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Research article

Stock market volatility from the Covid-19 pandemic: New evidence from the Asia-Pacific region

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ABSTRACT

Responses from stock markets to the Covid-19 pandemic appear to change over time. Recent responses might differ as herd mentality in stock markets tends to become herd immunity to the pandemic. This study revisits the pandemic's effects on the Asia-Pacific countries' market volatility over the past 25 months. Primarily, we examine the changes of the impacts of the pandemic on volatility between the first pandemic period (2020) and the second period (January 2021–January 2022). Our findings indicate that implementing pandemic control measures helps reduce market volatility at the country and region levels. The effects of new Covid-19 cases and pandemic control measures on market volatility have been dramatically fading since 2021. The Toda-Yamamoto causality test and the panel impulse response functions from panel VAR estimation are also used for robustness analysis. Based on our findings, it appears that the current pandemic may no longer be blamed for stock market volatility in the Asia-Pacific region.

1. Introduction

Since the coronavirus emerged in Wuhan, China, the pandemic has spread across various countries, although governments have tried to curb the virus, including travel restrictions and quarantine policies. Accordingly, the World Health Organization (WHO) declared the outbreak of coronavirus (Covid-19) to be a pandemic on 11 March 2020 (Carter et al., 2021; Kamaludin et al., 2021). When writing this paper, the pandemic affects 225 countries and territories (Worldometer, 2022). More than 450 million Covid-19 confirmed cases have been confirmed, with over 6 million deaths worldwide (WHO, 2022). The Covid-19 pandemic has been generally considered an event for the 2020 stock market crash worldwide (from February to April 2020). The pandemic appears to cause various financial issues such as declined stock returns (Al-Awadhi et al., 2020); increased stock volatilities (Baig et al., 2021; Zaremba et al., 2020); liquidity crunch (Baig et al., 2021; De Vito and Gómez, 2020; Kamaludin et al., 2021); high level of debt (Zhang et al., 2020); and high cases of bankruptcy (Akhtaruzzaman et al., 2021). Furthermore, recent empirical studies indicate significant increases in the transmission of risk, volatility and fear shock among financial markets worldwide and sectors within a financial market during periods of crisis, including the Covid-19 pandemic (Abuzayed et al., 2021; Bossman et al., 2022; Huynh et al., 2021; Shen et al., 2022).

Volatility is crucial to the financial market's operation. Volatility is regarded as a barometer of uncertainty or financial risk relating to investments in financial assets, leading to concern among investors, fund managers, regulators and policymakers (Baek et al., 2020). During periods of high volatility in financial markets, the accurate prediction of the downside risk is of great significance (Berger and Missong, 2014). Extant literature on financial risk management presents different approaches to estimating and forecasting downside risk. The Value-at-Risk (VaR) is generally considered a highly used technique for the purpose (Baig et al., 2022). VaR is normally utilized to forecast extreme declines in financial market returns and formulate appropriate strategies for risk management (Anjum and Malik, 2020; Ewing et al., 2019). Volatility shift is a characteristic of financial markets (Stărică and Granger, 2005). Moreover, recent empirical studies indicate that models incorporating volatility shifts or structural breaks could produce more accurate VaR forecasts (Anjum and Malik, 2020; Baig et al., 2022; Ewing et al., 2019).

Recent literature documents that the Covid-19 pandemic could lead to a rise in stock market volatility and a decline in stock returns (Al-Awadhi et al., 2020; Ashraf, 2020; Kusumahadi and Permana, 2021; Zhang et al., 2020). Additionally, empirical studies show evidence that government responses to the Covid-19 pandemic could alleviate market volatility and improve market quality (Bakry et al., 2021; Ibrahim et al., 2020; Vo and Doan, 2021; Zaremba et al., 2020). However, implementing restrictions

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and lockdowns appear to deteriorate the stability and liquidity of equity markets (Baig et al., 2021; Zhang et al., 2020).

Market participants have considered the pandemic part of their new norms over time. The stock market's herd mentality has become herd immunity to the pandemic. As a result, investors have acquired the so-called "endemic" - rather than "pandemic" mindset and hence, become less sensitive and vulnerable to Covid-19-related incidents (Anderson, 2022). Figure 1 demonstrates this shift using the CBOE Volatility Index (VIX), often referred to as the level of fear, risk, or stress in the US stock market and is widely regarded as the "fear index". The VIX soared in March 2020 when the pandemic spread across the globe, especially after the WHO declared the Covid-19 pandemic. However, the index returned to around 40 in April 2020, dropping to the 20s in Summer (2020). Interestingly, the VIX were below 30 from January 2021 to January 2022, regardless of the upswing of the Delta and Omicron variant cases. The VIX's movements over the past two years of the pandemic imply that the stock market appears more rational and less responsive. As a result, it has gradually been accepted that the current pandemic has become more manageable (Anderson, 2022).

Volatility is considered a barometer of financial risk to investments and is crucial to the operations of stock markets. As such, investigating the effects of the Covid-19 pandemic on market volatility is of great importance for policymakers and investors. As stock markets have been generally regarded as a complex adaptive system (Mauboussin, 2002), their responses to the pandemic have continuously changed. Recent reactions to the Covid-19 pandemic appear significantly different from the responses when the pandemic emerged in March 2020. As such, revisiting the impacts of the pandemic on stock market volatility after more than 24 months of its emergence can be considered important and valuable. The findings provide insightful implications to policymakers in implementing effective policies and investors in designing appropriate investment portfolios for risk minimization in the “new” normal.

In that respect, the contributions of this study to the existing literature are twofold. *First*, to the best of our knowledge, this is one of the first studies to investigate the differences in the effects of the Covid-19 pandemic on market volatility between the first pandemic period (January 2020–December 2020) and the second period (January 2021–January 2022) in the Asia-Pacific countries. Several studies document the significant effects of the Covid-19 pandemic and the government's control measures on financial markets in the context of the Asia-Pacific region (Ho et al., 2021; Hunjra et al., 2021; Ibrahim et al., 2020; Kamaludin et al., 2021; Topcu and Gulal, 2020; Vo and Doan, 2021). However, previous studies primarily focus on the first pandemic year 2020. *Second*, we use different GARCH family models (i.e., ARMA-GARCH, EGARCH and GJR-GARCH) to estimate the market volatility of the Asia-Pacific countries in the sample. Additionally, we employ the OLS regression with Newey and West's (1987) standard errors at the country level and the panel VAR (PVAR) at the regional level to examine the impacts of the Covid-19 pandemic on the market volatility. The Toda and Yamamoto (1995) Granger causality analysis is also adopted to identify the causality relationship between the Covid-19 pandemic and market volatility.

The Asia-Pacific region is selected in our analysis for several reasons. *First*, up to early March 2022, the daily new cases in Asia reached approximately 44.7 per cent of the global daily cases, making the Asia-Pacific region the most infectious region globally. Many countries in the region have struggled to control the pandemic. *Second*, the stock market prices of the Asia-Pacific countries have experienced a steep decline during the Covid-19 pandemic, especially in the first pandemic year of 2022. As indicated in Figure 2, all market indices in the region plunged in March 2020 when the daily new cases were rocketing. However, after a few months, most indices bounced back and increased up to January 2022 despite the rapidly increasing infection cases and the emergence of new variants. This phenomenon makes the Asia-Pacific region an exciting and worthwhile case for investigation. *Third*, literature shows that responses of stock markets to a major event appear conditional on the market's geographic proximity (Engelberg and Parsons, 2011; Ichev and Marinč, 2018). As such, market participants in the Asia-Pacific stock markets are likely to react strongly to the pandemic outbreak due to their geographic proximity to China, where Covid-19 first emerged.

Our findings indicate that the implementation of Covid-19 control measures helps alleviate market volatility at the country and region level from January 2020 to January 2022. In addition, the WHO's declaration of the Covid-19 pandemic appears to be associated with increased market volatility in the Asia-Pacific region. These findings are in line with previous studies on the Asia-Pacific region, such as Ibrahim et al. (2020), Hunjra et al. (2021) and Vo and Doan (2021). However, the effects of daily new cases and Covid-19 control measures on market volatility have been significantly diminishing since 2021. Robustness analyses are conducted using the Toda-Yamamoto Granger causality test and panel impulse response analysis from the PVAR framework. Empirical results have largely remained unchanged. Therefore, we consider that the current Covid-19 pandemic can no longer be blamed for stock market volatility in the Asia-Pacific region.

Following this introduction, the remainder of this paper is structured as follows. Section 2 presents the data and research methodology. The empirical results are presented and discussed in section 3. The robustness tests are described in section 4. Finally, section 5 highlights the main conclusions and policy implications.

2. Data and research methodology

2.1. Data

This paper examines the effects of the Covid-19 pandemic on stock market volatility. As such, we use the daily closing price of the market index of 12 countries in the Asia-Pacific region to estimate the market volatility. Additionally, we employ variables of interest, including (i) the containment and health index, which is a proxy for the governments' Covid-19 control measures, (ii) the number of daily new Covid-19 cases, (iii) the number of daily new vaccinated people, (iv) the economic policy uncertainty (EPU), represented by the equity market volatility - infectious disease tracker. Additionally, we use dummy variables to mark critical events, including (a) the initial crisis since the WHO's declaration of the Covid-19 pandemic (from 11 March to 31 December 2020), (b) the rise of Delta variant cases (from 30 June to 31 August 2021), and (c) the upswing of Omicron variant (from 01 November 2021 to 31 January 2022) (Anderson, 2022). Furthermore, we also include key macroeconomic factors in our regression models, including oil price, gold price, exchange rates and 3-month London Interbank Offered Rate (LIBOR). Our sample covers the whole Covid-19 pandemic period from the beginning of the pandemic (02 January 2020) until January 2022. The variables and their data sources are presented in Table 1.

2.2. Methodology

In this study, the stock market indices and macroeconomic fundamentals (including oil price, gold price, exchange rates and LIBOR) are transformed into logarithmic forms as in Eq. (1).

$$R_t^i = \ln\left(\frac{P_t^i}{P_{t-1}^i}\right) \quad (1)$$

where P_t^i is the price or value of the variable i at time t. R_t^i is the return of the variable i at time t.

First, the time series stationarity is tested for each country in the sample using three different tests, including the augmented Dickey-Fuller test (ADF), the Phillips-Perron test (PP) and the Zivot-Andrews structural

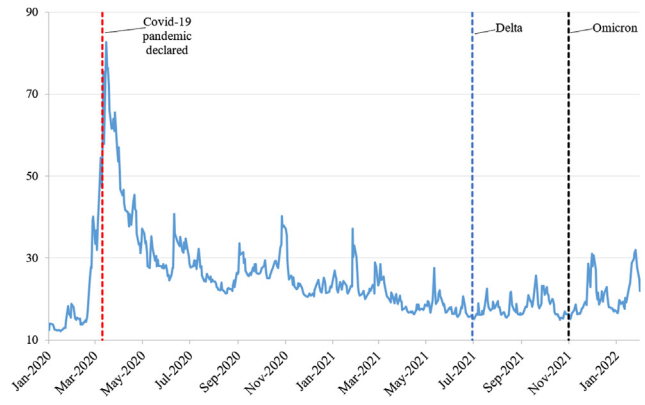

Figure 1. CBOE Volatility Index (VIX) over January 2020–January 2022. Notes: The red dashed line marks the date of 11 March 2020, when the WHO declared the coronavirus outbreak (Covid-19) a pandemic. The blue dashed line marks the rise of the Delta variant cases (30 June 2021). The black dashed line marks when the Omicron-influenced upswing began (01 November 2021) (Anderson, 2022). *Source*: Yahoo Finance.

break unit root test (ZA). We also perform the panel unit root tests, using the Fisher-type unit root test (Choi, 2001) and Im et al. (2003) unit root test (see Appendices A1 and A2). Based on considering above unit root test results, all variables included in our regression models are ensured to be stationary at I (0) or I (1).

Next, we estimate the stock market volatility of each country using the ARMA-GARCH model, which comprises the ARMA and GARCH processes. While the ARMA process is adopted to model the time series' conditional mean, the GARCH process is used to model the time series' conditional variance. The ARMA (r,s)-GARCH (p,q) is expressed in Eqs. (2) and (3) as follows:

$$y_t = \alpha_0 + \sum_{i=1}^{r} \theta_i y_{t-i} + \varepsilon_t + \sum_{j=1}^{s} \varphi_j \varepsilon_{t-j} \tag{2}$$

$$\begin{aligned} \varepsilon_t &= \sigma_t u_t \quad with \quad u_t \sim WN(0,1) \\ \sigma_t^2 &= \gamma_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2 \end{aligned} \tag{3}$$

As our objectives are to examine how the Covid-19 pandemic affects the stock market volatility of each country in the sample, we employ the regression model as in Eq. (4):

$$\widehat{\sigma}^2{}_t = \mu + \beta_0 Z_t + \alpha_0 X_t + \varepsilon_t \tag{4}$$

where: $\widehat{\sigma}^2{}_t$ is the stock market volatility of each country. Z_t represents our variables of interest, including (i) the containment and health index ($Containment_t$), representing the governments' pandemic control measures; (ii) the economic policy uncertainty index (EPU_t), (iii) the daily new Covid-19 cases ($Newcase_t$), (iv) the daily new vaccinated people ($Vaccine_t$), (v) dummy variables, including (*a*) the initial crisis since the WHO's declaration of the Covid-19 pandemic ($Declaration_t$) (from 11 March to 31 December 2020), (*b*) the rise of Delta variant cases ($Delta_t$) (from 30 June to 31 August 2021), and (*c*) the upswing of the Omicron variant ($Omicron_t$) (from 01 November 2021 to 31 January 2022) (Anderson, 2022). Meanwhile, X_t is a vector of control variables, including the changes in the oil price (Oil_t), the changes in gold price ($Gold_t$), the change in the exchange rate ($Exchange_t$) and the change in LIBOR ($Libor_t$). ε_t is the residual.

We apply model (4) for each country in the sample over the entire period of January 2020 to January 2022 to examine the overall impact of the current pandemic on market volatility. However, we assume that over 25 months, the market participants appear less sensitive and vulnerable to Covid-19-related incidents. Anderson (2022) also argues that the stock market volatility should no longer be blamed on the pandemic. Therefore, we will investigate the effects of the pandemic on market volatility for two subsamples, period 1 (from January 2020 to December 2020) and period 2 (from January 2021 to January 2022 - the end of our sample period). Comparing the two subsamples' regression results helps us conclude if the Covid-19 pandemic impacts have been fading across two pandemic periods.

The regressions (4) are estimated using the Ordinary Least Square (OLS). Moreover, the p-values should be corrected for Newey and West's (1987) standard errors. The correction is considered robust to autocorrelation and heteroskedasticity (Narayan et al., 2021).

Together with our primary empirical analysis, we perform the robustness tests using the alternative estimations of the market volatility using EGARCH and GJR-GARCH, the Toda and Yamamoto (1995) Granger causality analysis. We also conduct different estimations at the regional level using the panel vector autoregressive model (PVAR) and impulse response function.

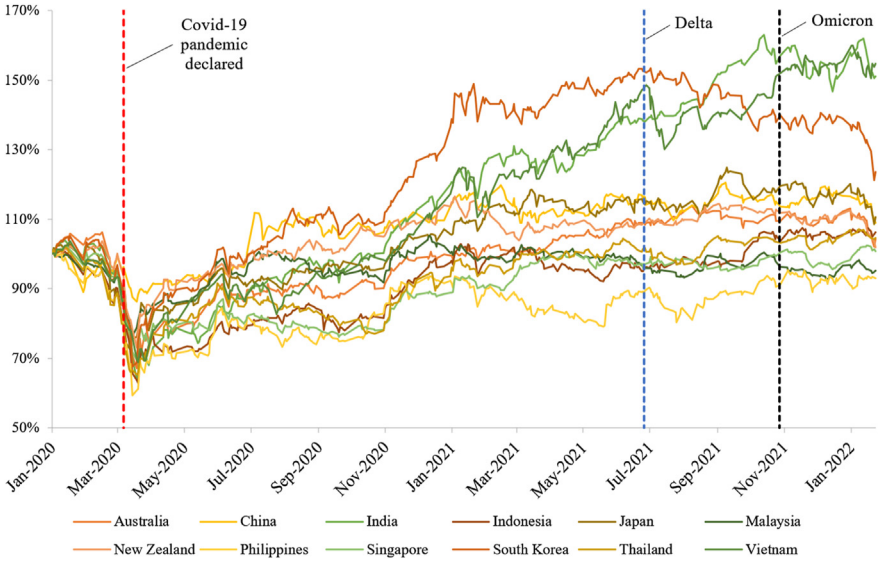

Figure 2. Stock market indices of selected Asia-Pacific countries over January 2020–January 2022. Notes: 06 January 2020 = 100%. The red dashed line marks the date of 11 March 2020, when the WHO declared the coronavirus outbreak (Covid-19) a pandemic. The blue dashed line marks the rise of the Delta variant cases (30 June 2021). The black dashed line marks when the Omicron-influenced upswing began (01 November 2021) (Anderson, 2022). *Source*: Investing.com and The Wall Street Journal.

Table 1. List of the variables and their respective source of collection.

Variable	Description	Data source
Stock market indices	S&P/ASX300 (Australia); Shanghai Composite (China); NIFTY-500 (India); IDX Composite (Indonesia); TOPIX (Japan); FTSE Bursa Malaysia KLCI (Malaysia); S&P/NZX50 (New Zealand); PSEi Composite (The Philippines); FTSE Straits Times Index (Singapore); KOSPI (South Korea); Thailand SET (Thailand); VN-Index (Vietnam)	Investing.com & The Wall Street Journal
Variables of interest	Containment and Health Index	Our World in Data (Dong et al., 2020; Hale et al., 2021; Ritchie et al., 2020)
	Daily new Covid-19 cases	
	Daily new people vaccinated	
	Economic Policy Uncertainty (*Equity market volatility - infectious disease tracker*)	Fred Economic Data (Baker et al., 2020)
	Dummy variables: (i) WHO's declaration, (ii) Delta, and (iii) Omicron	Anderson (2022)
Macroeconomic fundamentals	Crude Oil Prices–West Texas Intermediate (WTI) (US dollars per Barrel)	Fred Economic Data
	Gold spot price (XAU/USD)	Investing.com
	Exchange rate (per one US dollar)	The Wall Street Journal
	3 Month London Interbank Offered Rate–LIBOR (in USD)	Marketwatch

Table 2. ARMA-GARCH estimation results.

	Constant	ARCH (α)	GARCH (β)	(α + β)
Australia	0.00001***	0.14947***	0.80158***	0.95105
	(0.00000)	(0.02397)	(0.03076)	
China	0.00000*	0.09153***	0.86157***	0.95310
	(0.00000)	(0.02281)	(0.04054)	
India	0.00002***	0.27468***	0.61760***	0.89228
	(0.00000)	(0.05394)	(0.06576)	
Indonesia	0.00002***	0.25572***	0.62061***	0.87633
	(0.00001)	(0.05308)	(0.07573)	
Japan	0.00003***	0.28930***	0.48140***	0.77070
	(0.00001)	(0.05194)	(0.09006)	
Malaysia	0.00001**	0.11709***	0.80243***	0.91952
	(0.00000)	(0.02930)	(0.05294)	
New Zealand	0.00000**	0.15762***	0.80717***	0.96479
	(0.00000)	(0.03524)	(0.03973)	
Philippines	0.00002***	0.30065***	0.64457***	0.94522
	(0.00001)	(0.05546)	(0.06039)	
Singapore	0.00001***	0.27068***	0.63389***	0.90457
	(0.00000)	(0.04657)	(0.06077)	
South Korea	0.00000	0.15939***	0.83248***	0.99187
	(0.00000)	(0.04362)	(0.05038)	
Thailand	0.00001***	0.13985***	0.79552***	0.93537
	(0.00000)	(0.01948)	(0.02073)	
Vietnam	0.00002***	0.11244***	0.78183***	0.89427
	(0.00001)	(0.02864)	(0.05748)	

Note: Standard errors in parentheses. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.

3. Empirical results

3.1. The stock market volatility

This section presents and discusses the results of ARMA-GARCH estimations in which the stock market volatilities or the conditional variances of stock returns are estimated for further analysis. It is essential to conduct an ARCH effects test for the heteroskedasticity of the time series of stock market returns before the estimations. Our test results confirm strong evidence of the ARCH effects in the residuals of stock return series for all countries in the sample. These findings confirm that it is appropriate to perform the ARMA-GARCH models.

The estimation results presented in Table 2 confirm the evidence of ARCH and GARCH effects at the significance level of 1 per cent for all countries. While the ARCH effect signifies that the stock market volatility in country i is affected by the shocks of previous periods, the GARCH effect indicates that the market volatility is influenced by the volatility of prior periods. Among 12 countries in our sample, China's market volatility is witnessed the most impacts from its past volatility, followed by South Korea and New Zealand. In contrast, the volatility in the Japanese stock market experienced the least effects from its previous volatility.

In addition to the ARCH and GARCH effects, Table 2 indicates that the market indices of all countries in the sample demonstrate the mean-reverting process because the sum of ARCH and GARCH coefficients is less than 1 ($\alpha + \beta < 1$). Besides, we find evidence of the persistence of market volatility in all nations. This finding is confirmed because a sum of the estimated coefficients ($\alpha + \beta$) is close to 1, implying that the volatility is persistent. Additionally, the absolute value of ($\alpha + \beta$) affects the speed of the mean reversion of market indices. The higher the absolute value of ($\alpha + \beta$) is, the slower the mean reversion of a market index. In our sample, the KOSPI (South Korea) and S&P/NZX 50 (New Zealand) are found to experience the longest mean reversion, whereas the TOPIX (Japan) has the fastest mean reversion.

Figure 3 depicts the conditional variance from the ARMA-GARCH process, which is proxied for stock market volatility of 12 countries in our sample (Figure 3(a, b, c, d, e, f, g, h, i, j, k, l)). The market volatility of all selected countries had rocketed since the WHO's declaration of the Covid-19 pandemic on 11 March 2020 (marked by the red dashed lines). Surprisingly, most countries' market volatility was not significantly responsive to the rise of the Delta variant cases, except for China, the Philippines and Vietnam (Figure 3(b, h and l)), where the stock volatility bounced up after 30 June 2021 (the blue dashed lines). Likewise, the Omicron-influenced upswing since 01 November 2021 (the black dashed lines) appears not to cause remarkable responses from market volatility in all Asia-Pacific countries. Based on observations from Figure 3, we then perform the regression models to examine the effects of the Covid-19 pandemic on the market volatility of 12 countries in our sample over the past 25 months in the next section.

3.2. Market volatility and the Covid-19 pandemic

3.2.1. The estimation using the full sample period (January 2020–January 2022)

Using the market volatility for each country from the ARMA-GARCH models, we examine the Covid-19 impacts on the stock market volatility of 12 countries in our sample. Table 3 presents the estimation results from January 2020 to January 2022.

Concerning policy responses to the pandemic, as presented in Table 3, we note that enacting the Covid-19 control measures (represented by *Containment*) is likely to help mitigate market volatility for most of the countries in our sample. Significantly, Singapore and Australia are two developed markets that have experienced the most significant effects of government control measures. In contrast, a frontier market, Vietnam has witnessed the weakest impacts. Additionally, we find that an increase in economic policy uncertainty (*EPU*) is associated with increased market volatility. This finding is confirmed for all selected countries. Moreover, it is reported that the Covid-19 vaccination program (*Vaccine*) does not significantly affect

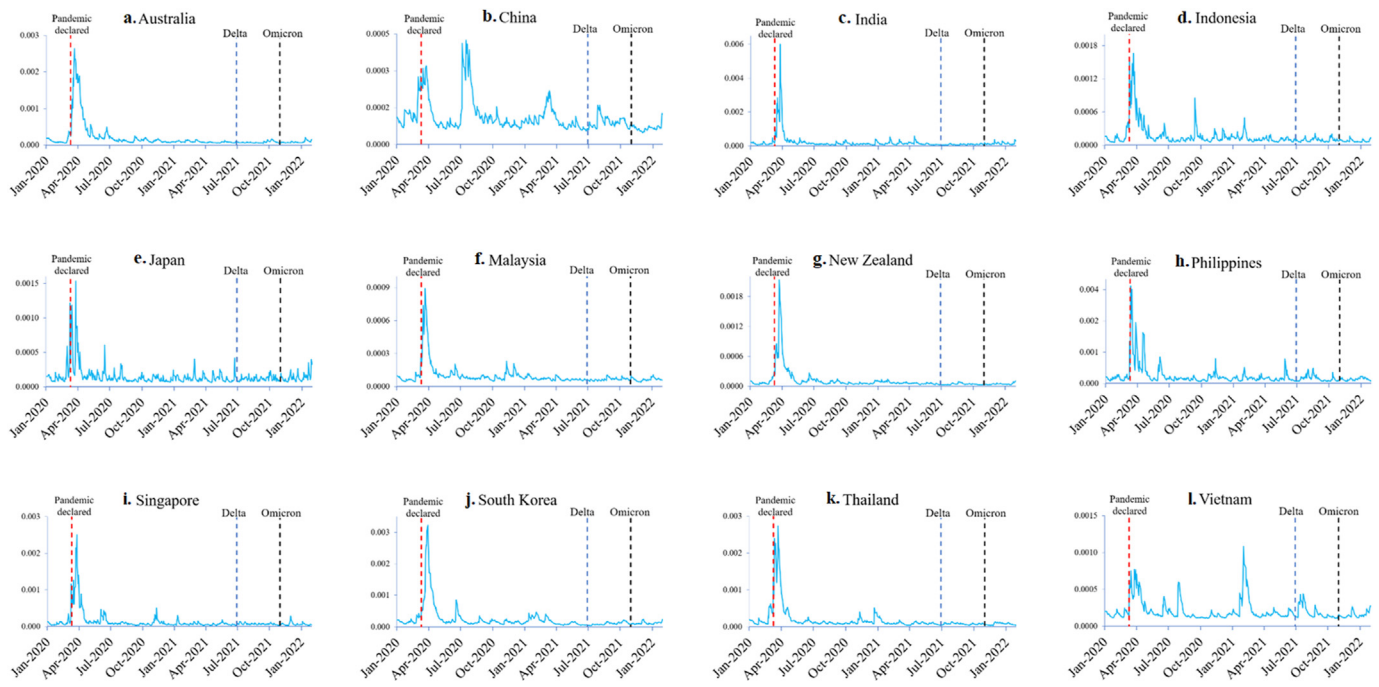

Figure 3. The market volatility of 12 countries in the sample over the period from January 2020 to January 2022 (estimated by ARMA-GARCH), including a) Australia, b) China, c) India, d) Indonesia, e) Japan, f) Malaysia, g) New Zealand, h) Philippines, i) Singapore, j) South Korea, k) Thailand and l) Vietnam. *Notes*: The red dashed line marks the date of 11 March 2020, when the WHO declared the coronavirus outbreak (Covid-19) a pandemic. The blue dashed line marks the rise of the Delta variant cases (30 June 2021). The black dashed line marks when the Omicron-influenced upswing began (01 November 2021) (Anderson, 2022).

volatility in most countries, except for China, where the increased number of people vaccinated appears to help reduce stock market volatility.

Regarding the emergence of the coronavirus pandemic, results from Table 3 confirm that the WHO's declaration of the Covid-19 pandemic on 11 March 2020 (*Declaration*) did amplify the market volatility in various countries in the sample. Australia and Thailand appear to witness the most significant impacts. In addition, we find evidence of significant effect from the daily Covid-19 cases to market volatility in 8 out of 12 countries in our sample. Among the countries with a significant impact, an increase in new Covid-19 cases appears to be associated with an increase in market volatility in Australia, China, Japan, New Zealand, and Singapore. We note that these countries have been ranked relatively low in the Green-zone rankings by EndCoronavirus (2022), indicating that they have still experienced a high number of new Covid-19 cases.[1] Interestingly, the estimation results do not show strong evidence of the effect of the rise of the *Delta* and *Omicron* variant cases on market volatility. We find that the upswing of those variants' infection cases appears to increase market volatility in only a few countries, such as Indonesia, the Philippines, Singapore (in case of the Delta variant) and Japan (in case of the Omicron variant).

Furthermore, findings from Table 3 indicate little evidence of the effects of macroeconomic fundamentals on market volatility during the research period. However, in the countries with significant effects, we note that a decline in interest rates (*Libor*) appears to be linked to a decrease in market volatility. Meanwhile, the decreases in the oil price (*Oil*), gold price (*Gold*) and exchange rates (*Exchange*) are associated with increased market volatility during the pandemic.

[1] In detail, up to early March 2022, among 144 countries on the list, China ranks 44th with approximately 7 thousand cases in the last 14 days, followed by New Zealand, ranking 50th with nearly 9 thousand cases. Singapore ranks 105th with about 153 thousand cases; Australia ranks 119th with approximately 323 thousand cases; and Japan ranks 137th with more than 1.2 million cases.

3.2.2. *The comparison between two subsamples: period 1 (January 2020–December 2020) and period 2 (January 2021–January 2022)*

We consider that over two years since the coronavirus has emerged, the herd mentality of stock markets appears to evolve into a herd immunity to the current pandemic. As such, stock markets have become less responsive to the Covid-19-related events. In this analysis, we estimate the impact of the pandemic on market volatility using two distinct subsamples: period 1 (from January 2020 to December 2020) and period 2 (from January 2021 to January 2022).

Table 4 compares the effects of the current pandemic on market volatility between two periods. Our full regression results are presented in Appendices B1 and B2. Findings presented in Table 4 confirm that fewer significant effects in period 2 are observed compared to period 1, especially in terms of the daily new Covid-19 cases (*Newcase*).

4. Robustness tests

4.1. Estimating market volatility using EGARCH and GJR-GARCH

The GARCH model has one significant restriction the model enforces a symmetric reaction of volatility to positive and negative news (Brooks, 2019). As such, in this section, we use exponential-GARCH (or EGARCH) (Nelson, 1991) and the GJR-GARCH model (Glosten et al., 1993) to estimate the market volatility of each country in the sample. These models allow the asymmetric effects of positive and negative shocks on stock market volatility. The EGARCH and GJR-GARCH model are presented in Eqs. (5) and (6), respectively (Brooks, 2019).

$$\ln\left(\sigma_t^2\right) = \omega + \beta \ln\left(\sigma_{t-1}^2\right) + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha \left[\frac{|u_{t-1}|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{\frac{2}{\pi}} \right] \tag{5}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta \sigma_{t-1}^2 + \gamma\, u_{t-1}^2\, I_{t-1}, \quad I_{t-1} = \begin{cases} 1 \text{ if } u_{t-1} < 0 \\ 0 \text{ otherwise} \end{cases} \tag{6}$$

Next, we re-run our earlier analysis using regression model (4) for each country. Finally, market volatility is estimated using EGARCH and GJR-

Table 3. The effects of the Covid-19 pandemic on market volatility (estimated by ARMA-GARCH) over the period January 2020–January 2022.

	Australia	China	India	Indonesia	Japan	Malaysia	New Zealand	Philippines	Singapore	South Korea	Thailand	Vietnam
Containment	−0.00015***	−0.000038**	0.000101	−0.000004	−0.000059**	−0.000030**	−0.00006**	0.000003	−0.000468**	−0.00006**	−0.00008***	−0.000019*
	(0.000058)	(0.000019)	(0.000074)	(0.000034)	(0.000023)	(0.000012)	(0.000027)	(0.000022)	(0.000201)	(0.000029)	(0.000029)	(0.000010)
EPU	0.000174**	0.000018**	0.000126**	0.000090***	0.000066***	0.000044**	0.000083**	0.000150***	0.000142***	0.000145**	0.000168***	0.000059***
	(0.000071)	(0.000008)	(0.000053)	(0.000034)	(0.000025)	(0.000019)	(0.000035)	(0.000055)	(0.000054)	(0.000061)	(0.000064)	(0.000017)
Vaccine	−0.000000	−0.000001*	−0.000001	−0.000000	0.000000	−0.000000	0.000000	−0.000001	0.000001	0.000000	0.000000	−0.000000
	(0.000001)	(0.000000)	(0.000001)	(0.000001)	(0.000001)	(0.000000)	(0.000001)	(0.000002)	(0.000001)	(0.000001)	(0.000001)	(0.000001)
Declaration	0.000156***	0.000026	0.000107*	0.000074**	−0.000001	0.000043***	0.000079**	0.000082*	0.000041	0.000100	0.000118**	−0.000013
	(0.000047)	(0.000017)	(0.000060)	(0.000032)	(0.000020)	(0.000013)	(0.000033)	(0.000045)	(0.000027)	(0.000061)	(0.000051)	(0.000036)
Newcase	0.000032*	0.000008*	−0.00006**	−0.000026**	0.000001**	0.000000	0.000043*	−0.000042**	0.000025**	−0.000002	0.000000	0.000001
	(0.000017)	(0.000004)	(0.000029)	(0.000011)	(0.000001)	(0.000000)	(0.000025)	(0.000017)	(0.000012)	(0.000002)	(0.000001)	(0.000001)
Delta	−0.000006	−0.000003	0.000014	0.000081**	0.000002	0.000008	0.000002	0.000175***	0.000095**	−0.000055	0.000065	0.000044
	(0.000028)	(0.000010)	(0.000043)	(0.000041)	(0.000014)	(0.000011)	(0.000021)	(0.000059)	(0.000044)	(0.000034)	(0.000041)	(0.000038)
Omicron	−0.000070	−0.00004***	0.000047	−0.000030	0.000033**	0.000004	−0.000095	−0.000001	0.000014	0.000008	0.000063	−0.000020
	(0.000066)	(0.000007)	(0.000042)	(0.000022)	(0.000017)	(0.000008)	(0.000061)	(0.000047)	(0.000031)	(0.000034)	(0.000042)	(0.000029)
Oil	−0.000082	−0.000129**	−0.000899	−0.000338	−0.000297	−0.000115	−0.000330	−0.000263	−0.000349	−0.000192	−0.000548	−0.000094
	(0.000459)	(0.000051)	(0.000870)	(0.000340)	(0.000218)	(0.000138)	(0.000387)	(0.000501)	(0.000435)	(0.000715)	(0.000440)	(0.000180)
Gold	0.002737	0.000584	0.001306	0.000920	−0.000783	0.000795	0.000381	−0.003986*	0.000485	0.001943	0.001112	−0.000283
	(0.002019)	(0.000424)	(0.001819)	(0.001733)	(0.000824)	(0.000792)	(0.000872)	(0.002376)	(0.001363)	(0.001479)	(0.002898)	(0.000662)
Exchange	−0.002219	0.001477	−0.005839	0.004198	0.000357	0.001090	−0.000666	−0.007597*	−0.003347	−0.001970	0.006422	−0.000674
	(0.003441)	(0.001123)	(0.012899)	(0.004035)	(0.003471)	(0.003446)	(0.002524)	(0.004289)	(0.009371)	(0.005171)	(0.005392)	(0.007138)
Libor	0.000364	0.000099	0.002106*	0.000488	0.000446	0.000432*	0.000416	0.002317	0.000865*	0.000387	0.001427	0.000229
	(0.000573)	(0.000118)	(0.001178)	(0.000358)	(0.000378)	(0.000255)	(0.000440)	(0.001491)	(0.000492)	(0.000631)	(0.001050)	(0.000231)
Constant	0.000136***	0.000203***	−0.000131	0.000060	0.000196***	0.000078***	−0.000017	0.000055	0.001761**	0.000017	−0.000055	0.000113***
	(0.000047)	(0.000062)	(0.000188)	(0.000084)	(0.000039)	(0.000015)	(0.000051)	(0.000061)	(0.000756)	(0.000096)	(0.000099)	(0.000026)

Table 4. The effects of the Covid-19 pandemic on market volatility (estimated by ARMA-GARCH): the comparison between period 1 (January 2020–December 2020) and period 2 (January 2021–January 2022).

	Containment		*Newcase*	
	Period 1	Period 2	Period 1	Period 2
Australia	(−)	n	(+)	n
China	n	(−)	n	n
India	n	(−)	(−)	n
Indonesia	n	(−)	(−)	(+)
Japan	(−)	n	(+)	n
Malaysia	(−)	n	n	n
New Zealand	(−)	n	(+)	n
Philippines	n	n	(−)	(+)
Singapore	(−)	n	(+)	n
South Korea	(−)	(+)	n	n
Thailand	(−)	n	n	n
Vietnam	(−)	n	n	n

Note: *Containment* stands for the government's pandemic control measures. *Newcase* represents the daily new Covid-19 cases. (+) and (−) denote the statistically significant positive and negative impact, respectively. "n" stands for "no statistically significant impact". Period 1 ranges from January 2020 to December 2020. Period 2 ranges from January 2021 to January 2022. The full regression results are presented in Appendices B1 and B2.

GARCH models (see Table 5). We note that results from these additional analyses largely remain unchanged compared to our initial findings.

4.2. The Toda and Yamamoto (1995) Granger causality test

We also perform the Toda and Yamamoto (1995) Granger causality analysis for each subsample to identify the causality relationship between the Covid-19 pandemic and market volatility and compare the results between the two subsamples (see Table 6). The Toda-Yamamoto procedure estimates a vector autoregressive model (VAR) at levels. This approach could minimize the risks of incorrectly identifying the time series' order of integration and the co-integration amongst the variables. Additionally, the Toda-Yamamoto method ensures the usual test statistic has convenient asymptotic distribution so that well-founded inferences can be conducted (Amiri and Ventelou, 2012).

Results from Table 6 indicate that, in period 2 (January 2021–January 2022), the number of countries in which market volatility is affected by the pandemic has declined compared to the first period, especially in terms of daily new Covid-19 cases (*Newcase*). Interestingly, Singapore is the only country whose market volatility is still responsive to daily new cases and the government's Covid-19 control measures since 2021. In addition, the government's control measures still affect the volatility in the stock markets during the second pandemic period in Japan and Thailand. On balance, our empirical results confirm that the effects of the Covid-19 pandemic on market volatility have been significantly diminishing in most Asia-Pacific countries since 2021.

4.3. Panel vector autoregressive model and panel impulse response analysis

Results from the OLS regression for each country do not indicate responses of the market volatility to the Covid-19 pandemic over time. As such, we now employ the panel vector autoregressive (PVAR) and panel impulse response function (PIRF) to re-estimate our results using model (4). On the one hand, PVAR has an advantage as the technique can overcome endogenous problems by treating each variable as the dependent variable. However, on the other hand, the PIRF can present the responses of the market volatility to the Covid-19 pandemic over time. As such, the combination of PVAR and PIRF is desirable to estimate the overall effects of the Covid-19 pandemic on the market volatility in the Asia-Pacific region.

Table 7 presents estimation results using the PVAR estimation. Findings from the entire sample confirm that the pandemic control measures (*Containment*) and Covid-19 vaccination program (*Vaccine*) help reduce market volatility in the Asia-Pacific region. We also note that the WHO's declaration of the Covid-19 pandemic and the emergence of Delta and Omicron variant cases increased stock market volatility in the region. We note that the effects of the government's control measures (*Containment*) on market volatility in the Asia-Pacific region have been diminishing since 2021. In addition, empirical results using the panel impulse response analysis presented in Figure 4 indicate that the effects of Covid-19 new cases and the government's control measures have become faded at the regional level in period 2 (January 2021–January 2022) (Figure 4(a2 and b2), respectively) compared to the first pandemic year of 2020 (Figure 4(a1 and b1), respectively).

Table 5. The effects of the Covid-19 pandemic on market volatility (estimated using EGARCH & GJR-GARCH): Period 1 versus Period 2.

	EGARCH				GJR-GARCH			
	Containment		Newcase		Containment		Newcase	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Australia	(−)	n	(+)	n	(−)	n	(+)	n
China	n	(−)	(+)	n	n	(−)	n	n
India	n	(−)	(−)	(+)	n	(−)	(−)	n
Indonesia	(−)	(−)	(−)	(+)	n	(−)	(−)	(+)
Japan	(−)	n	n	n	(−)	n	n	n
Malaysia	(−)	n	n	n	(−)	(−)	n	n
New Zealand	(−)	(−)	(+)	n	(−)	(−)	(+)	n
Philippines	n	n	(−)	(+)	n	n	(−)	(+)
Singapore	(−)	n	(+)	n	(−)	n	(+)	n
South Korea	(−)	(+)	n	n	(−)	n	n	n
Thailand	(−)	n	n	n	(−)	n	n	n
Vietnam	(−)	n	n	n	(−)	(+)	n	n

Note: *Containment* stands for the government's pandemic control measures. *Newcase* represents the daily new Covid-19 cases. (+) and (−) denote the statistically significant positive and negative impact, respectively. "n" stands for "no statistically significant impact". Period 1 ranges from January 2020 to December 2020. Period 2 ranges from January 2021 to January 2022. The full regression results are presented in Appendices C1, C2, D1 and D2.

Table 6. Results of the Toda-Yamamoto Granger causality test: the comparison between period 1 (January 2020–December 2020) and period 2 (January 2021–January 2022).

	ARMA-GARCH				EGARCH				GJR-GARCH			
	Containment		Newcase		Containment		Newcase		Containment		Newcase	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Australia	n	n	New → Vol	n	n	n	New → Vol	New → Vol	n	n	New → Vol	n
China	n	n	n	n	n	n	New → Vol	n	n	n	n	n
India	Cont → Vol	n	New → Vol	n	Cont → Vol	n	New → Vol	n	Cont → Vol	n	New → Vol	n
Indonesia	n	n	New → Vol	n	n	n	New → Vol	n	n	n	New → Vol	n
Japan	Cont → Vol	Cont → Vol	New → Vol	n	Cont → Vol	Cont → Vol	New → Vol	n	Cont → Vol	Cont → Vol	New → Vol	n
Malaysia	n	n	n	n	n	n	n	n	n	n	n	n
New Zealand	n	n	New → Vol	n	n	n	New → Vol	n	n	n	New → Vol	n
Philippines	n	n	New → Vol	New → Vol	n	n	New → Vol	n	n	n	New → Vol	n
Singapore	n	Cont → Vol	New → Vol	New → Vol	Cont → Vol	Cont → Vol	New → Vol	New → Vol	n	Cont → Vol	New → Vol	New → Vol
South Korea	Cont → Vol	n	New → Vol	n	Cont → Vol	n	New → Vol	n	Cont → Vol	n	New → Vol	New → Vol
Thailand	Cont → Vol	Cont → Vol	n	n	Cont → Vol	Cont → Vol	n	New → Vol	Cont → Vol	Cont → Vol	n	n
Vietnam	n	n	New → Vol	n	n	n	n	n	n	n	New → Vol	n

Note: *Containment* stands for the government's pandemic control measures. *Newcase* represents the daily new Covid-19 cases.
"Cont → *Vol*" denotes the statistically significant causality from *containment* to market volatility.
"New → *Vol*" denotes the statistically significant causality from *Newcase* to market volatility.
"n" stands *for* "no statistically significant causality".
Period 1 *ranges* from January 2020 to December 2020. Period 2 ranges from January 2021 to January 2022. The full results of the Toda-Yamamoto Granger causality test are presented in Appendix E.

Table 7. The effects of the Covid-19 pandemic on market volatility (estimated by PVAR).

	Full sample (January 2020–January 2022)	Period 1 (January 2020–December 2020)	Period 2 (January 2021–January 2022)
Containment	−0.00002*	−0.00002**	−0.00004
	(0.00001)	(0.00001)	(0.000028)
EPU	0.00000	0.00001	0.000002**
	(0.000002)	(0.000004)	(0.000001)
Newcase	−0.000001	0.00000	0.00000
	(0.000001)	(0.000001)	(0.000001)
Oil	0.00072***	−0.00004	0.00007*
	(0.00003)	(0.00005)	(0.00004)
Gold	−0.00246***	−0.00136***	0.00057***
	(0.00019)	(0.00022)	(0.00005)
Exchange	0.00569***	0.00277**	0.00363***
	(0.00122)	(0.00111)	(0.00047)
Libor	−0.00019***	−0.000163**	−0.00005**
	(0.00005)	(0.000071)	(0.00003)
Volatility (lags)	1.00404***	0.92681***	0.67816***
	(0.02204)	(0.03011)	(0.08210)
Vaccine	−0.000001***	-	-
	(0.000000)		
Declaration	0.00001***	-	-
	(0.000003)		
Delta	0.00001***	-	-
	(0.000002)		
Omicron	0.00001***	-	-
	(0.000002)		

Note: Standard errors in parentheses. "-" stands for not available results. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.

5. Conclusions and policy implications

5.1. Conclusions

The stock markets are generally considered to possess an adaptive feature. Therefore, their responses to the Covid-19 pandemic tend to change over time, implying that their recent responses appear to be significantly different from when the pandemic first emerged in 2020. This study re-examines the effects of the Covid-19 pandemic on market volatility of the Asia-Pacific countries over the past 25 months (from its emergence in January 2020 until January 2022). Besides, we also investigate the changes in effects of the pandemic on stock market volatility between the first pandemic year (2020) and the following years (January 2021–January 2022). We revisit this important issue as we consider that over more than two years, the herd mentality of the stock markets appears to evolve into a herd immunity to the pandemic and become less responsive to the Covid-19 pandemic. Together with the OLS regression, we also employ the panel vector autoregressive (PVAR) and panel impulse response function (PIRF) for our robustness analyses. This consideration has largely been ignored in the existing literature. Key findings from this paper can be summarized as follows.

First, findings from the entire sample reveal that the implementation of Covid-19 control measures tends to help alleviate market volatility for countries in the Asia-Pacific region. Additionally, results from our robustness test using the PVAR model largely remain unchanged. *Second*, using the OLS regression for each country in our research sample and the PVAR technique for the Asia-Pacific region, we find that WHO's declaration of the Covid-19 pandemic increases stock market volatility in many countries in the region and at the regional level. Furthermore, our evidence indicates that an increase in daily new cases appears to be linked to increased market volatility in Australia, China, Japan, New Zealand, and Singapore. Interestingly, our findings fail to confirm the effects of the emergence of the Delta

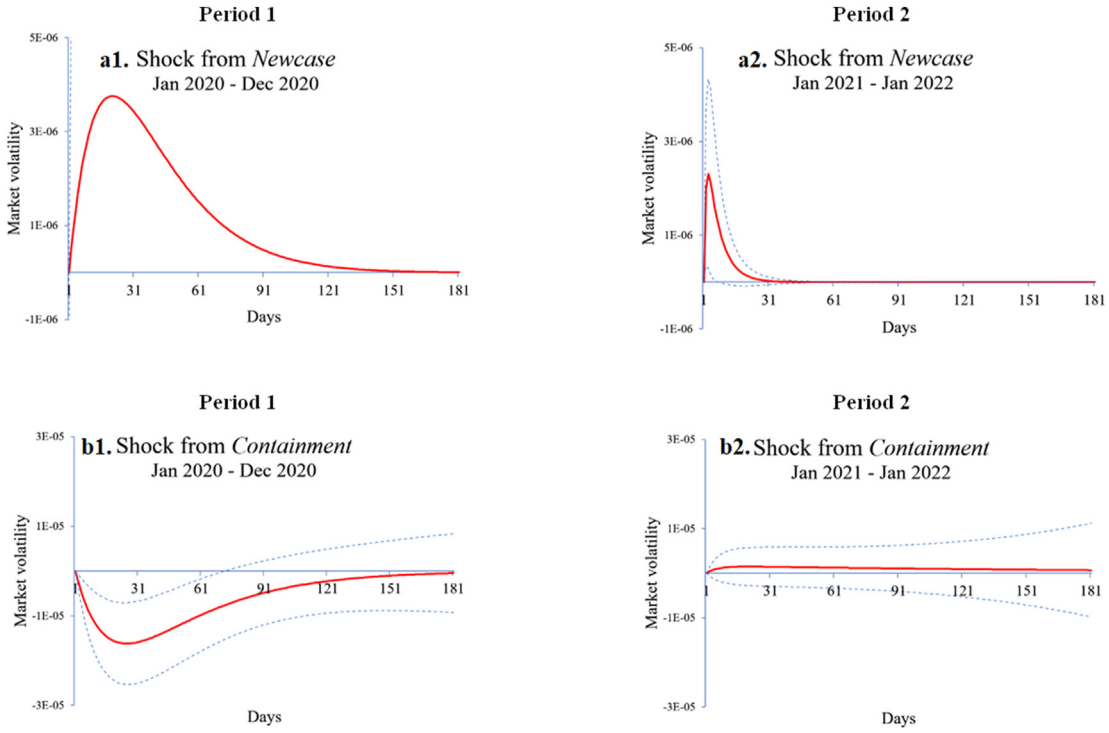

Figure 4. Orthogonalized impulse response functions: the comparison between period 1 (January 2020–December 2020) and period 2 (January 2021–January 2022). Figure 4a1 and 4a2 show the shock from the daily new Covid-19 cases (*Newcase*) to market volatility in period 1 and 2, respectively. Figure 4b1 and 4b2 show the shock from the government's pandemic control measures (*Containment*) to market volatility in period 1 and 2, respectively.

and Omicron variant cases on market volatility at the country level. However, our findings support the view that the emergence of these two variants is associated with increased market volatility at the regional level based on the PVAR estimation results. *Third*, our empirical results indicate that the effects of daily new cases and Covid-19 control measures on market volatility have been significantly fading since 2021 at the country and regional levels. The results largely remain unchanged in robustness analysis using the robustness tests using the Toda-Yamamoto Granger causality test and panel impulse response analysis. The current pandemic appears to no longer be blamed for stock market volatility in the Asia-Pacific region.

5.2. Policy implications

Policy implications have emerged based on the findings from our analysis. *First*, findings from our study confirm that the Covid-19 impacts on stock market volatility have been diminishing in the second pandemic period (January 2021–January 2022), regardless of the surge of the Delta and Omicron variants. Thanks to effective pandemic control measures and numerous safe and effective Covid-19 vaccines, many countries have brought the coronavirus transmission under control and reopened their national borders, entering a "new normal" phase. However, we still encounter several obstacles and inconveniences, such as quarantine requirements, proof of negative pre-trip PCR test results and other entry restrictions when entering foreign countries. The sooner we end the Covid-19 pandemic and return to a pre-pandemic normal, the better for society and the economy. The governments in the region should be consistent in adopting the WHO's comprehensive measures to curb coronavirus transmission. *Second*, our findings also confirm that the emergence of Covid-19 significantly impacted market volatility in several countries in the region within the first pandemic year. The severity of such a global pandemic appears to lead to fear and turbulence in stock markets in the first few months since its emergence in the early months of 2020. As such, governments need to prepare for similar health crises in the future to alleviate their adverse effects on economic growth and stabilize the financial markets.

Declarations

Author contribution statement

Duc Hong Vo: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Chi Minh Ho: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Tam Hoang-Nhat Dang: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

APPENDICES.

Appendix A1. Results from the unit root test for each country in the sample.

	Unit root test	Australia	China	India	Indonesia	Japan	Malaysia	New Zealand	Philippines	Singapore	South Korea	Thailand	Vietnam
Market return	ADF	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−29.537***	−21.224***	−23.066***	−21.257***	−20.076***	−21.710***	−21.189***	−22.014***	−23.380***	−22.054***	−23.624***	−21.259***
	PP	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−752.67***	−477.52***	−503.89***	−509.62***	−402.90***	−529.72***	−521.80***	−522.81***	−605.64***	−533.52***	−556.42***	−477.31***
	ZA	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−8.073***	−21.442***	−7.432***	−7.914***	−12.872***	−10.801***	−9.6***	−14.407***	−7.893***	−12.857***	−7.584***	−9.020***
Market volatility	ADF	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−3.025**	−3.887***	−7.582***	−6.182***	−9.274***	−4.036***	−3.752***	−7.577***	−5.095***	−2.592*	−4.192***	−4.849***
	PP	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−20.516**	−26.286***	−90.830***	−55.078***	−139.95***	−34.208***	−33.269***	−99.429***	−43.801***	−28.185***	−27.940***	−46.376***
	ZA	I (1)	I (0)	I (0)	I (1)	I (0)	I (1)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)
		−7.695***	−21.442*	−4.931*	−12.860***	−5.109**	−6.911***	−11.055***	−7.988***	−10.056***	−6.638***	−12.074***	−5.742***
Containment	ADF	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−5.475***	−9.827***	−5.471***	−10.867***	−10.666***	−7.191***	−5.138***	−5.858***	−5.684***	−7.501***	−4.160***	−6.300***
	PP	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−20.737***	−38.390***	−19.324***	−37.098***	−32.521***	−26.581***	−18.853***	−19.900***	−13.815***	−19.933***	−8.430***	−20.657***
	ZA	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (1)	I (0)	I (0)	I (0)
		−5.326**	−8.421***	−5.006*	−5.795***	−8.735***	−8.793***	−5.677***	−5.302**	−10.207***	−7.229***	−5.992***	−5.902***
EPU	ADF	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−8.622***	−8.622***	−8.622***	−8.622***	−8.622***	−8.622***	−8.622***	−8.622***	−8.622***	−8.622***	−8.622***	−8.622***
	PP	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−112.1***	−112.1***	−112.1***	−112.1***	−112.1***	−112.1***	−112.1***	−112.1***	−112.1***	−112.1***	−112.1***	−112.1***
	ZA	I (0)	I (1)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−5.501**	−15.426***	−5.175**	−5.455**	−5.422**	−5.784***	−5.606***	−5.498**	−5.379**	-5.579***	-5.434**	−5.401**
Vaccine	ADF	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)
		−13.728***	−7.55***	−20.158***	−18.816***	−13.487***	−10.813***	−11.271***	−13.501***	−10.617***	−10.619***	−13.614***	−13.355***
	PP	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)	I (1)
		−332.77***	−106.81***	−511.29***	−463.59***	−300.46***	−203.21***	−218.06***	−284.83***	−194.01***	−195.29***	−288.71***	−271.51***
	ZA	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (1)	I (0)	I (0)	I (0)	I (0)
		−19.578***	−56.99***	−29.262***	−25.895***	−8.199***	−11.494***	−9.731***	−11.75***	−10.898***	−14.884***	−13.123***	−8.793***
Newcase	ADF	I (0)	I (0)	I (0)	I (0)	I (0)	I (1)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−3.326**	−6.488***	−3.712***	−3.527***	−2.616*	−27.257***	−8.840***	−6.106***	−5.492***	−3.072**	−3.023**	−3.995***
	PP	I (0)	I (0)	I (0)	I (0)	I (1)	I (1)	I (0)	I (0)	I (0)	I (1)	I (1)	I (1)
		−25.648**	−59.029***	−9.735**	−8.824*	−441.62***	−507.15**	−122.12***	−38.35***	−29.72***	−655.04***	−496.53***	−753.98***
	ZA	I (1)	I (0)	I (1)	I (1)	I (1)	I (1)	I (0)	I (1)	I (1)	I (1)	I (1)	I (1)
		−7.960***	−5.886***	−5.522**	−8.467***	−6.66***	−11.294***	−5.121**	−9.449***	−9.983***	−6.814***	−11.405***	−7.933***

(*continued on next page*)

(*continued*)

	Unit root test	Australia	China	India	Indonesia	Japan	Malaysia	New Zealand	Philippines	Singapore	South Korea	Thailand	Vietnam
Oil	ADF	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−24.316***	−24.316***	−24.316***	−24.316***	−24.316***	−24.316***	−24.316***	−24.316***	−24.316***	−24.316***	−24.316***	−24.316***
	PP	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−501.8***	−501.8***	−501.8***	−501.8***	−501.8***	−501.8***	−501.8***	−501.8***	−501.8***	−501.8***	−501.8***	−501.8***
	ZA	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−15.208***	−15.766***	−8.938***	−14.670***	−12.365***	−15.083***	−15.165***	−12.102***	−15.295***	−15.769***	−15.263***	−12.656***
Gold	ADF	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−21.063***	−21.063***	−21.063***	−21.063***	−21.063***	−21.063***	−21.063***	−21.063***	−21.063***	−21.063***	−21.063***	−21.063***
	PP	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−444.66***	−444.66***	−444.66***	−444.66***	−444.66***	−444.66***	−444.66***	−444.66***	−444.66***	−444.66***	−444.66***	−444.66***
	ZA	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−12.198***	−11.815***	−12.505***	−19.479***	−20.722***	−19.679***	−20.774***	−12.07***	−20.552***	−19.776***	−13.536***	−20.041***
Exchange	ADF	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−19.885***	−25.718***	−24.691***	−18.936***	−25.401***	−20.905***	−21.657***	−24.706***	−22.476***	−25.184***	−19.726***	−20.305***
	PP	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−458.9***	−571.68***	−569.32***	−500.32***	−599.04***	−493.03***	−500.58***	−550.17***	−556.12***	−603.10***	−469.99***	−464.03***
	ZA	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−13.741***	−23.412***	−21.606***	−6.853***	−11.895***	−12.325***	−11.641***	−14.399***	−12.92***	−13.442***	−13.025***	−11.546***
Libor	ADF	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−20.841***	−20.841***	−20.841***	−20.841***	−20.841***	−20.841***	−20.841***	−20.841***	−20.841***	−20.841***	−20.841***	−20.841***
	PP	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−597.25***	−597.25***	−597.25***	−597.25***	−597.25***	−597.25***	−597.25***	−597.25***	−597.25***	−597.25***	−597.25***	−597.25***
	ZA	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)	I (0)
		−9.911***	−9.806***	−10.006***	−9.248***	−9.194***	−9.217***	−9.9***	−9.796***	−7.488***	−9.444***	−9.002***	−9.833***

Note: ADF, PP and ZA stand for the augmented Dickey-Fuller test, the Phillips-Perron test and the Zivot-Andrews structural break unit root test, respectively. I (0) means that the variable is stationary at level while I (1) means that the variable is stationary at the first difference. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.
All variables included in our regression models are ensured to be stationary based on considering above unit root test results.

Appendix A2. Results from the panel data unit-root tests.

	Fisher-type unit-root test (Choi, 2001)	Im et al. (2003) unit-root test
Market volatility	I (0)	I (0)
	−15.2049***	−14.3229***
Containment	I (0)	I (0)
	−19.4434***	−21.0863***
EPU	I (0)	I (0)
	−27.1843***	−27.0488***
Vaccine	I (1)	I (1)
	−27.7031***	−39.9344***
Newcase	I (0)	I (0)
	−9.2047***	−11.3457***
Oil	I (0)	I (0)
	−28.1489***	−60.8666***
Gold	I (0)	I (0)
	−28.1489***	−57.7574***
Exchange	I (0)	I (0)
	−28.1489***	−59.6747***
Libor	I (0)	I (0)
	−28.1489***	−57.3074***

Note: I (0) means that the variable is stationary at level while I (1) means that the variable is stationary at the first difference. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.
All variables included in our panel VAR models are ensured to be stationary based on considering above panel unit root test results.

Appendix B1. The effects of the Covid-19 pandemic on market volatility (estimated by ARMA-GARCH) over Period 1 (January 2020–December 2020).

	Australia	China	India	Indonesia	Japan	Malaysia	New Zealand	Philippines	Singapore	South Korea	Thailand	Vietnam
Containment	−0.000227***	−0.000020	0.000039	−0.000094	−0.000106***	−0.000041**	−0.000077**	−0.000033	−0.000820***	−0.000112**	−0.000116**	−0.000032**
	(0.000078)	(0.000031)	(0.000063)	(0.000073)	(0.000037)	(0.000016)	(0.000031)	(0.000032)	(0.000268)	(0.000056)	(0.000045)	(0.000016)
EPU	0.000280***	0.000022**	0.000274***	0.000179***	0.000114***	0.000078***	0.000107***	0.000294***	0.000246***	0.000251**	0.000303***	0.000072***
	(0.000092)	(0.000010)	(0.000099)	(0.000057)	(0.000036)	(0.000028)	(0.000040)	(0.000083)	(0.000070)	(0.000102)	(0.000096)	(0.000025)
Newcase	0.000073**	0.000007	−0.000068**	−0.000022*	0.000003**	0.000001	0.000101**	−0.000070***	0.000059***	−0.000009	0.000003	−0.000000
	(0.000035)	(0.000006)	(0.000029)	(0.000013)	(0.000002)	(0.000001)	(0.000041)	(0.000024)	(0.000022)	(0.000008)	(0.000008)	(0.000004)
Oil	0.000109	−0.000121**	−0.000787	−0.000262	−0.000312	−0.000092	−0.000285	−0.000027	−0.000291	−0.000139	−0.000427	−0.000136
	(0.000555)	(0.000060)	(0.001064)	(0.000285)	(0.000227)	(0.000160)	(0.000335)	(0.000454)	(0.000408)	(0.000906)	(0.000475)	(0.000209)
Gold	0.003978	0.000765	0.001046	0.001639	−0.001586	0.001011	0.000040	−0.006061**	0.000149	0.003153	0.001445	0.000182
	(0.003112)	(0.000591)	(0.002856)	(0.002444)	(0.001198)	(0.001179)	(0.001533)	(0.002847)	(0.001862)	(0.002424)	(0.003821)	(0.000896)
Exchange	−0.002835	0.001559	−0.011022	0.001775	0.000317	0.000455	−0.000913	−0.008947	−0.006378	−0.003476	0.013746	0.005417
	(0.005438)	(0.001535)	(0.021630)	(0.004104)	(0.004393)	(0.004862)	(0.003827)	(0.010269)	(0.013822)	(0.009340)	(0.008680)	(0.012045)
Libor	0.000794	0.000189	0.003348**	0.000959**	0.000674	0.000752**	0.000709	0.003874**	0.001293**	0.000984	0.002495*	0.000343
	(0.000701)	(0.000153)	(0.001507)	(0.000450)	(0.000529)	(0.000321)	(0.000540)	(0.001778)	(0.000567)	(0.000912)	(0.001287)	(0.000292)
Constant	0.000100	0.000129	−0.000207	0.000181	0.000243***	0.000057***	−0.000009	−0.000022	0.002924***	−0.000012	−0.000266*	0.000113***
	(0.000062)	(0.000100)	(0.000188)	(0.000147)	(0.000070)	(0.000019)	(0.000043)	(0.000075)	(0.000969)	(0.000092)	(0.000158)	(0.000024)

Note: Standard errors in parentheses. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.
The p-values are corrected for Newey and West (1987) standard errors, which are considered to be robust to autocorrelation and heteroskedasticity.

Appendix B2. The effects of the Covid-19 pandemic on market volatility (estimated by ARMA-GARCH) over Period 2 (January 2021–January 2022).

	Australia	China	India	Indonesia	Japan	Malaysia	New Zealand	Philippines	Singapore	South Korea	Thailand	Vietnam
Containment	−0.000015	−0.000194***	−0.000115*	−0.000162*	0.000093	−0.000020	−0.000008	−0.000077	−0.000095	0.000490***	0.000025	0.000107
	(0.000022)	(0.000050)	(0.000062)	(0.000087)	(0.000095)	(0.000012)	(0.000007)	(0.000079)	(0.000081)	(0.000152)	(0.000032)	(0.000091)
EPU	0.000006**	0.000011***	0.000023***	0.000009	0.000003	0.000004**	0.000007***	0.000014	0.000005	0.000021**	0.000013*	0.000055**
	(0.000003)	(0.000003)	(0.000008)	(0.000006)	(0.000008)	(0.000002)	(0.000003)	(0.000012)	(0.000004)	(0.000010)	(0.000007)	(0.000023)
Newcase	0.000001	−0.000000	0.000006	0.000009*	0.000001	0.000000	−0.000001	0.000007**	−0.000000	0.000000	−0.000000	0.000001
	(0.000001)	(0.000003)	(0.000005)	(0.000005)	(0.000000)	(0.000000)	(0.000001)	(0.000003)	(0.000002)	(0.000001)	(0.000000)	(0.000001)
Oil	0.000104*	−0.000026	0.000113	0.000258	−0.000021	0.000076**	0.000039	−0.000292	0.000088	0.000435*	0.000151	0.000527
	(0.000058)	(0.000069)	(0.000199)	(0.000166)	(0.000159)	(0.000035)	(0.000055)	(0.000371)	(0.000113)	(0.000239)	(0.000120)	(0.000506)
Gold	−0.000142	−0.000028	−0.000240	−0.000341	0.000107	0.000080	−0.000160	0.000308	0.000188	−0.000357	−0.000243	−0.001394
	(0.000149)	(0.000194)	(0.000770)	(0.000483)	(0.000403)	(0.000084)	(0.000134)	(0.000562)	(0.000224)	(0.000562)	(0.000440)	(0.001049)
Exchange	−0.000256	−0.000188	−0.000512	−0.001254	−0.000130	−0.000225	−0.000225	−0.003612	0.000953	−0.000011	−0.000256	−0.007415
	(0.000276)	(0.000668)	(0.001673)	(0.000946)	(0.001171)	(0.000473)	(0.000223)	(0.002358)	(0.000951)	(0.001151)	(0.000666)	(0.005357)
Libor	−0.000028	−0.000095**	0.000015	−0.000197**	0.000178	−0.000031	−0.000038	−0.000028	0.000036	−0.000098	−0.000136	−0.000241
	(0.000040)	(0.000047)	(0.000130)	(0.000086)	(0.000132)	(0.000023)	(0.000039)	(0.000195)	(0.000072)	(0.000126)	(0.000083)	(0.000236)
Constant	0.000130	0.001031***	0.000556*	0.000785**	−0.000313	0.000152**	0.000072**	0.000464	0.000516	−0.002288***	−0.000070	−0.000497
	(0.000103)	(0.000246)	(0.000284)	(0.000382)	(0.000440)	(0.000060)	(0.000028)	(0.000398)	(0.000387)	(0.000733)	(0.000166)	(0.000477)

Note: Standard errors in parentheses. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.
The p-values are corrected for Newey and West (1987) standard errors, which are considered to be robust to autocorrelation and heteroskedasticity.

Appendix C1. The effects of the Covid-19 pandemic on market volatility (estimated by EGARCH) over Period 1 (January 2020–December 2020).

	Australia	China	India	Indonesia	Japan	Malaysia	New Zealand	Philippines	Singapore	South Korea	Thailand	Vietnam
Containment	−0.000280***	−0.000040	0.000013	−0.000089*	−0.000084***	−0.000041***	−0.000075**	−0.000046	−0.000717***	−0.000111**	−0.000125***	−0.000076**
	(0.000082)	(0.000028)	(0.000043)	(0.000052)	(0.000032)	(0.000014)	(0.000029)	(0.000035)	(0.000188)	(0.000050)	(0.000045)	(0.000030)
EPU	0.000366***	0.000028**	0.000281***	0.000151***	0.000087***	0.000071***	0.000111***	0.000282***	0.000218***	0.000199**	0.000303***	0.000132***
	(0.000101)	(0.000011)	(0.000081)	(0.000040)	(0.000030)	(0.000023)	(0.000042)	(0.000083)	(0.000052)	(0.000082)	(0.000093)	(0.000043)
Newcase	0.000063**	0.000010**	−0.000065***	−0.000019**	0.000001	0.000001	0.000071***	−0.000066***	0.000050***	−0.000005	0.000005	0.000008
	(0.000029)	(0.000005)	(0.000022)	(0.000009)	(0.000001)	(0.000001)	(0.000027)	(0.000022)	(0.000015)	(0.000005)	(0.000006)	(0.000006)
Oil	−0.000234	−0.000121*	−0.000370	−0.000126	−0.000128	−0.000109	−0.000345	0.000097	−0.000183	−0.000618	−0.000623	0.000054
	(0.000473)	(0.000064)	(0.000547)	(0.000252)	(0.000155)	(0.000144)	(0.000261)	(0.000356)	(0.000311)	(0.000391)	(0.000418)	(0.000203)
Gold	0.002184	0.000584	0.003004	−0.000666	−0.000792	0.000735	0.000665	−0.005981*	0.000451	0.002675	−0.000058	−0.000661
	(0.002823)	(0.000559)	(0.003867)	(0.001456)	(0.001069)	(0.000876)	(0.001499)	(0.003142)	(0.001531)	(0.003325)	(0.003579)	(0.001840)
Exchange	0.005813	0.001734	−0.002237	0.001556	0.003166	0.001006	0.001435	−0.010663	0.001675	−0.002157	0.012755	0.032566**
	(0.005793)	(0.001488)	(0.006232)	(0.002583)	(0.003258)	(0.003961)	(0.003200)	(0.009174)	(0.008801)	(0.005438)	(0.008162)	(0.013240)
Libor	0.001865*	0.000252	0.002720***	0.000764**	0.000194	0.000671**	0.000726	0.003379**	0.001001**	0.001273*	0.002540*	0.000822**
	(0.000987)	(0.000159)	(0.000957)	(0.000346)	(0.000408)	(0.000295)	(0.000526)	(0.001649)	(0.000402)	(0.000669)	(0.001411)	(0.000385)
Constant	0.000086	0.000194**	−0.000162	0.000201*	0.000222***	0.000072***	−0.000005	0.000033	0.002564***	0.000064*	−0.000235	0.000110***
	(0.000090)	(0.000089)	(0.000149)	(0.000107)	(0.000061)	(0.000018)	(0.000037)	(0.000054)	(0.000677)	(0.000038)	(0.000148)	(0.000028)

Note: Standard errors in parentheses. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.
The p-values are corrected for Newey and West (1987) standard errors, which are considered to be robust to autocorrelation and heteroskedasticity.

Appendix C2. The effects of the Covid-19 pandemic on market volatility (estimated by EGARCH) over Period 2 (January 2021–January 2022).

	Australia	China	India	Indonesia	Japan	Malaysia	New Zealand	Philippines	Singapore	South Korea	Thailand	Vietnam
Containment	−0.000013	−0.000213***	−0.000204***	−0.000182*	0.000113	−0.000009	−0.000018**	−0.000027	−0.000018	0.000289*	0.000035	0.000120
	(0.000027)	(0.000054)	(0.000068)	(0.000104)	(0.000118)	(0.000013)	(0.000007)	(0.000082)	(0.000059)	(0.000156)	(0.000038)	(0.000143)
EPU	0.000017***	0.000014***	0.000034***	0.000014*	0.000007	0.000008***	0.000013***	0.000022*	0.000003	0.000035***	0.000020**	0.000064*
	(0.000006)	(0.000004)	(0.000009)	(0.000008)	(0.000010)	(0.000002)	(0.000003)	(0.000012)	(0.000004)	(0.000013)	(0.000009)	(0.000034)
Newcase	0.000001	−0.000001	0.000014**	0.000011**	0.000001	0.000000	0.000000	0.000007**	0.000000	0.000001	−0.000000	0.000002
	(0.000002)	(0.000003)	(0.000006)	(0.000005)	(0.000001)	(0.000000)	(0.000001)	(0.000004)	(0.000002)	(0.000001)	(0.000000)	(0.000002)
Oil	0.000196*	0.000008	0.000208	0.000264*	−0.000154	0.000096*	0.000048	−0.000418	0.000098	0.000490*	0.000211	0.000736
	(0.000105)	(0.000080)	(0.000207)	(0.000154)	(0.000225)	(0.000050)	(0.000063)	(0.000417)	(0.000111)	(0.000265)	(0.000147)	(0.000505)
Gold	−0.000255	−0.000049	−0.000126	0.000106	0.000463	0.000010	−0.000171	0.000180	0.000184	0.000054	−0.000348	−0.000385
	(0.000293)	(0.000212)	(0.000519)	(0.000331)	(0.000488)	(0.000131)	(0.000168)	(0.000549)	(0.000212)	(0.000654)	(0.000537)	(0.000937)
Exchange	−0.000213	−0.000040	−0.000746	−0.000107	0.000895	0.000073	−0.000082	−0.003351	0.000647	0.000784	−0.000344	−0.002808
	(0.000460)	(0.000772)	(0.001850)	(0.001092)	(0.001625)	(0.000453)	(0.000234)	(0.002084)	(0.000868)	(0.001285)	(0.000650)	(0.008183)
Libor	0.000079	−0.000098*	0.000049	−0.000095	0.000179	−0.000027	−0.000029	0.000047	0.000035	0.000113	−0.000099	−0.000729*
	(0.000123)	(0.000057)	(0.000123)	(0.000114)	(0.000150)	(0.000028)	(0.000043)	(0.000204)	(0.000069)	(0.000224)	(0.000094)	(0.000395)
Constant	0.000078	0.001123***	0.000857***	0.000846*	−0.000419	0.000087	0.000100***	0.000193	0.000144	−0.001362*	−0.000154	−0.000592
	(0.000132)	(0.000267)	(0.000309)	(0.000456)	(0.000549)	(0.000064)	(0.000035)	(0.000403)	(0.000283)	(0.000753)	(0.000196)	(0.000713)

Note: Standard errors in parentheses. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.
The p-values are corrected for Newey and West (1987) standard errors, which are considered to be robust to autocorrelation and heteroskedasticity.

Appendix D1. The effects of the Covid-19 pandemic on market volatility (estimated by GJR-GARCH) over Period 1 (January 2020–December 2020).

	Australia	China	India	Indonesia	Japan	Malaysia	New Zealand	Philippines	Singapore	South Korea	Thailand	Vietnam
Containment	−0.000231***	−0.000017	0.000044	−0.000094	−0.000108**	−0.000052***	−0.000088**	−0.000050	−0.000943***	−0.000140**	−0.000159***	−0.000036**
	(0.000078)	(0.000032)	(0.000069)	(0.000073)	(0.000043)	(0.000018)	(0.000035)	(0.000039)	(0.000270)	(0.000068)	(0.000058)	(0.000017)
EPU	0.000287***	0.000021**	0.000301***	0.000179***	0.000117***	0.000088***	0.000124**	0.000368***	0.000286***	0.000261**	0.000392***	0.000075***
	(0.000092)	(0.000010)	(0.000107)	(0.000057)	(0.000042)	(0.000030)	(0.000049)	(0.000112)	(0.000073)	(0.000111)	(0.000122)	(0.000026)
Newcase	0.000073**	0.000007	−0.000075**	−0.000022*	0.000002	0.000001	0.000101***	−0.000089***	0.000063***	−0.000007	0.000004	−0.000000
	(0.000035)	(0.000006)	(0.000032)	(0.000013)	(0.000002)	(0.000001)	(0.000038)	(0.000032)	(0.000021)	(0.000006)	(0.000009)	(0.000003)
Oil	0.000133	−0.000121**	−0.000542	−0.000263	−0.000199	−0.000147	−0.000382	−0.000123	−0.000259	−0.000817	−0.000717	−0.000093
	(0.000529)	(0.000060)	(0.001065)	(0.000286)	(0.000208)	(0.000180)	(0.000337)	(0.000580)	(0.000433)	(0.000554)	(0.000580)	(0.000185)
Gold	0.004104	0.000765	0.001935	0.001643	−0.001682	0.000723	0.000657	−0.007634**	0.000469	0.004298	0.000314	−0.000036
	(0.003085)	(0.000585)	(0.003316)	(0.002450)	(0.001619)	(0.001060)	(0.001859)	(0.003831)	(0.002017)	(0.004874)	(0.004381)	(0.000957)
Exchange	−0.003571	0.001555	−0.005747	0.001785	0.003224	0.001861	0.000322	−0.010534	−0.001547	−0.003781	0.019514*	0.009114
	(0.005419)	(0.001533)	(0.019838)	(0.004112)	(0.004122)	(0.004963)	(0.003961)	(0.011847)	(0.012938)	(0.007262)	(0.011136)	(0.014589)
Libor	0.000525	0.000180	0.003413**	0.000961**	0.000513	0.000825**	0.000919	0.004893**	0.001396**	0.001728**	0.003440*	0.000348
	(0.000718)	(0.000150)	(0.001481)	(0.000451)	(0.000574)	(0.000378)	(0.000596)	(0.002430)	(0.000556)	(0.000843)	(0.001797)	(0.000316)
Constant	0.000096	0.000120	−0.000247	0.000181	0.000236***	0.000070***	−0.000016	−0.000049	0.003350***	0.000008	−0.000366*	0.000114***
	(0.000063)	(0.000103)	(0.000210)	(0.000147)	(0.000083)	(0.000026)	(0.000046)	(0.000091)	(0.000976)	(0.000056)	(0.000194)	(0.000021)

Note: Standard errors in parentheses. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.
The p-values are corrected for Newey and West (1987) standard errors, which are considered to be robust to autocorrelation and heteroskedasticity.

Appendix D2. The effects of the Covid-19 pandemic on market volatility (estimated by GJR-GARCH) over Period 2 (January 2021–January 2022).

	Australia	China	India	Indonesia	Japan	Malaysia	New Zealand	Philippines	Singapore	South Korea	Thailand	Vietnam
Containment	−0.000002	−0.000198***	−0.000123*	−0.000162*	0.000122	−0.000021**	−0.000013**	−0.000083	−0.000062	0.000226	0.000018	0.000151*
	(0.000022)	(0.000048)	(0.000066)	(0.000087)	(0.000109)	(0.000011)	(0.000006)	(0.000087)	(0.000063)	(0.000144)	(0.000026)	(0.000090)
EPU	0.000007**	0.000011***	0.000024***	0.000009	0.000008	0.000006***	0.000009***	0.000023*	0.000003	0.000035***	0.000013**	0.000054**
	(0.000003)	(0.000003)	(0.000009)	(0.000006)	(0.000009)	(0.000002)	(0.000002)	(0.000013)	(0.000003)	(0.000013)	(0.000006)	(0.000022)
Newcase	0.000001	−0.000000	0.000006	0.000009*	0.000001	0.000000	0.000000	0.000007**	0.000000	0.000001	0.000000	0.000001
	(0.000001)	(0.000003)	(0.000005)	(0.000005)	(0.000001)	(0.000000)	(0.000001)	(0.000003)	(0.000002)	(0.000001)	(0.000000)	(0.000001)
Oil	0.000073	−0.000021	0.000071	0.000258	−0.000166	0.000064	0.000043	−0.000412	0.000095	0.000437	0.000153	0.000417
	(0.000056)	(0.000066)	(0.000187)	(0.000166)	(0.000197)	(0.000039)	(0.000052)	(0.000422)	(0.000114)	(0.000277)	(0.000111)	(0.000480)
Gold	−0.000042	−0.000036	0.000066	−0.000342	0.000350	0.000046	−0.000119	0.000320	0.000210	−0.000107	−0.000128	−0.001243
	(0.000144)	(0.000187)	(0.000716)	(0.000483)	(0.000422)	(0.000099)	(0.000112)	(0.000566)	(0.000203)	(0.000645)	(0.000372)	(0.000945)
Exchange	−0.000191	−0.000261	−0.000091	−0.001256	0.001099	0.000021	−0.000088	−0.003369	0.000822	0.000805	−0.000154	−0.006225
	(0.000254)	(0.000658)	(0.001795)	(0.000947)	(0.001433)	(0.000330)	(0.000195)	(0.002127)	(0.000898)	(0.001309)	(0.000468)	(0.005288)
Libor	−0.000007	−0.000096**	0.000006	−0.000197**	0.000160	−0.000017	−0.000020	−0.000013	0.000055	0.000093	−0.000045	−0.000206
	(0.000039)	(0.000047)	(0.000119)	(0.000086)	(0.000140)	(0.000022)	(0.000034)	(0.000214)	(0.000069)	(0.000250)	(0.000071)	(0.000235)
Constant	0.000067	0.001049***	0.000587*	0.000786**	−0.000464	0.000151***	0.000085***	0.000468	0.000357	−0.001068	−0.000048	−0.000717
	(0.000101)	(0.000234)	(0.000302)	(0.000383)	(0.000507)	(0.000051)	(0.000026)	(0.000431)	(0.000303)	(0.000701)	(0.000138)	(0.000470)

Note: Standard errors in parentheses. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively.
The p-values are corrected for Newey and West (1987) standard errors, which are considered to be robust to autocorrelation and heteroskedasticity.

Appendix E. Results of the Toda-Yamamoto Granger causality test: the comparison between period 1 (January 2020–December 2020) and period 2 (January 2021–January 2022).

	ARMA-GARCH				EGARCH				GJR-GARCH			
	Containment		Newcase		Containment		Newcase		Containment		Newcase	
	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
Australia	2.53	5.90	64.16***	15.12	4.06	7.35	41.08***	24.21**	2.96	7.52	70.39***	12.54
China	1.40	5.48	5.60	0.63	1.54	5.83	6.71*	0.03	1.51	5.40	5.16	0.83
India	159.68***	2.32	787.96***	4.65	149.47***	3.23	524.63***	6.75	156.48***	2.71	781.57***	4.73
Indonesia	7.67	2.15	139.80***	2.12	7.53	4.10	89.18***	2.31	7.67	2.15	139.94***	2.12
Japan	85.65***	22.33**	59.79***	11.89	96.77***	22.00**	63.57***	15.46	100.42***	21.03**	66.24***	14.80
Malaysia	2.49	2.60	6.02	3.27	1.25	4.59	8.53	7.49	1.29	2.52	7.13	4.85
New Zealand	8.40	1.88	20.74***	1.02	7.78	4.86	19.04**	0.92	9.48	2.07	19.12**	0.81
Philippines	1.30	4.74	69.19***	6.63*	0.98	3.41	54.27***	2.27	1.46	3.967	64.61***	2.83
Singapore	16.19	36.15***	69.25***	30.36***	26.92*	34.71***	69.26***	51.03***	19.64	40.18***	68.69***	54.65***
South Korea	48.32***	3.83	90.19***	1.59	38.32***	4.70	106.84***	8.66	39.37***	5.67	113.04***	14.34**
Thailand	946.15***	30.77***	16.27	5.91	736.96***	23.80***	17.24	16.19*	1018.21***	19.92**	19.63	14.66
Vietnam	7.79	3.77	18.98*	6.47	5.79	2.28	7.57	0.93	6.55	3.84	22.29**	4.87

Note: The numbers in the table are the values of Chi-square. Superscript *, ** and *** denote the significance level of 10 per cent, 5 per cent and 1 per cent, respectively. Period 1 ranges from January 2020 to December 2020. Period 2 ranges from January 2021 to January 2022.

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