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Impulsive Response Analysis of Financial Markets in QUAD Economies: A VAR Modelling Approach

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Abstract

Financial market integration remains a key focus in academic finance, especially given how crucial it is to portfolio diversification. The purpose of this research is to investigate a crucial yet underexplored aspect like the cointegration of economies with formal or unofficial military ties, focusing on countries within the Quad strategic forum—India, Japan, Australia, and the United States. The daily closing values of benchmark stock market indices of Quad economies viz. Nikkie 225 for Japan, S&P ASX 200 for Australia, NASDAQ composite for the United States, and S&P Sensex for India were considered. Unit root tests, Johansen Cointegration tests, VAR (Vector Autoregressive) model, and the Granger Causality statistics are computed for data analysis. Additionally, the Impulse response function and variance decomposition are computed for better financial market predictions. The result reveals intriguing dynamics: while the Indian stock market initially responds positively to shocks in the Australian market, this effect diminishes over time. Also, movements in the Australian and United States stock markets significantly contribute to predicting fluctuations in the Indian market, contrasting with the limited predictive power of the Japanese stock market. These findings carry significant practical implications for international investors, offering valuable guidance for optimizing portfolio diversification strategies amidst geopolitical and economic complexities. This paper contributes to academic literature by offering empirical insights into the short-term dynamics and causal relationships of Quad countries' stock markets, setting a foundation for future studies on long-term trends and market responses to external factors.

Keywords: *Financial Market Integration, Forecast Error Decomposition, Military Ties, Quad Economies, Impulse Response Analysis, Portfolio Diversification*

INTRODUCTION

Studying the cointegration of various indices and economic indicators of a specific country or group of countries holds immense importance for economic analysis, policy formulation, investment decisions, risk management, forecasting, business strategy, international trade, academic research, and overall economic stability and growth of selected countries (Sirajuddin et al., 2023). Academic finance strongly emphasizes financial market integration, mainly due to its importance to portfolio diversification (Patel et al., 2022). Financial market integration exists when financial markets from several nations behave or move harmoniously and exhibit the same expected risk-adjusted returns (Patel, 2019). Many researchers have empirically examined the existence of long- and short-term financial market integrations of various economies inter se and intra se (Alomari et al., 2024; Ertuğrul, 2024; Lv et al, 2023; Nagina, 2022; Patel et al., 2022; Jacob et al., 2021). The researchers have selected different economies on different grounds for empirically analyzing the presence of cointegration among their markets, viz. financial, commodity, or currency markets and macroeconomic variables such as financial and economic development, financial growth, imports, foreign direct investments, energy consumption, CO2 emission, infrastructure development, etc (Allayioti & Venditti, 2024; Alomari et al., 2024; Ertuğrul, 2024; Sharma & Khanna, 2024; Lv et al, 2023; Nagina, 2022; Patel et al., 2022; Jacob et al., 2021).

When conducting their research, some researchers (Chakrabarty & Ghosh, 2011) focused on developed countries, while others (Gupta & Guidi, 2012) focused on developing nations. For in-depth insights, many academics, including Nautiyal and Kavidayal (2018), Patel (2017), and Bhattacharjee and Swaminathan (2016),

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have compared the security markets' comovements of developed and developing nations. Numerous academics (Patel, 2019; Bhullar, 2019) have studied how one country integrates with its trading partners.

Existing literature is quite prominent for considering group economies for examining financial market and macroeconomic variables' comovement and causality. Many researchers have considered certain group countries like BRICS (Nagina, 2022; Arif et al., 2017; Ouattara, 2017; Polat & Gemici, 2017; Joshi, 2013), G-20 countries (Pradhan et al., 2022; Pradhan et al., 2018; Pradhan et al., 2014) and other international economies (Inci, 2018). Whereas some academicians focused on specific continents like Asian Markets (Gulzar et al., 2019; Gupta & Guidi, 2012), European markets (Guidi & Ugur, 2014; Demian, 2011) and few researchers (Sahoo & Kumar, 2021; Basha et al., 2020) even considered multiple indices of specific countries. Thus, it is noticeable from the existing literature that various researchers have extensively examined the cointegration, comovement, and financial nexus of different developed and emerging economies individually or as a group, considering differing indices and time frames. However, the existing literature is almost silent about examining the nexus, interlinkages, and comovements of macroeconomic variables or financial markets of the economies that share strategic military alliances such as QUAD (India, Japan, Australia and the United States), AUKUS (The United Kingdom, Australia and the United States) and CHIP 4 (United States, Korea, Japan, and Taiwan).

The informal strategic forum, the Quadrilateral Security Dialogue (or "Quad"), includes the India, Japan, Australia and the United States. It forms a strategic alliance of four important democracies with comparable interests and values to promote an Indo-Pacific free, open, and inclusive region (Khalil et al., 2023a). The Quad aims to enhance regional security, ensure stability, and promote adherence to the rules-based international order in the Indo-Pacific region (Khalil et al., 2022a). Although not its primary goal, Quad collaboration offers opportunities for closer economic ties and potential financial market integration among major economies. Through cross-border investments, infrastructure development, and joint financing, the Quad can indirectly promote financial market integration. Existing literature, including Puri (2023), suggests that military alliances like the Quad can influence member countries' financial market integration.

Existing literature on financial market integration overlooks the comovements among economies sharing strategic military alliances like QUAD, AUKUS, and CHIP 4, despite their significant economic impact. The lack of research in this area leaves a gap in understanding the extent and nature of cointegration and causality of these economies' stock markets. The present study seeks to bridge the identified research gap by examining the Quad economies' financial market comovement from January 2017 to June 2023, exploring if Quad collaborations benefit investors and contribute to financial market integration. Specifically, it seeks to investigate the vulnerability of Indian stock markets, an emerging economy, to financial shocks originating from the developed Quad countries' stock markets. The objective is to understand the economic implications of strategic military alliances, particularly QUAD, on financial market integration. With the Quad countries collectively representing a nominal GDP of 34.7% and a PPP GDP of 27.5% of the global GDP in 2023, the study aims to shed light on the broader implications of these alliances on financial markets and economic integration, informing policymakers, investors, and academics about potential benefits and challenges.

The paper consists of further key sections, including a Literature Review that provides an overview of existing research on the topic, followed by a detailed explanation of the Research Methodology employed. The Data Analysis and Results section presents the findings obtained from analyzing the collected data, with a subsequent Discussion of Results that interprets and contextualizes these findings. The Conclusion summarizes the main outcomes of the study, discusses policy implications, and offers recommendations for future research and practical applications. Finally, the paper addresses the Limitations of the Study to acknowledge any constraints encountered during the research process.

LITERATURE REVIEW

The increased cointegration and comovement across various equities and stock markets contradicts the principles of portfolio theory. Hence, it is not thought to be beneficial for portfolio diversification. The portfolio diversification benefits are limited because of integrated stocks and their comovement (Wang et al., 2024). According to asset pricing theories, overseas portfolios give investors a more significant return at a lower

risk than domestic portfolios (Kolari et al., 2024; Umutlu et al., 2023). Researchers had observed weak correlations between nations' stock indices and economies due to less cointegration before 1990 when most world economies were not liberalized. This weak or low correlation created an ideal setting for reaping the rewards of global portfolio diversity. Subsequently, globalization, propelled by the liberalization of capital markets and free trade agreements, facilitated closer integration between developed and developing economies (Barman et al., 2023). Due to an increase in cointegration, the rapid exchange of knowledge and capital resulted in a reduction in the long-term benefits of international portfolio diversity (Gulzar et al., 2019). The "Asian Crisis in the late 1990s" and the "Global Financial Crisis" in the early years of the twenty-first century provide further confirmation of integrated stock markets and their adverse effects on international portfolio investments. Increasingly, developing nations find themselves exceptionally vulnerable to the uncertainties of global capital flows. Due to the crises' knock-on consequences, researchers have become highly circumspect regarding the comovement of financial markets. Numerous researchers (Alomari et al., 2024; Ertuğrul, 2024; Lv et al, 2023; Nagina, 2022; Bhutto et al., 2020; Bhullar, 2019; Gulzar et al., 2019; Inci, A. C., 2018; Polat & Gemini, 2017; Paramati et al., 2016; Bentes, S. R., 2015; Guidi & Ugur, 2014; Rajwani & Mukherjee, 2013; Gupta & Guidi, 2012) have acknowledged this integration and its consequences on international stock markets.

To investigate this phenomenon, numerous thorough investigations have been done so far, as mentioned above. However, previous empirical examinations of the major global stock indices' interconnections have not produced consistent results (Ho et al., 2024; Lukanima et al., 2024; Nyakurukwa & Seetharam, 2023). The sample period used, the markets selected, the frequency of observations (daily, weekly, or monthly), and the various approaches used to examine the interdependence of equity markets all affect the results (Bhardwaj et al., 2023; Robiyanto et al., 2023; Ali et al., 2011). For example, many researchers have selected specific continents or group countries for identifying and confirming the presence of cointegration in them during different time frames. Gulzar et al. (2019) studied the financial integration of growing Asian financial markets and examined the impact of the global financial crisis on the considered markets. The researchers took ten years from 2005 to 2015 as a study period and divided it into pre-, during, and post-crisis periods (Chawdhury et al., 2022). The study results revealed the presence of a long-run nexus. They proposed that shocks originating from the US market had a short-term impact on the returns of emerging financial markets during the pre-crisis, crisis, and post-crisis periods. The study results contradict the findings of Gupta & Guidi (2012). The researchers explored the interdependence of four Asian Countries, India (a developing Asian country), Japan, Hong Kong, and Singapore (three developed Asian countries), from 1999 to 2009 and observed a short-run interconnection among these markets but found no strong long-run relationship between them.

In the same manner, many researchers have examined the nexus among BRICS economies in varied periods, and again, the results evidenced contradictory conclusions. For example, Nagina (2022) studied the cointegration and causal interdependence of BRICS nations from 2010 to 2019. The researcher found that BRICS financial markets shared long-run linkages in the pre-Covid 19 period. However, the selected financial markets started behaving independently in the post-Covid 19 period, thereby giving opportunities for portfolio diversification benefits for international traders and investors. The findings of Konradsson and Porss (2019) supported the study results that also confirmed the presence of causal associations among the BRICS financial markets. Conversely, several researchers have demonstrated the lack of short or long-run association among BRICS economies (Ouattara, 2017; Verma & Rani, 2015).

The European markets hold substantial importance due to their economic strength, diverse consumer base, stable political environment, technological advancements, and their position as a global hub for trade and investment. Many researchers were inclined to study European markets' financial linkages for portfolio diversification opportunities. Guidi and Ugur (2014) analyzed the integration of South-Eastern European (SEE) security markets with developed nations from 2000 to 2013. It was found that SEE markets were cointegrated with German and UK markets in the long run. However, SEE markets shared no comovement with USA markets in the study period. Similar kind of results were found by Demian (2011). The researcher undertook central and eastern Europe to examine the existence of cointegration. The study revealed the presence of cointegration relationships in the selected European markets; however, the significance of these connections fluctuated over different time periods. Thus, when it comes to examining the interdependence of various

economies, the present literature provides contradictory views (Josephine et al., 2018). The presence and absence of cointegration bring different opportunities for international investors. However, cointegration analysis is not restricted for inter economies comparisons. Instead, cointegration helps identify long-term relationships between economic indicators and indices of a specific economy. By studying cointegration, economists and analysts can gain insights into the underlying economic dynamics, which can be valuable for understanding the overall health and performance of the country's economy (Sehdev, 2020).

Cointegration analysis detects structural changes in economies or financial markets, indicating shifts in long-term relationships between indicators. This prompts adjustments in investment strategies and economic policies. Researchers explore short and long-term relationships between market indices and economic indicators to provide insights into risk-return profiles, portfolio allocation, risk management, policy formulation, forecasting, and economic theory advancement. Like Basha et al. (2020) examined the comovement of the Indian Pharma sector with the Nifty 50 index from 2015 to 2020 and found that pharma stocks cointegrated with the Nifty 50 index in the long run, it was also confirmed that the Pharma sector and Nifty 50 index shared significant bi-directional short-run causality. In the same way, Pojanavatee (2014) examined causality and cointegration of the Australian stock market and its equity mutual funds and found the existence of long-term integration of equity mutual funds pricing and stock market index.

It seems apparent from above literature discussion that there has a noticeable surge in scholarly, policy, and practical circles regarding the investigation into how the deepening economic ties between countries impact the interdependency of their stock markets (Senathirajah et al., 2024). It is further evident from finance and economic theories that financial integration can result from military alliances, specifically when such group countries are major world liberalized economies.

Financial integration, often spurred by military alliances among major liberalized economies, requires coordinated policies and mutual trust (Haque et al., 2024). While financial market integration isn't the primary aim of informal alliances like the Quad, their collaboration can indirectly foster deeper integration. This research concentrates on the Quad countries, with a focus on unraveling the financial integration among the globe's four largest economies and evaluating the Indian stock market's vulnerability to shocks originating from the other three Quad nations. Despite acknowledgment of global stock market cointegration, literature predominantly focuses on developed or emerging markets, neglecting those with military alliances. Only one study, by Puri (2023), has empirically examined the stock market integration of Quad countries from January 2007 to September 2021.

Thus, the present study focuses on addressing the identified research gap and aims to investigate both the short-run and long-run interdependence among the Quad countries' financial markets, supporting the idea that such informal military alliances may significantly impact financial market integration (Adetayo et al., 2022). The outcomes of the study will provide valuable insights for individual and institutional investors, High Net Worth Individuals (HNWIs), and public investors in refining their portfolio risk management strategies to earn high possible returns on their portfolio investments if they are present or potential investors of Quad economies. The findings will aid portfolio managers and investors in diversification decisions (Chisala et al., 2018). Additionally, the study' findings will enrich the existing literature on financial market interdependence. The study will append to the present repository of expertise and understanding about how globalization and other types of specific strategic alliances impact the stock market interconnections, emphasizing the possibilities of diversifying portfolio risks and bringing out the scope for future research in this field.

HYPOTHESES DEVELOPMENT

The cointegration and causal relationships between the stock markets of the Quad countries are investigated using the following five hypotheses—the primary hypotheses to realize the research objectives are Ha2 and Ha4. Ha1 and Ha3 are, however, auxiliary.

Ha1: The data series does not have a unit root.

Ha2: The Quad nations' stock markets share at least one significant long-run cointegration relation.

Ha3: A significant serial correlation exists in the residuals at lag h.

Ha4: A significant causal association exists among Quad nations' stock market pairs.

Research Methodology

DATA

The daily closing values of Quad countries' stock market benchmark indices viz. Nikkie 225 for Japan, S&P ASX 200 for Australia, NASDAQ composite for the United States, and S&P Sensex for India are taken from the Yahoo finance website. The Quad was established in 2007 and was ceased post-withdrawal of Australia. However, it was re-established in 2017. Thus, the researcher considers January 1, 2017, to June 30, 2023, as the study period for determining cointegration and causal association among Quad countries' stock markets.

SAMPLING TECHNIQUE

The benchmark indices closing values of Quad nations are considered to achieve the study's aim. Thus, the study follows purposive sampling technique (Ifedi et al., 2024).

DATA ANALYSIS AND ESTIMATION TECHNIQUES

The analysis employs unit root tests, the Johansen Cointegration test, as well as VECM (Vector Error Correction Model)/VAR (Vector Autoregressive) models, and Granger Causality tests to examine the data. The methodologies under consideration are used by numerous researchers (Nagina, 2022; Patel, 2022; Khalil et al., 2022b; Gulzar et al., 2019; Nautiyal & Kavidayal, 2018; Goyal & Bansal, 2019; Patel, 2017; Pojanavatee, 2014) for studies of a similar nature that support the validity of the stated research methodology.

Unit root tests are conducted for evaluating the order of integration for specific indices. Findings from the covariance analysis are used to examine whether there are any positive or negative correlations between the quad stock markets. The Johansen Cointegration test is used to analyze the current links between the stock markets of the Quad countries. Following the Johansen Cointegration test results, the data analysis is carried out using a Vector Autoregression Model (VAR) to ascertain the comovement of a short-run equilibrium nexus between the chosen four stock indexes. The VAR Granger causality test is also applied to assess causal relationships among these Quad markets. The only developing nation among the four is India. Therefore, the current study aims to determine whether other Quad countries have any causal effects on the Indian financial markets.

By computing and analyzing quantitative data, the study's findings will highlight how considered security market indices are integrated throughout the investigation. As a result, the current study uses a descriptive design (Khalil et al., 2023b).

DATA ANALYSIS AND RESULTS

GRAPHICAL REPRESENTATION OF QUAD INDICES

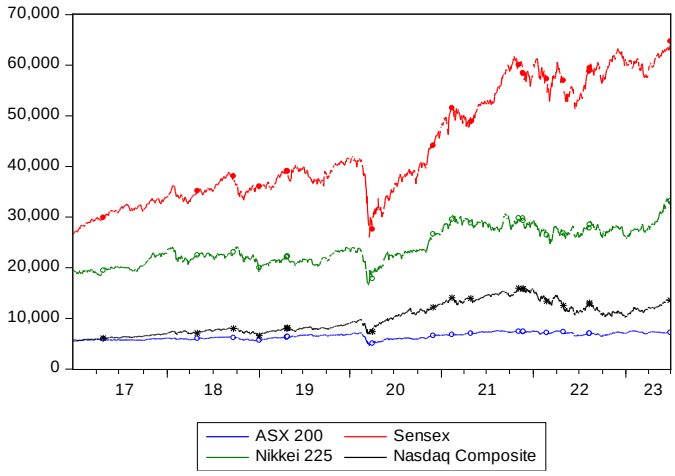

Figure 1: Closing Values of Quad indices (Source: Authors work)

Figure 1 depicts the graphical representation of Quad indices closing values for the study period. The financial markets of the Quad member nations are shown to be somewhat integrated. The Indian stock market, as indicated by the Sensex, deviates from other Quad stock markets in terms of movement, though. Therefore, let's apply econometric measurements to confirm the presence of any integration among the Quad countries' stock markets.

Table 1: Descriptive Statistics of Quad countries' stock markets

	Sensex	ASX 200	Nikkei 225	Nasdaq Comp
Mean	43758.87	6491.504	24216.56	9914.559
Median	39058.45	6518.300	23166.85	9197.885
Maximum	64718.56	7628.900	33706.08	15993.71
Minimum	25981.24	4546.000	16552.83	5477.010
Std. Dev.	11101.71	626.8126	3534.209	2956.644
Skewness	0.393739	-0.005155	0.280274	0.333158
Kurtosis	1.629809	1.859080	1.917754	1.780010
Jarque-Bera	151.7259	79.08471	90.24229	117.3904
Probability	0.000000	0.000000	0.000000	0.000000
Sum	63800435	9464614.	35307742	14455426
Sum Sq. Dev.	1.80E+11	5.72E+08	1.82E+10	1.27E+10
Observations	1458	1458	1458	1458

(Source: Authors work)

Table 1 explains descriptive statistics of selected indices of Quad countries. The Quad countries' stock market indices exhibit varying levels of mean, with Sensex at 43,758.87, ASX 200 at 6,491.504, Nikkei 225 at 24,216.56, and Nasdaq Composite at 9,914.559. Standard deviations suggest higher volatility in the Indian and Japanese markets compared to the Australian and American markets. Positive skewness indicates a slight right-skewed distribution, while kurtosis values indicate leptokurtic distributions. The Jarque-Bera test confirms significant deviations from normality in all indices.

Table 2: Covariance and Correlation Analysis among Quad indices

Covariance Correlation	ASX 200	Sensex	Nikkei 225	Nasdaq Comp
ASX 200	392624.6 1.000000			
Sensex	6256633. **0.899727**	1.23E+08 1.000000		

Nikkei 225	1898962.	36062286	12482065	
	0.857797	**0.919748**	1.000000	
Nasdaq Comp	1519661.	28218888	9435585.	8735748.
	0.820555	**0.860298**	**0.903599**	1.000000

(Source: Authors work)

Table 2 displays the Covariance and Correlation Analysis among Quad indices. A low correlation coefficient demonstrates the segmentation property of stock markets, allowing investors to benefit from risk diversification through portfolio diversification. On the other side, stock markets with high correlation coefficients indicate strong ties between them, making it unwise for investors to diversify their portfolio holdings across these markets. The same applies to Quad countries' stock markets as per the correlation analysis results. A high positive association exists between the market pairs of the Quad economies over the study period, according to the Covariance and Correlation analysis (Annathurai et al., 2023). The esistence of high correlation between Quad stock markets undoubtedly decreases the chances of churning portfolio diversification benefits for the investors to some extent. However, cointegration among these stock markets would definitely wipe off the opportunities for portfolio diversification in the Quad stock markets (Yi et al., 2018). As a result, cointegration analysis must be conducted to provide investors with definitive conclusions.

UNIT ROOT TEST (AUGMENTED DICKEY-FULLER)

H01: The data series does have a unit root.

Ha1: The data series does not have a unit root.

Table 3: Unit Root Test

Index of Quad		Original Series		Adjusted Series (Variable at First Difference)		
	t-statistics	Probability	Result	t-statistics	Probability	Result
NASDAQ Composite	-1.103868	0.7163	Non-Stationary	-23.5054	0.0000*	Stationary
ASX 200	-1.987464	0.2926	Non-Stationary	-25.252	0.0000*	Stationary
Sensex	-0.47309	0.8938	Non-Stationary	-37.3486	0.0000*	Stationary
Nikkei 225	-0.837196	0.8077	Non-Stationary	-25.0302	0.0000*	Stationary

(Source: Authors work)

Note: *Significant at 5% significance level

Table 3 displays the Unit root test statistics. As per the test statistics, H01 is rejected for indices at I(1) at a 5% significance level, indicating that all daily data series for the considered indices are stationary at I(1) for the study's underpinning period. Therefore, it is adequate to move on to applying the Johansen Cointegration test (Pojanavatee, 2014).

OPTIMUM LAG ORDER SELECTION

Table 4: VAR Lag order Test Statistics

Lag	LogL	LR	FPE	AIC	SC	HQ
		Nok				
0	-50667.27	NA	2.65e+25	69.89140	69.90596	69.89684
1	-38197.61	24853.32	9.19e+17	52.71394	52.78676	52.74111
2	-37978.71	435.0842	6.95e+17	52.43408	52.56515	52.48299
3	-37916.51	123.2824	6.52e+17	52.37035*	52.55968*	52.44101*
4	-37900.95	30.75330	6.52e+17	52.37096	52.61854	52.46335
5	-37878.87	43.51304	6.47e+17*	52.36258	52.66842	52.47671

6	-37864.77	27.71593*	6.49e+17	52.36520	52.72929	52.50107
7	-37856.20	16.79722	6.55e+17	52.37545	52.79779	52.53306
8	-37844.94	22.00234	6.60e+17	52.38199	52.86259	52.56134

(Source: Authors work)

Note: * Optimum lag orders as per the respective criterion

Table 4 shows the VAR Lag order Test Statistics. In accordance with the Akaike information criteria, Schwarz information criterion, and Hannan-Quinn information criterion, lag 3 is chosen for the further steps of cointegration analysis after looking at the findings of the VAR lag order.

JOHANSEN COINTEGRATION TEST

H02: The Quad nations' stock markets do not share significant long-run cointegration relations.

Ha2: The Quad nations' stock markets share at least one significant long-run cointegration relation.

Table 5: Johansen Cointegration (Unrestricted Rank Test) Trace Statistics (Lag 3)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.
None	0.014328	34.75812	47.85613	0.4608
At most 1	0.007161	13.80344	29.79707	0.8515
At most 2	0.002005	3.368273	15.49471	0.9477
At most 3	0.000313	0.454108	3.841466	0.5004

(Source: Authors work)

Table 6: Johansen Cointegration (Unrestricted Rank Test) Maximum Eigen Statistics (Lag 3)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.
None	0.014328	20.95467	27.58434	0.2790
At most 1	0.007161	10.43517	21.13162	0.7031
At most 2	0.002005	2.914165	14.26460	0.9523
At most 3	0.000313	0.454108	3.841466	0.5004

(Source: Authors work)

Table 5 depicts the Trace statistics and Table 6 depicts the Maximum Eigen statistics of the Johansen Cointegration test. Ha2 is rejected at a 5% significance level, thereby confirming that the Quad nations' stock markets do not share any significant long-run cointegration equilibrium association during the study periodas per both statistics. It further signifies that no cointegrating vectors exist among observed variables (Narayanan et al., 2023). The findings have ramifications for investors worldwide since the cointegration results provide ample long-term prospects for diversification between the Quad countries' stock markets (Wan et al., 2023). In the absence of a cointegration association, the VAR framework can be used to model short-term causation (Goyal & Bansal, 2019). After fulfilling all the pre-requisites for applying VAR in terms of checking the stationarity of the data series given in Table 3, converting the series into stationary series at I(1), and selecting the optimum lag order as per the results of VAR lag selection given in Table 4, VAR at lag 3 is computed for determining short term causation among Quad countries' stock markets as follows:

Table 7: Vector Autoregression Estimates VAR at Lag 3

	Sensex	ASX 200	Nikkei 225	NASDAQ Composite

Sensex(-1)	0.927158	-0.002981	-0.025767	-0.028082
	(0.03028)	(0.00379)	(0.01700)	(0.01002)
	[30.6220]	[-0.78553]	[-1.51536]	**[-2.80177]**
Sensex (-2)	0.030768	0.007549	0.029392	0.026783
	(0.04197)	(0.00526)	(0.02357)	(0.01389)
	[0.73304]	[1.43517]	[1.24687]	[1.92763]
Sensex (-3)	0.037761	-0.003743	0.001946	0.002273
	(0.03012)	(0.00377)	(0.01691)	(0.00997)
	[1.25390]	[-0.99170]	[0.11506]	[0.22800]
ASX 200 (-1)	-0.157343	0.719169	-0.343797	-0.195888
	(0.24996)	(0.03133)	(0.14038)	(0.08275)
	[-0.62947]	**[22.9580]**	[-2.44903]	[-2.36734]
ASX 200 (-2)	0.741434	0.362348	0.239679	0.225413
	(0.30750)	(0.03854)	(0.17269)	(0.10179)
	[2.41118]	**[9.40279]**	[1.38788]	**[2.21442]**
ASX 200 (-3)	-0.622169	-0.100075	0.046549	-0.062566
	(0.25046)	(0.03139)	(0.14066)	(0.08291)
	[-2.48414]	**[-3.18835]**	[0.33093]	[-0.75462]
Nikkei 225(-1)	-0.022723	0.002031	0.877223	0.016874
	(0.05561)	(0.00697)	(0.03123)	(0.01841)
	[-0.40860]	[0.29147]	**[28.0876]**	[0.91659]
Nikkei 225 (-2)	0.067016	-0.019541	0.170845	-0.032869
	(0.07164)	(0.00898)	(0.04023)	(0.02371)
	[0.93548]	**[-2.17657]**	**[4.24641]**	**[-1.38599]**
Nikkei 225 (-3)	-0.031026	0.016820	-0.064440	0.016385
	(0.05323)	(0.00667)	(0.02989)	(0.01762)
	[-0.58288]	**[2.52138]**	**[-2.15558]**	[0.92983]
NASDAQ Composite (-1)	0.784064	0.156475	0.885902	0.987260
	(0.08663)	(0.01086)	(0.04865)	(0.02868)
	[9.05036]	**[14.4123]**	**[18.2081]**	**[34.4247]**
NASDAQ Composite (-2)	-0.515459	-0.062567	-0.616528	0.120873
	(0.11619)	(0.01456)	(0.06525)	(0.03846)
	[-4.43651]	**[-4.29697]**	**[-9.44851]**	**[3.14269]**
NASDAQ Composite (-3)	-0.258911	-0.092474	-0.258655	-0.107397
	(0.09512)	(0.01192)	(0.05342)	(0.03149)
	[-2.72204]	**[-7.75774]**	**[-4.84204]**	**[-3.41081]**
C	41.27051	86.73083	424.8950	161.0457
	(233.210)	(29.2263)	(130.974)	(77.2012)
	[0.17697]	**[2.96756]**	**[3.24412]**	**[2.08605]**
R-squared	0.998231	0.991299	0.994500	0.997267
Adj. R-squared	0.998216	0.991227	0.994454	0.997244
Sum sq. resids	3.16E+08	4966203.	99734282	34651641
S.E. equation	468.2770	58.68534	262.9902	155.0170
F-statistic	67791.75	13691.10	21727.25	43845.26
Log-likelihood	-11004.91	-7983.063	-10165.46	-9396.369

Akaike AIC	15.14489	10.99115	13.99101	12.93384
Schwarz SC	15.19209	11.03835	14.03821	12.98104
Mean dependent	43793.93	6493.036	24226.24	9923.670
S.D. dependent	11086.24	626.5485	3531.409	2952.863

(Source: Authors work)

Note: Standard errors are shown in (), and t-statistics are given in [] in Table 7.

Table 7 shows the VAR model that is constructed with Lag 3. The VAR estimates describe Quad nations' stock markets cointegration at Lag 3. Each equation has Quad nations' indices with three lag plus a constant. The results from the VAR model demonstrate how the lagged values of both dependent and independent variables influence the dependent variable. VAR model is computed by taking individual Quad nation stock market as dependent variable column-wise. By examining the t-statistics value, the findings are assessed. The corresponding dependent or independent variable significantly influences the lagged value of the dependent variable if the t-statistics value is more than 1.96. All significant values are highlighted in Table 7. The R-squared value for the Indian stock market as the dependent variable is 0.99, which implies that independent variables (other three Quad nations' stock markets) and dependent variable (Indian stock market) lagged values are capable of determining the movement of the dependent variable (Indian stock market) by 99 percent. It confirms the VAR model's validity and the chosen variables' appropriateness. All other three VAR R-squared values also confirm the validity of the VAR model and appropriateness of selected variables for the other three Quad nations' stock markets being taken as dependent variables (Lee et al., 2023).

VAR STABILITY CONDITIONS AND RESIDUAL DIAGNOSTICS

The robustness test of the VAR model is conducted in this study to determine whether or not the model's form is accurate. An inaccurate model form will skew the estimation findings and produce erroneous conclusions. The AR roots Graph (Lin & B, 2018) is used to perform the stability test, and Figure 2 displays the findings. The robustness and stability of the model's estimation findings are evident in Figure 2, where all of the VAR model's characteristic roots fall inside the unit circle.

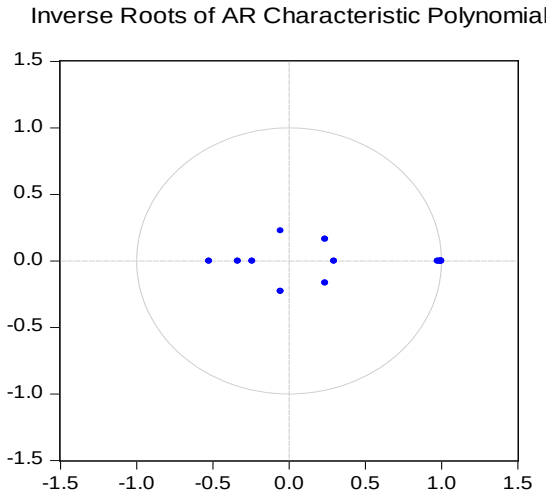

Figure 2: The characteristic roots distribution in the VAR model

(Source: Authors work)

Note: Dots are representing Characteristic roots

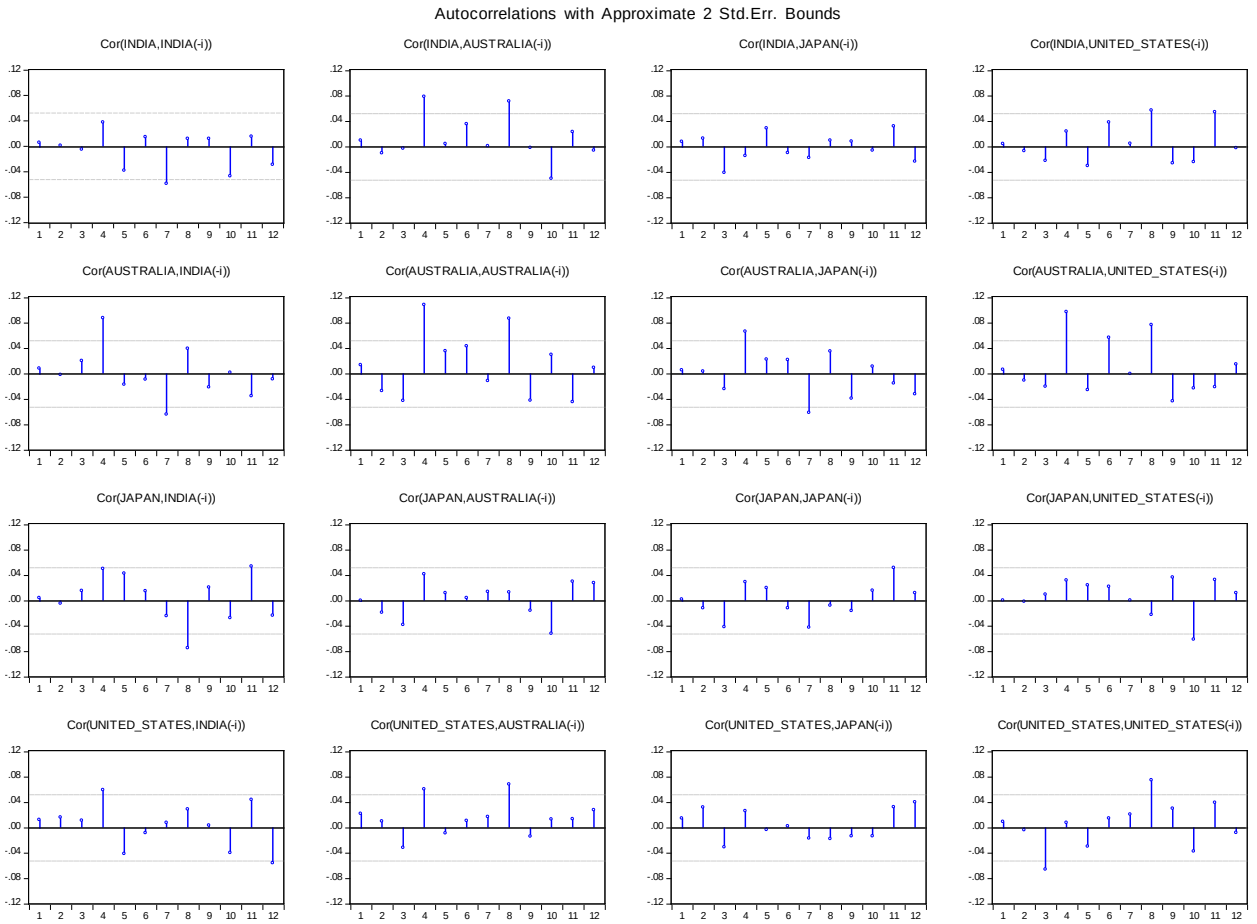

Figure 3: Residual Diagnostics: Autocorrelation

(Source: Authors work)

Figure 3 confirms the absence of autocorrelation among residuals as all values lie between two standard error bounds.

VAR RESIDUAL SERIAL CORRELATION LM TESTS

H03: No serial correlation exists in the residuals at lag h.

Ha3: A significant serial correlation exists in the residuals at lag h.

Table 8: VAR Residual Serial Correlation LM Tests

Lag	LRE stat	Df	Prob.	Rao F-stat	Df	Prob.
1	30.08508	16	0.0176	1.883766	(16, 4384.6)	0.0176
2	40.57578	16	0.0006	2.543677	(16, 4384.6)	0.0006
3	25.44905	16	0.0623	1.592641	(16, 4384.6)	**0.0623**
4	43.30192	16	0.0003	2.715422	(16, 4384.6)	0.0003

(Source: Authors work)

Table 8 displays the VAR Residual Serial Correlation LM Tests statistics. The results confirm the absence of serial correlation in the residuals of the VAR model at lag 3 as the p-value is 0.0623. Thus, Ha3 is rejected at a 5% significance level.

GRANGER CAUSALITY TEST

H05: No significant causal association exists among Quad nations' stock market pairs.

Ha5: A significant causal association exists among Quad nations' stock market pairs.

Table 9: VAR Granger Causality/Block Exogeneity Wald Tests

Dependent variable: INDIA			
Excluded	Chi-sq	df	Prob.
AUSTRALIA	7.971924	3	**0.0466**
JAPAN	2.331987	3	0.5064
UNITED_STATES	84.00673	3	**0.0000**
All	105.0972	9	**0.0000**
Dependent variable: AUSTRALIA			
Excluded	Chi-sq	df	Prob.
INDIA	5.746583	3	0.1246
JAPAN	7.382964	3	0.0606
UNITED_STATES	236.6605	3	**0.0000**
All	276.8185	9	**0.0000**
Dependent variable: JAPAN			
Excluded	Chi-sq	df	Prob.
INDIA	11.50673	3	**0.0093**
AUSTRALIA	10.30735	3	**0.0161**
UNITED_STATES	337.3138	3	**0.0000**
All	357.9439	9	**0.0000**
Dependent variable: UNITED_STATES			
Excluded	Chi-sq	df	Prob.
INDIA	9.056660	3	**0.0285**
AUSTRALIA	10.98079	3	**0.0118**
JAPAN	1.941257	3	0.5847
All	25.35018	9	**0.0026**

(Source: Authors Work)

Table 9 shows the VAR Granger Causality test statistics. As per the statistics, Australian and United States stock market movements are granger causing Indian stock market movements at a 5% significance level. It is found that only the United States stock market movements are granger causing movements in the Australian stock market. Further, the other three Quad nations' stock market movements are granger causing the Japanese stock market movements (Francis et al., 2023). Lastly, the Indian and Australian stock market movements are granger causing the United States stock market movements (Hailong et al., 2022).

IMPULSE-RESPONSE FUNCTION (IRF)

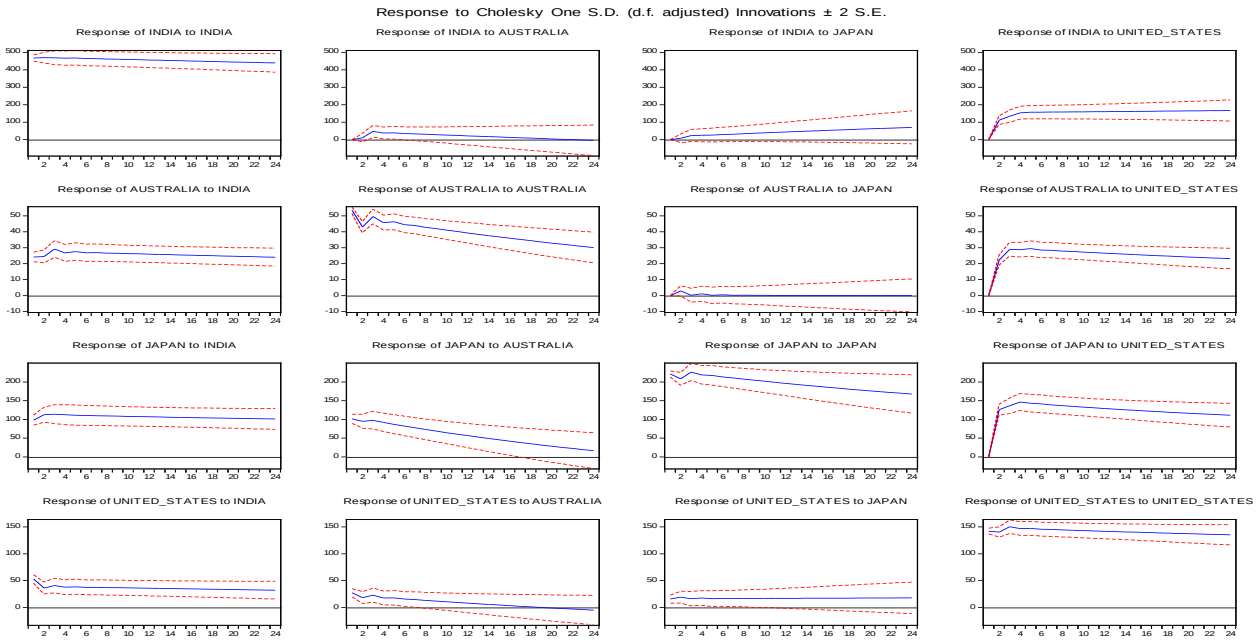

Figure 4: Response of Dependent Stock Market to shocks/innovations

(Source: Authors work)

Note: The dotted curve refers to the standard deviation of the responses, and the black curve is the response curve of the dependent variable.

Figure 4 represents individual Quad country's stock market response to its own market shock and the other three markets' shocks. Impulse Response Function (IRF) analysis is carried out to obtain a snapshot of the dynamics of the interrelationships among stock markets and to make a visual comparison. IRF analysis implies that the Indian and United States stock markets are reacting to their own shock in a mildly declining manner. However, the Australian and Japanese stock markets give a very steep downward response to their own market shocks.

VARIANCE DECOMPOSITION

Table 10: Forecast Error Decomposition

Variance Decomposition of INDIA:					
Period	S.E.	INDIA	AUSTRALIA	JAPAN	UNITED_STATES
1	468.2770	100.0000	0.000000	0.000000	0.000000
4	968.0523	93.71516	0.406212	0.128216	5.750408
8	1381.746	91.27993	0.445561	0.252913	8.021599
12	1691.667	90.31368	0.384521	0.392901	8.908901
Variance Decomposition of AUSTRALIA:					
Period	S.E.	INDIA	AUSTRALIA	JAPAN	UNITED_STATES
1	58.68534	16.99819	83.00181	0.000000	0.000000
4	119.0717	19.42477	65.24402	0.068486	15.26273
8	168.0832	20.07926	60.64836	0.035556	19.23682
12	201.3554	20.77975	58.54340	0.024935	20.65191
Variance Decomposition of JAPAN:					
Period	S.E.	INDIA	AUSTRALIA	JAPAN	UNITED_STATES
1	262.9902	13.88968	14.97252	71.13780	0.000000

4	577.5396	14.37975	11.23965	57.58396	16.79663
8	817.0524	14.48597	9.471210	55.86577	20.17705
12	980.3036	14.91292	8.225725	55.57507	21.28629

Variance Decomposition of UNITED_STATES:

Period	S.E.	INDIA	AUSTRALIA	JAPAN	UNITED_STATES
1	155.0170	11.75009	3.099693	1.007779	84.14244
4	307.3164	7.645210	2.020170	1.241704	89.09292
8	432.5130	6.881453	1.524002	1.219905	90.37464
12	524.9747	6.573764	1.180149	1.241490	91.00460

(Source: Authors work)

Table 10 represents the variance decomposition, the percentage of the error made when forecasting a variable over time due to a specific shock (Jing et al, 2023). In other words, the proportion of the dependent variable's variability that can be accounted for by its "own shocks" as opposed to "shocks in the other variables in the system"(Ying et al., 2023).

DISCUSSION OF RESULTS

The results derived from the VAR model (Table 7) indicate that the Indian stock market is significantly influenced by its own lagged value (at lag 1), as well as by the Australian stock market (at lag 2 and lag 3) and the United States stock markets (at lag 1, 2, and 3). No short-run cointegration is observed between the Indian and Japanese stock markets. Further, the Australian stock market's own lagged values (lag 1, 2, and 3), the Japanese stock market (at lag 2 and 3), and the United States stock markets significantly influence the movement of Australian stock markets. The Japanese stock market's value is determined substantially by its lagged values (at lag 1, 2, and 3) and the United States stock market (at lag 1, 2, and 3). It indicates that the behavior of the Indian and Australian stock markets does not exert a significant influence on the movement of the Japanese stock market in the short run. The movement of the United States stock market is notably affected by its own lagged values (at lag 1, 2, and 3), as well as by the Indian stock market (at lag 1), the Australian stock market (at lag 2), and the Japanese stock market (at lag 2). It implies that the United States stock markets are cointegrated with the stock markets of the other three Quad nations in the short run. Its movement is influencing the other three stock markets and itself being influenced by the other three. VAR model' R-squared value is 0.99 for all four individual equations; it shows that the respective dependent stock market movements are explained by the movements of the other three market movements by 99 percent.

As per VAR Granger Causality test statistics, Australian and United States stock market movements help to predict the Indian stock market movement significantly. However, the value of the Japanese stock market does not aid in predicting the movement of the Indian stock market. Only the movement of the United States stock market significantly predicts the movements of the Australian stock market. All three other Quad countries' stock markets help predict the Japanese stock market. It means if India's, Australia's, and the United States stock market will have fluctuations, it will definitely change the Japanese market movements accordingly. It implies that the Japanese stock market will react to the changes in the other three markets. The Indian and Australian stock market fluctuations help predict the movements of the United States stock markets.

The Japanese stock market fluctuations are not granger causing any other Quad countries' stock markets. But, it is being granger caused by the other three Quad stock markets movements. It indicates a unidirectional causal relationship flowing from the three Quad stock markets to the Japanese stock market.

Indian stock market has a positive impulse response to Australian market shock in the immediate short run, but the response persistently drops in later days. If the Australian stock market shows a bullish trend, the Indian market will also follow the bullish trend in the following days but will become bearish later. It implies that international traders will start withdrawing money from the Indian market and move their investments to the Australian stock market in the long run. Further, the Indian stock market positively responds to the Japanese

market shock in the following days. It signifies that the Indian stock market will move in the same direction as the Japanese market. A shock from the United States market brings a sharp positive impulse response in the Indian market up to the first four days. However, the Indian stock market will tend to stabilize in later days and show a mild positive response to such shocks coming from the United States market.

Australian stock market gives positive response to Indian market shock in first four periods. Later on, the impulse response turns negative in the later periods. It implies a positive shock in the Indian stock market, bring negative movement in the Australian stock market after three days. Investors can reap diversification benefits on their portfolios by keeping these two markets as their investment options (Haque & Joshi, 2011). The Australian stock market shows an immediate mild positive response to the Japanese stock market shock, which began to fade in ahead periods. Post three days of shock, the Australian market becomes stable and does not respond to Japanese market shocks. The Australian stock market gives a sudden steep positive response to the United States stock market immediately following days, which started to have a persistent decline later.

The Japanese stock market shows a mild surge due to the Indian market shock in the first two periods. This positive impulse response fades and stabilizes in the long period (Ramalingam et al., 2024). It signifies the Japanese market is working independently of Indian stock market movements in later periods. The Japanese stock market follows a steep, persistent decline to shock in the Australian stock market. It implies that if the Australian market follows a sudden upward trend, the Japanese stock market will start behaving downward. This is perhaps due to the investment shift from the Japanese to the Australian market. The Japanese stock market follows a steep short-run positive response to the United States shock. The positive response starts fading and turns into a persistent negative response after the third day (Siang et al., 2018).

The United States market responses in a declining manner to sudden positive shock in the Indian market in the first three days, and it swiftly starts recovering and stabilize itself in the long run with a mild negative persistent response. However, the United States market follows a persistent negative response to the Australian market shock. It opens up portfolio diversification opportunities for international investors. The United States stock market remains quiet due to the Japanese market shock. It does not react positively or negatively to the Japanese market movement. The other significant implication for international investors is that the Indian stock market follows the Japanese market somewhat in the same direction (Khalil & Haque, 2022). However, the Japanese stock market gives a weak negative response to Indian market shocks. The study results are in line of findings of previous researchers (Puri, 2023; Alomari et al., 2024; Bhardwaj et al., 2023; Bhattacharjee & Swaminathan, 2016; Goyal & Bansal, 2019) but in contradiction to the findings of few previous studies (Bhullar, 2019; Gulzar et al., 2019; Nautiyal & Kavidayal, 2018).

CONCLUSION

As far as the portfolio diversification opportunities among these Quad stock markets are concerned, these are available firstly amidst the Indian and Australian stock markets in the long term. However, it's noteworthy that in the long run, the Indian stock market exhibits a stronger negative response to shocks from the Australian market compared to the speed at which the Australian stock market reacts negatively to shocks from the Indian market (Senathirajah et al., 2023). It signifies significant unidirectional causation run from the Australian market to the Indian stock market. Secondly, portfolio diversification benefits are available in the United States and Australian stock markets. However, the investors should know that both markets negatively respond to each other stock market shocks in the long term. It signifies the presence of a bi-directional causal relation among this pair. Thirdly, portfolio risk management opportunities are available amidst the Indian and United States markets. However, the Indian market is positively responding to United States market shocks very steeply in the following few days and steadily in the next few days. However, the United States market is negatively responding to shocks in the Indian stock market in the following and later days. Fourthly, such risk diversification benefits exist among Australian and Japanese stock markets. However, investors should note that the Australian market does not respond to the Japanese stock market in short or long days. However, the Japanese stock markets responds in a sharp decline way to Australian and United States market positive shocks (Wickneswary et al., 2024). The United and Australian stock markets are not significantly responding to the movements of Japanese stock markets. The Indian and United States investors are not highly impulsive towards

shocks in their own country's stock markets relative to Australian and Japanese investors. Australian and Japanese stock markets show steep negative impulsive responses to their own market shocks (Yixin et al., 2018). The existent interlinkages of Quad economies' stock markets, as computed and analyzed in the present study, can be leveraged by international investors for portfolio risk diversification and investment decisions.

POLICY IMPLICATIONS AND CONTRIBUTIONS

The VAR model and Granger Causality statistics results provide valuable insights for investors, policymakers, and market regulators (Haque & Srivastava, 2014). Firstly, international investors can capitalize on diversifying their portfolios across Indian, Australian, Japanese, and the United States stock markets, considering the short-term and long-term responses of each market to shocks from the others. Policymakers should closely monitor market interdependencies among Quad countries to formulate effective policies aimed at enhancing market stability and investor confidence (Ahmed et al., 2022). Initiatives to promote cross-border investment, harmonize regulatory frameworks, and deepen economic cooperation could strengthen market integration efforts (Osman et al., 2024). Market participants should consider the implications of cross-market shocks and correlations when designing risk management strategies, using hedging techniques and diversification approaches tailored to the specific dynamics of Quad countries' stock markets. Furthermore, the study enhances the existing literature by delivering empirical insights into the short-term dynamics and causal relationships among the stock markets of Quad countries, laying the groundwork for future research to explore long-term trends, structural changes, and the impact of external factors on market interdependencies (Wai et al., 2024). Overall, understanding these dynamics can help stakeholders make more informed decisions to promote financial stability, enhance market efficiency, and foster sustainable economic growth.

FUTURE RECOMMENDATIONS

The present study can be extended to other worldwide economic and military blocs by considering different datasets of variables and periods (Ahmed et al., 2024). The study can be developed further to study the comovements of different stock and commodity indices of various countries inter se and intra se for better formulation of prediction and portfolio diversification strategies.

LIMITATIONS

The VAR techniques described here have several restrictions. One is that if any of the variables are highly persistent, the findings of the traditional statistical inference methods (such as generating standard errors for impulse responses) may be deceptive (Fei et al., 2024). Standard VARs also have the drawback of missing nonlinearities, conditional heteroscedasticity, and parameter drifts or breaks when used without modification.

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