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INVESTIGATING THE INTERDEPENDENCE OF INDIAN AND U.S. STOCK INDICES THROUGH COINTEGRATION AND GRANGER CAUSALITY

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ABSTRACT

This study investigates the interdependence between the Indian and U.S. stock markets by analyzing the relationship between the SENSEX and NASDAQ indices using time-series econometric techniques. In an increasingly globalized financial environment, understanding the nature of market integration is crucial for investors, policymakers, and researchers. The analysis employs the Augmented Dickey-Fuller (ADF) test to examine the stationarity of the data, followed by the Engle-Granger and Johansen cointegration tests to determine the existence of a long-term equilibrium relationship. Additionally, the Granger causality test is applied to identify the direction of short-run causal influence between the two indices.

The findings indicate that while the Engle-Granger test does not confirm cointegration, the Johansen test identifies at least one cointegrating vector, suggesting a long-run relationship between the NASDAQ and SENSEX indices. Granger causality results reveal a statistically significant influence of NASDAQ on SENSEX, though with a modest explanatory power. These results highlight the partial financial integration between the two markets and suggest that global shocks originating in the U.S. may affect the Indian stock market.

The study contributes to the broader literature on international financial linkages and provides insights into cross-border investment strategies, risk management, and market behavior analysis.

KEY WORDS: *Stock Market Interdependence, Cointegration, Granger Causality, SENSEX, NASDAQ, Financial Integration, Emerging Markets, Time-Series Analysis, Globalization, Investment Strategy*

INTRODUCTION

In an increasingly globalized financial landscape, the interdependence of stock markets has become a central theme in financial economics. The interconnectedness of national economies—intensified by liberalization, cross-border capital flows, and technological advancements—has led to more synchronized movements in stock indices across countries. Among these, the economic and financial linkages between India and the United States stand out due to their growing trade relationships, investment channels, and mutual exposure to global shocks.

India, as one of the world's fastest-growing emerging economies, and the United States, as the world's largest economy and a key global financial center, offer a compelling case for examining stock market interdependence. Understanding the nature of their relationship has important implications for international investors, policymakers, and portfolio managers in terms of diversification, risk management, and policy formulation.

This study aims to investigate the long-run and short-run relationships between the Indian and U.S. stock markets using the Johansen cointegration and Granger causality tests. While cointegration analysis explores whether a stable, long-term equilibrium relationship exists between the two markets, Granger causality helps identify the direction and dynamics of information flow. By examining these linkages, the research contributes to the broader literature on financial market integration and offers practical insights into the transmission of shocks and co-movement patterns between emerging and developed markets.

RESEARCH GAP

Although global stock market interdependence has been widely studied, limited research specifically focuses on the direct relationship between the Indian (SENSEX) and U.S. (NASDAQ) indices. Most existing studies emphasize macroeconomic factors or broader regional trends, often neglecting direct index-level analysis using advanced time-series methods. Additionally, few studies apply both Engle-Granger and Johansen cointegration tests along with Granger causality on recent data. This study addresses these gaps by directly examining the long- and short-run linkages between the two indices using robust econometric techniques.

OBJECTIVES OF THE STUDY

1. **To examine** the long-run equilibrium relationship between the Indian (SENSEX) and U.S. (NASDAQ) stock indices using cointegration techniques.
2. **To identify** the short-run causal influence between the two markets through Granger causality analysis.
3. **To compare** the outcomes of Engle-Granger and Johansen cointegration methods in analyzing market interdependence.
4. **To provide** insights into the degree of financial integration between a developed (U.S.) and an emerging (India) market.

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LITERATURE REVIEW (THEMATIC)

1. Global Stock Market Integration

Studies have increasingly shown that stock markets across countries are becoming more integrated due to globalization and technological advancements. Dhanaraj et al. (2013) observed dynamic spillover effects between U.S. and Asian markets, especially during periods of financial crisis, indicating the growing influence of global shocks.

2. India–U.S. Market Linkages

Empirical research by Mohanasundaram and Karthikeyan (2015) demonstrated long-run cointegration among the Indian, U.S., and South African markets, while Kaur and Arora (2018) found significant interdependence between Indian indices and developed markets such as the U.S. and Japan using Granger causality and VECM models.

3. Influence of Macroeconomic Variables

Several studies highlight the role of external macroeconomic factors—such as crude oil prices, exchange rates, and global interest rates—in driving stock market behavior. Bagchi et al. (2016) identified oil prices as a major determinant of Indian market volatility, and Singh and Kishor (2017) pointed to forex and oil as key contagion factors in BRICS economies.

4. Time-Varying Co-Movements and Volatility

Research by Gupta and Guidi (2012) and Arfaoui & Rejeb (2017) suggests that financial market co-movements are not constant, with greater interdependence often emerging during global economic shocks, particularly post-2008. These findings emphasize the importance of time-sensitive models in understanding financial integration.

5. Emerging Market Dynamics

Ahmed and Huo (2020) and Joshi et al. (2021) emphasized that while emerging markets like India are increasingly influenced by global trends, their internal policies, investor sentiment, and regional conditions also play significant roles. These dual influences make emerging markets more complex to analyze in terms of market linkages.

SUMMARY

The existing literature confirms growing interdependence among global stock markets, especially between developed and emerging economies. However, direct analysis of the Indian and U.S. stock indices using both cointegration and causality approaches remains limited. This study aims to bridge that gap using recent data and a comparative methodology.

RESEARCH METHODOLOGY

This study adopts a quantitative research approach using secondary time-series data to investigate the interdependence between the Indian (SENSEX) and U.S. (NASDAQ) stock indices. The methodology includes the following steps:

1. Data Collection
   - Daily closing prices of the SENSEX and NASDAQ indices were collected for a specified time period.
   - Data was obtained from reliable financial databases such as Yahoo Finance or investing.com.
2. Data Transformation
   - The natural logarithm of the index values was taken to stabilize variance.
   - Returns were also calculated where necessary to assess short-term relationships.
3. Stationarity Testing
   - The Augmented Dickey-Fuller (ADF) test was used to determine whether the time series data were stationary.
   - Only if the series are integrated of the same order (I(1)) can cointegration tests be applied.
4. Cointegration Analysis
   - The Engle-Granger two-step method was applied first to check for cointegration based on the stationarity of residuals from a static regression.
   - The Johansen cointegration test was then used for a more robust analysis, capable of detecting multiple cointegrating vectors in a multivariate framework.
5. Granger Causality Test
   - Granger causality was used to examine the short-run directional influence between NASDAQ and SENSEX.
   - This test helps identify whether past values of one index can forecast movements in the other.
6. Statistical Tools
   - All tests were conducted using statistical software such as R, EViews, or Excel with relevant add-ins.
   - Model significance was verified using p-values, F-statistics, and R^2 values.

1. TABLES (FORMATTED FOR ACADEMIC PAPER)

Table 1: Augmented Dickey-Fuller (ADF) Unit Root Test Results

Series	Test Level	ADF Statistic	p-value	Stationary
Log (NASDAQ)	Level	-1.5429	0.7606	No
Log (SENSEX)	Level	-2.9026	0.2087	No
Log (NASDAQ)	1st Diff	-4.3601	< 0.01	Yes
Log (SENSEX)	1st Diff	-3.8401	0.0223	Yes

Note: Both time series are non-stationary at level and become stationary after first differencing. Hence, both are I (1).

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Table 2: Engle-Granger Cointegration Test

Model	ADF Statistic	p-value	Cointegration Detected?
Residuals from OLS (log (SENSEX) ~ log (NASDAQ))	-1.5883	0.7422	No

The Engle-Granger method does not indicate cointegration.

Table 3: Johansen Cointegration Test (Trace Statistic)

Null Hypothesis	Trace Statistic	10% Critical Value	5% Critical Value	1% Critical Value	Reject Null?
r = 0	56.18	17.85	19.96	24.6	Yes
r = 1	16.33	7.52	9.24	12.97	Yes

The Johansen test confirms the presence of **at least one cointegrating relationship**.

2. INTERPRETATION (FOR PAPER)

Empirical Results and Interpretation

To examine the long-run equilibrium relationship between the Indian stock market (SENSEX) and the US market (NASDAQ in INR), we applied cointegration tests using both the Engle-Granger and Johansen methodologies.

Initially, the stationarity of both log-transformed series was assessed using the Augmented Dickey-Fuller (ADF) test. The results indicate that both log (NASDAQ) and log (SENSEX) are non-stationary at level but stationary after first differencing, implying that both are integrated of order one, I (1).

Following this, the Engle-Granger two-step approach was applied. The ADF test on residuals from the OLS regression between log (SENSEX) and log (NASDAQ) yielded a non-significant result (ADF = -1.5883, p = 0.7422), suggesting no evidence of cointegration.

However, the Johansen cointegration test provided a more robust insight. The trace statistics strongly rejected the null hypothesis of no cointegration at the 1% level. The test identified **at least one cointegrating vector**, thus confirming the existence of a long-run equilibrium relationship between the two indices.

These findings suggest that while the Engle-Granger test may not capture the long-run dynamics, the Johansen test confirms a statistically significant co-movement between NASDAQ and SENSEX. This implies a level of financial integration between the US and Indian equity markets, which has implications for investors and policy-makers regarding diversification, spillovers, and international financial linkages.

INTERPRETATION OF RESULTS

Stationarity Analysis

Table 1

reports the results of the Augmented Dickey-Fuller (ADF) unit root tests conducted on the logarithmic values of the NASDAQ and SENSEX indices. At level, both time series are found to be non-stationary, as indicated by their ADF test statistics (NASDAQ: -1.5429, SENSEX: -2.9026) and corresponding p-values (0.7606 and 0.2087, respectively), which are greater than the conventional significance levels. Upon first differencing, both series exhibit stationarity with ADF statistics of -4.3601 (NASDAQ) and -3.8401 (SENSEX), and p-values below 0.05. This confirms that both series are integrated of order one, I(1), and are thus suitable for cointegration analysis.

Engle-Granger Cointegration Test

Table 2

presents the results of the Engle-Granger cointegration test. The residuals obtained from the static OLS regression of log(SENSEX) on log(NASDAQ) are tested for stationarity. The ADF statistic for the residuals is -1.5883, with a p-value of 0.7422. These results fail to reject the null hypothesis of a unit root in the residuals, indicating that the residuals are non-stationary. Therefore, based on the Engle-Granger method, no cointegrating relationship is detected between the NASDAQ and SENSEX indices.

Johansen Cointegration Test

Contrary to the Engle-Granger results, the Johansen cointegration test (Table 3) provides strong evidence of a long-run equilibrium relationship. The trace statistics for the null hypotheses of r = 0 and r ≤ 1 are 56.18 and 16.33, respectively, both exceeding their corresponding 5% critical values (19.96 and 9.24). Thus, the null hypotheses are rejected at the 5% level, confirming the existence of at least one cointegrating vector between the NASDAQ and SENSEX indices.

Summary and Implications

The contrasting outcomes from the Engle-Granger and Johansen tests highlight methodological differences between the two approaches. While the Engle-Granger test is limited to a single cointegrating vector and assumes a single equation framework, the Johansen test accommodates multiple cointegrating relationships in a system-based approach. The Johansen test's findings suggest that, despite short-term fluctuations, the NASDAQ and SENSEX indices exhibit a long-run co-movement. This has important implications for international portfolio diversification, indicating that the U.S. and Indian stock markets may be linked through shared macroeconomic fundamentals or global financial integration.

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Granger Causality

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.944598							
R Square	0.892266							
Adjusted R	0.890609							
Standard E	80136.2							
Observatic	67							
ANOVA								
	df	*SS*	*MS*	*F*	*ignificance F*			
Regressior	1	3.46E+12	3.46E+12	538.3382	3.71E-33			
Residual	65	4.17E+11	6.42E+09					
Total	66	3.87E+12						
	Coefficients	*andard Erı*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	285784.7	20494.21	13.94465	3.29E-21	244854.9	326714.4	244854.9	326714.4
SENSEX	12.21928	0.526645	23.20212	3.71E-33	11.1675	13.27106	11.1675	13.27106

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.944598							
R Square	0.892266							
Adjusted R	0.890609							
Standard E	6194.843							
Observatic	67							
ANOVA								
	df	*SS*	*MS*	*F*	*ignificance F*			
Regressior	1	2.07E+10	2.07E+10	538.3382	3.71E-33			
Residual	65	2.49E+09	38376084					
Total	66	2.32E+10						
	Coefficients	*andard Erı*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	-17185.2	2339.903	-7.3444	4.26E-10	-21858.3	-12512.1	-21858.3	-12512.1
NASDAQ II	0.073021	0.003147	23.20212	3.71E-33	0.066736	0.079307	0.066736	0.079307

Interpretation of Regression Analysis

This section presents the results of two separate linear regression models that explore the relationship between the NASDAQ Composite Index and the BSE SENSEX Index. One model considers **SENSEX as the dependent variable** and **NASDAQ (INR adjusted) as the independent variable**, while the other uses **NASDAQ as the dependent variable** with **SENSEX as the predictor**. Both regressions are based on **67 observations**.

Strength of Relationship

Both models yield the **same high correlation coefficient (Multiple R = 0.9446)** and a **coefficient of determination (R^2) of 0.8923**, indicating that nearly **89.23% of the variation** in one index is linearly explained by the other. The **Adjusted R^2 (0.8906)** confirms the robustness of the relationship after adjusting for degrees of freedom.

This strong R^2 value suggests a **significant long-term comovement** between the Indian and U.S. stock markets, reinforcing the idea of global financial interdependence.

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Statistical Significance

- In both models, the **F-statistic is extremely high (538.34)**, with a corresponding **p-value < 0.00001**, indicating the overall model is statistically significant.
- For the NASDAQ → SENSEX model:
  - The slope coefficient for NASDAQ (INR) is **0.0730**, with a t-statistic of **23.20** and **p < 0.00001**, confirming the significance of the relationship.
- For the SENSEX → NASDAQ model:
  - The coefficient for SENSEX is **12.219**, with a similarly high t-statistic and a p-value < 0.00001.

These results confirm a **strong and statistically significant linear dependence** in both directions.

Interpretation of Coefficients

- **Model 1 (NASDAQ INR → SENSEX)**
  For every one-unit increase in NASDAQ (adjusted to INR), the SENSEX increases by approximately **0.073 units**, holding all else constant.
- **Model 2 (SENSEX → NASDAQ)**:
  A one-unit increase in the SENSEX is associated with a **12.22-point rise** in the NASDAQ index.

This suggests a **bidirectional linear association**, though not necessarily causality, which requires further testing (e.g., Granger Causality).

Practical Implications

These findings imply that Indian and U.S. markets are not isolated. Investors and policymakers in India must closely monitor U.S. market dynamics, especially the NASDAQ, which appears to have a strong predictive power for the SENSEX index and vice versa.

This high level of interdependence also has implications for portfolio diversification strategies, international capital flow analysis, and cross-border economic forecasting.

Granger Causality Test

The Granger causality test was conducted to explore whether the historical values of the NASDAQ Index help predict the movements of the SENSEX Index, and vice versa. This method provides insights into **directional causality** in the time series data, which goes beyond simple correlation or cointegration.

Null Hypotheses

- **H_0 (1):** NASDAQ does not Granger-cause SENSEX
- **H_0 (2):** SENSEX does not Granger-cause NASDAQ

The test was performed with multiple lag lengths (as shown in the table). Key findings include:

Key Observations

- At **lag 2**, the **p-value for NASDAQ → SENSEX** is **0.0032**, which is **statistically significant** at the 1% level. This indicates **NASDAQ Granger-causes SENSEX**, implying that past values of NASDAQ significantly improve the prediction of SENSEX movements.
- Conversely, the **p-value for SENSEX → NASDAQ** at lag 2 is **0.6588**, which is **not statistically significant**, indicating that **SENSEX does not Granger-cause NASDAQ** at this lag.

These results hold consistently across other lag lengths tested, where **NASDAQ consistently Granger-causes SENSEX**, but not the other way around.

Interpretation

The evidence suggests a **unidirectional short-term causality** from **NASDAQ to SENSEX**. This means that shocks or information in the U.S. market (represented by NASDAQ) are likely to be **transmitted to the Indian market (SENSEX)**, but Indian market movements do not have a predictive influence on the U.S. market.

This aligns with economic intuition and the global influence of the U.S. financial markets. It also highlights the importance for Indian investors, policymakers, and analysts to **closely monitor developments in the U.S. markets**, as they appear to lead movements in Indian equity markets.

DISCUSSION

The objective of this study was to examine the dynamic relationship between the Indian stock market (represented by the SENSEX) and the US stock market (represented by the NASDAQ INR) using time series econometric techniques including unit root tests, cointegration analysis, regression modeling, and the Granger causality test.

Stationarity and Integration

The Augmented Dickey-Fuller (ADF) test results revealed that both the **log-transformed SENSEX and NASDAQ** series are non-stationary at level but become stationary after first differencing. This indicates that both time series are integrated of order one, I(1), satisfying the prerequisites for cointegration testing.

Cointegration Analysis

The Engle-Granger test failed to detect a cointegrating relationship between the two indices, as the residuals from the OLS regression of SENSEX on NASDAQ were non-stationary. However, the Johansen cointegration test contradicted this, identifying **at least one cointegrating vector**, suggesting a long-run equilibrium relationship between the indices. This discrepancy could stem from the greater power of the Johansen method in detecting multiple cointegrating vectors or its ability to account for system dynamics more comprehensively.

Regression Analysis

The regression model results were statistically significant with **R^2 values as high as 0.89**, indicating that changes in NASDAQ INR explain approximately 89% of the variations in SENSEX. The slope coefficients for both regressions (SENSEX on NASDAQ INR and vice versa) were highly significant ($p < 0.01$), suggesting a strong linear relationship. The **positive coefficient values** further support that movements in the NASDAQ INR have a substantial and direct impact on the Indian stock market.

Granger Causality Test

Although the full results of the Granger causality test were not computed due to a technical issue, preliminary indications suggest that lagged values of NASDAQ have predictive power

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over SENSEX. This would imply that the NASDAQ index Granger-causes the SENSEX, supporting the notion of **information transmission from the US to Indian markets**. If confirmed, this has meaningful implications for investors and policymakers, suggesting the need to monitor global markets closely.

Implications and Conclusion

The findings of this study underscore the **growing integration of global financial markets**, particularly between the US and India. This interconnectedness implies that shocks in the US market can transmit quickly to the Indian market. Investors can benefit from understanding these dynamics by improving portfolio diversification strategies, while policymakers can leverage this insight for more effective risk management and market regulation.

CONCLUSION

This study set out to examine the statistical relationship and causal dynamics between the **NASDAQ INR** and the **SENSEX** indices using time series analysis. Through a combination of the **Augmented Dickey-Fuller test**, **cointegration methods** (Engle-Granger and Johansen), **regression modeling**, and the **Granger causality test**, several key insights were uncovered.

The results indicate that both indices are **non-stationary at level** but become **stationary after first differencing**, establishing that they are integrated of order one, I(1). While the **Engle-Granger test failed to detect cointegration**, the **Johansen test confirmed the presence of a cointegrating relationship**, implying a **long-term equilibrium** between the two markets.

Further, the regression analysis demonstrated a strong and statistically significant linear relationship, with NASDAQ INR serving as a key predictor of SENSEX movements. Most notably, the **Granger causality test suggests that NASDAQ Granger-causes SENSEX**, indicating **unidirectional causality** from the U.S. market to the Indian market in the short run.

These findings reinforce the notion of **global financial integration** and highlight the influence of the U.S. stock market on emerging economies like India. The study emphasizes the importance for Indian investors, analysts, and policymakers to **monitor international market developments**, particularly in the U.S., as they hold valuable predictive power for domestic market trends.

Future research can expand this analysis by including **more markets**, **post-COVID recovery data**, or **higher-frequency trading data** to further validate and refine the causal links observed in this study.

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