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Stock market co-integration and error-correction of global capital markets: a study of ADR issuing Asian countries

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Stock market co-integration and error-correction of global capital markets: a study of ADR issuing Asian countries

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Abstract: The study examines the significance of cross-listing assets as an opportunity to diversify portfolios for retail investors from developing nations as a result of the global financial markets' partial integration. Recently, the global stock markets experienced extreme volatility due to the COVID-19 pandemic. The importance of assessing the extent of interconnectedness across major global stock markets is emphasised by this fact. Investors are inclined to find the most exogenous stock market with the sole objective of maximising wealth through portfolio diversification. The Johansen co-integration test is being used to determine the degree of interdependence between the stock markets of selected countries. Furthermore, the VEC model is applied for examining the effect of one market on another and also shows the speed of adjustment among the stock market indices. The US market shows the better speed of adjustment and has statistical significance throughout the sample period.

Keywords: Asian stock market; variance decomposition analysis; VECM; impulse response function; Johansen co-integration test.

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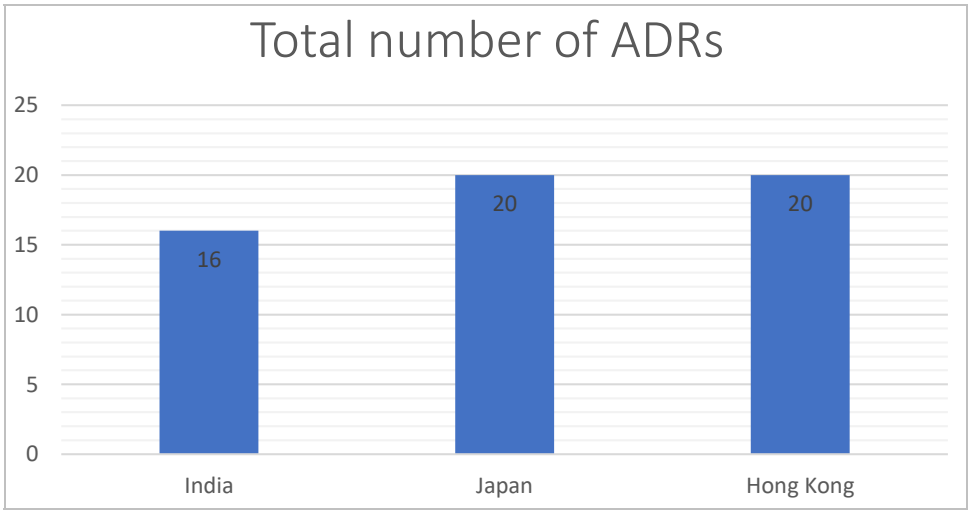
1 Introduction

Cross-listing of assets on foreign stock markets, in addition to the domestic market, appears to be a very significant factor for attracting capital from abroad and also contributes to the growth of the domestic market. As the world is changing into a global village, the economic linkages have intensified. Any significant event occurring anywhere in the world has a huge impact on global financial markets, both directly and indirectly, as well as on the companies listed on exchanges. Considering that if the opportunity has been provided to investors to invest entirely in foreign investment avenues, and they can trade among each asset class across the globe without interruption, in this instance of total market integration, investors will be exposed to a similar risk factor in an international market (Sachdeva et al., 2021). Cross-listed assets in foreign stock exchanges, i.e., tradable assets, such as American depository receipts (ADRs), is the leading cause of financial market integration. As given in Figure 1, Asian companies are the second-largest issuers of depository program (Altig et al., 2020). The issuance of ADRs offers a complex challenge to stock market integration, requiring scrutiny.

Figure 1 Total number of ADRs issued country-wise (see online version for colours)



Source: https://www.adrbnymellon.com

This has an influence on asset values in the foreign market, showing the investment barrier's existence and a partial integration of the global economy. Investors seek to invest in fewer linked assets and diversify their portfolio as far as possible to lower risk (Nammouri et al., 2021). Another powerful phenomenon of the market situation is market

segmentation, which raises an issue in the market because similar securities are not valued equally in the markets (Hanif et al., 2021).

Table 1 Asian company issuing ADRs

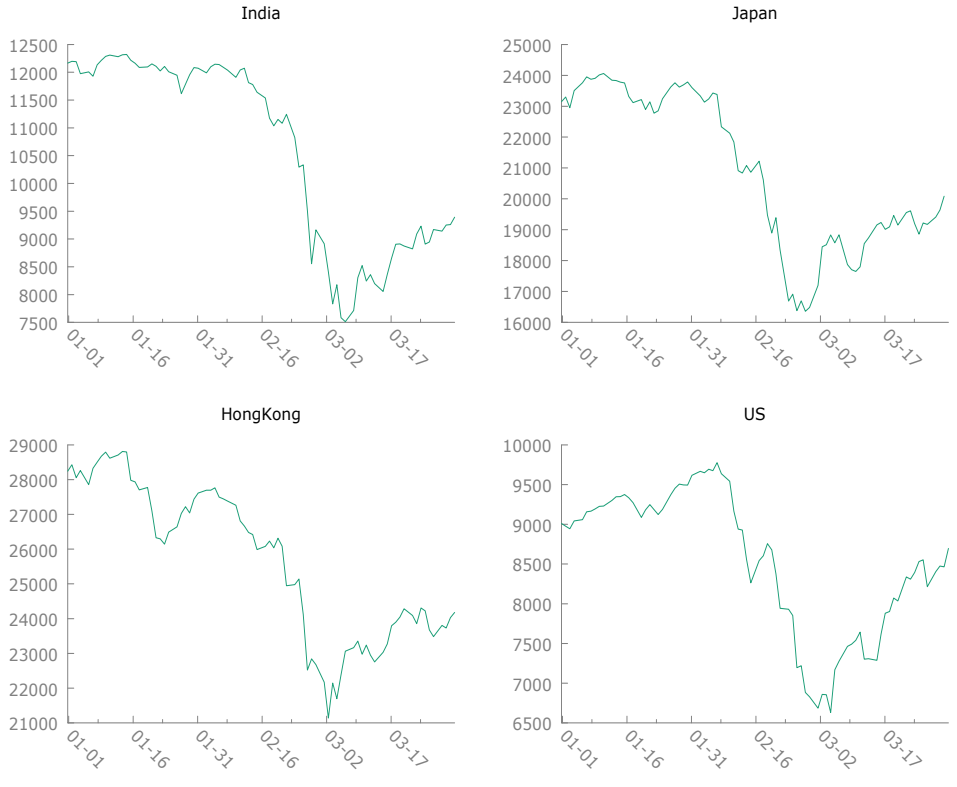
Hong Kong ADRs	*Japan ADRs*	*India ADRs*
Melco Resorts & Entertainment	Mitsubishi U.F.J. Financial A.D.R.	Infosys A.D.R.
Futu	Takeda Pharma ADR	ICICI Bank A.D.R.
Integrated Media Tech	Sumitomo Mitsui Financial A.D.R.	Tata Motors A.D.R.
Takung Art	Honda Motor A.D.R.	Wipro A.D.R.
Lion Group Holding	Nomura ADR	HDFC Bank ADR
AGM A	Sony A.D.R.	Sify
HUTCHMED DRC	Mizuho Financial A.D.R.	Renew Energy Global
Silicon Motion	Toyota Motor A.D.R.	Azure Power Global
Oriental Culture	Japan Smaller Capitalization Closed	MakeMyTrip
BIT Mining	Canon A.D.R.	Yatra Online
Bridgetown Holdings	Orix	W.N.S. Holdings
A.P. Acquisition Unit	Medirom Healthcare	Dr. Reddy's Labs ADR
SPI Energy	Tokyo Electric Power Co., Inc.	Mahanagar Telephone Nigam PK
China Natural Resources	W.B. Burgers Asia	Vedanta Ltd.
CITIC Capital Acquisition	Panasonic	Axis Bank A.D.R.
Moxian	Yoshitsu A.D.R.	Rediff.com India
Bridgetown 2 Holdings	Wacoal	
iClick Interactive Asia	Internet Initiative Japan ADR	
HHL Acquisition Co.	Mitsui & Company	
CLPS	Makita	

Source: https://www.adrbnymellon.com

The COVID-19 impacted the financial markets significantly and raised the question of the contagion effect among the economies (Okorie and Lin, 2021). Figure 2 shows that the co-integration of stock markets leads to the simultaneous decline in stock prices of the major Asian stock markets (Cepoi, 2020; Ghosh et al., 2021; Hung and Vo, 2021), and it gives rise to studying the interdependence of stock markets, which is arising through ADRs, and the significant effect of the pandemic has been seen from January 2020 to April 2020.

"Thus it can be concluded with the above conflicting issues that the international financial market is partially integrated providing the opportunity to investors for portfolio diversification" (Lee and Sachdeva, 2020). The deregulations among the financial market leads to the cross-listing of assets on foreign exchanges.

Figure 2 Impact of COVID-19 on the stock market (see online version for colours)



Source: Author's work

2 Literature review

In the current era of cross border trade, countries want to survive in the global market for effective development of the stock market (Singh and Gautam, 2019). The linkages between the stock markets always have a significant effect and need wide attention. A detailed review of studies focusing on the inter-linkages between the financial markets is presented in this section.

The earlier literature which is available on the linkages among the international bond markets, e.g., Christiansen (2007), Piñeiro-Chousa et al. (2021) and Kiss et al. (2022) and associations between equity markets (Schöllhammer and Sand, 1985; Goyal and Mtttal, 2018; Agoraki et al., 2019; Gulzar et al., 2019), there are limited studies which have focused on the links between international financial markets with consideration to major Asian ADRs issuing stock markets as ADRs are an ideal method for cross-listing, which leads to stock market integration (Caporale et al., 2022).

The Johansen co-integration technique is one of the predominant techniques to analyse the integration among the financial markets. Application of co-integration analysis between the six markets did not show any linkages between these six markets with one another (Nandy and Chattopadhyay, 2019). Several researchers confirm that the

movement in the US market cannot be explained by any single market (Eun and Shim, 1989; Karolyi and Stulz, 2016). By contrast, various researchers reported that there is significant co-integration across stock markets (Schöllhammer and Sand, 1985; Gulzar et al., 2019). The empirical results show that the question of whether the market is cointegrated or not is entirely subjective and reflects a variety of dimensions and viewpoints, which justifies a detailed examination of the connections between the stock markets. The co-integration approach was used to establish exogeneity among the UK, the USA, Germany, and Japan and found that the markets are endogenous (Hung, 2019). The empirical analysis of co-integration among the several markets shows the diversification opportunity for short-term investors (Smith, 2002). The test indicates that the markets share co-integration vectors, which is better for predicting the movements in a particular market (Sachdeva et al., 2021). In their study, researchers find the absence of market linkages between the Indian market and the US market (Menon et al., 2009). The stock markets of India and Hong Kong behave similarly, as they move independently in the long-run. There is no co-integration between the markets of South Asian countries, allowing investors to diversify their portfolios (Sharma and Bodla, 2011). There is bidirectional causation between the financial markets and there is evidence of stock market co-integration (Goyal and Mtttal, 2018).

Due of the COVID-19 epidemic, stock markets throughout the world are experiencing varied degrees of volatility and presented a challenge among the investors for diversifying their portfolio (Cepoi, 2020; Onali, 2020; Uddin et al., 2021). The current study thoroughly explores the relationships between the world's stock markets, including their long-term co-integration with market returns and their movements (Bhatia and Gupta, 2020; Shahzad et al., 2021). Various aspects have been discussed in this paper, contributing to the literature in several ways. Firstly, it examines the issue of non-(existent) of international financial market co-integration and short-run adjustments with the help of the recursive co-integration technique, which tests whether there is a co-integration relationship for the given sample period. Secondly, the vector error correction model is applied to explore the relationship among these indices and also examined for the impact (Dutt and Sehgal, 2018; Corbet et al., 2020; Nammouri et al., 2021). The relationships between the indexes, including India, Hong Kong, Japan, and the USA, are examined using daily adjusted closing data from January 2010 to May 2021.

3 Research methodology

To achieve the study's objectives, apart from the USA, three Asian countries are selected based on cross-listing of stocks in the form of ADRs. The following are the four main stock markets being studied: the stock markets of Nifty 50 (India), Nasdaq (the USA), Nikkei 225 (Japan), and Hang Seng (Hong Kong) are considered and data is collected from the website of nseindia.com, Prowess IQ database and Yahoo Finance. The sample consists of 2,780 observations. The previous studies (Maity and Malar, 2021; Nammouri et al., 2021; Caporale et al., 2022) employed daily adjusted prices of the stock indices as well as concentrated on these due to their significant presence in the global financial market.

The vector auto regression (VAR) framework is used to examine the impact of one stock market's performance on another. The stationarity test is essential to check for each index before applying the Johansen co-integration test. Here, the augmented Dickey-Fuller (ADF) test is applied to check unit root in the series. A co-integration model is then calculated, and the integration of all financial markets is checked. The next step is to choose the ideal lag length using the HQ, SIC and AIC. These parameters are used to determine the ideal lag.

Stock index price series is denoted by the vector X_t of four countries' stock markets presented as:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \mu + e_t \quad (t = 1, \mathrm{A}\ , T) \tag{1}$$

The presence of a total number of cointegrating vectors over a period of time determines the interdependence of the stock market throughout the period, r, as follows:

$$H(r): \quad \Pi = \alpha\beta' \tag{2}$$

The formula for the trace test is given as:

$$Trace(r, k) = -T\Sigma^k \ln\left(1 - \lambda_i\right), i - rp1 \tag{3}$$

If no co-integration exists, then we have to apply a VAR methodology. If the y_t and x_t series are cointegrated, then VECM methodology can be used for modelling the corrections. Sargan was the first to apply the error correction mechanism (ECM), which was later adopted by Engle and Granger, to demonstrate the coefficient corrections for disequilibrium.

Let X_t be a vector of four distinct nations' stock index prices (p = 4), then the model be stated as:

$$\Delta X_t = \pi X_{t-1} + \sum\nolimits_{i=1}^{k-1} \tau_i \Delta X_{t-i} + \mu + e_t \ (t = 1, \mathrm{A}\ , T) \tag{4}$$

Except for the lagged level of X_{t-1}, the cointegrated information for the long-run among the p variables is provided by the parameter matrix, π. When the two variables Y and X are cointegrated, the connection between them may be stated as ECM, which is presented as:

$$\Delta Y_t = \alpha_0 + \alpha_1 \Delta X_t + \alpha_2 u_{t-1} + \varepsilon_t \tag{5}$$

where

ε_t denotes white noise error term

u_{t-1} is a lagged value of error term

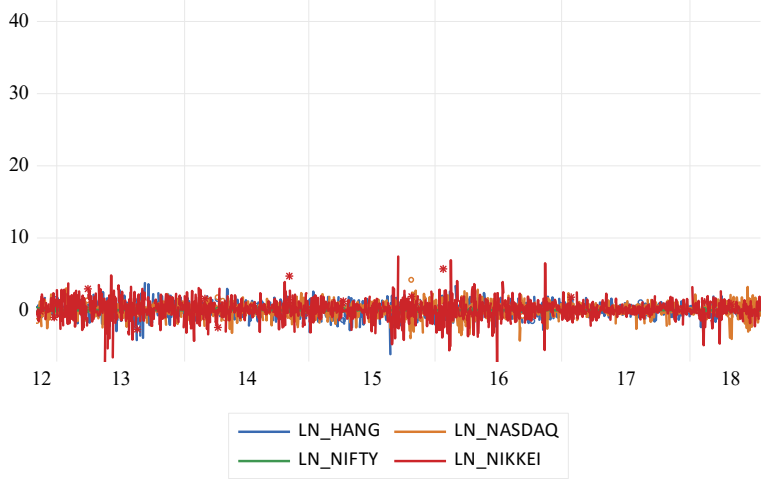
As the VAR model coefficients are difficult to interpret, hence the application of forecast error variance decomposition and impulse response function assists to highlight the interconnection of the financial markets of the four nations.

4 Data analysis and interpretation

4.1 Unit root tests

Figure 3 shows the combined return of all four stock exchanges during the study period. It is indicated from Figure 3, which shows that the stock exchanges' returns are stationary.

Figure 3 Unit root test (see online version for colours)



Source: Author's work

The results obtained from Table 2 and suggest that all the indices representing their respective stock markets are non-stationary series in their natural order; the ADF and PP tests confirm the non-stationarity of the series at level, with a deterministic trend including both intercept and time trend. In Table 3, it is visible that the series became stationary on the first differences. Therefore, the selected stock market series are first-order integrated or follow the $I(1)$ process.

Table 2 ADF unit root test (at level)

Country	*Exchange index*	*t-statistics*	*Prob.*
India	Nifty 50	–0.183723	0.9381
USA	Nasdaq	1.968414	0.9999
Japan	Nikkei 225	–0.591848	0.8700
Hong Kong	Hang Seng	–2.179429	0.2140

Source: Author's work

The test follows the following regression equation:

$$Dx_t = a_0 + a_1 x_{t-1} + \sum_{j=1}^{m} b_j Dx_{t-j} + v_t$$

The stock market index is denoted by X_t, and v_t is an error term.

Table 3 ADF unit root test (at 1st difference)

Country	*Exchange index*	*t-statistics*	*Prob.*
India	Nifty 50	–52.44066	0.0001
USA	Nasdaq	–55.41436	0.0001
Japan	Nikkei 225	–54.24388	0.0001
Hong Kong	Hang Seng	–53.09385	0.0001

Source: Author's work

4.2 Co-integration test

After making the series stationary, the co-integration of stock market index series was investigated. We used the Johansen co-integration test to verify the co-integration. The co-integration test must be used after selecting the optimum lag. Based on the criterion, we picked a lag of 2 in Table 4's lag structure, which is shown using the lag exclusion test and Wald test in Table 5. The whole sample's results show that there has been co-integration for stock indices, rejecting the null hypothesis that since there is no co-integration among stock market indices. Trace tests and max-eigen tests are used for this. One or more cointegrating equations are shown by the results of the trace and eigenvalue tests, both of which have a 5% level of significance.

Table 4 Var. lag order selection criteria

Lag	*AIC*	*SC*	*HQ*
2		–23.23053*	
4			–23.16606*
8	–23.23053*		

Notes: AIC – Akaike information criterion, SC – Schwarz information criterion and HQ – Hannan-Quinn information.
*Indicates the lag order selected by the criterion.

Source: Author's work

Table 5 VEC lag exclusion Wald test

Lag	*India*	*Japan*	*USA*	*Hong Kong*
2	33.77690 (0.000)	14.3983 (0.006)	11.57851 (0.0208)	25.71845 (0.0000)

Source: Author's work

At the 5% significance level, the trace test in Table 6 reveals the existence of one cointegrating equation. This cointegrating equation states that despite short-term deviations from equilibrium values, there is only one linear combination of the variables that forces these indices to have a connection over the sample time.

Table 7 shows the results of the maximum eigenvalue test to validate the results of Johansen's trace test.

The maximum eigenvalue test further confirms the trace test results by revealing the presence of one cointegrating equation at a 5% level. As a result, the cointegrating relationship is confirmed during the sample period by these two tests.

Table 6 Johansen co-integration test

Johansen co-integration result – trace test				
Sample (April 2010–May 2021)				
Included observation = 2,780				
Series included = LN_Nifty, LN_Nasdaq, LN_HangSeng, LN_Nikkei				
Hypothesised number of cointegrating equations	*Trace statistics*	*0.05 critical value*	*Probability*	*Significance at 5% level*
None	62.0499	47.8561	0.0014	Yes
At most 1	26.4979	29.7970	0.1145	-
At most 2	11.9951	15.4947	0.1572	-
At most 3	3.9621	3.8414	0.0665	-

Source: Author's work

Table 7 Max-eigenvalue statistic

Hypothesised number of cointegrating equations	*Max-eigenvalue statistic*	*0.05 critical value*	*Probability*	*Significance at 5% level*
None	35.5520	27.5834	0.0039	Yes
At most 1	14.5028	21.1316	0.3252	-
At most 2	8.0330	14.2646	0.3754	-
At most 3	3.9621	3.8414	0.0665	-

Source: Author's work

4.3 Vector error correction analysis

Table 8 shows how these stock exchanges correct for mistakes and how other stock markets have changed.

Table 8 Normalised cointegrating coefficients

Ln_Nikkei	*Ln_Nifty*	*Ln_Nasdaq*	*Ln_HangSeng*
1.0000	–0.9236	0.1285	–0.03508
	(0.06097)	(0.02589)	(0.03903)
	[–22.5466]	[4.96685]	[–0.04039]

Note: (Standard error in parentheses) and [t-statistics in brackets].

Source: Author's work

The interdependence of stock exchanges is determined using VECM; it is significant if the computed t-value is greater than 1.96. Table 4 shows the co-integration equation for India, the USA, Japan and Hong Kong. The return of Japan (Nikkei) at lag 1 and lag 2 influences the returns in the USA, Japan and Hong Kong exchanges. The return of India at lag 1 and lag 2 significantly influences the return of other exchanges. The return of Nasdaq at lag 1 has significant influence over itself, and the return of Japan at lag 2 has a significant impact on Japan only.

Table 9 Error correction (speed of adjustment)

Error correction	*Ln_Nikkei(–1)*	*Ln_Nifty(–1)*	*Ln_Nasdaq(–1)*	*Ln_HangSeng(–1)*
Cointegrating equation	–0.6554	0.4337	–0.1693	0.3123
	(0.0289)	(0.0249)	(0.0421)	(0.0271)
	[–2.6691]	[4.9828]	[–1.98431]	[11.4933]

Notes: ((–1) is difference one), (standard error in parentheses) and [t statistics in brackets].
The error correction terms in Table 9 show the speed of adjustment.

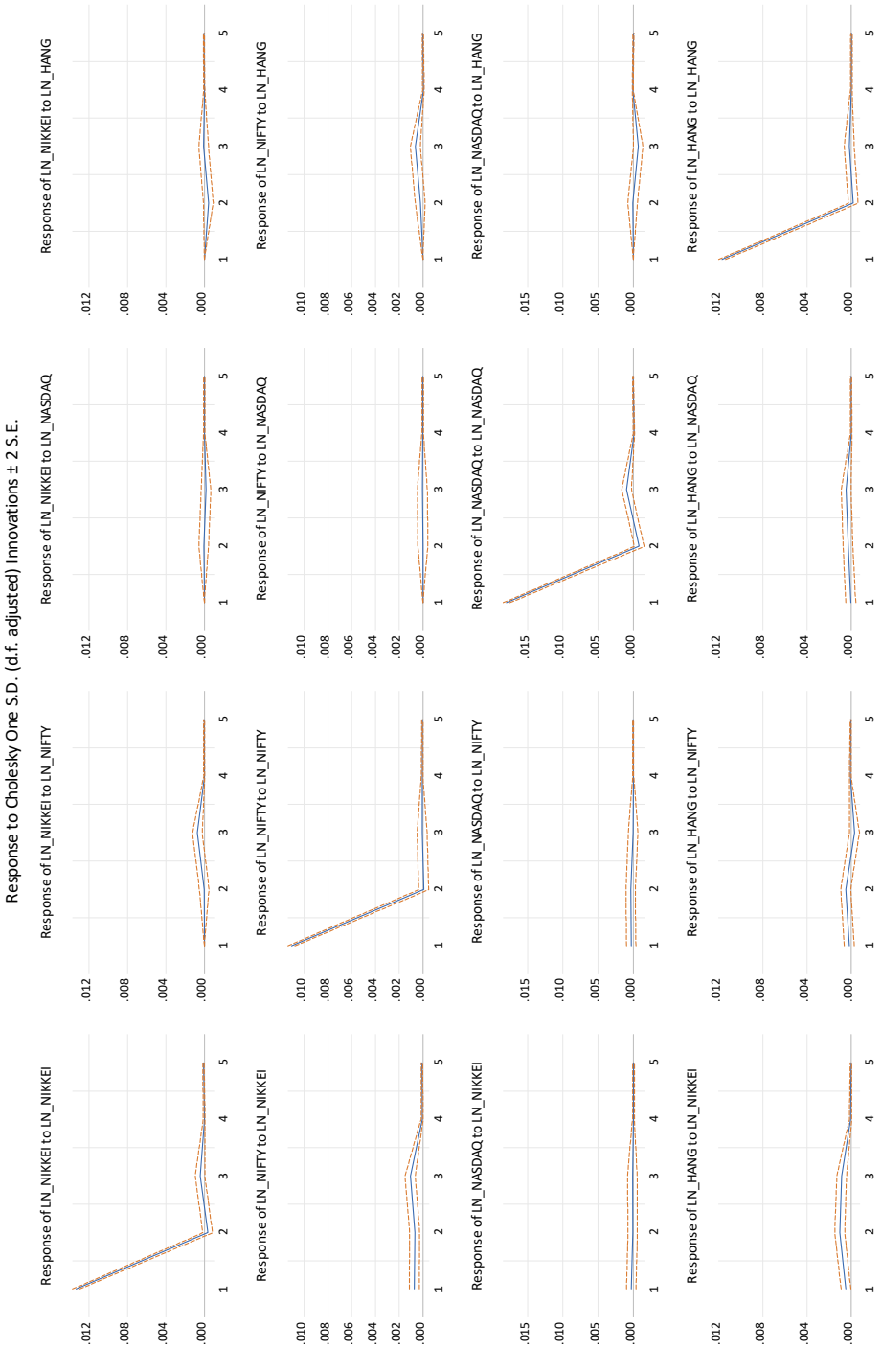
Source: Author's work

Table 10 Variance decomposition analysis

Variance decomposition of LN NIKKEI:					
Period	*S.E.*	*LN NIKKEI*	*LN NIFTY*	*LN NASDAQ*	*LN HANG*
1	0.014137	100.0000	0.00000	0.00000	0.00000
2	0.014334	98.67896	1.069983	0.068928	0.182133
3	0.015067	94.32664	4.421307	0.389558	0.862499
4	0.016204	86.68164	10.88131	0.616656	1.820388
5	0.016781	85.01535	12.27792	0.705389	2.001351
Variance decomposition of LN NIFTY:					
Period	*S.E.*	*LN NIKKEI*	*LN NIFTY*	*LN NASDAQ*	*LN HANG*
1	0.012206	2.289543	97.71046	0.000000	0.000000
2	0.012710	5.550821	93.68817	0.050423	0.710582
3	0.013672	11.56044	87.20338	0.154756	1.081423
4	0.014841	15.02453	83.28045	0.254261	1.440758
5	0.015594	16.83441	81.21974	0.272503	1.673352
Variance decomposition of LN NASDAQ:					
Period	*S.E.*	*LN NIKKEI*	*LN NIFTY*	*LN NASDAQ*	*LN HANG*
1	0.020623	0.027203	0.106045	99.86675	0.000000
2	0.021399	0.118595	0.270091	99.59205	0.019268
3	0.023533	0.274968	0.340535	99.33046	0.054041
4	0.026241	0.488542	0.676389	98.69610	0.138967
5	0.027731	0.534368	0.749576	98.59161	0.124442
Variance decomposition of LN HANG:					
Period	*S.E.*	*LN NIKKEI*	*LN NIFTY*	*LN NASDAQ*	*LN HANG*
1	0.013287	0.851926	0.743955	0.033564	98.37055
2	0.013942	2.668559	1.300788	0.223658	95.80699
3	0.015228	4.117286	3.069421	0.474816	92.33848
4	0.017135	5.677160	4.411977	0.446748	89.46412
5	0.018132	6.220826	4.755815	0.548326	88.47503
Cholesky ordering: LN_NIKKEI LN_NIFTY LN_NASDAQ LN_HANG					

Source: Eviews output

Figure 4 Impulse response function (see online version for colours)



Source: Eviews output

For the study period, the Ln_Nasadaq demonstrated statistical significance at the 5% level, showing a positive association with the Ln_Nikkei. As per the coefficient, a 1% increase in Ln_Nasdaq leads to a 0.12% increase in Ln_Nikkei in the long-term.

Ln_Nasdaq has statistical significance throughout the sample period, is faster to adapt than the other indices evaluated, and is statistically significant, whereas the others are not. The Ln_Nikkei and Ln_Nasdaq, on the other hand, burden the system's return to equilibrium, whereas other variables demonstrate modest exogeneity.

4.4 Variance decomposition analysis

Table 10 presents the variance decomposition analysis of four stock exchanges. The returns for the four stock exchanges from 1 to 5 are decomposed and are shown in Table 10.

As presented in Table 10, the variance decomposition analysis discloses that in Nikkei (Japan), the impact of the Indian stock market is visible. There is a somewhat visible impact of the Hong Kong exchange throughout 1 to 5. In the Indian market, the effect of the Japanese stock market is highly significant, while there is a somewhat visible impact of the Hong Kong market from periods 1 to 5. In Nasdaq (the USA), the effect of other stock exchanges under the study is negligible. Table 5 also shows a visible impact of the Japanese and Indian market over the Hong Kong market.

Figure 4 depicts the impulse response of Japan, India, the USA, and Hong Kong to each other. Figure 4 shows the number of days on the *x*-axis and the shock responses on the *y*-axis. Figure 4 exhibits how many days the shock at other exchanges cools down.

5 Conclusions and implications

This study explored the stock market co-integration and error-correction among the major ADR-issuing Asian countries. Findings of the study demonstrate that the financial markets move in the same direction in the long-run. The study proposed an empirical framework combining the Johansen co-integration test, vector error correction model, variance decomposition analysis and impulse response function, which gives a holistic approach to the interconnection between these countries and also shows how these countries are recovering from the shocks. The latest study by Agoraki et al. (2019) also depicted the interconnectedness of the US market with these countries. The finding is consistent with previous studies which also show the dominance of the US market over the world stock market (Nammouri et al., 2022; Yu et al., 2022). The results are not surprising, as they correlate to the current time in which corporations' cross-list their assets in the form of ADRs on foreign exchanges. The decline in stock markets worldwide, particularly in Asia, during the COVID-19 period leads to an evaluation of the level of integration between the major ADRs issuing nations and the US market, which causes volatility and necessitates the search for a market that can provide investors with portfolio diversification.

In parallel to the US market, the Japanese market has a substantial influence on the Indian and Hong Kong stock markets, making the Japanese market an exogenous one for portfolio diversification. It is also shown through error correction adjustment. This demonstrates that the Japanese market has a low degree of exogeneity compared to other markets. This type of interrelationship in the global equity market has not been studied in

prior research (Sachdeva et al., 2021). Hong Kong's stock market changes are affected by those of the world's other three largest stock exchanges. It is correct to conclude that stock price swings in the USA, India, and Japan markets are somewhat responsible for the innovation happening in the Hong Kong market.

The present internationalisation phase of the stock market allows free money movement across borders, resulting in FIIs investment. It helps investors with the portfolio diversification as developed-country markets become saturated. In keeping with the findings of prior research, we are able to draw the conclusion that recognising the spread of contagion in the stock market during this pandemic is of utmost relevance for portfolio diversification. In addition, the findings have implications for policymakers and for several market players, including regulators, investors and others. Policymakers are able to devise suitable policies to minimise risk resulting from the co-movement of financial assets when they have access to co-movement assessment tools. Lastly, the analysis reveals; "the worldwide financial market is neither entirely interconnected nor totally separated", suggesting a chance for global diversification. As in our analysis, there is not a major influence from other markets on the Japanese market since it is somewhat insulated from others. The investor must look beyond the relative importance of different stock markets to potential investment opportunities such as macroeconomic variables that also affect the returns. Considering this will give the direction for future research to the countries where macroeconomic elements like foreign exchange, bond and currency market fluctuations can be investigated. Cross-listing and trading of a company's stock on foreign exchanges increases the risk of volatility spillover from such exchanges. So, future research can look at the effect that cross-listing has on India when foreign markets spill over into India.

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