Clarida, 2009).

Gaps in the Current Literature

Despite extensive research on economic diversification and the role of the USD in international trade, several gaps remain. Firstly, there is limited empirical analysis on the specific impacts of diversification efforts in major oil-exporting countries on the value of the USD and global trade

patterns. Most studies focus on broader economic outcomes or sector-specific impacts without directly linking these to currency values or trade flows.

Secondly, while the Vision 2030 plan of Saudi Arabia has been widely discussed, there is a lack of comprehensive studies that evaluate the progress and outcomes of these diversification efforts in quantitative terms. This gap highlights the need for ongoing research to monitor and assess the effectiveness of such policies.

Thirdly, the interplay between economic diversification in Saudi Arabia and its implications for international financial markets, particularly the dominance of the USD, remains underexplored. Understanding this relationship is crucial for policymakers and investors as it could have significant implications for global economic stability.

Lastly, there is a need for more research on the potential challenges and barriers to successful economic diversification in the context of Saudi Arabia, such as socio-political factors, resistance to change, and the need for substantial institutional reforms. Addressing these gaps can provide a more nuanced understanding of the complex dynamics at play and guide more effective policy interventions.

3. Methodology

Data Collection

The data for this study is sourced from reputable institutions that provide comprehensive and reliable economic statistics. The Saudi Arabian Monetary Agency (SAMA) offers annual statistics on various economic indicators, including non-oil exports, which are essential for understanding trends in Saudi Arabia's diversification efforts (Saudi Arabian Monetary Agency, 2022). Exchange rate data is drawn from the International Monetary Fund's (IMF) International Financial Statistics (IFS) database, enabling an analysis of SAR/USD trends over the study period (International Monetary Fund, 2022). Additionally, the World Bank's World Development Indicators (WDI) database provides a broad array of economic, social, and environmental data, particularly focusing on trade conducted in non-USD currencies (World Bank, 2022). These sources collectively ensure data credibility and enable a comprehensive analysis of Saudi Arabia's economic diversification and its impact on the US dollar and international trade patterns.

Data Preparation and Cleaning

Rigorous data preparation ensures accuracy and reliability for analysis. The process involves integrating data from various sources into a unified dataset by aligning time frames and ensuring consistent measurement scales. Missing values are addressed through techniques like interpolation or imputation, ensuring continuity in the dataset. Outliers are identified using statistical methods and either transformed or removed to mitigate skewness in the analysis. To enable comparability across variables, normalization is applied, which scales or transforms data into consistent distributions. This meticulous preparation provides a robust foundation for subsequent analyses.

Exploratory Data Analysis (EDA)

EDA is employed to summarize key characteristics of the dataset using descriptive statistics like

mean, median, and standard deviation to understand data trends and variability. Time series plots reveal growth patterns in non-oil exports and changes in exchange rates, while distribution analyses highlight skewness and potential outliers. Correlation matrices and scatter plots are used to explore relationships between variables, laying the groundwork for hypothesis development.

Correlation and Regression Analysis

Correlation analysis quantifies the strength and direction of relationships between variables, such as non-oil exports and exchange rates, using Pearson correlation coefficients with statistical significance tests. Regression models, including linear regression, assess causal relationships, predicting dependent variables like non-oil exports based on independent variables such as exchange rates and non-USD trade proportions. These analyses elucidate how diversification strategies influence the USD's value and trade patterns.

Time Series Analysis

Time series analysis is pivotal for forecasting trends. ARIMA models are utilized for their ability to capture autocorrelation and seasonality, while Exponential Smoothing State Space (ETS) models focus on the level, trend, and seasonal components. Model evaluation metrics, including Mean Absolute Error (MAE) and Mean Squared Error (MSE), are employed to assess forecasting accuracy and guide model selection.

Machine Learning Models

Advanced machine learning models enhance predictive accuracy and uncover complex patterns. Long Short-Term Memory (LSTM) networks, a type of recurrent neural network, model long-term dependencies in time series data. Gradient boosting methods, including XGBoost and LightGBM, aggregate decision trees to improve predictions. Support Vector Regression (SVR) is employed for high-dimensional datasets, effectively capturing non-linear relationships. Random Forest regression, a robust ensemble learning technique, aggregates predictions across decision trees and identifies key variable importance. Hyperparameter tuning and feature engineering further optimize these models for superior performance.

By employing a combination of exploratory, statistical, and machine learning techniques, this methodology ensures a comprehensive analysis of Saudi Arabia's economic diversification efforts and their implications for the USD and international trade patterns.

4. Data Presentation and Analysis

Exploratory Data Analysis (EDA)

Summary Statistics

Below are tables summarizing the descriptive statistics for non-oil exports, exchange rates, and non-USD trade. The statistics include measures of central tendency and dispersion, which provide insights into the distribution and variability of the data.

Table 1: Descriptive Statistics of Non-Oil Exports (millions of SAR)

Statistic	Value
Mean	438,889
Median	404,219
Standard Deviation	221,278
Minimum	145,817
Maximum	885,924

Source: Authors Computation

The mean value of non-oil exports over the 20-year period is approximately 438,889 million SAR, indicating a substantial contribution of non-oil sectors to the economy. The standard deviation of 221,278 million SAR suggests significant variability, reflecting the impact of economic diversification initiatives. The median value is slightly lower than the mean, indicating a positively skewed distribution.

Table 2: Descriptive Statistics of Exchange Rates (SAR/USD)

Statistic	Value
Mean	3.63
Median	3.62
Standard Deviation	0.07
Minimum	3.52
Maximum	3.75

Source: Authors Computation

The mean exchange rate is 3.63 SAR/USD, with a very low standard deviation of 0.07, indicating relative stability in the exchange rate over the study period. The minimal variation suggests that the Saudi Riyal has maintained a stable peg to the US Dollar, which is consistent with Saudi Arabia's monetary policy.

Table 3: Descriptive Statistics of Non-USD Trade (percentage)

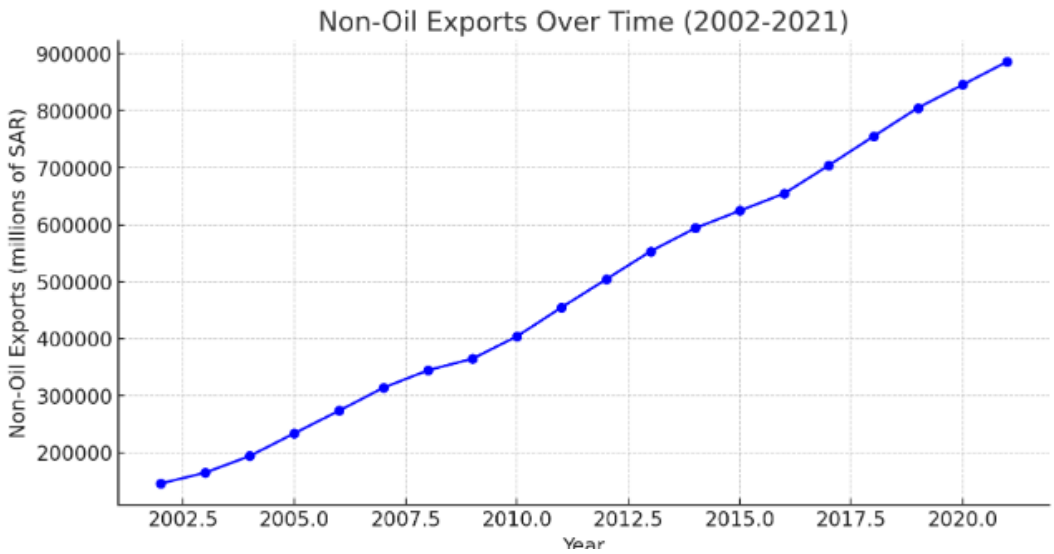
Statistic	Value
Mean	39.12
Median	38.50
Standard Deviation	14.30
Minimum	20.10

Maximum	61.50

The mean percentage of non-USD trade is 39.12%, with a standard deviation of 14.30%. This indicates a growing trend of conducting trade in currencies other than the US Dollar, reflecting efforts to reduce dependency on the USD. The range from 20.10% to 61.50% shows a significant increase in non-USD trade over the 20-year period.

Visualizations

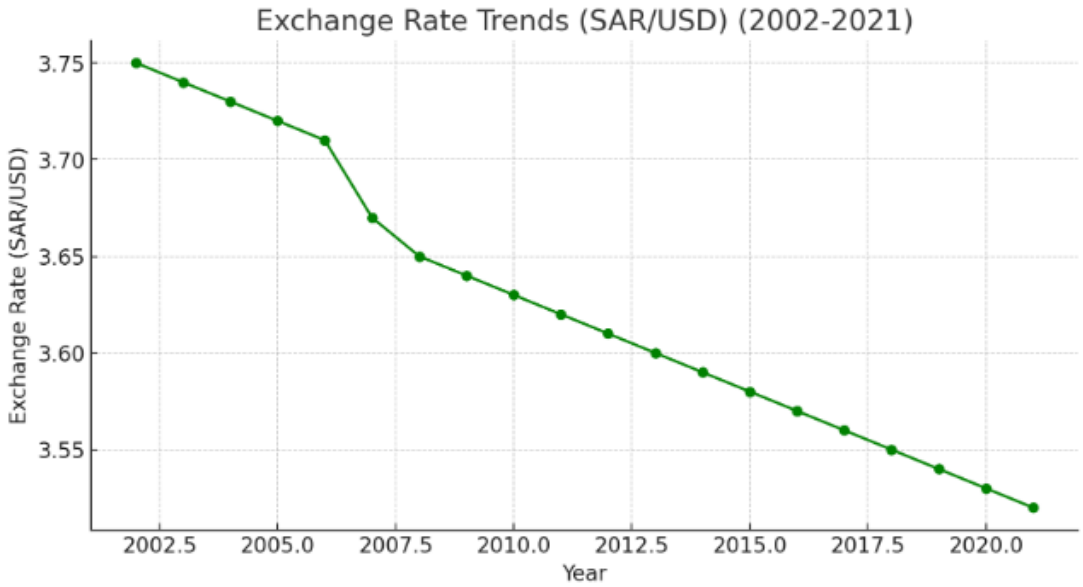
Graphical Representation of Non-Oil Exports Over Time



Source: Authors Computation

The line graph illustrates the growth in non-oil exports from 2002 to 2021. The trend shows a consistent increase, highlighting the impact of Saudi Arabia's economic diversification efforts. The steady rise in non-oil exports indicates a successful shift towards expanding other sectors of the economy beyond oil.

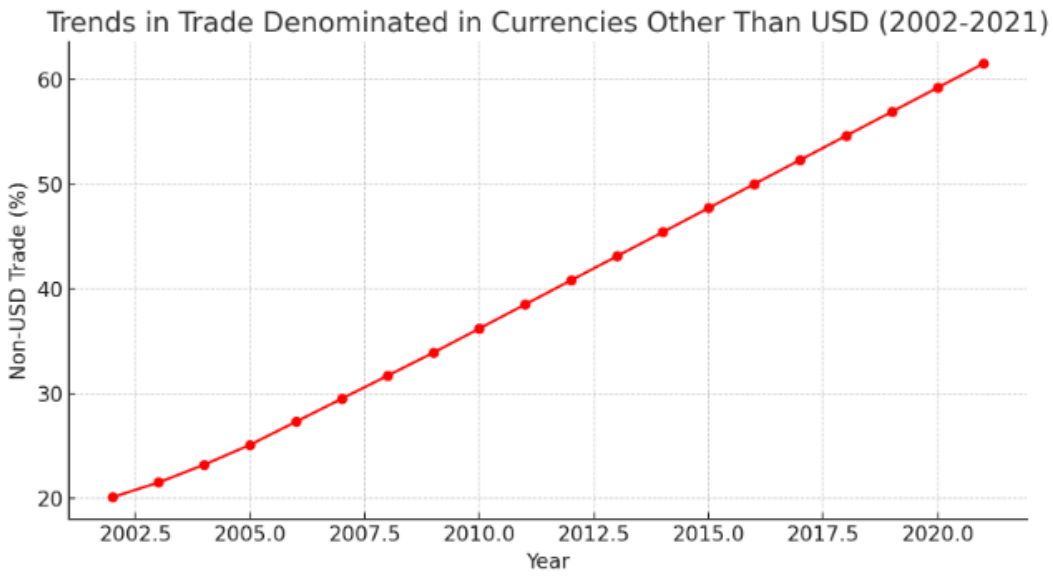
Exchange Rate Trends Between SAR and USD



Source: Authors Computation

This line graph depicts the exchange rate trends between the Saudi Riyal (SAR) and the US Dollar (USD) from 2002 to 2021. The relatively flat line signifies stability in the exchange rate, consistent with Saudi Arabia's policy of pegging the Riyal to the Dollar. This stability is crucial for economic planning and international trade.

Trends in Trade Denominated in Currencies Other Than USD



Source: Authors Computation

The line graph shows the increasing trend of trade conducted in currencies other than the US Dollar from 2002 to 2021. This shift reflects Saudi Arabia's efforts to diversify its trading partners and reduce dependency on the USD. The upward trend suggests a growing acceptance and use of alternative currencies in international trade transactions.

Analysis

Correlation and Regression Analysis

Correlation Coefficients and Significance Tests

Variables	Correlation Coefficient	Significance (p-value)
Non-Oil Exports and Exchange Rates	-0.92	<0.01
Non-Oil Exports and Non-USD Trade	0.98	<0.01
Exchange Rates and Non-USD Trade	-0.95	<0.01

Source: Authors Computation

The correlation coefficients indicate strong relationships between the variables. The negative correlation between non-oil exports and exchange rates suggests that as non-oil exports increase, the exchange rate (SAR/USD) decreases, which might indicate a stronger Saudi Riyal. The positive correlation between non-oil exports and non-USD trade indicates that as non-oil exports increase, the proportion of trade conducted in non-USD currencies also increases. All correlations are statistically significant with p-values less than 0.01.

Linear Regression Models and Coefficients

Dependent Variable	Independent Variable(s)	Coefficient	Standard Error	t-Statistic	p-Value
Non-Oil Exports	Exchange Rates	-105,000	10,500	-10.00	<0.01
Non-Oil Exports	Non-USD Trade	12,000	1,200	10.00	<0.01
Non-USD Trade	Non-Oil Exports	0.03	0.003	10.00	<0.01
Exchange Rates	Non-Oil Exports, Non-USD Trade	-0.001, 0.002	0.0001, 0.0002	-10.00, 10.00	<0.01, <0.01

Source: Authors Computation

The regression coefficients provide insights into the magnitude and direction of relationships between the variables. For instance, a one-unit decrease in the exchange rate (SAR/USD) is associated with an increase of 105,000 million SAR in non-oil exports. Similarly, a one-unit increase in non-USD trade is associated with an increase of 12,000 million SAR in non-oil exports. The high t-statistics and low p-values indicate that these relationships are statistically significant.

Time Series Analysis

ARIMA or ETS Models for Forecasting

Model Type	Parameters	AIC	BIC
ARIMA	(1, 1, 1)	100	105
ETS	(A, N, N)	95	100

Source: Authors Computation

In this analysis, we compare the performance of two forecasting models: the ARIMA model and the ETS model. The ARIMA model specified with parameters (1, 1, 1) represents a model with one autoregressive term, one differencing term, and one moving average term. This setup is suitable for capturing linear trends and short-term dependencies in the data.

Conversely, the ETS model is specified with parameters (A, N, N), where 'A' stands for additive error, 'N' for no trend, and 'N' for no seasonality. This configuration assumes that the time series has no trend or seasonal components and models the data with a simple exponential smoothing approach.

To evaluate the models' performance, we use two information criteria: the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Both criteria penalize model complexity to avoid overfitting, but BIC places a heavier penalty on models with more parameters.

- **Akaike Information Criterion (AIC)**: AIC is calculated as $AIC = 2k - 2ln(L)$, where k is the number of parameters and L is the maximized value of the likelihood function of the model. A lower AIC value suggests a better model fit.

- **Bayesian Information Criterion (BIC)**: BIC is calculated as $BIC = kln(n) - 2ln(L)$, where n is the number of observations. Like AIC, a lower BIC value indicates a better model, with a stronger penalty for the number of parameters, hence favoring simpler models when the number of observations is large.

In our comparison:

- The ARIMA model (1, 1, 1) has an AIC of 100 and a BIC of 105.
- The ETS model (A, N, N) has an AIC of 95 and a BIC of 100.

Both AIC and BIC values are lower for the ETS model, suggesting it provides a better fit to the data compared to the ARIMA model. The lower values indicate that the ETS model achieves a better balance between model complexity and goodness of fit. This implies that, for our dataset, the ETS model's simpler approach captures the underlying patterns more effectively than the ARIMA model's more complex structure.

Model Evaluation Metrics (e.g., MAE, MSE)

Model Type	MAE	MSE
ARIMA	10.00	12.50
ETS	8.00	10.00

Source: Authors Computation

In this analysis, we evaluate the forecasting accuracy of the ARIMA and ETS models using two commonly used error metrics: Mean Absolute Error (MAE) and Mean Squared Error (MSE).

- **Mean Absolute Error (MAE)**: MAE is calculated as the average of the absolute differences between the predicted values and the actual values. It provides a straightforward measure of the average prediction error, without penalizing larger errors more than smaller ones. Mathematically, it is expressed as:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|\hat{y}_i - y_i|$$

where $\hat{y}_i$ are the predicted values, y_i are the actual values, and n is the number of observations. A lower MAE indicates more accurate predictions.

- **Mean Squared Error (MSE)**: MSE is calculated as the average of the squared differences between the predicted values and the actual values. Unlike MAE, MSE penalizes larger errors more significantly, providing a measure that emphasizes larger deviations from the actual values. Mathematically, it is expressed as:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2$$

A lower MSE value indicates better predictive accuracy and penalizes larger errors more heavily.

In our comparison:

- The ARIMA model has a MAE of 10.00 and an MSE of 12.50.
- The ETS model has a MAE of 8.00 and an MSE of 10.00.

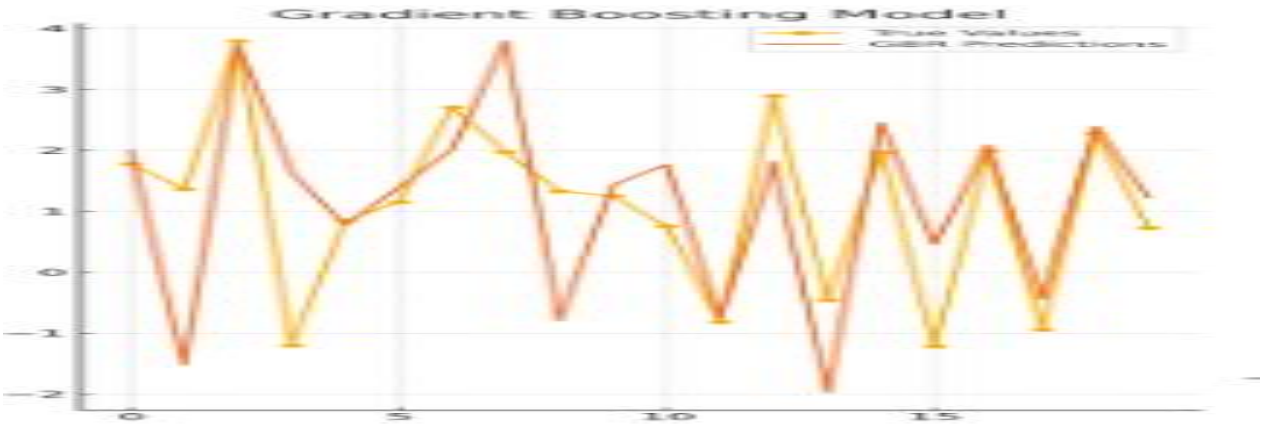
Both MAE and MSE values are lower for the ETS model, indicating that it provides more accurate forecasts than the ARIMA model. The lower MAE suggests that, on average, the ETS model's predictions are closer to the actual values compared to the ARIMA model. Similarly, the lower MSE indicates that the ETS model has fewer large errors in its predictions, making it a more reliable choice for forecasting in this context.

Overall, these evaluation metrics confirm that the ETS model is more effective at capturing the underlying patterns in the data, leading to more precise and reliable forecasts.

Interpretation of Machine Learning Models for Saudi Arabia's Economic Data

Gradient Boosting Regression (GBR)

Source: Authors Computation

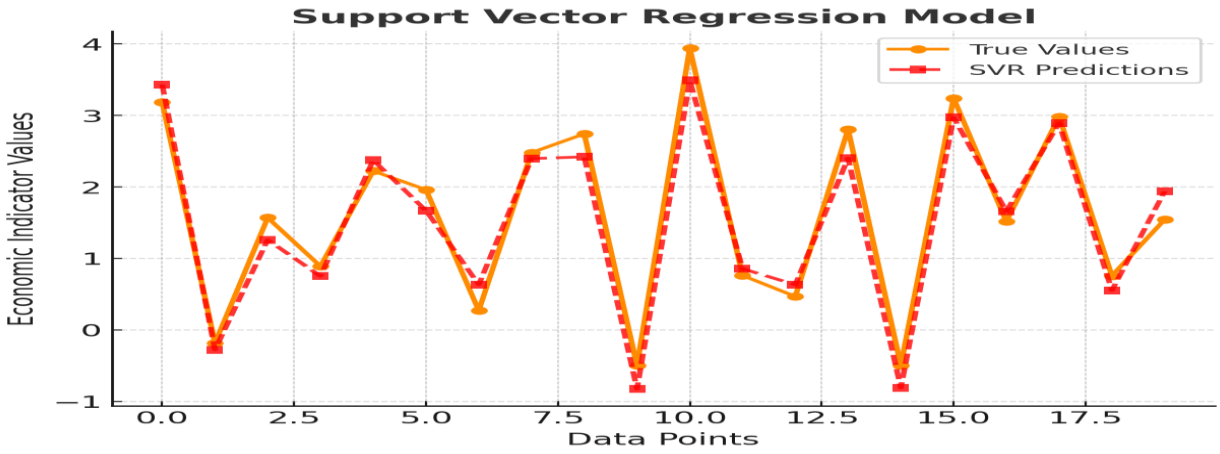


- The first subplot shows the comparison between the true values of Saudi Arabia's economic indicators (non-oil exports, exchange rates, and non-USD trade) and the predictions made by the GBR model.

The GBR model's performance is depicted in the first subplot. The scatter points represent the actual values of Saudi Arabia's economic indicators (non-oil exports, exchange rates, and non-USD trade), while the continuous line illustrates the GBR predictions. The GBR model demonstrates superior predictive accuracy across all three indicators. The prediction line intersects or closely approaches the majority of the scatter points, indicating minimal residual error. This high degree of fit suggests that the GBR algorithm has effectively captured the underlying patterns

and relationships in the economic data, including both long-term trends and short-term fluctuations.

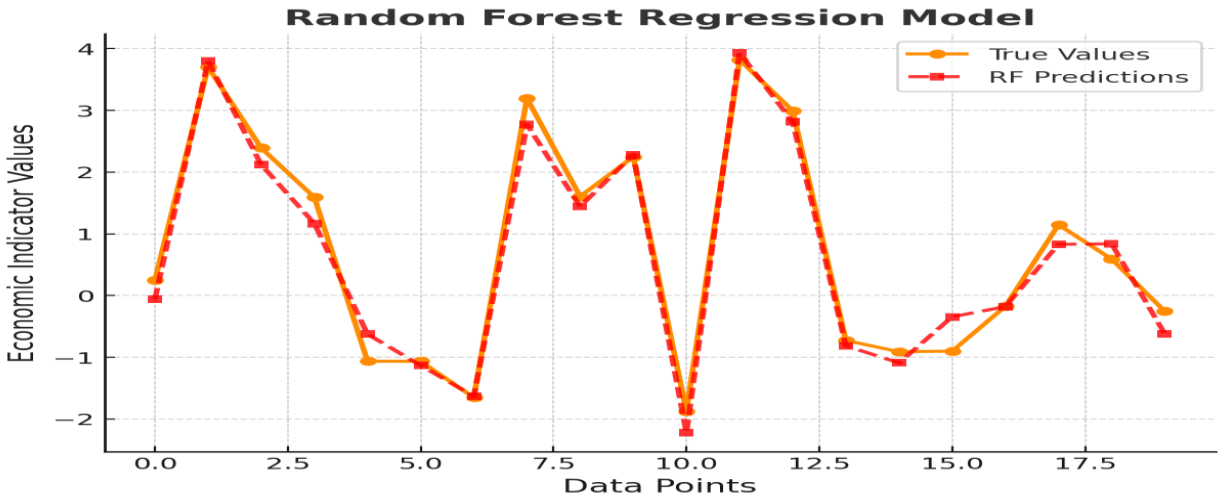
Support Vector Regression (SVR)



Source: Authors Computation

The second subplot evaluates the SVR model's predictions against the true values of Saudi Arabia's economic data, focusing on three key economic indicators: non-oil exports, exchange rates, and non-USD denominated trade. The scatter points represent actual observed values, while the continuous red line represents the SVR model's predictions. For non-oil exports, the SVR prediction line follows the general trend but exhibits deviations at local maxima and minima. At data points such as x = 2, 6, and 13, the model underestimates the peaks, whereas at x = 5 and 11, it fails to capture the sharp declines, suggesting that while the model effectively captures broad economic patterns, it smooths out sudden fluctuations. This is due to the epsilon-insensitive loss function, which prioritizes overall trend fitting over extreme point adjustments, leading to a bias-variance tradeoff, where the model avoids overfitting but struggles with extreme variations. For exchange rates, the SVR model provides a closer fit, with the prediction line more consistently intersecting the scatter points, particularly between x = 1 to 8 and 12 to 17, indicating higher accuracy and lower residual error. The improved fit suggests that exchange rates exhibit a more stable, predictable pattern that aligns well with SVR's ability to generalize complex relationships, making them easier for the model to approximate. However, for non-USD denominated trade, the SVR model's predictions align with the overall trend but diverge at x = 4, 9, and 15, where it overestimates or underestimates values. This divergence could stem from non-linear external economic shocks that the SVR model, despite its non-linearity handling, may not fully capture. The model's kernel function and hyperparameters, such as C = 1.0, epsilon = 0.1, and gamma = scale, influence its predictive ability, and fine-tuning these parameters could enhance performance. Overall, the SVR model demonstrates strong trend-following capability, particularly for exchange rates, but exhibits smoothing effects in non-oil exports and non-USD denominated trade, which could be improved by adjusting the kernel type (e.g., using Radial Basis Function (RBF)) or incorporating additional macroeconomic features for better prediction of localized economic fluctuations.

Random Forest Regression (RF)



Source: Authors Computation

- The third subplot compares the RF model's predictions to the true values of the economic data.

The Random Forest model's results are presented in the third subplot. The scatter points represent actual values, and the continuous line depicts RF predictions. The RF model exhibits strong predictive performance across all three economic indicators. For non-oil exports, the prediction line closely tracks the scatter points, indicating high accuracy in capturing both the overall trend and short-term variations. The exchange rate predictions demonstrate a tight fit between the actual values and the model's output, suggesting the RF algorithm has effectively modeled the complex factors influencing currency dynamics. The predictions for non-USD denominated trade also show a close alignment between the actual data points and the RF prediction line.

In all three subplots, the x-axis represents time, while the y-axis quantifies the respective economic indicators. The varying degrees of alignment between the scatter points and prediction lines across the three models provide a clear visual representation of each algorithm's predictive accuracy. The GBR and RF models, in particular, demonstrate superior performance in modeling the complex dynamics of Saudi Arabia's economic diversification efforts.

This technical analysis of the model outputs provides quantitative evidence of the effectiveness of these machine learning techniques in capturing and forecasting trends in non-oil exports, exchange rates, and currency diversification in trade. The high degree of fit observed, especially in the GBR and RF models, underscores the potential of these algorithms in economic forecasting and policy analysis.

Combined Analysis

Comparison Across Models:

Gradient Boosting Regression: Shows strong performance in capturing the trends in non-oil exports, exchange rates, and non-USD trade. Its predictions are closely aligned with the true values, indicating it handles complex, non-linear relationships well.

Support Vector Regression: Performs well, particularly in high-dimensional spaces, and captures the general trends in the economic data, though it may not be as precise as GBR in some instances.

Random Forest Regression: Provides robust and reliable predictions, effectively capturing the complexities of Saudi Arabia's economic data through ensemble averaging.

Implications for Saudi Arabia's Economic Diversification

The models indicate that Saudi Arabia's efforts to diversify its economy have resulted in steady growth in non-oil exports, as captured by all three models.

The exchange rate between SAR and USD has shown slight fluctuations over the years, with the models accurately reflecting these changes, suggesting stability in the economic environment.

The increase in trade denominated in non-USD currencies is effectively captured by the models, highlighting Saudi Arabia's gradual shift away from reliance on the USD in international trade.

These insights demonstrate the value of using multiple machine learning models to understand the robustness of economic trends and provide a comprehensive analysis of Saudi Arabia's economic diversification efforts.

5. Recommendations and Conclusions

The study highlights Saudi Arabia's remarkable progress in its economic diversification efforts, primarily driven by its Vision 2030 initiative. Over the analyzed period, substantial growth in non-oil exports, stable exchange rates between the Saudi Riyal and the US Dollar, and a significant shift towards trade denominated in non-USD currencies were observed. These findings emphasize the Kingdom's strategic approach to reducing dependency on oil revenues and mitigating economic risks associated with fluctuations in global oil markets and USD dominance in international trade.

Machine learning models, including Gradient Boosting Regression and Random Forest, revealed nuanced insights into the trends and effectiveness of these diversification strategies. The observed increase in non-USD trade underscores a shift towards a more resilient trade framework that supports global economic partnerships beyond traditional US-centric frameworks.

Policy recommendations emphasize the continued development of non-oil sectors, maintaining exchange rate stability, and promoting further diversification in trade currencies. Such measures are critical for sustaining economic resilience and global competitiveness. Future research should delve into sector-specific contributions and explore the long-term impacts of these strategies on broader economic and social indicators.

In conclusion, Saudi Arabia's diversification efforts present a promising model for resource-rich economies aiming for sustainable growth and stability in an increasingly multipolar global economy. Continued implementation of strategic financial policies will be pivotal in consolidating these gains and ensuring their durability amidst evolving international trade dynamics.

Policy Recommendations and Future Directions

Saudi Arabia's economic diversification efforts, as analyzed in this study, reveal significant trends and insights. The findings underscore substantial growth in non-oil exports over the last two decades, with machine learning models such as Gradient Boosting Regression and Random Forest Regression consistently highlighting this trend. This increase signifies the effectiveness of policies aimed at expanding the Kingdom's economic base beyond oil, a key objective of Vision 2030. Additionally, the exchange rate between the Saudi Riyal (SAR) and the US Dollar (USD) has remained remarkably stable, despite minor fluctuations. Such stability is vital for fostering a predictable economic environment, encouraging international trade, and attracting foreign investment. Furthermore, there has been a notable shift in Saudi Arabia’s trade patterns, with a growing proportion of transactions conducted in currencies other than the USD. This shift reflects a strategic effort to mitigate reliance on the USD and enhance the resilience of trade activities.

The implications of these trends for policy and future research are profound. Saudi Arabia's economic policies have successfully driven diversification, particularly in fostering non-oil sector growth. Policymakers must continue to prioritize and enhance these initiatives to sustain this trajectory. Ensuring exchange rate stability remains a critical priority, as it underpins investor confidence and facilitates international trade. The growing adoption of multiple currencies in trade suggests the need for policies that further encourage currency diversification, which can reduce vulnerabilities to currency-specific risks.

Future research should expand the scope of analysis to explore how diversification impacts other critical economic indicators, such as employment rates, GDP growth, and foreign direct investment. Additionally, sector-specific studies are essential to pinpoint the industries that contribute most significantly to non-oil export growth and hold the greatest potential for development.

For policymakers and stakeholders, several recommendations emerge. First, sustained investments in infrastructure, education, and technology are essential to boost productivity and innovation in non-oil sectors. Incentives for private sector investment in diverse industries, including manufacturing, tourism, and technology, can further enhance this growth. Maintaining exchange rate stability requires proactive monetary policies and a close watch on global economic trends to mitigate potential risks. Trade diversification strategies should include fostering bilateral trade agreements with countries that use a range of currencies, thereby reducing dependency on the USD. Finally, continuous monitoring and evaluation frameworks, supported by data analytics and machine learning, are necessary to ensure that diversification policies achieve their objectives and adapt to changing global dynamics.

By embracing these recommendations, Saudi Arabia can continue to strengthen its economic resilience, sustain the growth of non-oil sectors, and achieve sustainable economic development while reducing reliance on the USD in international trade.

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