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Research paper

Macroeconomic Factors Affecting Petroleum Products Export: Evidence From The Frequentist and Bayesian Regression

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Abstract

This study delves into the intricacies of India's export of petroleum products within the dynamic landscape of the Gulf Cooperation Council (GCC) countries by utilizing extensive export data. Besides this, some critical macroeconomic variables affecting India's export of petroleum products, namely OPEC oil prices and India's economic size, which is epitomized by gross domestic product, are analyzed. The empirical analysis time frame is from 2000 to 2023. To examine linkages between the variables with their coefficient signs, this study uses autoregressive distributed lag bound testing to obtain short and long-run estimates with an error correction model and ordinary least squares. Moreover, non-frequentist Bayesian linear regression is used for validity estimations. The findings reveal that both frequentist and non-frequentist approaches justify that the OPEC oil prices and India's GDP significantly affect India's export of petroleum products to GCC countries. Lastly, diagnostic tests are applied to check stability and robustness in both frequentist and non-frequentist Bayesian regression.

***Keywords**: ARDL, Bayesian Regression, OPEC, OLS, Petroleum Products*

1. Introduction

India embarked upon liberalization and reforms of its economy in 1991, extending reforms to the petroleum sector a few years later, directly affecting petroleum product exports (Azhar, 2021). With the strong relationship between India and the GCC regions, the demand for oil products increased for daily use in the Gulf region. Good economic ties and foreign investment among both regions enable Indian refineries to increase their throughput (Noor & Noor, 2024), and finally, India emerges as a petroleum products exporter (Shalu et al., 2023). Petroleum products are crucial to India's economy and development, supplying raw materials, energy, gasoline, and lubricants across various sectors. Known as mineral oil, petroleum stands as India's second-largest energy source after coal. Despite India's production of petroleum products, 82% of its oil requirements are met through imports. To reduce dependence on imported oil, India aims to enhance its use of domestic resources and position itself as an export hub for petroleum products in the near future. India's petroleum sector stands at the crossroads of tradition and transformation, embodying the nation's journey from agrarian roots to becoming one of the world's fastest-growing economies. There is a substantial amount of crude oil imports in our country, refined to produce various petroleum products like gasoline, diesel, and other fuels. Petroleum products play a crucial role in both our imports and exports. Petroleum products are derived from crude oil through refining processes in oil refineries. Most crude oil is transformed into these products, encompassing various fuel categories such as diesel, LPG, coal, kerosene, gasoline, coke, etc. Petroleum products export up 3.10% from USD 6.42 billion in April 2023 to USD 6.62 billion in April 2024. After 2000, the exports of petroleum products from India rose sharply, reaching a peak in 2022, and it became India's highest-traded commodity. The specific increasing trend of petroleum products export and combined growth in OPEC oil prices and GDP is shown in Figures 1 and 2. The top regions where India exported its petroleum products in the FY 2022 are Asia, Europe, the Middle East, and North Africa. In this study, six countries of the GCC are taken where India exports its highest-traded petroleum commodities, as shown in Figures 6 to 15 in the appendix, as per the availability of data.
As GCC is a cartel of petroleum-exporting countries, India is exporting vast amounts of petroleum products due to the large diaspora in the Middle East and North African region, and rising consumption demand for petroleum and its products. In this scenario, for empirical testing of India's export of petroleum products and factors influencing these exports, crucial macroeconomic variables are taken, namely OPEC oil prices and India's GDP, which directly affect India's export of Petroleum products, and for instance, the study takes the Gulf Cooperation Council countries in total, where India exports petroleum products item HS-2710. This study aims to determine the deeper association by explaining trends in India's export of petroleum products to the GCC while analyzing its dynamic linkages with OPEC oil prices and India's GDP. As found by (Gupta & Goyal, 2015a), OPEC oil prices play a crucial role in determining the Indian economy and

trade. (Roy, 2023) uses dynamic ARDL modelling to assess the linkages between oil price, trade, GDP, and remittances. Aidarova et al. (2024) use the ARDL model to examine the relationship between oil exports and economic growth. This study uses the same approach of ARDL and bound testing to examine the economic linkages between petroleum products export, OPEC oil prices, and India's GDP, with further enhancement of including OLS and non-frequentist Bayesian linear regression for validity estimates as used by (Nguyen et al., 2019; Thach, 2023, 2025), where no prior studies follow this approach in the context of the petroleum products export, OPEC oil prices and GDP of India.

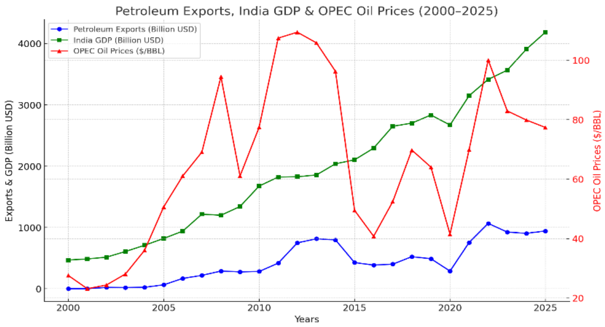


Fig 1: Combined graph of trends in India's total petroleum products export to GCC, India's GDP, and OPEC oil prices. ***Source:*** Author's

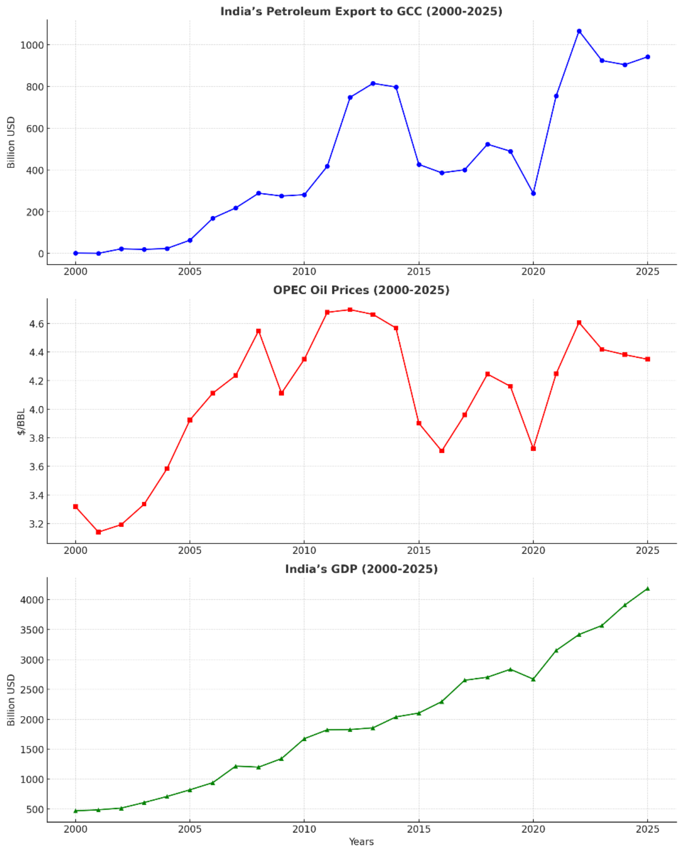


Fig 2: Stylized growth and fluctuation in India's total petroleum products export to GCC, India's GDP, and OPEC oil prices from 2000 to 2025. ***Source:*** Author's

The OPEC oil prices persistently declined from 2015 to 2020 and again after 2021 to 2025, causing India's exports of petroleum products to rise and reducing the deficit. In 2022, the OPEC oil price was 100.8 $ per barrel, while this figure declined to 82.95 $ per barrel and went down to 79.89 $ per barrel to 78.16 $ per barrel in the years 2024 to 2025. Besides these recent years, OPEC oil prices were still very low in 2015 at 49.49 $ per barrel and dropped to 40.16 in 2016 (opec.org.in). The OPEC oil prices affect the petroleum products exported from India because OPEC oil prices have a massive effect on India's petroleum industries and refineries. The decline in OPEC oil prices will raise the country's exports and production of petroleum products. In addition, India's economic growth and development, as depicted by the GDP, play a vast role in the export of petroleum products from India. India's GDP growth directly affects economic revenue and surplus, which stimulates more production in refineries due to consumption expansion and raises exports of petroleum products from India's refineries to other countries.

Studies based on oil prices and growth using all these frequentist regressions by (Gupta & Goyal, 2015; Latief et al., 2020; Negi, 2015; Rahiman & Kodikal, 2019; Rao & Parikh, 1996; Sarkar & Mathew, 2018; Soundarapandiyan & Ganesh, 2017; Tiwari, 2015; Zavaleta et al., 2015) are less empirical, and no particular study is on OPEC oil prices. OPEC oil prices and the economic size of India are affecting the growth in petroleum exports by promoting refinery throughput as there is a decline in the oil prices of OPEC directly affecting petroleum exports as India is getting more oil from different regions, and this will increase the production in the oil refineries and increase in export, the economic size of India which is taken into account by the GDP as growth in GDP also promoting export, all the trend and fluctuation in triangulation in OPEC prices, GDP of India, and Petroleum products export can be seen from the Figure 1 and 2. To execute the model, the frequentist approach is used, which is ARDL regression Pesaran et al., 2001; Pesaran & Shin, 1995), Ordinary Least Squares, and a

non-frequentist Bayesian regression approach for validity estimation, as used by to compare whether frequentist or non-frequentist approaches are compatible for this analysis with current variables. The studies of (Briggs, 2023; Dagar & Malik, 2023; Drachal & Pawłowski, 2024; Jiao et al., 2021; Kalia, 2024a; Lee & Huh, 2017; Mehrara et al., 2017; Nguyen et al., 2019; Periwal, 2023) used the non-frequentist approach.
The main contribution of this study is to explore the more sophisticated integrated linkages between India's Petroleum products exports, OPEC oil prices, and the GDP growth of India, in the current literature. Bayesian linear regression has the advantage of using prior information to get the posterior distribution and to check the validity and robustness of the Bayesian linear regression, and it works more appropriately with small datasets and observations, unlike frequentist methods, where more observations are needed for probabilistic inference. So, this study uses both frequentist and Bayesian linear approaches to test the compatibility and to determine how factors like OPEC oil prices and the GDP of India affect petroleum products exports from India. Moreover, the convergence in the Bayesian model is shown by MCMC convergence trace plots, which are derived to check the overall fit and convergence in the predictive model with selected variables depicted in Figure 3. The convergence of the dependent variable, namely Lnexport (India's petroleum product exports), with the independent variables LNOPEC (OPEC oil prices) and LNGDP (GDP of India) shows the long-run economic linkages between them, where India's petroleum product exports are affected in the long run by OPEC oil prices and GDP growth of India.

2. Review of Literature

Some prior studies are critically analyzed in this study, with specific research gaps related to India's petroleum products exports, oil prices, and India's GDP. Moreover, previously used empirical techniques are discussed in this study with their limitations. A few of the studies done on India's petroleum products exports are those by Kulkarni, Tikyani, and Singh (2023) explore the impact of COVID-19 on the import and export of petroleum products and crude oil in India. It discusses the significant contribution of imports and exports to economies of scale and industrialization, particularly in the oil and gas industry. This study also covers changes in petroleum products' consumption, production, and exchange rates before and after the COVID-19 outbreak. The research focuses specifically on the impact of COVID-19 on the import and export of petroleum products and crude oil in India, potentially overlooking broader economic factors. The study may only consider some variables influencing the import-export dynamics of petroleum products, leading to a limited scope of analysis. Azhar (2021), India's Emergence as a Petroleum Products Exporter, analyzes the recent trend in Petroleum Products Export and Import by India. The author analyzes the time series data from 2000 to 2017 on the Petroleum product trade in India. Meanwhile, the study provides vast knowledge of petroleum products. Still, it does not include other Petroleum Products like Petroleum Jelly, Petroleum Coke, Pitch Coke, Lubricating oil, and Petroleum Resins, and the study period does not include recent years. Bhattacharyya and Blake (2009) The research paper analyzes the domestic demand for petroleum products in the Middle East and North African (MENA) countries from 1982 to 2005. It focuses on the evolution of petroleum product demand in MENA and conducts an econometric analysis for gasoline, diesel, kerosene, and fuel oil in seven countries. Results show rapid demand growth due to low fuel prices and rising incomes, with the gasoline demand model performing the best. The study focuses on MENA countries only, potentially limiting the generalizability of findings beyond this region. The analysis covers a specific period (1982-2005), which may not reflect current trends in petroleum product demand. The study uses a simple log-linear specification for demand analysis, which may oversimplify the complex factors influencing demand. The study by Rajan (2012) analyses the impact of globalization on India's petroleum exports. The primary goal of introducing globalization in India was to enhance economic growth and achieve other macroeconomic objectives. The current account in the balance of payments serves as a reflection of a country's economic development. Balance of payments challenges in a country can arise due to factors such as weak domestic financial systems, large and persistent fiscal deficits, high levels of external or public debt, exchange rates fixed at inappropriate levels, natural disasters, armed conflicts, or sudden and sharp increases in the prices of essential commodities like food and fuel.
Studies done on OPEC oil prices and international oil prices that affect the trade and economy are by Olayungbo et al. (2023). The study analyses oil production and price determination among OPEC and non-OPEC countries from 1965 to 2021. It identifies Saudi Arabia as the leading oil producer and Russia as a key determinant of global oil prices, with the USA acting as a stabilizer. The findings suggest that cooperation among these countries is essential for stabilizing oil prices and the global economy. The study's results are supported by low in-sample forecast errors, indicating reliability. The study focuses on a specific time frame (1965-2021), which may not capture recent developments or shifts in the oil market dynamics. The reliance on Bayesian graphical network causality and Granger causality tests may introduce methodological biases, depending on the assumptions made in these models. The findings emphasize the roles of Saudi Arabia, Russia, and the USA, potentially overlooking other influential factors or countries in the global oil market. The study's implications for cooperation among oil-producing countries may not account for geopolitical tensions that could affect collaboration.
Montant (2024) studied how well OPEC+ coordination strategies worked from 2009 to 2023, finding that some strategies existed before OPEC+ was formed but did not significantly affect oil prices until after 2016. It also shows that countries' timeframes for production influence their compliance with production limits, and OPEC+ notably impacted oil prices from 2016 to 2022. However, the study's short period may introduce biased results, and it does not report heteroscedasticity in the panel data, nor do some p-values appear insignificant in the findings tables, nor has it applied several diagnostic tests to see stability in the model. Obadi & Korcek's (2024) analysis has determined the short and long-term associations between geopolitical incidents and crude oil price changes across 2000-2023. The study uses the Autoregressive Distributed Lag (ARDL) model to find cointegrating relationships between variables that work for data integration levels. The model displays limitations regarding the ability to include other significant factors affecting oil prices through speculation, primarily because the relevant dataset is unavailable. The growth of Indian GDP was removed from the model because it proved statistically insignificant, thus reducing the analysis span. Table 3 shows ARDL results, which are insignificant and with no economic interpretation. Abdelsalam's (2023) study examines the impact of crude oil price movements on economic growth in the MENA region and explains the distinct results that oil exporters and importers receive. The research approach for monitoring different data distribution quantiles during analysis adopts the Panel quantile regression methodology. According to the research outcomes, institutional quality is the controlling variable. Research data collected from MENA countries lacks validity for predicting areas that do not engage in similar economic operations or oil-based industries. In their study, the GARCH model has an insignificant constant. In the linear model, the GMM results contain insignificant variables, and the same problem is found in the pooled OLS, which is a significant hindrance to the study. P. Sharma & Shrivastava (2024) examined how initial crude oil price modifications in the market repeatedly influenced significant economic factors, including GDP performance, employment rates, industrial production, inflation rates, foreign exchange rates, and stock market valuation in India. The research indicates that GDP creates positive effects on stock prices. The research evaluates the Indian economy without considering economic patterns from other regions or the national level. Results from the 30-year study period might be influenced by current economic changes and disruptive elements, leading to potential distortion in final research outcomes. The study has limitations

because the long-run association with GDP does not exist. It is the central motive of the study, and the p-value is not highly significant. Kathiravan et al., (2023) paper sought to find the relationship between the change in the price of crude oil and GDP per capita and the change in the exchange rate. This paper showed a mutual and significant unidirectional Granger causality between Dubai crude oil prices and exchange rates. In the OLS model, the dependent variable that captured the attention was the exchange rate, where Dubai crude oil prices were significant, too. On the other hand, WTI crude oil prices were substantial in terms of GDP per capita and exchange rate. The study covered the period 1990 to 2020, which would exclude certain advancements in the 2021 calendar year. In this process, the actual influence of elements such as volatility and trends in 'oil prices, GDP per capita, and exchange rates' may not have been fully captured due to the inherent limitations of the employed statistical tools. Al Humssi et al., (2022) study demonstrates that higher world oil prices generate direct growth in the UAE's GDP. The study shows that the UAE needs to develop non-oil economic sectors to fight potential price volatility because its petroleum-centered economy threatens future economic durability. The research analysis period from 2001 to 2020 fails to reflect contemporary economic changes and global events that affect oil prices and GDP, thus limiting the practical use of the resulting conclusions. The use of ADF, OLS, ARDL, and Granger causality statistical approaches brings limitations despite the failure to support model general assumptions and handle essential variables. The research fails to account for crucial economic factors that impact the United Arab Emirates because it examines only oil prices and does not provide a complete comprehension of the economic trend. Meanwhile, several variables' t-statistics with high standard errors are not significant, which may induce a lack of confidence in interpretation. Salem et al. (2024) investigate the substantial effects of increasing petroleum prices on worldwide economies concerning national production volumes and economic equilibrium maintenance. Governments should implement policy adjustments to handle alterations in oil price movements. The study results exhibit heteroscedasticity, and the analysis of several countries shows that macroeconomic elements of consumption and investment do not produce significant findings from their findings diagnostics table in the paper. Studies related to India's GDP growth, done using Bayesian regression, are by Pandey et al., (2023), which include export-import, inflation, and unemployment in their model, and the regression analysis estimates India's GDP. Compared to OLS regression, SR improves the selection and credibility of a model because it shows a decrease in DIC values. The linear regression model assumes a linear relationship between GDP and covariates, which may not capture complex economic interactions effectively; the OLS variables' coefficients are mostly insignificant. Moreover, the study does not include oil prices, which are important factors in determining GDP. One of the most crucial demerits of their study is that in Tables 2 and 3 of OLS and Bayesian estimates, most of the p-values of parameters are insignificant, leading to biased results.

Prior literature, based on Bayesian regression such as Baumeister & Hamilton's (2021), applies Bayesian VARs to analyze oil price shocks and macroeconomic policy implications. It demonstrates how priors improve inference in small-sample macroeconomic data. However, its focus is largely on policy interpretation in the U.S., which may limit direct application to emerging economies like India. Chan & Eisenstat (2022) employ Bayesian model averaging in oil market analysis. This work shows how accounting for model uncertainty improves robustness in estimating oil demand and supply elasticities. The limitation is its technical emphasis on model comparison rather than broader trade implications. Petrović & Vukadinović's (2022) paper uses Bayesian quantile regression to assess crude oil price volatility. It highlights the advantage of Bayesian approaches in capturing asymmetric effects. Still, its narrow focus on volatility limits insights for broader macroeconomic linkages like trade or GDP. Koop & Korobilis (2021) work on large Bayesian VARs with stochastic volatility underscores the strength of shrinkage priors in handling high-dimensional data for forecasting trade and GDP. While methodologically rigorous, it may be computationally demanding and less accessible for smaller applied studies. Karlsson's (2021) review chapter synthesizes Bayesian methods in economic forecasting, emphasizing advantages over frequentist models in terms of flexibility and handling uncertainty. However, it is more conceptual than empirical, offering limited direct evidence on energy or trade contexts. Del Negro & Primiceri (2022) develop time-varying structural VARs using Bayesian methods to study monetary policy shocks. Although highly influential for macroeconomic modeling, the application is central-bank oriented, with limited focus on trade flows or energy sectors. Rafiqul & Alam (2022) study applies Bayesian hierarchical regression to CO_2 emissions and energy use in Asia. It provides evidence of Bayesian methods capturing country-level heterogeneity effectively. Yet, it is more focused on environmental impacts than trade performance. Liu and Chen (2023) used Bayesian structural equation modeling. This paper examines links between renewable energy, oil prices, and GDP in emerging economies. Its strength is capturing latent structures and complex causal pathways, though it does not directly analyze petroleum product exports. Wang & Zhang (2021) introduce a Bayesian graphical regression approach to analyze global energy trade networks, showing how Bayesian methods map interdependencies across countries. A drawback is its highly technical nature, making policy translation less straightforward. Carriero, Clark, & Marcellino (2022) assess specification choices in Bayesian VARs and their effect on forecast accuracy. The study illustrates Bayesian robustness in macroeconomic forecasting but is mainly methodological, not sector-specific. Hastie & Tibshirani (2022) paper advances Bayesian shrinkage priors in regression, demonstrating efficiency gains in parameter estimation. While methodologically important, its contribution is statistical rather than directly applied to energy trade or macroeconomics. Giannone, Lenza, & Primiceri (2021) focus on prior specification for long-run Bayesian regressions. This work strengthens the credibility of Bayesian inference in macroeconomics. However, its contribution is more theoretical, with limited immediate application to empirical petroleum trade studies. Pandey et al. (2024) trade, rates of inflation, and levels of unemployment can all affect GDP. It is proposed to use a linear regression model to accurately estimate India's GDP based on the information given by the World Bank. Using step-wise regression to study GDP leads to clearer results than old methods by lowering the Deviance Information Criterion. The paper explores using a Bayesian approach for GDP statistics, compared to frequentist methods. The model and the actual values from 2022 are closely in line: India's GDP is estimated at $3.38 trillion. While comparing OLS to Bayes, they look at mean absolute deviation, root mean square error, and mean absolute percent error, but do not consider the other parameters' signs and impact, because these are insignificant and may add some bias. The paper by Parikh, Purohit, & Maitra (2007) discusses the relationship between energy consumption and economic growth in India, highlighting the country's significant commercial consumption growth. It reviews various energy demand models, presents forecasts for petroleum products and natural gas demand, and discusses policy implications. Assumptions about economic development, energy utilization rates, and inter-fuel substitution possibilities may influence the study's projections. The log-linear specification for demand projections did not find significant relationships with critical variables like GDP per capita, population, and price.

No previous literature work used the Bayesian regression analysis in the context of finding the economic linkages between India's export in petroleum products, OPEC oil prices, and the GDP of India, in view of comparison with ARDL and OLS outcomes. This study fills the previous gap with a more calibrated, diverse regression analysis to know the current scenario between the sophisticated regressors and how they impact the export of petroleum products to the Gulf Cooperation Council.

3. Data and Methodology

This study has included crucial variables, like petroleum product item HS-2710 export to Gulf Cooperation Council countries by India as dependent variables, the GDP of India as a proxy variable for economic growth and development, and OPEC oil prices as independent variables in a linear equation, and there is a two-sided log-log relationship. OPEC oil prices, dollar per barrel, are the combined average spot prices total of 13 oil exporter countries of OPEC, namely "Algeria (Saharan Blend), Angola (Girassol), Congo (Djeno), Equatorial Guinea (Zafiro), Gabon (Rabi Light), IR Iran (Iran Heavy), Iraq (Basrah Light), Kuwait (Kuwait Export), Libya (Ess Sider), Nigeria (Bonny Light), Saudi Arabia (Arab Light), United Arab Emirates (Murban), Venezuela (Merey)." India's Petroleum product HS-2710 export to GCC taken from the export-import data bank, the Ministry of Commerce and Industry, from 2000 to 2023, and is used for empirical analysis. The OPEC oil prices are taken from the Organization of the Petroleum Exporting Countries, and India's GDP current USD is taken from the World Development Indicators for the same time frame (WDI_DataBank.html). The availability of data on India's petroleum product (HS-2710) export to GCC from India is from 2000 to 2023; therefore, the time frame of this study is from 2000 to 2023. For the investigation and data processing, we employed E-Views 12 and STATA 17. The empirical estimates of the relationship between India's petroleum product export, OPEC oil prices, and GDP are tested using the ARDL bound testing approach, ordinary least squares, and, lastly, the Bayesian linear regression. First, the stationarity of the variables is checked through the unit root test, then the ARDL bound test is employed to determine the cointegration and long-run association, and then the ARDL short and long-run estimates are calculated with the error correction model mechanism ECM to know the speed of adjustment toward the long-run equilibrium. Then, the ARDL results are compared with OLS. The Bayesian linear regression is executed to determine whether there is any major difference from frequentist analysis, and the robustness of Bayesian estimates is checked through the MCMC convergence trace plots.

A) The following equation (1) can specify the ARDL model:

$$\Delta y_t = \alpha_o + \sum_{i=1}^{p} \beta_i \, \Delta y_{t-i} + \sum_{i=1}^{p} \delta_i \, \Delta x_{t-i} + \sum_{i=1}^{p} \varepsilon_i \, \Delta z_{t-i} + \lambda 1 y_{t-i} + \lambda 2 x_{t-i} + \lambda 3 z_{t-i} + \mu_t \quad (1)$$

Here, the variable being tested is yt, and λ1, λ2, and λ3 are long-run coefficients, and βi, δi, and i are short-run dynamics coefficients where αo and μt are constants and error terms, respectively. In Table 2, the F-bounds test value is 57.11, confirming a long-run relationship among the variables, which means they move together in the long run, though it leads to short-run departure. Equation (2) shows how short-term and long-term changes are connected.

$$\Delta \ln Exp = \alpha_o + \sum_{i=1}^{p} \beta_i \, \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \delta_i \, \Delta \ln OPEC_{t-i} + \lambda 1 \ln GDP_{t-i} + \lambda 2 \ln OPEC_{t-i} + \mu_t \quad (2)$$

The bound testing approach reveals a long-run relationship among the variables, and the null hypothesis of no relationship among the variables is rejected, and the alternative hypothesis is accepted. The least squares technique is employed by applying the error correction model to ascertain the speed at which changes transit towards the long-run equilibrium depicted in Table 3 in ARDL short-run dynamics. It measures the extent of flexibility of the dependent variable in responding to any form of disruption of the hypothesized equilibrium. It shows how fast the system changes in response to short-term shocks and the size and signs of the changes. The error correction term also helps us estimate the short-run relationship between the independent and dependent variables. Equation (3) presents the general model describing the ECM. Where all coefficients refer to the short-term behavior of the variables moving towards a long-run equilibrium, ECMt−1 is the error correction term, and δ is the convergence speed following a short-term disturbance shown in Equation 3 and Table 3.

$$\Delta \ln Exp = \alpha_o + \sum_{i=1}^{p} \beta_i \, \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \delta_i \, \Delta \ln OPEC_{t-i} + \delta ECM + \mu_t \quad (3)$$

3.1 Unit Root Examination for Stationarity

By conducting the Augmented Dickey-Fuller (ADF), Dickey-Fuller Generalized Least Squares (DF-GLS), and the Phillips-Perron (PP) test, we get the stationarity at the first difference I (1), so the null hypothesis is rejected for all the tests, indicating that the time series data has a unit root, indicating it is non-stationary. The results of the unit root test (ADF, DF-GLS, and PP) demonstrate that all of the variables in Table 1, including LNEXPORT, LNGDP, and LNOPECOIL, are stationary at I (1) first difference and do not have a unit root. After knowing stationarity of the variables, we use the ARDL bounds testing approach to determine whether co-integration exists for the long-term relationship between the variables over 2000-2023.

Table 1: Unit Root Test

Variables	Augmented Dickey Fuller		DF-GLS		Phillips Perron	
t & p-value	t-stats	p-value	t-value	p-value	t-value	p-value
LNEXPORT	-2.103	0.245	-0.594	0.558	-2.103	0.04
DLNEXPORT	-3.724	0.011	-3.563	0.001	-3.724	0.001
LNGDP	-1.71	0.001	-0.391	0.700	-1.710	0.101
DLNGDP	-4.53	0.000	-4.445	0.002	-4.534	0.000
LNOPECOIL	-1.830	0.081	-1.516	0.143	-1.830	0.081
DLNOPECOIL	-4.145	0.000	-4.001	0.000	-4.154	0.000

Source: *Author's*

3.2 Estimates of Bound Tests for the ARDL Model

Table 2 shows that even when the model meets all best-fit requirements, the "ARDL bound testing technique developed by Pesaran et al. (2001); Pesaran & Shin (1995)" is used to assess whether there is a long-run correlation between the factors. Using AIC, we have determined that the maximum lag order for ARDL estimation is two, and the selected model's lag is (1, 0, 2). We did not find any trends after running the model. The ARDL is measured using the AIC. As per Pesaran, "The computed F-statistics at the 1, 2.5, 5, and 10% significant levels are 57.11, which is represented by I(1) > I(0). Bound testing, an extension of ARDL modelling, uses f and t-statistics to assess the significance of lagged levels of variables in a univariate equilibrium correction system. It is utilized when it is uncertain whether the datagenerating process of a time series is trend stationary or first difference stationary. This method helps determine the appropriate model to use based on the stationarity properties of the data. We are given model lags by this ARDL bound test approach, which facilitates the verification of the short-term and long-term links. In this computed model, the latency is (1, 2). The F-statistic is greater than the lower and upper bounds, showing a long-run relation and cointegration among the variables at every critical value. The f-statistic is greater than the lower and upper bounds, which shows the excellent effect of cointegration among the variables LNEXPORT of Petroleum Products HS-2710, LNGDP of India, and LNOPEC oil prices, which is the combined oil reference basket of 13 oil exporter countries of OPEC, were taken in this study as independent and dependent variables. This study finds a long-term co-integration relationship between the variables. The next step is to find the long-term relationship of the variables in the model with the ECM mechanism to see the speed of adjustment from the short to the long-run equilibrium, if there are any disturbances in the long term.

Table 2: Bound Test

K	F-Statistic	Critical	Lower Bounds, I (0)	Upper Bounds, I (1)
2	57.11	10 %	2.63	3.35
		5 %	3.1	3.87
		2.5 %	3.55	4.38
		1 %	4.13	5

Source: *Author's*

3.3 Short and Long-Term Outcome of ARDL

Table 3 displays the long-run parameters. At the 1% level, if India's economic size (GDP) increases, it will affect the export of petroleum products by 0.82% to rise proportionately. The exports depend on development within the petroleum sector in India, new refinery establishment and privatization, reforms in fuel technology, and an increase in the economic size, which affects the petroleum products exports from India to other countries due to a hike in exports from India. Moreover, petroleum exports rise by 0.45% if there is a 1 unit per cent fluctuation in the oil prices of OPEC oil. The increase in the value of petroleum exports is slight, which shows less dominance of OPEC members on oil prices over India. In the long term, India will not be severely affected by OPEC oil prices due to the persistent decline in OPEC oil prices. It will benefit India's economy and refineries to export more petroleum products to the GCC. Nevertheless, in the short run, it may act erratically. The next step is to run the short-term estimates with error-correction representations. The constant value in the long-run forecast of the ARDL estimator is also statistically significant, which means the error term is evenly distributed in the population sample. Now, after the f-bound test reveals a long-run relationship in the variables, we can go for the short-run estimates of the ARDL and error correction interpretation in the model. Table 3, D denotes the difference in the variable. India's petroleum products export will decrease by 0.16% if OPEC's oil prices rise by 1%. An illustration of the short-run coefficient of the variables OPEC oil prices and petroleum export shows that they act erratically in the short run for a short period, which affects the petroleum export. Meanwhile, over time, the exports are not severely affected by OPEC oil prices and move toward long-term equilibrium. Long-term adjustment is depicted by the ECM term in Table 3. The rate at which equilibrium is reached over the long term is represented by the ECMt-1 coefficient. ECMt-1 is -0.75, meaning that for every year, there is a 75% shift from the short-run to the long-run of the period. This sign of error correction is always negative and depicts the rate of adjustment by chance. If this term becomes positive, it represents that the model is not fit and suitable for work, but in this study, the sign is negative and shows that the model is a good fit. The R2 value is 0.95, which shows that the independent variable, OPEC oil prices, explains 95 percent of the variation in the dependent variable, India's petroleum products exports. Economies adjust to the equilibrium growth rate faster with a higher error term. The Durbin-Watson term of 2.21 indicates that the variables do not autocorrelate. Every statistical result (R2, Adj. R2, D-W) shows the model's strength and appropriateness. Over the time period from 2000 to 2023, there is stability and association between the dependent variable (LNEXPORT), petroleum products exports, and the independent variables (LNGDP and LNOPEC), as seen from the CUSUM and CUSUMSQ tests.

Table 3: Results of ARDL, OLS, and Bayesian Linear Regression

ARDL Long-Run Estimates	Variables	Coefficients	Std. Error	T-Value	P-Value
	LNGDP	0.8218	0.0281	29.1743	0.0000***
	LNOPEC	0.4585	0.0323	14.1889	0.0000***
	Constant	-1.3379	0.3589	-3.7269	0.0018***
ARDL Short-Run Estimates and ECM	Variables	Coefficients	Std. Error	T-Value	P-Value
	D(LNOPEC)	0.3871	0.0224	17.2214	0.000***
	DLNOPEC -1	-0.1622	0.0227	-7.1331	0.000***
	ECM $_{t-1}$	-0.7593	0.0461	-16.4713	0.000***
	R^2		Adjusted R^2		Durbin-Watson
	0.95		0.95		2.21
OLS Regression	Variable's	Coefficients	Std. Error	T-Value	P-Value
	LNGDP	0.91	0.028	31.989	0.000***
	LNOPEC	0.36	0.038	10.419	0.000***
	Constant	-2.441	0.3227	-7.56	0.000***
	R^2			Adjusted R^2	
	0.99			0.99	
Bayesian Regression	Variable's	Posterior Mean	MCSE	Equal-tailed [95% credible interval]	
	LNGDP	0.91	0.032	0.847	0.975
	LNOPEC	0.39	0.044	0.307	0.484
	Constant	-2.44	0.357	-3.12	-1.71
	Sigma2	0.005	0.001	0.003	0.01

*Note: Calculated Coefficients is LNEXPORT, which is an explanatory variable (Petroleum Products Export). ARDL Short-run and Long-run estimates all covariates of Equation (2) and (3), and OLS and Bayesian Linear regression estimate all covariates of Equation (4). P-Value * 10%, P-Value ** 5%, and P-Value *** 1% except for Bayesian regression. Bayesian linear regression is a non-frequentist approach with a credible interval and posterior mean as a proxy for the confidence interval and variable coefficient.* ***Source:*** *Author's*

B) The following Equation (4) estimates the OLS and Bayesian Regression model:
Our Empirical Model is as follows:

$$\ln Export_{(t)} = \alpha_o + \beta_1 \ln GDP_t + \beta_2 \ln OPEC_t + \varepsilon_t \quad (4)$$

LNEXP = Log of Petroleum Products Export of India in (US$ million) at period (t).
LNGDP = Log of Gross Domestic Product at current (US$ million) at time (t).
LNOPEC = Log value of OPEC ORB spot prices in period (t).
t = show's time from 2000 to 2023.
ε = shows the relevant parameters are errors represented by β1 and β2.

3.4 Outcomes of Ordinary Least Squares

The regression coefficient of ordinary least squares is statistically significant with the same impact sign as of ARDL long-run outcomes. It shows India's export of petroleum products is positively associated with India's GDP and the plunge in the OPEC oil prices. As the frequentist approach deals with t and p values, as shown in Table 3, all are statistically significant. The R2 value for OLS is 0.99, which means that 99 percent of the variation is explained by the independent variables, GDP and OPEC oil prices. Based on the statistical explanation, we can say that with a unit per cent rise in India's GDP, the petroleum products export will rise by 0.91 per cent. Meanwhile, a unit percentage rise and fluctuation in OPEC oil prices cause India's petroleum products export to rise by 0.36 per cent. Both ARDL and OLS show the same sign of coefficients, while OLS is more robust, as noticed by (Dion, 2022; Kotsakis, 2023; Michaelides, 2025; Wooditch et al., 2021). The reason that India's petroleum products export positively correlates with GDP is due to economic development within country, reforms and privatization in petroleum sector in India, the building of new refineries in India and new sources for clean fuel and energy like EVs and blending of fuel like ethanol and bio-fuel and bio-diesel, Liquified natural gas as fuel source all new technological innovation in fuel throughput increase the export of petroleum products from India. Conversely, OPEC members lost their dominance over oil prices in the international market, and new sources of crude and petroleum products emerged from non-OPEC countries. OPEC members' supremacy over oil prices does not affect emerging economies like India. Another factor is the persistent decline in the OPEC oil prices over the years, which increases the export potential of petroleum products as India gets oil at low prices. The OPEC oil prices persistently declined from 2015 to 2020 and again from 2021 to 2025, causing India's exports of petroleum products to rise. In 2022, the OPEC prices were 100.8 $ per barrel, while this figure declined to 82.95 $ per barrel and went down to 79.89 $ per barrel to 78.16 $ per barrel from January 2024 to January 2025. See the green trend line in Figure 1. OPEC oil prices decline over time. Besides these recent years, prices were still very low in 2015, at 49.49 $ per barrel; in 2016, it was 40.76. This persistent downfall in OPEC oil prices caused a rise in India's export of petroleum products. This is all about the frequentist approach to dealing with India's petroleum products exports and how it is affected by OPEC oil prices and GDP.

4. Bayesian Regression and Superiority over the Frequentist Approach

Bayesian analysis is a statistical approach that uses probability statements to answer research questions on uncertain characteristics in statistical models. One of the most substantial criteria in Bayesian methods is using Bayes' rule to derive the posterior distribution of model parameters. The Bayesian approach has some unique advantages over the traditional frequentist techniques of analysis (Thach, 2025). This enables integrating prior beliefs or knowledge into the process, which increases the applicability and personalization of results using available information. The advantages of Bayesian analysis have led to its growing importance in social sciences, especially in economics (Block & Wagner, 2014; Kalia, 2024; Tuan et al., 2019). According to Van Doorn et al. (2021), the Bayesian analysis in research consists of four sequential stages. Planning, executing, interpreting, and reporting. The current study falls in the third stage of the analysis since it involves interpretation and testing for the robustness of the estimates. Thus, this study employs the Bayesian linear regression random-walk Metropolis-Hastening sampling for Markov Chain Monte Carlo (MCMC) simulation to check the convergence in the model, with an MCMC sample size of 20000, with a 2500-burn-in simulation showing an acceptance rate of 0.37 percent and with minimum efficiency of 0.67 percent, average efficiency of 0.74 percent, and maximum efficiency of 0.82. The Bayesian analysis uses the credible interval, a concept in Bayesian statistics. Its primary role is to report on and provide a measure of the level of uncertainty regarding the parameters. In Table 3, in Bayesian regression, sigma2 represents the variance of the error term with a mean value between the credible interval, indicating that the error term in the distribution and constant is an intercept in Bayesian linear regression, like a constant in the frequentist approach and further it uses Monte-Carlo standard error which are more robust than normal standard error in the frequentist approach. The posterior mean values of parameters are like the coefficients in the frequentist ARDL and OLS regression and lie between the credible interval, which is different from the confidence interval because it is based on prior beliefs instead of probability. The posterior mean value in the Bayesian analysis is more representative and robust than the coefficients in the frequentist ARDL and OLS estimates because Bayesian linear regression is a more powerful technique, handling small data sets and limited variables, and observations (Fraza et al., 2021; Georgiou, 2024) as compared to the frequentist model (Abbasi et al., 2022; Iqbal et al., 2023) so the OPEC oil prices and India's GDP are more calibrated in Bayesian linear regression, while their impact signs of posterior mean for both regressors are approximately similar to the frequentist approach. Overall, the non-frequentist Bayesian regression shows good working and convergence through MCMC trace plots, shown in Figure 5.

To check the robustness, normal priors are used for all parameters in Bayesian estimates, which show similar coefficient signs of posterior mean values of LNGDP, LNOPEC, constant, and sigma2, as OLS and ARDL means. The selected prior for each parameter is such that β1 GDP ~ Normal (0, 1), β2 OPEC ~ Normal (0, 1), and intercept α ~ Normal (0, 2), and error σ ~ (3, 1), This set of priors informative enough to stabilize the fit with N≈24, yet not so tight that it overrules the data. A crucial component of Bayesian linear regression is the specification of prior distributions for the model parameters. Priors are not arbitrary but instead reflect informed expectations regarding the plausible range of values for coefficients, while ensuring that the observed data retains a dominant role in shaping the posterior distribution. In this study, priors were selected to balance two objectives: (i) providing enough informativeness to stabilize estimation given the relatively small sample size (2000–2023, N ≈ 24), and (ii) avoiding overly restrictive assumptions that could override the evidence contained in the data. The prior for the GDP elasticity of exports is centered at zero with unit variance. This reflects the expectation that GDP growth in India has a positive but bounded influence on petroleum product exports. While higher GDP facilitates greater refinery throughput and export potential, part of the increase in output is absorbed domestically through rising consumption. Hence, the prior assumes an effect that is economically significant yet realistically constrained below unit elasticity. This choice is consistent with historical studies showing GDP-trade elasticities that are positive but rarely exceed unity.

For OPEC oil prices, a similar Normal (0,1) prior was adopted. Oil prices affect India's petroleum exports through two channels: (i) lower input costs improve refinery margins and international competitiveness, while (ii) higher crude prices mechanically raise the nominal value of exports. The net effect is therefore expected to be positive but modest, with considerable uncertainty. A symmetric prior centered at zero but with variance equal to one ensures that both scenarios are feasible, while allowing the data to determine the dominant channel. The intercept captures baseline structural drivers of petroleum exports, such as refinery capacity, trade agreements, and regulatory reforms. Since these structural factors are less predictable ex ante, a looser prior with variance two was chosen. This specification acknowledges the role of unobserved country and sector-specific influences without imposing strong restrictions on the baseline level of exports. Before the variance of the error term follows a moderately informative specification, reflecting the inherent volatility of the petroleum trade. Export flows are highly sensitive to global oil market fluctuations, geopolitical risks, and shipping costs. A prior mean of three with variance one provides stability in estimation while still permitting substantial variability in the error process, thereby avoiding artificially narrow posterior intervals. In this study, prior choices are guided not only by statistical considerations but also by economic reasoning drawn from the literature on trade and energy markets. They ensure that posterior results reflect both empirical evidence and plausible economic behavior: GDP growth exerts a strong but less than unitary impact, oil price effects are positive but limited, and structural uncertainty remains embedded in the intercept and error terms. By grounding priors in economic rationale, the Bayesian approach enhances interpretability, credibility, and transparency relative to purely frequentist estimation. Furthermore, with the selected priors, the convergence is achieved as shown from the MCMC simulation trace plots.

5. Diagnostic Results

The Breusch-Godfrey Lagrange Multiplier test, shown in Table 4, demonstrates that the model lacks serial correlation; the p-value of the test is more than the significance level, which is 0.6596. This illustrates that the serial correlation problem is not present in the dataset. Moreover, the results of the Breusch-Pagan, Harvey, and Glejser tests point to the absence of autoregressive conditional heteroscedasticity, as the probability value of the Breusch-Pagan-Godfrey test for heteroscedasticity is 0.9597, which is also greater than the significance level. Hence, we accept the null hypothesis that there is no autoregressive conditional heteroscedasticity, so, like another test of the heteroscedasticity, like the Harvey test, the p-value is 0.9161, and the same for the Gleiβser test is 0.9919; all the heteroscedasticity tests executed in the model represent that there is no heteroscedasticity present in the model. The last diagnostic test conducted in the model is for normality in the data set, which is the Jarque-Bera test for normality in the dataset. After looking into the p-value of the test, we know the data are standard because the p-value is more than 0.82, and we need to accept the null hypothesis of normality in the data set. The p-value of all the tests is greater than the significance level of 5%, which explains that there is 'no serial correlation, or heteroscedasticity in the model'. Meanwhile, all the probability values and matching F-statistics are shown in Table 4. After the diagnostic analysis, we concluded that our test in the paper demonstrates the model's accuracy and suitability, and the model is far from severe econometric hurdles.

Table 4: Diagnostic Findings

Test	Observe R^2	F-Stats	P-Value*
Serial Correlation: LM Test Breusch-Godfrey	1.26	0.42	0.6596
Breusch-Pagan-Godfrey	1.26	0.19	0.9597
Harvey	1.78	0.28	0.9161
Glejser	0.65	0.09	0.9910
Normality (Jarque-Bera)	-	-	0.82

Source: Authors

5.1 Stability Estimates

The cumulative sum test finds gradual changes in the regression coefficients over time. On the other hand, the cumulative sum of squares test is employed to detect sudden deviations from the stability of the regression coefficients. These tests help identify systematic and abrupt alterations in the regression coefficients, which are essential in analyzing data trends and patterns. This research utilized the CUSUM and CUSUMSQ tests to assess the model's stability. The analysis determines whether the model is stable. Using the stability approach, the ARDL-based F bound test, and the diagnostic test, the ECM demonstrates our model, and through both tests in Figures 3 and 4, respectively, our model reveals the best fit. The red line, called the critical line of the value, represents the guides for the stability of the estimation methods and was not crossed by any of the blue line plots. The blue line in the graph represents the model line that is being analyzed. The upper and lower red dotted lines indicate the boundaries that the model is expected to fit. The blue line should fall between the upper and lower bounds for the model to be accurate. This visual representation helps assess how well the model aligns with the expected range of values. Both the CUSUM and CUSUMSQ tests explain the stability of the model. Over the long run, the blue line will not cross or be tangent to the red upper and lower bounds line. The x-axis of the period is there, showing that the model is stable over the period. The goodness of fit of this model is excellently stated. India would apply the concept to decision-making and policy consequences. The approach also emphasizes that it produces reliable outcomes.

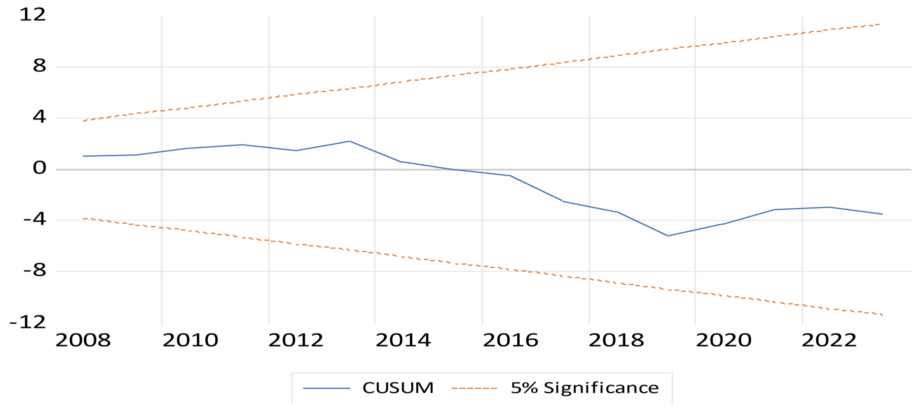


Fig 3: CUSUM

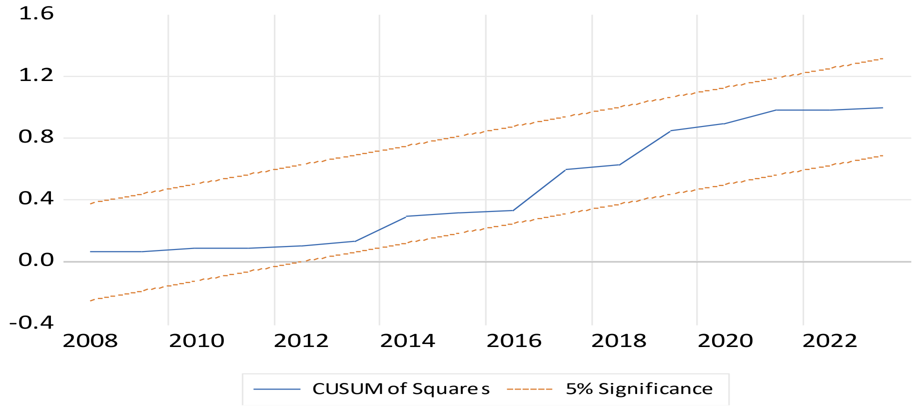
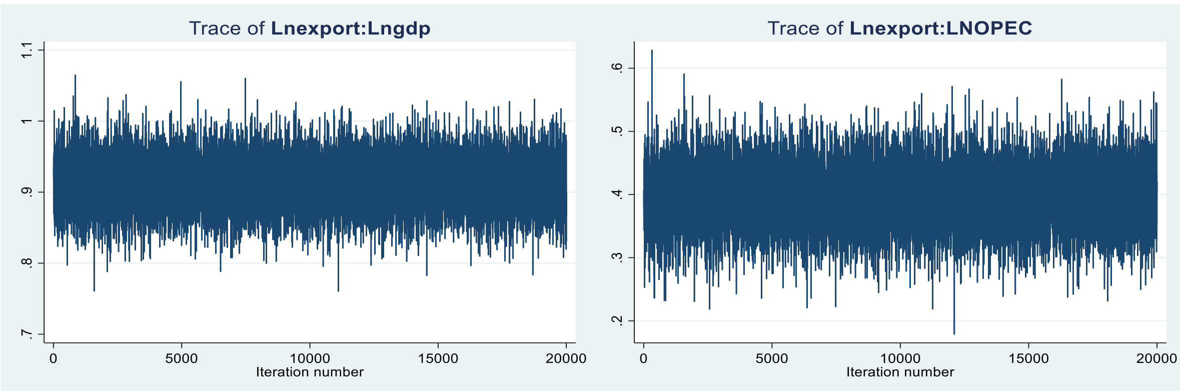


Fig 4: CUSUMSQ

Source: *Author's*

5.2 Bayesian Diagnostics Trace Plots

The 'Markov Chain Monte Carlo' convergence is an essential issue in MCMC simulation. However, Bayesian inference is only valid when the Markov chain converges. Figure 5 illustrates all variables through trace plots. A trace plot shows the estimated values of the parameter with respect to the iteration number. When it is a mixture of properties in a parameter exhibition, the trace plots quickly cover the entire posterior space while maintaining a stable mean and variance. The trace plots show convergence of LNEXPORT with GDP, OPEC oil prices, constant, and sigma2, where the mean is evenly distributed as seen from the trace plot. There are no hikes and trends in the parameters within the trace plots, and this demonstrates the convergence in the Bayesian regression, and it validates and affirms the robustness of the Bayesian linear regression. Equilibrium is a feature of Markov Chain Monte Carlo trace plots and is reached by building a Markov chain whose stationary distribution is the target probability distribution in the limit. More specifically, once enough iterations (or burn-in phase) have been performed, the samples output by the chain are independent and identically distributed according to the stationary distribution, which is a representative sample of the target distribution.



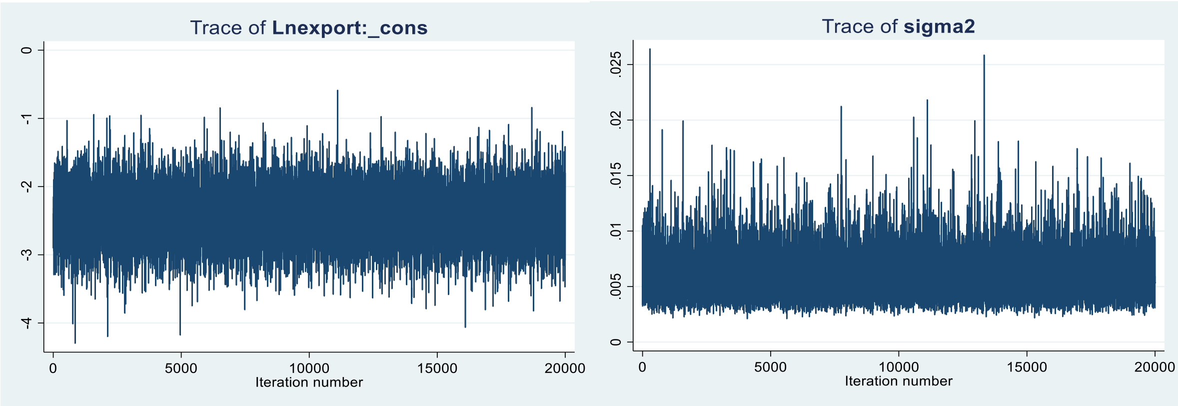


Fig 5: MCMC convergence trace plots.

Source: *Author's*

6. Conclusion

The case of management of the exportation of petroleum products and demand within the country poses a significant test to the Indian government. The country must generate adequate petroleum products to support its booming economy and satisfy its citizens. At the same time, India has evolved into a net exporter of petroleum products, central to the country's economy. Presently, India ranks fourth in refining capacity, and hence, to meet domestic needs at an affordable price, the government needs to invest more in this sector. India became a net exporter of petroleum products from the fiscal year 2001-2002. It has broadened the geographical spread of its exports to Asia, Africa, Europe, and North America. Trade has global political implications that are not merely commercial, as it positions India globally and gives it more recognition. It would be appropriate to state that petroleum products are one of India's crucial parts of the export basket. Petroleum products in HS-Code 2710 have remained the most significant single-category item in Indian exports from the period 2000 up to the current year. Crucial reforms in the petroleum industry in India, like reform in refining and oil-blending biofuel, bio-diesel, and ethanol blending, have therefore offered significant boosts to India's growth as a foremost exporter of petroleum products. Pivotal to these was the approval of private and foreign investment, the formation of which facilitated the development of private-sector refining. Out of these, the Reliance and Essar refineries occupy a one-third share of the total refining capability in India. Notably, private-sector refineries are prominent in India's exports of petroleum products and account for a staggering 90 per cent of the exports. This excess refining capacity and the administered petroleum products have been instrumental in India's exports of this much-needed commodity. However, the current study's findings show that efforts to enhance domestic demand and abolish the APM have destabilized exports of petroleum products and renewed refining interest in the home market. To maintain and strengthen these positions in the long term and meet both domestic requirements and the demand in the Indian market, India should increase its refining capacity. This can be done by venturing into establishing more refineries, either as export-oriented units or in special economic zones, to gear their exports and domestic supplies more to support the country's strong economic growth. In international market settlement, India gives payment in the form of rupees for its crude purchases, which increases the importance of local currency settlement for India and benefits India.

In this study, the autoregressive distributed lag and ordinary least squares model, which are frequentist methods based on t-value and probability estimates, reveal a significant role of GDP and OPEC oil prices on petroleum product exports from India, and diagnostic tests explain that there is no heteroscedasticity, autocorrelation, or multicollinearity problem in the model. The Cusum and Cusumsq test shows the stability in the ARDL modelling. Meanwhile, the non-frequentist approach of Bayesian linear regression does not so far differ from frequentist ARDL and OLS models and reveals the same association between the variables with the same impact signs. But the Bayesian linear regression has an advantage over frequentist methods by using prior information to predict the posterior distribution and handling small data sets. In this paper, to check the robustness of the Bayesian linear regression, MCMC convergence trace plots are derived, which represent the good mixing of the MCMC simulation algorithm in the Bayesian linear regression. This convergence of MCMC simulation through trace plots shows that over the time period, in the long run, the OPEC oil prices and GDP affect the petroleum products exports from India to the GCC countries. This convergence is depicted from the trace plots, with all parameters showing the long-run equilibrium condition where the selected regressors, OPEC oil prices and GDP of India, affect the petroleum products exports from India to GCC countries. Equilibrium is a feature of MCMC (Markov Chain Monte Carlo) algorithms, and is reached by building a Markov chain whose stationary distribution is the target probability distribution in the limit. More specifically, once enough iterations (or burn-in phase) have been performed, the samples output by the chain are independent and identically distributed according to the stationary distribution, which is a representative sample of the target distribution.

Despite India's strengthening position as a petroleum products exporter, several potential challenges could disrupt this trajectory. Geopolitical risks in the Gulf region, disruptions in shipping lanes, or sanctions on key crude suppliers could directly affect supply stability and trade flows. Moreover, increasingly stringent environmental regulations at the global level, such as carbon border adjustment mechanisms in Europe or new IMO emission rules for shipping, pose constraints on petroleum-based trade. These factors could reduce India's export competitiveness unless refiners adapt to cleaner technologies and compliance strategies. Looking ahead, while domestic reforms (e.g., ethanol blending, LNG infrastructure, and refinery expansion) support India's growth, the global energy transition presents both opportunities and risks. Rising adoption of biofuels, electric vehicles (EVs), and hydrogen technologies may gradually reduce international demand for traditional petroleum products. At the same time, India's refining capacity and experience could be leveraged to pivot toward exporting cleaner fuels, petrochemicals, and green hydrogen derivatives, positioning the country as a key player in the evolving global energy economy. Thus, India's export strategy must align not only with short-term market dynamics but also with the long-term shift toward decarbonization and energy diversification worldwide.

The study's findings will encourage other researchers and policymakers to extend the analysis to include exchange rates, global demand cycles, inflation, interest rates, and trade openness, which would provide a more holistic view of determinants influencing petroleum exports. Futures work should explicitly model the effects of OPEC+ production policies, global price volatility, and geopolitical disruptions in the Gulf region to assess India's trade resilience under stress conditions. Bayesian methods could be applied beyond petroleum products, for example, to natural gas, renewable energy, or coal exports, to test robustness and capture uncertainty in other segments of India's energy trade. Extending the framework to compare India's experience with other major petroleum exporters (e.g., China, Russia, or Brazil) could help benchmark India's global positioning. By embedding these extensions, future studies can generate deeper insights into India's energy trade under both stable and shock-driven global conditions.

The Bayesian framework adopted in this study strengthens transparency by making explicit the assumptions about how India's petroleum exports respond to macroeconomic drivers. Priors were calibrated to reflect both economic intuition and historical experience: GDP growth is expected to boost exports but with less than one-for-one elasticity, oil prices have a positive but modest impact, and structural uncertainties are captured through wider priors on the intercept and variance. Unlike frequentist estimates, these priors make the economic rationale visible, allowing policymakers to see how prior beliefs shape the results. Moreover, the Bayesian approach readily incorporates the possibility of external shocks, such as sudden changes in OPEC+ production policies, global price volatility, or geopolitical disruptions in the Gulf. By embedding uncertainty explicitly in the priors, the model produces posterior estimates that remain credible even when global oil market conditions shift. This ensures that India's trade position in petroleum products can be assessed under both stable and shock scenarios, making Bayesian methods particularly useful for forward-looking policy design in an era of heightened energy market volatility.

References

[1] Abbasi, K. R., Hussain, K., Radulescu, M., & Ozturk, I. (2022). Asymmetric impact of renewable and non-renewable energy on the industrial sector in Pakistan: Fresh evidence from Bayesian and non-linear ARDL. Renewable Energy, 187, 944–957. https://doi.org/10.1016/j.renene.2022.02.012.

[2] Abdelsalam, M. A. M. (2023). Oil price fluctuations and economic growth: The case of MENA countries. Review of Economics and Political Science, 8(5), 353–379. https://doi.org/10.1108/REPS-12-2019-0162.

[3] Aidarova, A. B., Mukhamediyeva, G., Yessentayeva, A. A., Utemissova, G., Tastanbekova, K., Mustafayeva, B., & Myrzabekkyzy, K. (2024). Relationship between oil exports, renewable energy consumption, agriculture industry, and economic growth in selected OPEC countries: A panel ARDL analysis. International Journal of Energy Economics and Policy, 14(6), 344–352. https://doi.org/10.32479/ijeep.17201.

[4] Al Humssi, A., Petrovskaya, M., & Abueva, M. (2022). Modelling the Impact of World Oil Prices and the Mining and Quarrying Sector on the United Arab Emirates' GDP. Mathematics, 11(1). https://doi.org/10.3390/math11010094.

[5] Alkahteeb, T. T., & Sultan, Z. A. (2019). Oil price and economic growth: The case of Indian economy. International Journal of Energy Economics and Policy, 9(3), 274–279. https://www.econjournals.com/index.php/ijeep/article/view/7602.

[6] Azhar, M. (2021). India's Emergence as a Petroleum Products Exporter. The Journal of Energy and Development, 47(1/2), 75–100. https://www.jstor.org/stable/27188914.

[7] Baumeister, C., & Hamilton, J. D. (2021). Drawing conclusions about economic policy from Bayesian vector autoregressions. Journal of Econometrics, 222(1), 271–293. https://ideas.repec.org/a/eee/jimfin/v109y2020ics0261560620302060.html.

[8] Bhattacharyya, S. C., & Blake, A. (2009). Domestic demand for petroleum products in MENA countries. Energy Policy, 37(4), 1552–1560. https://ideas.repec.org/a/eee/enepol/v37y2009i4p1552-1560.html.

[9] Block, J. H., & Wagner, M. (2014). The effect of family ownership on different dimensions of corporate social responsibility: Evidence from large US firms. Business Strategy and the Environment, 23(7), 475–492. https://onlinelibrary.wiley.com/doi/abs/10.1002/bse.1798.

[10] Briggs, W. M. (2023). A partial solution for the replication crisis in economics. Asian Journal of Economics and Banking, 7(2), 180–190. https://doi.org/10.1108/AJEB-03-2023-0027.

[11] Carriero, A., Clark, T. E., & Marcellino, M. (2022). Bayesian VARs: Specification choices and forecast accuracy. Journal of Applied Econometrics, 37(5), 901–920. https://ideas.repec.org/a/wly/japmet/v30y2015i1p46-73.html.

[12] Chan, J. C. C., & Eisenstat, E. (2022). Bayesian model averaging in oil market analysis. Energy Economics, 105.

[13] Dagar, V., & Malik, S. (2023). Nexus between macroeconomic uncertainty, oil prices, and exports: Evidence from quantile-on-quantile regression approach. Environmental Science and Pollution Research, 30(16), 48363–48374. https://link.springer.com/article/10.1007/s11356-023-25574-9.

[14] Del Negro, M., & Primiceri, G. E. (2022). Time-varying structural vector autoregressions and monetary policy. Review of Economic Studies, 89(2), 1002–1043. https://ideas.repec.org/a/oup/restud/v72y2005i3p821-852.html.

[15] Dion, M. L. (2022). Teaching ordinary least squares regression. In Teaching Graduate Political Methodology (pp. 134–142). Edward Elgar Publishing.

[16] Drachal, K., & Pawłowski, M. (2024). Forecasting Selected Commodities' Prices with the Bayesian Symbolic Regression. International Journal of Financial Studies, 12(2), 34. https://www.mdpi.com/2227-7072/12/2/34.

[17] Fraza, C. J., Dinga, R., Beckmann, C. F., & Marquand, A. F. (2021). Warped Bayesian linear regression for normative modelling of big data. NeuroImage, 245. https://doi.org/10.1016/j.neuroimage.2021.118715.

[18] Georgiou, G. P. (2024). Bayesian Models Are More Sensitive than Frequentist Models in Identifying Differences in Small Datasets Comprising Phonetic Data. Stats, 7(4). https://doi.org/10.3390/stats7040087.

[19] Giannone, D., Lenza, M., & Primiceri, G. E. (2021). Priors for the long run. Econometrica, 89(1), 151–194. https://ideas.repec.org/p/ecb/ecbwps/20182132.html.

[20] Gupta, P., & Goyal, A. (2015a). Impact of oil price fluctuations on Indian economy. OPEC Energy Review, 39(2), 141–161. https://onlinelibrary.wiley.com/doi/abs/10.1111/opec.12046.

[21] Gupta, P., & Goyal, A. (2015b). Impact of oil price fluctuations on Indian economy. OPEC Energy Review, 39(2), 141–161. https://onlinelibrary.wiley.com/doi/abs/10.1111/opec.12046.

[22] Hastie, T., & Tibshirani, R. (2022). Bayesian shrinkage priors in regression. Statistical Science, 37(2), 197–214.

[23] Iqbal, M., Arif, A. S., Jadoon, A. K., & Rana, A. D. (2023). The impact of debt service and inflation on economic growth in Pakistan: Evidence from ARDL model and approximate Bayesian analysis. Pakistan Journal of Commerce and Social Sciences (PJCSS), 17(2), 263–287. https://www.econstor.eu/handle/10419/278052.

[24] Jiao, Z., Sharma, R., Kautish, P., & Hussain, H. I. (2021). Unveiling the asymmetric impact of exports, oil prices, technological innovations, and income inequality on carbon emissions in India. Resources Policy, 74. https://ideas.repec.org/a/eee/jrpoli/v74y2021ics0301420721004177.html.

[25] Kalia, A. (2024a). CEO power and stock price crash risk in India: The moderating effect of insider trades. Asian Journal of Economics and Banking, ahead-of-print. https://doi.org/10.1108/AJEB-10-2023-0095.

[26] Kalia, A. (2024b). CEO power and stock price crash risk in India: The moderating effect of insider trades. Asian Journal of Economics and Banking, ahead-of-print. https://doi.org/10.1108/AJEB-10-2023-0095.

[27] Karlsson, S. (2021). Forecasting with Bayesian methods. In G. Elliott & A. Timmermann (Eds.), Handbook of economic forecasting (Vol. 2B, pp. 791–897). Elsevier. https://ideas.repec.org/h/eee/ecofch/2-791.html.

[28] Kathiravan, C., Selvam, M., Maniam, B., Dana, L. P., & Babu, M. (2023). The Effects of Crude Oil Price Surprises on National Income: Evidence from India. Energies, 16(3). https://doi.org/10.3390/en16031148.

[29] Koop, G., & Korobilis, D. (2021). Large time-varying parameter VARs with stochastic volatility. Journal of Econometrics, 222(1), 36–54. https://ideas.repec.org/a/eee/econom/v177y2013i2p185-198.html.

[30] Kotsakis, C. (2023). Ordinary Least Squares. In Encyclopedia of Mathematical Geosciences (pp. 1032–1038). Springer. https://doi.org/10.1007/978-3-030-85040-1_237.

[31] Kulkarni, M., Tikyani, J., & Singh, K. K. (2023). Impact of COVID-19 on Import and Export of Petroleum Products and Crude Oil in India. 21–31. https://www.springerprofessional.de/en/impact-of-covid-19-on-import-and-export-of-petroleum-products-an/24060730.

[32] Latief, N. F., Chauhan, R., Thakar, I., Maseleno, A., & Wahyudi, A. (2020). Impact, Cause and Trend: India's Trade of Crude and Petroleum Products. International Journal of Advanced Science and Technology, 29(06), 1823–1831. https://repository.iain-manado.ac.id/405/.

[33] Lee, C.-Y., & Huh, S.-Y. (2017). Forecasting long-term crude oil prices using a Bayesian model with informative priors. Sustainability, 9(2), 190. https://doi.org/10.3390/su9020190.

[34] Liu, H., & Chen, Y. (2023). Bayesian structural equation modeling of renewable energy, oil prices, and GDP in emerging economies. Renewable and Sustainable Energy Reviews, 174.

[35] Mehrara, M., Seijani, S., & Karsalari, A. R. (2017). Determinants of high-tech export in developing countries based on Bayesian model averaging. Zbornik Radova Ekonomskog Fakulteta u Rijeci: Časopis Za Ekonomsku Teoriju i Praksu, 35(1), 199–215. https://ideas.repec.org/a/rfe/zbefri/v35y2017i1p199-215.html.

[36] Michaelides, P. G. (2025). Ordinary Least Squares. In 21 Equations that Shaped the World Economy: Understanding the Theory Behind the Equations (pp. 29–44). Springer. https://doi.org/10.1007/978-3-031-76140-9.

[37] Montant, G. (2024). The Effectiveness of OPEC and Opec+ from 2009 to 2023: An Empirical Appraisal. https://dx.doi.org/10.2139/ssrn.4700404.

[38] Negi, P. (2015). Impact of oil price on economic growth: A study of BRIC nations. Indian Journal of Accounting, 47(1), 144–155. https://www.scirp.org/reference/referencespapers?referenceid=2694516.

[39] Nguyen, H. T., Trung, N. D., & Thach, N. N. (2019). Beyond traditional probabilistic methods in econometrics. 3–21. http://dx.doi.org/10.1007/978-3-030-04200-4_1.

[40] Noor, H., & Noor, S. (2024). A Gravity Model Approach for Determining Foreign Direct Investment Flows between India and the Gulf Cooperation Council (GCC) Countries. Saudi J Econ Fin, 8(7), 220-229. https://saudijournals.com/articles/10418/.

[41] Obadi, S. M., & Korcek, M. (2024). The relationship between geopolitical events and the crude oil prices: An application of ARDL model. International Journal of Energy Economics and Policy, 14(5), 85–97. https://doi.org/10.32479/ijeep.16487.

[42] Olayungbo, D. O., Zhuparova, A., & Al-Faryan, M. A. S. (2023). Oil supply and oil price determination among OPEC and non-OPEC countries: Bayesian Granger network analysis. Economic Change and Restructuring, 56(6), 4603–4628. http://dx.doi.org/10.1007/s10644-023-09565-x.

[43] Pandey, R., Chand, D. B., & Tolani, H. (2023). Bayesian Multiple Linear Regression Model for Gross Domestic Product in Bhutan. Advances and Applications in Statistics, 87(2), 161–190. http://dx.doi.org/10.17654/0972361723033.

[44] Pandey, R., Chand, D. B., & Tolani, H. (2024). Bayesian multiple linear regression model for GDP in India. International Journal of System Assurance Engineering and Management, 15(6), 2170–2187. https://doi.org/10.1007/s13198-023-02233-3.

[45] Parikh, J., Purohit, P., & Maitra, P. (2007). Demand projections of petroleum products and natural gas in India. Energy, 32(10), 1825–1837. https://doi.org/10.1016/j.energy.2007.02.008.

[46] Periwal, A. (2023). The Impact of Crude Oil Price Fluctuations on Indian Economy. International Journal for Research in Applied Science and Engineering Technology, 11(4), 3173–3202. https://doi.org/10.22214/ijraset.2023.50851.

[47] Pesaran, M. H., & Shin, Y. (1995). An autoregressive distributed lag modelling approach to cointegration analysis (Vol. 9514). Department of Applied Economics, University of Cambridge Cambridge, UK. https://ideas.repec.org/p/cam/camdae/9514.html.

[48] Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 16(3), 289–326. https://www.jstor.org/stable/2678547.

[49] Petrović, A., & Vukadinović, P. (2022). Bayesian quantile regression for crude oil price volatility. Applied Economics Letters, 29(20).

[50] Rahiman, H. U., & Kodikal, R. (2019). Ups and downs in the Indian economy: The impact of crude oil prices. Int. J. Sci. Technol. Res, 8(8), 846–857.

[51] Rajan, A. M. S. (2012). Globalization and Its Impact on India's Petroleum Exports. Journal Impact Factor, 3(3), 17–24. https://iaeme.com/Home/article_id/IJM_03_03_003.

[52] Rao, R. D., & Parikh, J. K. (1996). Forecast and analysis of demand for petroleum products in India. Energy Policy, 24(6), 583–592. https://ideas.repec.org/a/eee/enepol/v24y1996i6p583-592.html.

[53] Rafiqul, I., & Alam, S. (2022). Bayesian hierarchical modeling of CO_2 emissions and energy use in Asia. Energy Policy, 165, http://dx.doi.org/10.1177/21582440241268739.

[54] Roy, A. (2023). Nexus between economic growth, external debt, oil price, and remittances in India: New insight from novel DARDL simulations. Resources Policy, 83, https://doi.org/10.1016/j.resourpol.2023.103742.

[55] Salem, L. B., Nouira, R., Saafi, S., & Rault, C. (2024). How do oil prices affect the GDP and its components? New evidence from a time-varying threshold model. Energy Policy, 190, https://ideas.repec.org/a/eee/enepol/v190y2024ics0301421524001824.html.

[56] Sarkar, B., & Mathew, J. (2018). Causes of Indian Basket Crude Oil Price Fluctuations and Its Impact on Indian Economy. SDMIMD Journal of Management, 9(2), 9–22. https://doi.org/10.18311/sdmimd/2018/21683.

[57] Shalu, K., Singh, K., Kaur, S., & Sikka, P. (2023). Petroleum Export Performance in India: Analysis of Growth and Structural Dynamics. https://www.soed.in/article/889.

[58] Sharma, P., & Shrivastava, A. K. (2024). Economic activities and oil price shocks in Indian outlook: Direction of causality and testing cointegration. Global Business Review, 25(3), 771–790. https://doi.org/10.1177/0972150921990491.

[59] Soundarapandiyan, K., & Ganesh, M. (2017). An Analytical view of crude oil prices and its impact on Indian Economy. IOSR Journal of Business and Management (IOSR-JBM), 23–28.

[60] Thach, N. N. (2020). How to explain when the ES is lower than one? A Bayesian nonlinear mixed-effects approach. Journal of Risk and Financial Management, 13(2), 21. https://doi.org/10.3390/jrfm13020021.

[61] Thach, N. N. (2023). Applying Monte Carlo simulations to a small data analysis of a case of economic growth in COVID-19 times. Sage Open, 13(2), https://doi.org/10.1177/21582440231181540.

[62] Thach, N. N. (2025). Which, renewable or non-renewable energy, is more vital for the economic growth of OECD countries? A Bayesian hierarchical analysis. Heliyon. https://doi.org/10.1016/j.heliyon.2025.e42259.

[63] Thach, N. N., Kreinovich, V., Ha, D. T., & Trung, N. D. (2022). Financial econometrics: Bayesian analysis, quantum uncertainty, and related topics (Vol. 427). Springer Nature. http://dx.doi.org/10.1007/978-3-030-98689-6.

[64] Tiwari, A. K. (2015). On the dynamics of Indian GDP, crude oil production and imports. OPEC Energy Review, 39(2), 162–183. https://doi.org/10.1111/opec.12047.

[65] Tuan, T. A., Kreinovich, V., & Nguyen, T. N. (2019). Decision making under interval uncertainty: Beyond Hurwicz Pessimism-optimism criterion. 176–184. http://dx.doi.org/10.1007/978-3-030-04200-4_14.

[66] Van Doorn, J., Van Den Bergh, D., Böhm, U., Dablander, F., Derks, K., Draws, T., Etz, A., Evans, N. J., Gronau, Q. F., & Haaf, J. M. (2021). The JASP guidelines for conducting and reporting a Bayesian analysis. Psychonomic Bulletin & Review, 28, 813–826. https://doi.org/10.3758/s13423-020-01798-5.

[67] WDI_ DataBank.html. (2025).

[68] Wang, Z., & Zhang, L. (2021). A Bayesian approach to analyzing global energy trade networks. Energy Economics, 95, 105137.

[69] Wooditch, A., Johnson, N. J., Solymosi, R., Medina Ariza, J., & Langton, S. (2021). Ordinary least squares regression. In A Beginner's guide to statistics for criminology and criminal justice using R (pp. 245–268). Springer. http://dx.doi.org/10.1007/978-3-030-50625-4.

[70] Zavaleta, A., Walls, W., & Rusco, F. W. (2015). Refining for export and the convergence of petroleum product prices. Energy Economics, 47, 206–214. https://ideas.repec.org/a/eee/eneeco/v47y2015icp206-214.html.

Appendix:

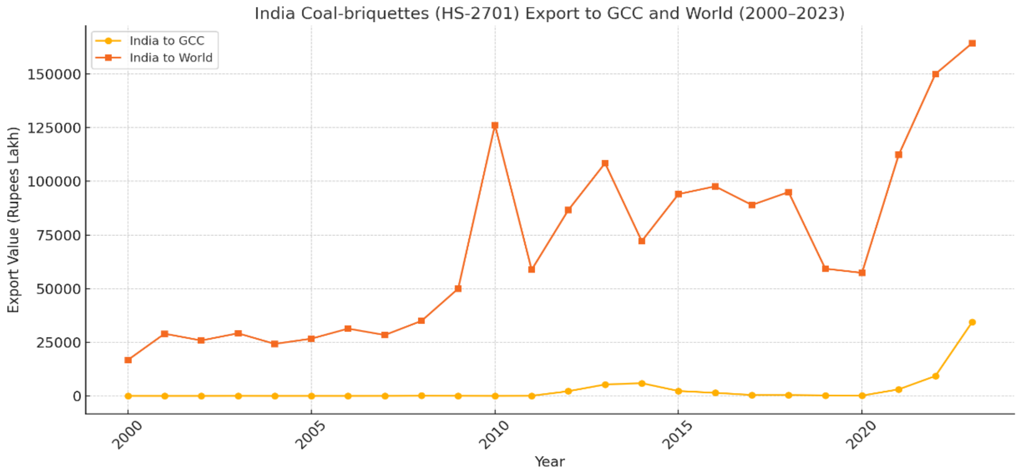


Fig 6: India's Export of HS-2701 to GCC and World.

Source: *Author's*

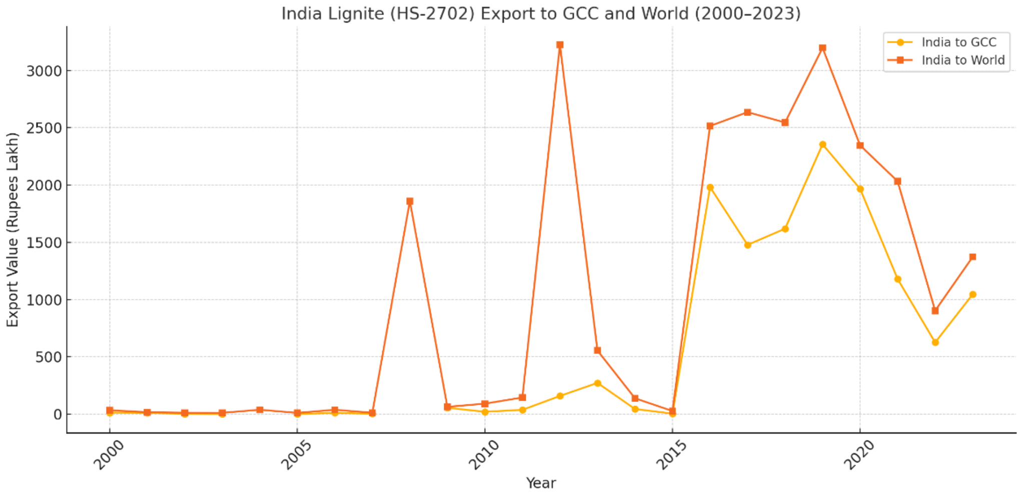


Fig 7: India's Export of HS-2702 to GCC and World.

Source: *Author's*

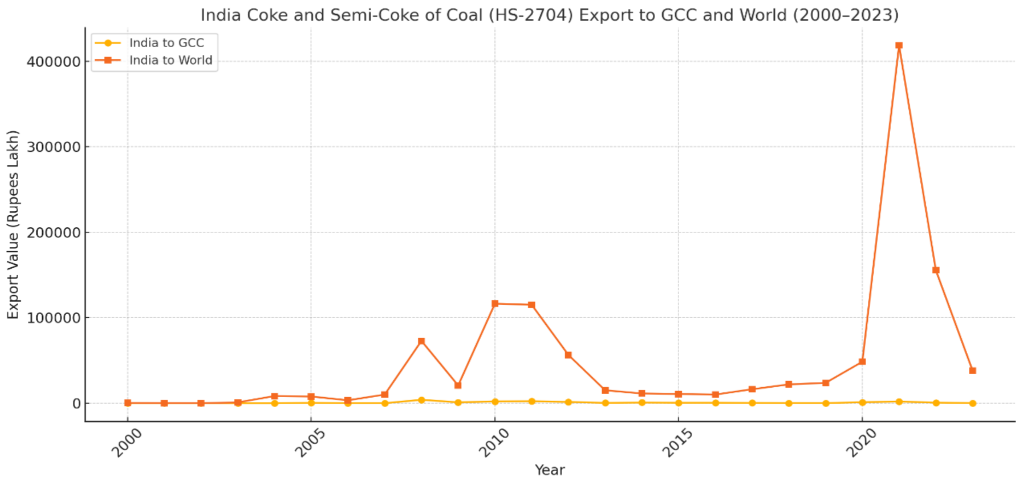


Fig 8: India's Export of HS-2704 to GCC and World.

Source: *Author's*

Fig 9: India's Export of HS-2707 to GCC and World.

Source: *Author's*

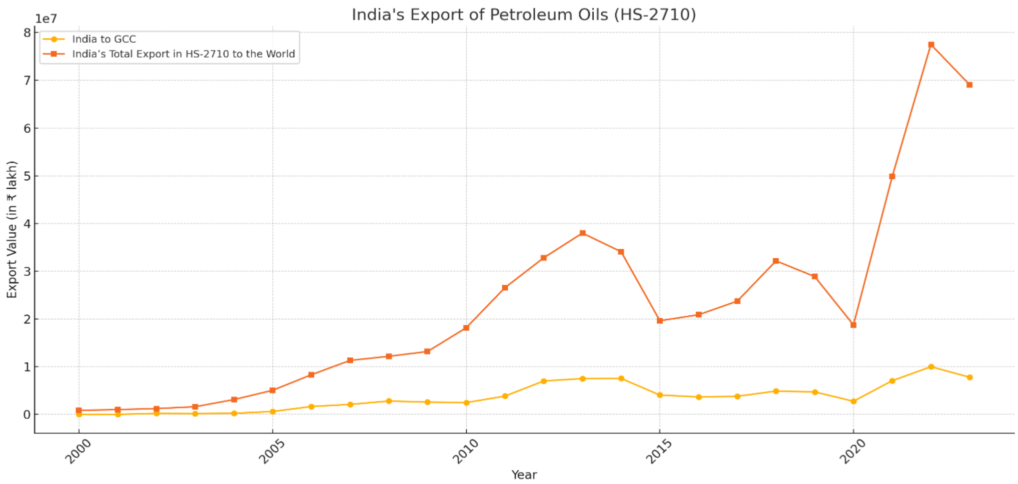


Fig 10: India's Export of HS-2710 to GCC and World.

Source: *Author's*

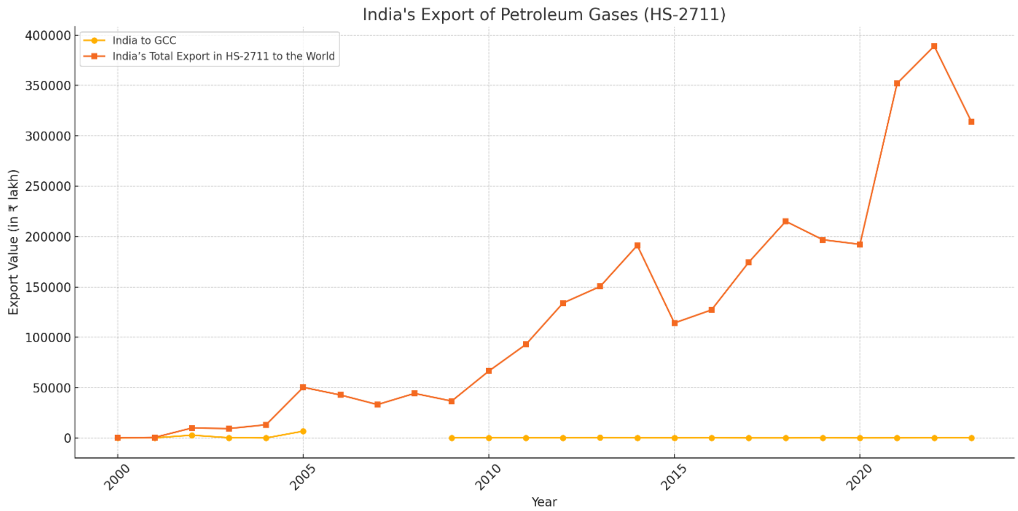


Fig 11: India's Export of HS-2711 to GCC and World.

Source: *Author's*

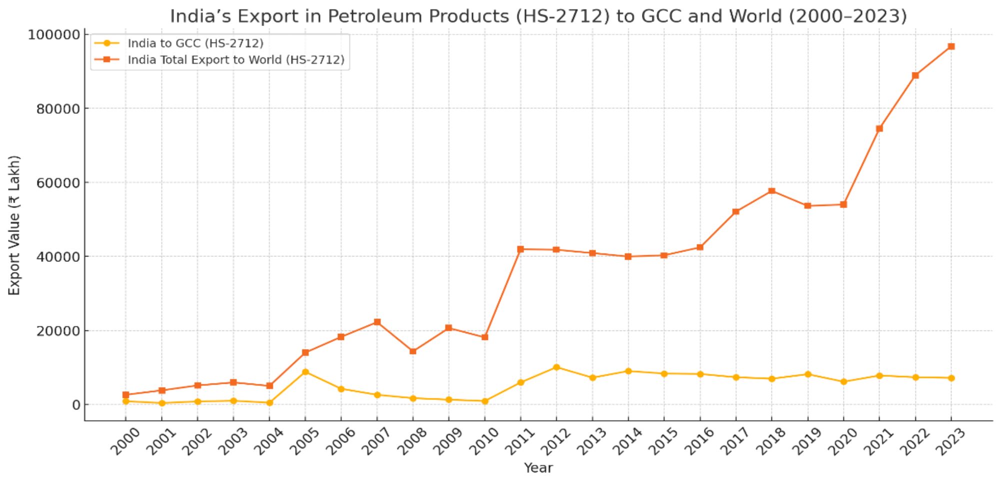


Fig 12: India's Export of HS-2712 to GCC and World.

Source: *Author's*

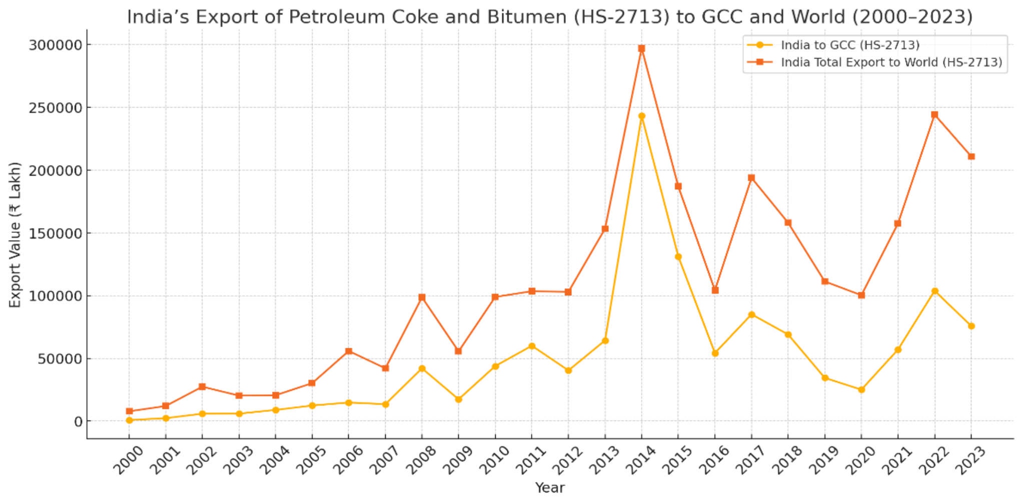


Fig 13: India's Export of HS-2713 to GCC and World.

Source: *Author's*

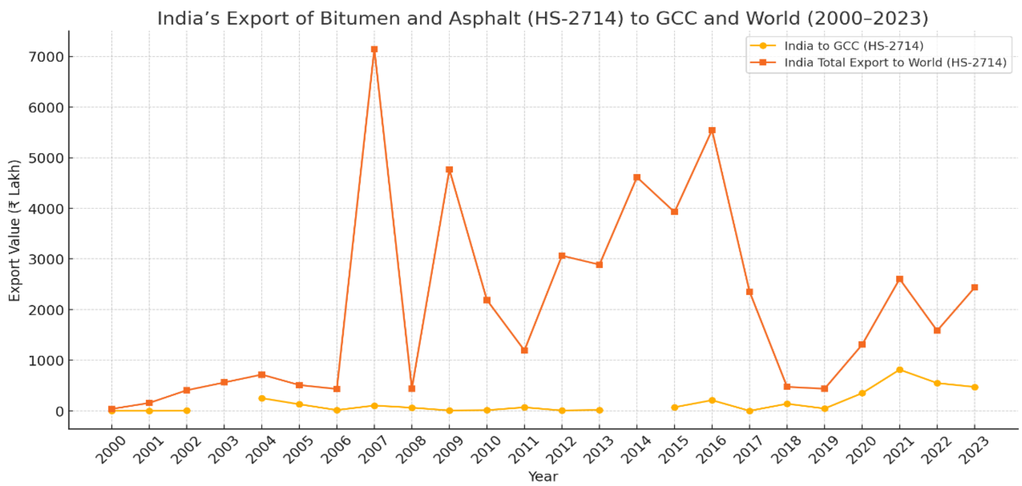


Fig 14: India's Export of HS-2714 to GCC and World.

Source: *Author's*

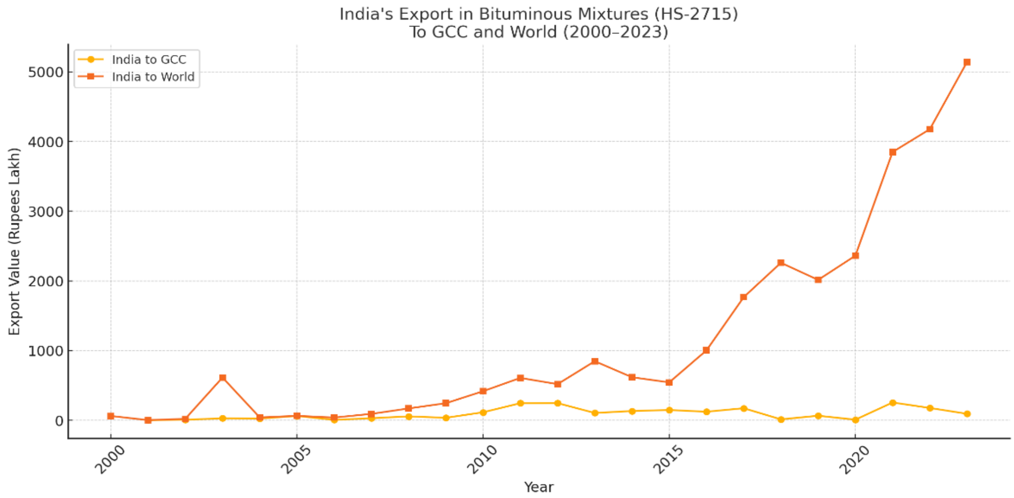


Fig 15: India's Export of HS-2715 to GCC and World.

Source: *Author's*