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Article

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Market dynamics in India: analysing interconnections among oil, stocks, gold and forex markets

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ABSTRACT

This paper examines the relationship between India's Stock Market, Forex Market, Oil Market, and Gold Market to capture interdependencies addressing both direct and indirect market linkages. The study provides new insights into the interdependencies of key markets within India, an emerging economic powerhouse and significant oil consumer. For the same, our analysis is divided into two parts. Part 1 is based on daily data, where we explore the long-run relationships from 1st January 2000 to 15th December 2023 among the markets (oil, stock, gold, and forex) using the Vector Error Correction Model. Further, monthly data from January 2000 to December 2023 (Part-2) has been employed to analyse market mechanisms through intermediary variables. We use data from 10 macroeconomic variables: Bombay Stock Exchange (BSE) Prices, INR/USD Exchange Rate, Consumer Price Index, Bank Interest Rate, 91-day Risk-free Government Bond Yield, Global WTI Oil Prices, WTI Futures, National Gold Prices, and India's and China's Imports and utilised Simultaneous Equation Models. As a major oil refiner, Indias deepening integration into global economy highligjts its markets' role in shaping international strategies and promoting insights into resilience and interdependencies amid uncertainty. Oil prices (WTI) are positively associated to WTI futures, reflecting the forward-looking nature, while gold shows a weak negative, though statistically insiginificant correlation with WTI, indicating minimal direct impact.

IMPACT STATEMENT

This research provides a comprehensive analysis of the interdependencies among India's stock, forex, oil, and gold markets, shedding light on their dynamic relationships and resilience in the context of a rapidly globalizing economy. The findings not only enhance our understanding of market interconnections in one of the world's largest oil consumers but also offer critical insights for policymakers, investors, and global economic strategists navigating uncertainty and volatility in interconnected markets.

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1. Introduction

The volatile nature of global market fluctuations is a growing concern in the current era. Investors, portfolio traders, foreign institutional investors (FII), and foreign direct investors (FDI) benefit from understanding the interactions between the oil, stock, forex, and gold markets. Insights into how changes in one market affect others are advantageous.

The stock market, reflecting investor sentiment and corporate performance, serves as an economic health indicator. Stock value fluctuations, influenced by economic growth, corporate profits, and geopolitical events, can trigger broader financial impacts and alter investor risk perceptions. The forex market, the largest and most liquid financial market globally plays a crucial role in determining currency values,

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influenced by factors like interest rates, inflation, and geopolitical events. These currency value changes affect global trade, impacting firms' profitability and competitiveness.

The oil market, pivotal to the global energy sector, influences economic conditions through price fluctuations driven by supply and demand, geopolitical factors, and macroeconomic indicators. These fluctuations affect various industries, impacting inflation and economic growth. Gold, seen as a safe investment, becomes a haven during economic instability, with its price dynamics influenced by interest rates, inflation expectations, and currency fluctuations, showing complex interconnections with the stock and forex markets.

Understanding these interrelations is vital for policymakers, investors, and businesses navigating the global economy. This study enhances the understanding of economic interdependencies between the stock, forex, oil, and gold markets, emphasising a comprehensive approach to financial analysis and risk management in a globalised financial landscape. This connectedness is crucial for understanding how economic shocks in one sector can propagate through others, impacting global financial stability. Specifically, the interconnectedness reflects on volatility spillovers among these markets, which are essential for risk management and investment strategies.

The independence model between variables is ambiguous, especially when assessing forex and stock data. Various studies on the relationships between gold, oil, exchange rates, and stock markets show mixed results. Using daily data, this study aims for more accurate findings by considering immediate and long-term effects via cointegration. The model aids FDI, FII, and investors optimise portfolios by analysing causal links among these factors. A sophisticated econometric model helps policymakers understand the interrelationships, aiding timely decision-making in economic contagion and external shocks.

Building on Arfaoui and Ben Rejeb (2017) work, this study explores the complex economic interconnections between the stock, forex, oil, and gold markets, providing insights into global financial environments. These markets, representing specific asset classes, are integral to the economic system, with changes in one affecting others. The study uses historical data, market trends, and financial indicators to clarify these interrelationships.

This paper distinguishes itself by focusing on four market variable dependencies, unlike most existing literature that examines bilateral or trilateral relationships, while in this study we have taken four types of markets. It adapts Arfaoui and Ben Rejeb's (2017) global model to the Indian context, our innovation is using daily data from 1 January 2000 to 15 December 2023, to analyse recent market patterns including the disruption period of Covid-19 pandemic, the ongoing conflicts of the Russia-Ukraine (2022 and ongoing) and Israel-Hamas (2023). First, we employ the Johansen Cointegration test on daily data to understand long-run relationships. Also, the study utilises monthly data over 23 years that have been examined to study the interdependencies via the simultaneous equation method.

High-frequency data is highly beneficial for obtaining more robust results in financial analyses due to its ability to capture more granular insights into market dynamics. For instance, intra-day data provide a much richer understanding of variable fluctuations compared to low-frequency data, thereby enhancing the precision of volatility estimates through the adoption of a high sampling frequency (Alam et al., 2019). It includes more observations within a given time frame, allowing for more detailed and timely detection of patterns, trends, and anomalies that lower-frequency data might miss. For instance, high-frequency data can reveal intra-day volatility, microstructural changes in the market, and immediate responses to news or economic events. This granularity enhances the accuracy of models that predict market movements, improves the assessment of risk, and allows researchers and practitioners to test economic theories with greater precision.

The Johansen Cointegration test reveals stable long-term relationships among the studied variables, indicating they move together over time despite short-term fluctuations. Oil prices (WTI) show a strong positive correlation with WTI futures, reflecting the forward-looking nature of the oil market. However, gold prices have a negative but non-significant correlation with WTI, suggesting minimal direct influence. The exchange rate (INR/USD) has a positive but statistically insignificant impact on WTI prices. The BSE Index inversely correlates with WTI prices, indicating that rising stock market indices are associated with a slight decline in oil prices. The CPI also shows a negative but statistically insignificant correlation with WTI prices, indicating no direct inflationary impact. Indian imports strongly correlate with WTI prices, highlighting increased demand's impact, while Chinese imports show an insignificant effect. The BSE

Index significantly interacts with the exchange rate, gold prices, WTI futures, and CPI, with a rising index linked to a stronger currency and higher stock prices. Gold prices are negatively affected by a thriving stock market and exchange rate depreciation, indicating shifts in investment preferences. Macroeconomic factors like the risk-free rate and bank rate also influence market dynamics, with the risk-free rate positively correlating with WTI prices and the bank rate showing an inverse correlation. Fluctuations in stock market indices and exchange rates significantly influence investor sentiment and behaviour, driving the interconnected dynamics of these markets.

India is one of the largest importers of crude oil and major exporter of refined oil products. Due to its limited domestic crude oil production, India heavily relies on crude oil imports to meet its energy needs. It imports crude oil from several countries, including Saudi Arabia, the United Arab Emirates, and the war-torn region (Russia). Conversely, India has a robust refining sector, which allows it to refine imported crude oil and export refined petroleum products. This capacity makes it one of the major players globally in exporting refined oil products such as diesel and gasoline. The extensive refinery network in India contributes significantly to the country's exports and positions India as a key supplier in the international market for refined oil products. Additionally, the revenue from exporting refined petroleum products plays a vital role in the country's GDP and fiscal health. Understanding the interplay between oil prices and stock market performance is crucial as many of India's large-cap stocks are in the energy sector. This study can provide insights into how variations in oil prices influence stock market trends and investor sentiment. Moreover, gold is often viewed as a hedge against inflation and currency depreciation, making it a critical factor in this analysis. By examining these interconnected markets, the study offers valuable insights for policymakers, investors, and financial analysts to make informed decisions, especially in a rapidly changing global economic landscape where energy markets play a pivotal role.

The studies suggest that the interconnectedness among these markets allows for the transmission of systematic risks and spillovers, which are crucial during times of economic turbulence, such as the 2008 financial crisis or the COVID-19 pandemic (Chatziantoniou et al., 2022; Ding et al., 2021). This transmission can significantly affect global economic stability and individual investment portfolios, making it essential to understand these dynamics for effective risk management and hedging strategies. Volatility in one market can lead to substantial impacts across others. For instance, a surge in oil prices can increase inflation expectations, affecting forex markets and the overall economic conditions, which in turn influence stock and gold prices (Husain et al., 2019; Gokmenoglu & Fazlollahi, 2015). Moreover, volatility indices like OVX (oil volatility) and GVZ (gold volatility) provide insights into the expected market turbulence, which can help in predicting future market movements and making more informed investment decisions (Gokmenoglu & Fazlollahi, 2015).

For policymakers, understanding the interlinkages among these markets is vital for developing strategies that stabilize one market to prevent cascading effects on others. This is particularly important for countries heavily reliant on commodities exports or those with significant forex market exposures (Naeem et al., 2020). Understanding the dynamic relationships among these markets helps in crafting effective risk management and hedging strategies. For instance, during periods of high oil price volatility, understanding its potential impact on currency and stock markets can help investors and companies better manage their exposure to risk (Trabelsi, 2019).

India is a crucial context for studying market interdependencies due to its status as one of the world's largest emerging economies and a significant consumer of oil and gold. The Bombay Stock Exchange (BSE), a major stock exchange in Asia, serves as a vital indicator of economic health and investor sentiment. Additionally, the INR/USD exchange rate is essential for understanding India's international economic competitiveness. The country's macroeconomic variables, such as the Consumer Price Index and Money Supply, further enrich the analysis. India's geopolitical influence and trade relationships, particularly with China, add complexity to market interactions. The nation's economic reforms and diverse investment landscape offer a unique setting to examine the interactions between traditional and modern financial instruments. Understanding these dynamics in India helps in formulating effective economic policies and investment strategies.

The study's findings suggest several key policy implications. To stabilize oil prices, policymakers should implement forward-looking strategies, such as strategic petroleum reserves and futures market interventions. Maintaining stable exchange rates and adjusting interest rates can also help manage oil

price volatility. Promoting stock market growth and encouraging diversified investment portfolios can dampen oil price increases and protect investors. Monitoring inflation and regulating oil imports are essential to control price fluctuations while promoting alternative energy sources and energy efficiency can reduce dependency on oil imports. Finally, understanding the impact of macroeconomic factors on investor sentiment can help design measures to stabilize markets and enhance investor decision-making through education and transparent information.

2. Literature review

Ingalhalli et al. (2016) examined the causal relationship between India's oil, gold, forex, and stock markets from 2005 to 2015. Found a unidirectional relationship where oil prices influence exchange rates and gold prices, with stock price fluctuations impacting oil prices. A. Kumar et al. (2019) analysed monthly data from 2010 to 2018, exploring the dynamic association between stock markets, forex, gold, and oil prices in India. The Granger causality test reveals that gold, oil, and forex precede the development of the Sensex, while none of these variables influence each other directly. Coronado et al. (2018) investigated relationships between crude oil, gold, and stock markets, concluding significant interactions among these markets, with oil prices notably impacting stock market returns. Arfaoui and Ben Rejeb (2017) examined interdependencies between oil, gold, the US dollar, and stock prices from 1995 to 2015. Found significant direct and indirect interactions among these markets, highlighting global interdependencies and the financialization of commodity markets.

Chkili and Nguyen (2014) studied exchange rate movements and stock market returns in BRICS countries within a regime-switching environment, emphasizing the impact of exchange rate fluctuations on stock market returns. Salisu et al. (2021) focused on BRICS countries, highlighting the strong influence of oil prices on stock market volatility and exchange rate movements. Rehan et al. (2019) explored the relationship between exchange rates and stock prices in South Asian countries, finding no consistent long-term relationship but identifying significant short-term interactions, particularly between exchange rates and stock market indices. Victor et al. (2021) analysed dynamic interlinkages between exchange rates and the NSE NIFTY index in India, finding no consistent long-term correlation but identifying short-term Granger causality between various exchange rates and the NSE NIFTY.

Mishra et al. (2007) explored volatility transmission between Indian stock and foreign currency markets using GARCH and EGARCH methods, finding reciprocal volatility spillovers between the markets. Apte (2001) investigated the interrelationship between stock market volatility and nominal exchange rate volatility in India using an E-GARCH model, finding significant volatility spillovers with asymmetric effects of positive and negative returns on volatility. Vyas et al. (2014) study is related to the subprime mortgage crisis, and investigated correlations between stock prices, money demand, interest rates, foreign institutional investment, and exchange rates in India. Found that stock return changes influence currency rates, foreign institutional investment, and money demand. S. Kumar and Prabheesh (2023) reassessed the interplay between stock, oil, and forex markets amid COVID-19-induced uncertainty in emerging market economies (EMEs). Confirmed that COVID-19 uncertainty negatively impacted oil industry profitability, stock returns, and exchange rates in developing countries. Asad et al. (2020) investigated asymmetric relationships between gold, oil, and exchange rate volatilities and the Bombay Stock Exchange (BSE) before, during, and after the 2008 global financial crisis using the Nonlinear Autoregressive Distributed Lag (NARDL) model.

Naik (2013) examined the relationship between macroeconomic factors and stock market behaviour in India using monthly data from 1994 to 2011. Found that stock prices in India are positively related to money supply and industrial production but negatively related to inflation. Aggarwal and Saqib (2017) studied macroeconomic factors impacting the Indian stock market, particularly the Nifty 50 index. Identified significant influences from the U.S. GDP, S&P index, gold prices, Indian wholesale price index, fiscal deficit, IPI, and exchange rate.

Yuan et al. (2020) observed the relationship between the Chinese stock market and exchange rates with a focus on the Belt and Road Initiative (BRI). Found a significant correlation between exchange rates and stock indices, indicating that the BRI strengthens the interconnection between China's foreign exchange market and its stock market. Javangwe & Takawira (2022) explored the relationship between exchange rates and stock market performance in South Africa from 1980 to 2020. Revealed a significant

long-term negative correlation between the stock market and both exchange rates and interest rates, as well as inflation. Sarno and Taylor (2002) reviewed extensive literature on purchasing power parity (PPP) and the real exchange rate. Highlighted significant findings, such as the presence of nonlinearities in the mean reversion of real exchange rates and the role of real shocks on long-term equilibrium levels.

Tran and Nguyen (2022) examined the dynamic correlation between stock markets, gold prices, and USD exchange rates during the COVID-19 pandemic in 55 Asian and 32 European countries. They found bidirectional causality between stock markets and gold prices in Asian countries, and unidirectional causality from stock markets to USD exchange rates. Mishra (2004) analysed the relationship between the stock and foreign currency markets in India using Granger's Causality test and Vector Auto Regression methods. Their study found no significant causal relationship between stock returns and exchange rate returns, suggesting policymakers might mitigate stock market crises by managing exchange rates. Bahmani-Oskooee and Saha (2015) examined the relationship between stock prices and currency rates post-1973, finding stronger correlations in Asian countries during the 1997 financial crisis, suggesting significant interdependencies between these markets.

The overall model of independence between variables appears ambiguous, particularly when evaluating the relationship between Forex and Stock market variables. Furthermore, most of these papers used monthly data to draw their findings. Daily and monthly data from 2000 till 2023 for this study would provide an additional benefit in attaining a more accurate conclusion of our findings. Using Simultaneous Equations, we conduct hypothesis testing to determine the presence and characteristics of links between variables. This encompasses the examination of cointegration and causation via testing. The primary reason for employing such models in our research is to enable dynamic analysis by considering the delayed impacts, making them appropriate for comprehending the temporal influence of changes in one variable on others. Such models provide the examination of both immediate and enduring interactions among both ends as well as intermediate variables. This is accomplished by considering the immediate effects over time using delayed terms and the long-term balance connection via cointegration. The primary purpose of constructing such a model is to assist in the timely decision-making of FDI, FII, traders, and investors in optimising their portfolios by analysing the causal link among these factors.

These studies explain why it helps investors, policymakers, and economists to make informed decisions, anticipate market movements, and develop strategies to mitigate risks and seize opportunities across different financial markets. These findings of numerous studies highlight the need for investors to diversify portfolios and for policymakers to consider the interdependencies of these financial markets during economic uncertainties such as the COVID-19 pandemic. The structure of the paper is outlined as follows: Section 3 discusses the study's theoretical framework. Section 4 provides an overview of the data used and the methodologies employed. Section 5 presents the findings, which are then discussed in depth in Section 6. Finally, Section 7 summarizes the conclusions drawn from the results.

3. Theoretical framework

3.1. Theoretical underpinnings

Crude oil is vital to the global economy, serving as both fuel for transport like cars, planes, and ships, and as a key ingredient in making chemicals, plastics, and other crucial products. Its widespread use means that any major disruptions in oil supply or price changes can deeply affect economies worldwide (Alam et al., 2019). This makes oil a frequent target for sanctions and a key factor in global politics. Oil is often the most sanctioned commodity due to its critical importance and the fact that large reserves are usually found in politically unstable regions, where it is leveraged by nations to wield power. As per the Center for Strategic and International Studies (CSIS)[1]: Energy sanctions have become an increasingly effective method to cut off income for oil-rich countries, with expanded measures against Iran, Russia, and Venezuela over the years. Many nations are involved in its distribution, placing it at the heart of international relations and making it prone to conflicts. The unpredictable prices of oil and the world's heavy reliance on it also heighten its role in geopolitical issues, particularly as we shift towards renewable energy.

Crude oil is a crucial global commodity capable of influencing numerous macroeconomic and monetary variables (Chen et al., 2024). Changes in oil prices can affect the stock values of a wide range of

companies (Kang et al., 2016), from those directly involved in oil extraction and refining to industries like transportation and manufacturing that are heavily dependent on oil as a cost factor. Higher oil prices typically increase production costs, affecting profit margins and thus stock prices. Gold is often seen as a safe-haven asset during economic instability (Baur & McDermott, 2016; Bredin et al., 2015). When oil prices rise sharply and create economic uncertainty (say during political turmoil and instability in the oil-rich nation), investors might flock to gold, driving up its price. Conversely, stable or falling oil prices can lead to decreased demand for gold as investors seek higher returns in other markets. Oil prices directly impact forex markets, particularly through countries that are major oil exporters or importers. For example, countries that export oil might see their currencies strengthen with rising oil prices, while import-heavy countries might see currency depreciation.

Islami and Welfens (2013) explore the dynamics between stock markets and exchange rates in Eastern Europe, emphasizing the varying degrees of market integration post-EU enlargement and its significant influence on capital flows and foreign exchange dynamics. Similarly, Ingalhalli et al. (2016) analyze the relationships between oil, gold, forex, and stock markets in India using Granger causality tests, revealing unidirectional impacts where oil prices help forecast forex and gold price movements. On a methodological front, Kal et al. (2015) employ a Markov-switching vector autoregressive model to study how currency valuation deviations affect bond and stock markets, highlighting the dependency on currency valuation states for risk-adjusted returns. Malik and Umar (2019) investigate the dynamic connection between oil price shocks and foreign exchange rates, identifying a significant increase in connectedness following the 2008 financial crisis, which underscores the substantial impact of oil price fluctuations on forex markets.

India, one of the world's largest importers of crude oil due to its limited domestic production, predominantly sources its oil from countries like Saudi Arabia, the UAE, and Russia. Despite this dependence, India's strong refining sector enables it to process imported crude into refined petroleum products, which it exports globally, significantly impacting its GDP and fiscal health. The country's extensive refinery network not only positions it as a major exporter of products like diesel and gasoline but also influences large-cap stocks in its energy sector, linking oil price fluctuations to stock market performance. Furthermore, the role of gold as a hedge against inflation and currency depreciation is vital in this context. This study's exploration of these interconnected markets offers critical insights for making informed policy and investment decisions, especially given the dynamic nature of global energy markets.

3.2. Methodological insights

The study by Jain and Biswal (2016) investigates the dynamic interactions among global gold and crude oil prices, the USD-INR exchange rate, and the stock market index (Sensex) in India, spanning the period from 2006 to 2015. The authors utilize the Dynamic Conditional Correlation-Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) model and non-linear causality tests to examine both the contemporaneous and lead-lag relationships among these variables. Their analysis reveals that declines in gold and crude oil prices are associated with a depreciation of the Indian Rupee and a decrease in the Sensex, suggesting that gold increasingly serves as an investment asset. However, this study adopted VECM as it is particularly useful when dealing even with non-stationary economic time series data that are cointegrated.

This study extends and enhances the existing research on the interplay between India's key financial markets by incorporating a broader array of macroeconomic variables, including the Consumer Price Index, bank interest rates, and government bond yields, which offer deeper insights into the influence of monetary policy and inflation on market dynamics. Covering data up to December 2023 provides an up-to-date analysis that includes recent global economic events, offering a more current perspective than previous studies, such as Jain and Biswal (2016). Moreover, by employing daily and monthly data, our research uniquely disentangles short-term market fluctuations from long-term economic trends, enhancing our understanding of the underlying mechanisms. Given that the variables in the study like gold prices, oil prices, exchange rates, and stock indices, might be expected to have long-term

relationships. Simultaneous equation modeling (Part 2) is another robust approach for analysing systems with multiple interdependent relationships.

Apergis and Miller (2009) employed Vector Error Correction Models (VECM) to dissect oil price changes into specific components such as oil-supply shocks, global aggregate-demand shocks, and idiosyncratic oil-demand shocks, aiming to understand the distinct impacts of each on stock market returns. This approach allows for a detailed examination of the dynamic interactions and individual effects of oil price variations. Ehikioya et al. (2020) also used VEC to analyse how past imbalances between oil prices and exchange rates in Sub-Saharan Africa realign over time, highlighting the model's utility in tracking adjustments following market shocks crucial for regional economies dependent on oil.

Similarly, Camba (2020) applied VEC for its efficacy in capturing both short-term and long-term dynamics in the Philippine stock market, where variables like stock market index volatility and the Peso-Dollar exchange rate show significant cointegration. This method provides insights into the rate and direction of market adjustments, essential for strategic financial planning. Nath Sahu et al. (2014) utilized VECM along with other econometric techniques to explore the relationships between the Indian stock market and oil prices, uncovering long-run causality from the stock market to oil prices, though short-term causality was absent, emphasizing the model's strength in revealing complex economic interactions.

Studies such as those by Danielle et al. (2022) and Arfaoui and Ben Rejeb (2017) have utilized simultaneous equation modeling to delve into the intricate, interwoven relationships among various key financial markets including oil, gold, the US dollar, and stock indices. This method is adept at addressing the complexities of these relationships by allowing the variables to be both influencers and influenced within the same model, effectively capturing the feedback loops and dynamic interactions. For instance, fluctuations in oil prices can affect gold prices and stock indices, which may subsequently impact the US dollar, creating a cycle where these changes influence oil prices in return. The simultaneous equation approach is essential for modeling such multifaceted interdependencies, recognizing the potential endogeneity where each variable is simultaneously affecting and being affected by others.

4. Data description and methodology

4.1. Data description

4.1.1. Part 1: Analysis based on daily data

The study utilises time-series data for four variables as shown in Table 1: The Stock Price Index from the BSE Sensex (India) official website, the Gold Price from the World Gold Council, the WTI Oil Price from the St Louis FRED website, and the foreign exchange rate (INR/USD), covering the period from 1 January 2000 to 15 December 2023. The focus on these four variables stems from the need to analyse daily data and the interrelationships among these variables specifically. Previous literature has examined multiple market variables to understand direct dependencies, while other studies have included intermediate macro variables to explore indirect dependencies. For this study, daily data from 1 January 2000 to 15 December 2023 was collected, amounting to 5664 observations. The chosen period reflects the contemporary availability of both long- and short-term data series.

Table 1. Variable description and data sources.

Variables	Unit	Data sources
Logarithm Returns of Bombay Stock Exchange (L_BSE)	INR	BSE Sensex
Logarithm Returns of Exchange Rate (L_ER)	INR/USD	St Louis FRED
Logarithm Returns of Gold Price (L_GOLD_PRICE)	INR/Oz	World Gold Council
Logarithm Returns of West Texas Intermediate (L_WTI)	Dollars/Barrel	St Louis FRED
Logarithm Returns of WTI Futures (L_WTI_FUTURES)	USD	Investing.com
Logarithm Returns of Chinese Imports (L_CHN_IM)	USD	St Louis FRED
Logarithm Returns of Indian Imports (L_IND_IM)	USD	St Louis FRED
Logarithm Returns of Consumer Price Index (L_CPI)	Index 2015 = 100	St Louis FRED
Bank Rate (BANK_RATE)	_	RBI
Risk-Free Return of 91-day Govt Bond (RFR_GTBY__91)	_	RBI

4.1.2. Part 2: Analysis based on monthly data

Next, monthly data for the four market variables is used alongside six intermediate variables: WTI Oil Futures from Investing.com, CPI from St Louis FRED, Bank Rate, Risk-Free Bond Yield for 91 days from the RBI Website, India's Imports, and Chinese Imports from St Louis FRED, covering the same period and totalling 288 observations. All variables were converted to their natural logarithmic return form. The data was organised and structured using a standardised framework, excluding dates when the market was not operational. Data collection was based on the closing value of the market on specific days, encompassing the BSE Sensex, the price of crude oil (USD), the price of gold (INR), and the forex rate (INR/USD) from 1 January 2008 to 15 December 2023. The structured data framework ensured consistency and non-operational market dates were omitted from the analysis.

4.2. Methodology selection

Unit Root Test: This study employs time-series data analysis to investigate the relationships between stock market returns, oil market returns, gold market returns, and forex market returns in India. A key concern in time-series analysis is determining whether a series is stationary or non-stationary. It is tested using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Unit Root tests. The ADF test involves regressing the variable series on its lagged values and differenced terms to check for unit roots.

As per the results provided in Supplementary Appendix A, Part 1, all log-transformed variables such as BSE, Oil Price, Gold Price, and INR/USD are Stationary at I (1) at a 1% level of significance. Our null hypothesis for the ADF test for the Log BSE variable has a unit root for Stock Price. Similarly, our null hypothesis for the Log of INR/USD, Oil Price, and Gold Price variables has a unit root. Based on the data results obtained, it is seen that all four variables are integrated at the first difference level I (1) rather than I (0).

Cointegration Test: To test for cointegration among integrated series, we use the Johansen Cointegration test. Cointegration indicates a stable, long-term relationship between non-stationary variables, meaning they move together over time despite short-term deviations. It suggests causality between variables but does not specify the direction. If cointegration is present, VECM can be employed to adjust for short-run changes and deviations from equilibrium.

The results provided in Supplementary Appendix A section, provide the results of the Johansen Cointegration test show both the Rank Test and Eigen Value Test results seem to be significant in terms of their results. Both support their claim of H_1: There is the presence of co-integrating vectors in the model. Supporting the assumption that the study variables have a long-run equilibrium relationship. Thus, claiming that the number of co-integrating vectors is one. As shown in the tables, all probability values are above the 1%, 5%, and 10% significance levels, providing the analysis so that the null hypothesis cannot be rejected. This claim of results is synchronised with the results of both the Trace Test and Maximum Eigenvalue Test.

The Granger causality test, developed by Clive Granger, determines if a one-time series variable can predict another. It does not imply true causality but indicates predictive causality or temporal precedence. This test evaluates if past values of one variable can improve the prediction of another variable. This method is pivotal in examining the predictive relationships between the mentioned variables in the study.

Supplementary Appendix A section provides the analysis of L_BSE and L_BRENT, the findings demonstrate a substantial causal relationship between L_BSE to L_BRENT. This implies that fluctuations in L_BSE may be used to forecast future changes in L_BRENT pricing. In contrast, the test indicates that there is no substantial causal link from L_BRENT to L_BSE. Similarly, there is evidence of a possible causal impact of L_ER on L_BRENT, but the significance is only minimal. However, there is no indication that L_BRENT causes L_ER according to the Granger causality test. There is no statistically significant evidence to suggest that there is a causal relationship between the changes in gold prices (L_GOLD_PRICE) and Brent crude oil prices (L_BRENT), as well as between the changes in the Bombay Stock Exchange (L_BSE) and the exchange rate (L_ER). These results are essential for comprehending the directional correlations between these variables, which assist in predicting, formulating policies, and developing risk management methods in financial and economic environments.

Supplementary Appendix A section analyses the null hypothesis regarding the relationship between L_ER and L_WTI. The null hypothesis that L_ER does not Granger cause L_WTI is not rejected, with an F-statistic of 1.47173 and a probability of 0.2296. However, the null hypothesis that L_WTI does not Granger cause L_ER is rejected, with an F-statistic of 3.30428 and a probability of 0.0368, indicating that L_WTI does Granger cause L_ER. Similarly, the test for L_GOLD PRICE and L_WTI shows that L_ER does not Granger cause L_WTI (F-statistic of 2.96671 and probability of 0.0516), but L_WTI does Granger cause L_GOLD PRICE (F-statistic of 13.2397 and probability of 2.E-06).

Additionally, L_BSE does not Granger cause L_WTI (F-statistic of 1.11534 and probability of 0.3279), whereas L_WTI does Granger cause BSE (F-statistic of 4.56555 and probability of 0.0104). For L_GOLD PRICE and L_ER, L_GOLD PRICE does Granger cause L_ER (F-statistic of 10.5384 and probability of 3.E-05), but L_ER does not Granger cause L_GOLD PRICE (F-statistic of 0.72126 and probability of 0.4862).

The test also shows that L_BSE Granger causes L_ER (F-statistic of 5.02590 and probability of 0.0066), and L_ER Granger causes L_BSE (F-statistic of 12.6820 and probability of 3.E-06). Lastly, L_BSE does not Granger cause L_GOLD PRICE (F-statistic of 2.43999 and probability of 0.0873), but L_GOLD PRICE does Granger cause L_BSE (F-statistic of 7.04016 and probability of 0.0009).

For Part 1, we have used the VEC approach as it provides a means to analyze both short-term and long-term relationships among integrated variables. Ehikioya et al. (2020) utilised VECM to investigate the impact of oil price fluctuations on exchange rates in Sub-Saharan Africa from 2004 to 2017, demonstrating VECM's capability to explore long-term relationships, which VAR models lack. Apergis and Miller (2009) applied VECM to study how structural oil-market shocks affect stock prices across eight countries, distinguishing the effects of various oil price shocks on stock markets effectively. Camba (2020) employed VECM to capture both the short-run and long-run causal behavior between the Philippine stock market volatility and economic variables such as exchange rates and oil prices, from 2000 to 2019. Nath Sahu et al. (2014) used VECM alongside Johansen's cointegration test and Granger causality to analyze the dynamic relationships between oil prices and the Indian stock market from 2001 to 2013, providing insights into the bi-directional influences between these markets.

For Part 2, we have used the simultaneous equation approach as it is particularly valuable in understanding how changes in one market can simultaneously influence others, enabling a more comprehensive analysis of interdependencies and market dynamics critical for making informed investment decisions and policy formulations. Arfaoui and Ben Rejeb (2017) employed a simultaneous equation system to explore the interdependencies between oil, gold, currency, and stock markets over the period from 1995 to 2015. They chose this method to reveal both direct and indirect connections among these variables, essential for understanding complex global market dynamics. Their goal was to extend beyond the bilateral focus of previous research by considering multilateral interactions, using a global perspective to avoid country-specific biases crucial for strategizing at the international level. Danielle et al. (2022) adopted regression analysis and a simultaneous equation approach to examine the interactions among oil, gold, the U.S. dollar, and stock prices from 2011 to 2021. These methods enabled them to detect both direct bilateral relationships and wider simultaneous effects across these markets.

5. Results

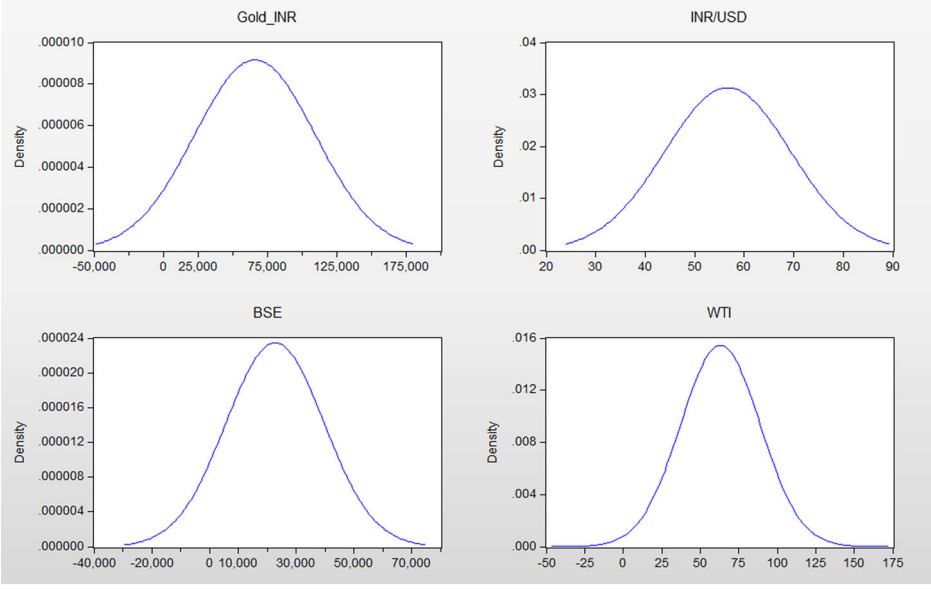
4.1. Part-1: Analysis based on daily data

Key Indian financial indicators, including the Brent oil price, the Bombay Stock Exchange (BSE) index, the INR/USD exchange rate, and gold value in Indian Rupees (INR), are effectively illustrated by the presented descriptive Table 2 and Figure 1. Understanding these indicators is crucial for investors, policymakers, and analysts in making informed decisions.

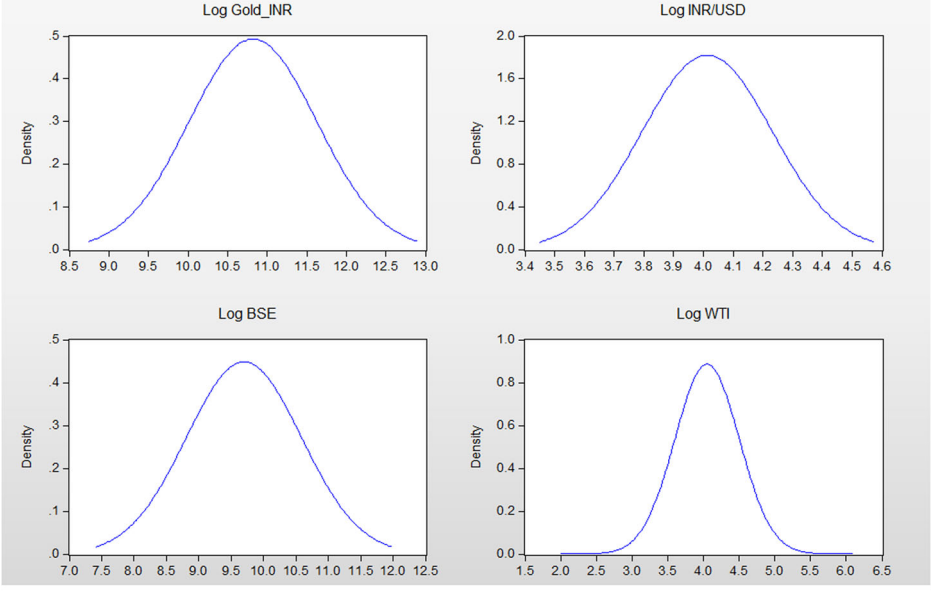
Key Indian financial indicators, including the Brent oil price, the Bombay Stock Exchange (BSE) index, the INR/USD exchange rate, and gold value (in INR), are effectively illustrated by the presented descriptive data in Figures 1–3. Understanding these indicators is crucial for investors, policymakers, and analysts in making informed decisions. The average Brent oil price is USD 66.04 per barrel, with significant volatility evidenced by its price range from USD 9.12 to USD 143.95 and a high standard deviation of USD 29.33. The positive skewness (0.29) and negative kurtosis (−0.91) indicate a distribution that is

Table 2. Descriptive statistics.

Particulars	Brent oil USD/Barrel	BSE	INR/USD	Gold_INR
Mean	66.04	22,780.32	56.68	66,278.69
S.E.	0.39	226.1	0.17	578.96
Median	63.7	18,452.59	50.14	72,276.57
Mode	29.25	3,943.54	43.65	19,309.15
S.D.	29.33	17,016.28	12.76	43,572.3
Sample variance	860.19	289,553,676	162.83	1,898,545,739
Kurtosis	−0.91	0.02	−1.13	−0.76
Skewness	0.29	0.91	0.51	0.48
Range	134.83	67,914.08	44.92	158,852.19
Minimum	9.12	2,600.12	38.48	11,936.13
Maximum	143.95	70,514.2	83.4	170,788.32
Sum	374,034.79	129,027,728	321,008.99	375,402,519
Count	5,664	5,664	5,664	5,664



(a)



(b)

Figure 1. Frequency density distribution of variables. *Source*: Authors' representation.

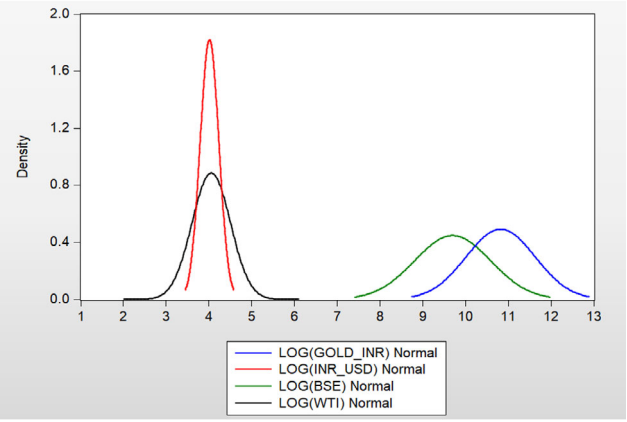


Figure 2. Consolidated frequency distribution of variables. *Source*: Authors' representation.

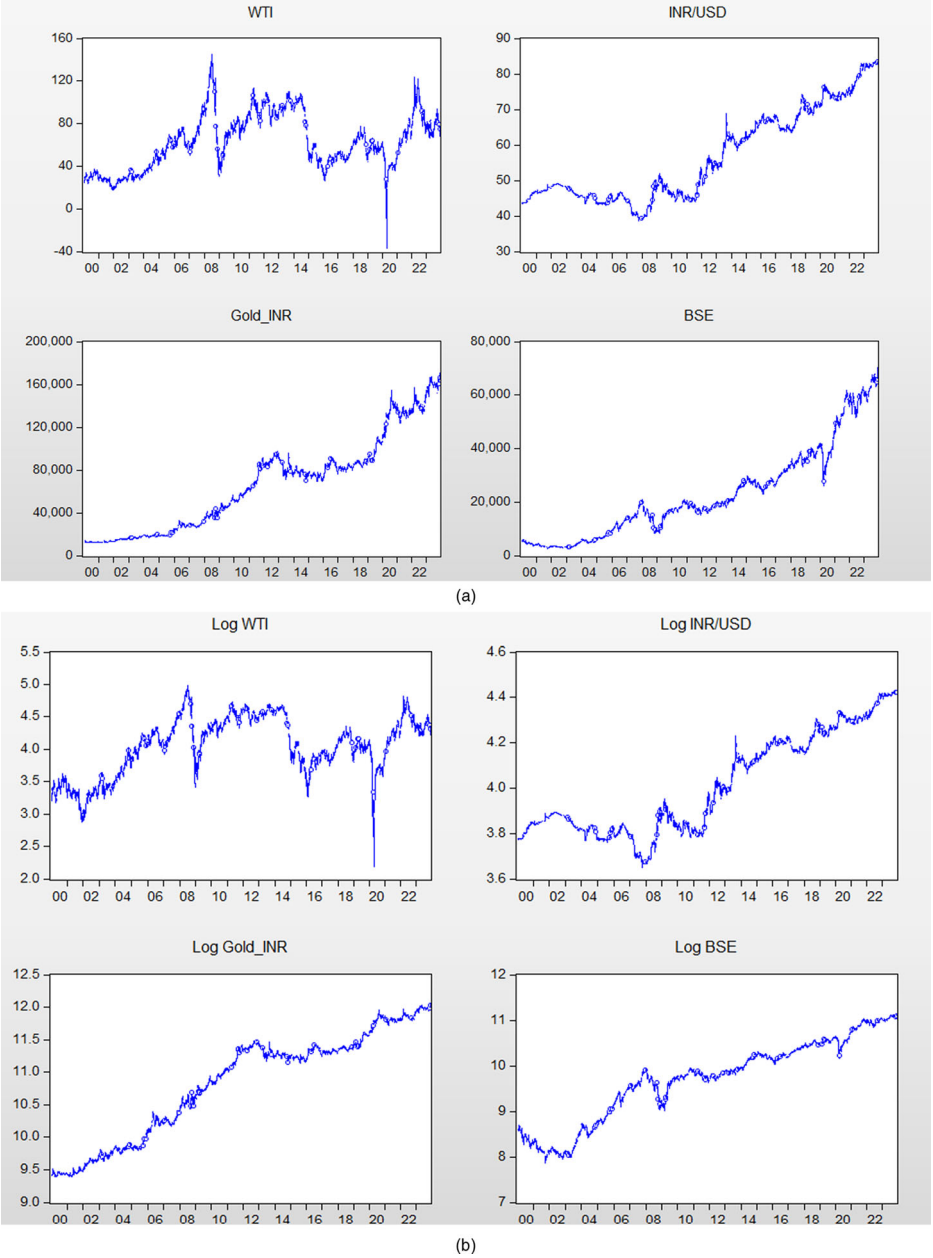


Figure 3. Time series data of economic variables (a) Variables in Natural Form. (b) Variables in Logarithmic Form. *Source*: Authors' representation.

Table 3. Optimal lag selection.

Lag	LogL	LR	FPE	AIC	SIC	HIC
0	50.86547	NA	8.41e-06	−0.334753	−0.282828	−0.313926
1	2,200.622	4222.736	2.02e-12	−15.57587	−15.31624*	−15.47174
2	2,245.084	86.06506	1.65e-12*	−15.77917*	−15.31184	−15.59172*
3	2,253.722	16.47444	1.74e-12	−15.72659	−15.05155	−15.45583
4	2,260.823	13.33890	1.85e-12	−15.66302	−14.78028	−15.30895
5	2,268.229	13.70101	1.97e-12	−15.60163	−14.5112	−15.16426
6	2,283.249	27.35906*	1.99e-12	−15.59464	−14.2965	−15.07395
7	2,289.234	10.73007	2.14e-12	−15.5231	−14.01726	−14.91911
8	2,297.839	15.18187	2.26e-12	−15.47028	−13.75674	−14.78298

Source: Authors' estimation.

somewhat right-skewed and platykurtic, suggesting occasional sharp increases in oil prices. These fluctuations in Brent oil prices can significantly impact India's economy, affecting various industries and consumer expenditures due to the country's heavy reliance on energy.

The descriptive data presented on key Indian financial indicators, including Brent oil prices, the Bombay Stock Exchange (BSE) index, the INR/USD exchange rate, and gold values in Indian Rupees (INR), provide crucial insights into the Indian market landscape. These insights are valuable for investors, policymakers, and analysts. The average Brent oil price of USD 66.04 per barrel reflects a moderate level, yet the market shows significant volatility with prices ranging from USD 9.12 to USD 143.95 and a high standard deviation of USD 29.33. The distribution is somewhat right-skewed and platykurtic, as indicated by a positive skewness of 0.29 and a negative kurtosis of −0.91, suggesting occasional sharp increases in oil prices. Such fluctuations in Brent oil prices can have substantial implications for India's energy-dependent economy, affecting various industries and consumer spending.

The BSE index value of 22,780.32 represents the average stock market level. The substantial range (2,600.12–70,514.20) and large standard deviation (17,016.28) indicate considerable volatility and unpredictability in stock prices. A positive skewness (0.91) suggests a right-skewed distribution, indicating potential outliers raising the mean. However, the kurtosis value of 0.02 indicates a near-normal distribution with a modest level of peakedness. The Indian stock market experiences significant volatility, influencing investor sentiment, economic growth, and business performance. The average INR/USD exchange rate of 56.68 reflects the Indian Rupee's relative strength against the US Dollar, with a range of 38.48–83.40 and a low standard deviation of 12.76, indicating relative stability. The positive skewness of 0.51 and negative kurtosis of −1.13 suggest the distribution is right-skewed and flatter than normal, indicating periodic depreciation. These exchange rate fluctuations can affect exports, imports, inflation, and foreign investments in India.

In autoregressive models, the lag length of each variable is crucial. Excessive lags can lead to loss of degrees of freedom, multicollinearity, serial correlations in error terms, and model misspecification. To avoid these issues, we use optimal lag length selection criteria such as Final Prediction Error, Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hannan-Quinn Information Criterion (HIC) as shown in Table 3. Generally, a lower value in these criteria indicates a better model. According to AIC, this study uses an optimal lag length of 2.

Regarding Auto regressive models, the length of the model is crucial in terms of the lag length of each variable. Many lags in the model unnecessarily would lead to a loss of degrees of freedom and cause problems of multicollinearity, serial correlations in error terms, and model misspecification. To avoid such issues in the model, we use any of the optimal lag length selection criteria: Final prediction error, AIC, SIC, and HIC. As a rule of thumb, we choose a lag length with a lower value in information criteria to estimate a better model. Concerning Table 2, as per SIC, we choose the lag length of the variables in our model to be 1. This claim of results is synchronised with the results of both the Trace Test and Maximum Eigenvalue Tests.

4.2. Johansen long-run equation from VECM model

$$\text{LBSE}\ (-1) = 11.633 + 4.430\ \text{LER}\ (-1) - 0.357\ \text{LGP}\ (-1) + -4.217\ \text{LWTIP}\ (-1)$$

Table 4. A vector error correction model coefficients.

A				
Cointegrating Eq:				Cointegration equation
L_BSE(−1)				1.000
L_ER(−1)				−4.43
				(−4.835)
L_GOLD_PRICE(−1)				0.357
				−1.192
L_WTI(−1)				−4.217
				(−5.704)
B				
Error correction:	D(L_BSE)	D(L_ER)	D(L_GOLD_PRICE)	D(L_WTI)
CointEq1	−0.004***	−0.001***	0.011***	0.025***
	(−0.499)	(−0.869)	(2.398)	(4.693)
D(L_BSE(−1))	0.026*	−0.050**	−0.005**	0.201**
	(0.400)	(−3.335)	(−0.156)	(4.894)
D(L_BSE(−2))	−0.021*	0.028**	0.007**	−0.034**
	(−0.313)	(1.779)	(0.204)	(−0.798)
D(L_ER(−1))	−0.345	0.262*	0.085	0.152
	(−1.182)	(3.869)	(0.526)	(0.830)
D(L_ER(−2))	0.069	−0.053*	0.072	0.087
	(0.243)	(−0.802)	(0.454)	(0.489)
D(L_GOLD_PRICE(−1))	0.081	−0.049**	0.067*	0.045*
	(0.735)	(−1.937)	(1.086)	(0.661)
D(L_GOLD_PRICE(−2))	0.087	−0.007**	−0.127*	−0.096*
	(0.789)	(−0.274)	(−2.042)	(−1.385)
D(L_WTI(−1))	0.026*	−0.006**	−0.002*	0.284*
	(0.285)	(−0.295)	(−0.038)	(4.861)
D(L_WTI(−2))	0.053*	−0.023**	−0.042*	−0.069*
	(0.594)	(−1.132)	(−0.839)	(−1.230)
C	0.008***	0.002***	0.009***	−0.0005***
	(1.964)	(2.590)	(3.962)	(−0.191)

Note. ***, ** and * refer to significance at confidence levels 1%, 5% and 10%., respectively, and parentheses specify standard errors. *Source*: Authors' estimation.

The Vector Error Correction Model (VECM) results in the study provide insights into the dynamic relationships among India's stock prices, exchange rates, gold prices, and WTI oil prices over the period as shown in Table 4. The error correction term from the VECM is statistically significant for all the variables, indicating that any short-term disequilibrium in the market dynamics corrects itself over time, the error correction impacts the daily changes in the BSE, exchange rate (ER), gold prices, and WTI prices differently, with coefficients indicating the speed and direction of adjustment to long-term equilibrium. The strong correlation between WTI futures and actual oil prices reflects the forward-looking nature of the oil market. Direct daily influences of gold prices are minimal on other variables, suggesting gold prices are less reactive to daily fluctuations in the markets studied but are more influenced by broader economic or market trends. Various lags of the studied variables show significant effects on each other, indicating complex interdependencies that evolve over different time frames.

4.4. Part 2: Analysis based on monthly data

Next, we have utilised the Unit Root test on monthly data series for both direct and indirect macroeconomic variables within the Indian context. The intermediary variables include the Consumer Price Index, bank interest rates, the risk-free government bond yield for 91 days, WTI futures, and import data from India and China, covering the period from January 2000 to December 2023. The results indicate that all intermediary and market variables are stationary in their return series, suggesting that the interactions between direct and intermediary variables are based on their returns.

Simultaneous Equations:

$$\text{Stock Price}_1 = \alpha_1 + \beta_{11}\,\text{Exchange Rate} + \beta_{12}\,\text{Oil Price} + \beta_{13}\,\text{Gold Price} + \beta_{14} + u_1$$

$$\text{Exchange Rate}_2 = \alpha_2 + \beta_{21}\,\text{Stock Price} + \beta_{22}\,\text{Oil Price} + \beta_{23}\,\text{Gold Price} + \beta_{24} + u_2$$

$$\text{Oil Price}_3 = \alpha_3 + \beta_{31}\,\text{Exchange Rate} + \beta_{32}\,\text{Stock Price} + \beta_{33}\,\text{Gold Price} + \beta_{34} + u_3$$

$$\text{Gold Price}_4 = \alpha_4 + \beta_{41}\,\text{Exchange Rate} + \beta_{42}\,\text{Oil Price} + \beta_{43}\,\text{Stock Price} + \beta_{44} + u_4$$

The Simultaneous Equations are classified into two sets of independent variables: direct and indirect. In the case of direct, our study uses variables such as ER, Oil Price, and Gold price following in continuous to part 1 of our study. Indirect variables which are known to be intermediary variables affecting the relationship between the markets are listed under "beta" values. The system reveals complex connections between the exchange rate, oil prices, stock market index, and gold prices, influenced by various economic factors. The study identifies significant direct and indirect impacts, providing vital insights for academics, policymakers, and investors. These findings underscore the necessity of a comprehensive approach when analysing these intricate interconnections. The interconnectedness of oil prices, exchange rates, stock market performance, and gold prices necessitates considering multiple economic variables. Policymakers and investors must be aware of these dynamics, as changes in one variable can significantly and unexpectedly impact others.

This study uses ten variables to examine the relationship between the stock market, forex, gold, and oil markets in India. Employing a simultaneous equation method, the study classifies variables based on their direct and indirect contributions to the dependency analysis. Equation 1 models the log of the exchange rate as a function of log WTI, BSE, gold price, WTI futures, consumer price index, risk-free return, bank interest rate, and imports by India and China. Equation 2 describes the log of BSE as a function of log WTI, exchange rate, Gold price, WTI futures, consumer price index, risk-free return, bank interest rate, and imports made by India and China.

$$\text{LER} = \text{f}\,(\text{LWTI, LBSE, LGP, LWTIFutures, LCPI, LINDIM, LCHNIM, RFRGTBY91, BankRate}) \quad (1)$$

$$\text{LBSE} = \text{f}\,(\text{LWTI, LER, LGP, LWTIFutures, LCPI, LINDIM, LCHNIM, RFRGTBY91, BankRate}) \quad (2)$$

Under Equation 1, the model has a strong explanatory power, indicating that these factors account for almost 96% of exchange rate fluctuations. The correlation between crude oil prices and the exchange rate is positive but not statistically significant, suggesting that crude oil prices do not significantly affect the exchange rate over the analysed period. The BSE index has a significant negative impact on the exchange rate, with a rising BSE index correlating with a stronger currency as shown in Table 5.

WTI futures prices negatively influence the exchange rate but lack statistical significance, indicating a minimal role in determining the exchange rate. The Consumer Price Index (CPI) positively impacts the exchange rate, implying that higher inflation leads to currency devaluation, consistent with economic theory. The correlation between Indian imports and the exchange rate is negative but not statistically significant, indicating a minor effect. Imports from China have a significant negative impact on the

Table 5. Coefficients under simultaneous equation.

L_ER	Equation 1	L_BSE	Equation 2
L_WTI	0.076	L_ER	−1.502***
	(0.108)		(0.219)
L_BSE	−0.096***	L_WTI	−0.784*
	(0.013)		(0.426)
L_GoldPrice	−0.126***	L_GoldPrice	−0.423***
	(0.019)		(0.080)
L_WTI_Futures_	−0.030	L_WTI_Futures_	1.185*
	(0.107)		(0.418)
L_CPI	1.028***	L_CPI	2.543***
	(0.040)		(0.249)
L_IND_IM	−0.050	L_IND_IM	−0.662**
	(0.053)		(0.206)
L_CHN_IM	−0.272***	L_CHN_IM	−0.072
	(0.042)		(0.181)
RFR_GTBY91	−0.002	RFR_GTBY91	0.023**
	(0.002)		(0.009)
BankRate	−0.001	Bank Rate	−0.085***
	(0.003)		(0.011)
_cons	5.452***	_cons	1.889
	(0.363)		(1.946)
No. of Observations	288	No. of Observations	288
Adj R-squared	0.963	Adj R-squared	0.965

Note. ***, ** and * refer to significance at confidence levels 1%, 5% and 10%., respectively, and parentheses specify standard errors. *Source*: Authors' estimation.

exchange rate, suggesting that increased Chinese imports strengthen the domestic currency. The correlation between the risk-free rate and the exchange rate is negative but not statistically significant, implying little impact. The bank rate has a minimal negative effect on the exchange rate, indicating negligible influence.

Under Equation 2, the model explains around 96 percent of the variability in the BSE index, indicating a strong fit. The constant term is statistically insignificant, suggesting it does not capture the baseline BSE index level. Currency rate fluctuations have a negative and significant impact, with higher exchange rates (currency depreciation) reducing the BSE index. The correlation between crude oil prices and the BSE index is negative and statistically negligible at the 5% level, implying higher oil prices might adversely affect the stock market. Gold price fluctuations significantly affect the BSE index, with rising gold prices often leading investors to shift from equities to gold.

WTI futures prices positively impact the BSE index, suggesting favourable stock market predictions based on future oil prices. The Consumer Price Index (CPI) has a significant positive impact, with higher CPI values indicating economic growth and boosting investor confidence and stock prices. Indian imports positively correlate with the BSE index, reflecting strong domestic demand and economic activity. Chinese imports have a negative but statistically insignificant correlation. The risk-free rate positively influences the BSE index, encouraging stock market investment due to higher yields on low-risk assets. The bank rate negatively impacts the BSE index, as higher interest rates increase borrowing costs and reduce business profits.

$$\text{LGP} = \text{f}\left(\text{LWTI, LER, LBSE, LWTIFutures, LCPI, LINDIM, LCHNIM, RFRGTBY91, BankRate}\right) \quad (3)$$

$$\text{LWTI} = \text{f}\left(\text{LGP, LER, LBSE, LWTIFutures, LCPI, LINDIM, LCHNIM, RFRGTBY91, BankRate}\right) \quad (4)$$

Equation 3 expresses the log of gold price as a function of log WTI, BSE, ER, WTI futures, consumer price index (CPI), risk-free return, bank interest rate, and imports from India and China as shown in Table 6.

This model explains approximately 97% of the variability in gold prices, indicating high accuracy. The correlation between crude oil prices and gold prices is negative but not significant, suggesting oil price fluctuations don't greatly impact gold prices. The BSE index negatively impacts gold prices, as a thriving stock market diverts investment from gold. The exchange rate also negatively impacts gold prices, with currency depreciation increasing local gold costs, and reducing demand and prices.

WTI futures prices positively affect gold prices, indicating expected economic stability. The CPI positively impacts gold prices, with inflation driving investors to gold as a haven. Indian imports strongly correlate with gold prices due to India's significant consumption, while Chinese imports have a positive

Table 6. Coefficients under simultaneous equation.

L_GoldPrice	Equation 3	L_WTI	Equation 4
L_WTI	−0.428	L_GoldPrice	−0.016
	(0.304)		(0.011)
L_BSE	−0.214***	L_BSE	−0.015*
	(0.040)		(0.008)
L_ER	−1.003***	L_ER	−0.023
	(0.157)		(0.033)
L_WTI_Futures_	0.655**	L_WTI_Futures_	−0.932***
	(0.299)		(0.019)
L_CPI	1.967***	L_CPI	−0.364
	(0.171)		(0.040)
L_IND_IM	0.418*	L_IND_IM	0.091**
	(0.147)		(0.028)
L_CHN_IM	−0.189***	L_CHN_IM	0.025
	(0.129)		(0.025)
RFR_GTBY91	−0.004	RFR_GTBY91	0.004**
	(0.006)		(0.001)
BankRate	−0.007	BankRate	−0.003*
	(0.009)		(0.001)
_cons	1.024	_cons	−0.874**
	(1.387)		(0.363)
No. of Observations	288	No. of Observations	288
Adj R-squared	0.978	Adj R-squared	0.985

Note. ***, ** and * refer to significance at confidence levels 1%, 5% and 10%, respectively, and parentheses specify standard errors. *Source*: Authors' estimation.

but insignificant effect. The risk-free and bank rates have negligible, statistically insignificant effects on gold prices.

Equation 4 outlines the logarithm of Oil Prices as a function of log ER, BSE, Gold price, WTI futures, consumer price index, risk-free return, bank interest rate, and imports by India and China. The simultaneous equation model used to analyse WTI crude oil price drivers (L_WTI) incorporates various macroeconomic factors, examining both direct and indirect impacts. The three-stage least-squares regression reveals a strong explanatory power. While gold prices negatively correlate with WTI, this is not statistically significant at the 5% level, suggesting minimal influence within the studied timeframe. The BSE index inversely correlates with WTI prices, implying a slight decline in oil prices with rising stock market indices. The marginal significance ($p < 0.10$) indicates a modest negative correlation, potentially due to economic dynamics where stock market success reduces the need for oil as a hedge.

The exchange rate's positive coefficient (though statistically insignificant), indicates negligible direct impact on WTI prices. WTI futures prices strongly correlate with actual WTI prices, underscoring the oil market's forward-looking nature. The consumer price index (CPI) negatively correlates with WTI prices but is not statistically significant, indicating no direct impact from inflation. Indian imports strongly correlate with WTI prices, suggesting increased demand drives higher oil prices. Conversely, Chinese imports show a positive but statistically insignificant impact on WTI prices. The risk-free rate (GTBY91) shows a strong positive correlation with WTI prices, likely due to storage costs or opportunity costs. The bank rate exhibits a small yet statistically significant inverse correlation with WTI prices, suggesting that higher interest rates may slightly lower oil prices due to increased borrowing costs.

6. Discussion

Part 1 (VECM): This study investigates the relationships between India's stock market, forex market, oil market, and gold market from 1 January 2000 to 15 December 2023, using ten macroeconomic variables. Employing Johansen's Cointegration Test, the study identifies long-term relationships among these markets, highlighting that they move together over time. The Vector Error Correction Model (VECM) confirms long-run equilibrium relationships. Key findings reveal that WTI futures strongly correlate with oil prices, demonstrating the forward-looking nature of the oil market, while gold prices show minimal direct influence.

Given the influence of WTI oil prices on exchange rates, policies could focus on diversifying energy sources and enhancing energy security to stabilize domestic economic conditions. The stability of gold prices in contrast to the other variables suggests that gold could play a role in policy as a stabilizing asset during economic volatility. With significant lag effects identified, regulators may consider policies that address the transmission of shocks across markets, potentially through financial instruments or regulatory measures that dampen speculative trading and enhance market stability.

Part 2 (Simultaneous Equation Modeling): The exchange rate has a negligible direct impact on oil prices. The BSE index inversely correlates with oil prices, indicating a slight decline in oil prices with rising stock market indices. CPI does not significantly impact crude oil prices, suggesting no direct inflationary effect. Indian imports strongly correlate with higher oil prices due to increased demand, while Chinese imports show an insignificant impact. The BSE index's dynamics show significant interdependence with the exchange rate, gold prices, WTI futures, and CPI, suggesting that economic growth indicators drive higher stock prices. Gold prices are negatively impacted by a thriving stock market and currency depreciation, indicating shifts in investment preferences.

Oil Prices (WTI): Strong positive correlation with WTI futures, indicating the forward-looking nature of the oil market. However, gold prices show a negative but non-significant correlation with WTI, suggesting minimal direct influence within the studied timeframe. Exchange Rate (INR/USD): Exhibits a positive but statistically insignificant coefficient, indicating negligible direct impact on WTI prices. BSE Index: Inversely correlates with WTI prices, implying a slight decline in oil prices with rising stock market indices. CPI: Negatively correlates with WTI prices, but this is not statistically significant, indicating no direct inflationary impact on crude oil prices. Imports: Indian imports show a strong positive correlation with WTI prices, highlighting the impact of increased demand on oil prices. Conversely, Chinese imports have a positive but statistically insignificant impact. BSE Index: Shows significant interdependence with the

exchange rate, gold prices, WTI futures, and CPI. A rising BSE index correlates with a stronger currency and higher stock prices, driven by economic growth indicators like CPI and WTI futures. Gold Prices: Negatively impacted by a thriving stock market and exchange rate depreciation, indicating shifts in investment preferences during different economic conditions.

The study underscores the significance of macroeconomic factors such as the risk-free rate and bank rate in influencing market dynamics. The risk-free rate positively correlates with WTI prices, while the bank rate shows a small yet significant inverse correlation with oil prices. Fluctuations in stock market indices and exchange rates significantly influence investor sentiment and behaviour, driving the interconnected dynamics of these markets.

The results showing exchange rates' sensitivity to stock market performances and oil prices underline the need for monitoring and potentially regulating these markets to stabilize the currency. The significant correlation between gold prices and other economic variables such as the BSE index and oil prices suggests that gold remains a crucial safe-haven asset during economic uncertainties. The significant role of Indian and Chinese imports in affecting the stock market and exchange rates respectively underscores the importance of trade policies and their impacts on domestic markets. The positive impact of the CPI on exchange rates suggests that inflation may devalue the currency, which in turn could influence other economic sectors. This calls for careful inflation management strategies.

7. Concluding remarks

This study provides a comprehensive analysis of the interdependencies among India's stock market, forex market, oil market, and gold market from 1 January 2000, to 15 December 2023, using various macroeconomic variables. The findings reveal stable long-term relationships among these markets, as evidenced by the Johansen Cointegration test and Vector Error Correction Model (VECM), indicating that they move together over time despite short-term fluctuations. This interconnection and the identified long-term relationships underscore the complexity of economic dynamics and the necessity for sophisticated, responsive policy mechanisms that can handle the intricacies of these relationships. The findings highlight the importance of proactive economic management and the potential for strategic policy interventions aimed at ensuring economic stability and sustainable growth. Significant insights include the strong positive correlation between WTI futures and oil prices, the inverse relationship between the BSE index and oil prices, and the minimal direct impact of gold prices on oil prices. Furthermore, the study highlights the influence of macroeconomic factors (monthly analysis) such as the Consumer Price Index (CPI), bank rate, and risk-free rate on market dynamics. These results underscore the necessity for a nuanced understanding of market interactions to inform policy formulation and investment strategies, ultimately contributing to enhanced financial analysis and risk management in a globalized economy. Understanding these interdependencies helps in formulating policies that consider the broader economic impacts of changes in one market on others. Additionally, examining the impact of global economic events, such as the COVID-19 pandemic and geopolitical tensions, on these market interrelationships can provide valuable insights for understanding market dynamics and aiding policymakers and investors in making informed decisions.

Note

1. https://www.csis.org/analysis/oil-market-interventions-and-consequences.

Authors' contributions

Bhuvan Arora: Data curation, Formal analysis, Methodology, Conceptualization, Software, Writing – original draft, Writing – review and editing. Joseph Daniel: Data curation, Formal analysis, Methodology, Visualization, Software, Writing – original draft, Writing – review and editing. Anwesha Aditya: Conceptualization, Supervision, Validation, Writing – original draft, Writing – review and editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data that support the findings of this study are available from the corresponding author [BA] upon reasonable request.

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