The East-Asian Stock Markets During the COVID-19 Pandemic

Los mercados bursátiles de Asia oriental durante la pandemia de COVID-19

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Abstract. We study the dynamics and volatilities of six East Asian stock market indices during the COVID-19 pandemic with five types of ARCH/GARCH models. The main results are: 1) Most of the volatilities of the series of returns show leverage effects; 2) the FIGARCH(1,1,1) model is the best one to describe the series of returns associated to the Shenzen and Shangai-Composite indices; 3) the GJR-GARCH(1,1,1) model is the best one to describe the series associated to the Hang-Seng, KOSPI and Nikkei-225 indices; and, 4) the APARCH(1,1,1,1) model is the best one to describe the series associated to the Taiwan-Weighted index. We develop the study with daily indices for the period between January 2nd, 2020 and December 16th, 2021.

Keywords: Stock Markets; East Asia; COVID-19; ARCH/GARCH Models

Resumen. Estudiamos las dinámicas y volatilidades de seis índices bursátiles de Asía Oriental durante la pandemia de COVID-19 con cinco tipos de modelos ARCH/GARCH. Los principales resultados son: 1) La mayoría de las volatilidades de las series de rendimientos muestran efectos apalancamiento; 2) el modelo FIGARCH(1,1,1) es el mejor para describir las series de rendimientos asociadas a los índices Shenzen y Shangai-Composite; 3) el modelo GJR-GARCH(1,1,1) es el mejor para describir las series asociadas a los índices

Hang-Seng, KOSPI y Nikkei-225; y, 4) el modelo APARCH(1,1,1) es el mejor para describir la serie asociada al índice Taiwan-Weighted. Desarrollamos el estudio con índices diarios para el periodo comprendido entre el 2 de enero de 2020 y el 16 de diciembre de 2021.

Palabras Clave: Mercados Bursátiles; Asia Oriental; COVID-19; Modelos ARCH/GARCH

JEL: G15, G17

Introduction

The COVID-19 pandemic has been the most important cause of economic and financial disruption in the 21st century. The IMF has estimated the costs of this health crisis in no less than 12.5 trillion dollars (Shalal, 2022). Particularly, Li (2021) has pointed out that the pandemic has had an impact on the financial markets broader and deeper than the Great Depression (1929) and the Global Financial Crisis (2008). This impact has triggered extreme risk aversion, liquidity squeezes and massive sells of many financial assets worldwide (Bouhali, Dahbani and Dinar, 2021).

The impact of the COVID-19 pandemic has been notorious on the dynamics and volatilities of the series of stock market returns. These dynamics and volatilities are important because it is believed that the stock markets can signal futures changes in the economies (Pearce, 1983). This hypothesis is supported on the belief that stock prices reflect expectations about firms´ profitability, and that aggregate profitability is directly linked to economic activity. Thus, under this hypothesis, stock prices and stock market indices are considered as leading indicators of the direction of the economy.

Empirically, the COVID-19 pandemic has shown the existence of significant relationships between the performance of stock markets and the population health. This affirmation may seem obvious. However, the scarce pre-pandemic literature used to arrive to the opposite conclusion (Jonung and Roeger, 2006; Ullah, 2022). This consideration explains why the financial and economic impacts of the pandemic were completely unexpected and underestimated by policy makers, investors and analysts. Furthermore, it also explains why the studies on these relationships have flourished since 2020.

Here, we study the dynamics and volatilities of six series of returns representative of the East Asian stock markets during the COVID-19 pandemic.

We study the markets of China, Hong Kong, Japan, South Korea and Taiwan. We describe and analyze the series of stock market returns using statistical and modeling analyses. The analyses use descriptive statistics, pairwise correlations, five types of univariate ARCH/GARCH models, three goodness-of-fit estimators and several statistical tests. We use daily indices for the period between January 2nd, 2020 and December 16th, 2021.

The study relies on methodological and interpretative guidelines for analytical purposes. The methodological guidelines are the following: 1) ARCH/GARCH models are adequate to describe and analyze the series of stock market returns of the East Asian economies; 2) the best models to describe the series of returns may not be the same ones for all the markets analyzed; 3) the model that best fits a series can be determined with goodness-of-fit estimations; and, 4) lagged innovations, denominated as "informational shocks", can have different impacts on the current and future volatility of the stock markets.

The analytical framework of this study relies on certain interpretative guidelines. These guidelines are the following: 1) Stock market data are leading indicators of the direction of the economy; 2) there is a relationship between the performance of stock markets and the population health; 3) leverage effects reflect the existence of high levels of risk aversion in the stock markets; and, 4) the existence of statistical "long memory" in the series implies that the impact of informational shocks on the volatility of the series may be persistent in time.

Analytically, this study complements the studies by Yong, Ziaei and Szulczyk (2021), Zehri (2021) and Zhang, et.al. (2022). Its specific contributions focus on: 1) the study of the dynamics and volatilities of the series of East Asian returns during the COVID-19 pandemic; 2) the selection of the ARCH/GARCH model that best fits the series of returns using three goodness-of-fit estimations; 3) the analysis of the effects of informational shocks and their persistence on the volatility of the series; and, 4) the implications of such effects and persistence on the direction of the East Asian economies.

This study on the dynamics and volatilities of the series returns associated to the East Asian stock markets is organized into four sections. Particularly, Section 1 reviews the literature that use ARCH/GARCH models that have studied the Asian stock markets during the COVID-19 pandemic. Section 2 describes the series analyzed and explains the methodological issues that define the investigation. Sections 3 and 4 include the statistical and modeling analyses. The study concludes summarizing the main findings and discussing their implications for the expected growth of the East Asian economies.

Literature Review

ARCH/GARCH models are the most popular time-series models to analyze, describe and forecast the dynamics and the volatilities of financial series. ARCH/GARCH models are named this way because they assume that the series follow autoregressive processes with conditional heteroskedasticity. ARCH/GARCH models allow describing series with behaviors characterized, among others, by non-linearities, excessive volatilities, leverage effects, volatility clusters, non-constant volatilities and non-normal distributions. ARCH/GARCH models can describe such behaviors under certain assumptions.

ARCH/GARCH models are based on specific statistical assumptions regarding the dynamics and the volatility of the series. These assumptions refer to the number of series analyzed, the conditional mean, the conditional variance, the impact of informational shocks and the density distribution of the disturbances. Particularly, conditional variance assumptions are the most important ones because the "true" volatility, σ^2_{it}, is not observable. In fact, the assumptions regarding the specification of the conditional variance define the types of existing ARCH/GARCH models.

In the literature, ARCH/GARCH models have been used to describe and analyze the Asian stock markets during the COVID-19 pandemic. The studies that integrate this literature can be classified into two groups. The first group includes studies that analyze the Asian stock markets from a global perspective. These studies usually compare the dynamics and volatilities of several stock market returns. The second group includes studies that analyze particular issues regarding some Asian stock markets. Table 1 includes a list of such ARCH/GARCH studies and summarizes their main features.

Table 1. ARCH/GARCH studies used to describe and analyze the Asian stock markets during the COVID-19 pandemic

Group/Study	Purpose	ARCH/GARCH Models Used	Modeling Assumptions
Studies that describe the Asian markets from a global perspective			
Kusumahadi and Permana (2021)	Analyze the impact of Covid-19 on the volatilities of fifteen stock markets around the world	TGARCH model	Univariate model with Leverage Effects
Szczygielski, et. al. (2021)	Analyze the impact of Covid-19 uncertainty on the aggregate stock indices of Arabia, Asia, Latin-America, Africa, Europe and North-America	ARCH, GARCH and IGARCH models	Univariate models with Symmetric Effects
Chopra and Mehta (2022)	Analyze the behavior of the Asian stock markets during the Covid-19 pandemic with the respect the behaviors observed during the Asian Crisis, the US Subprime Crisis and the Eurozone Debt Crisis.	DCC-GARCH model	Multivariate model with Symmetric Effects
Studies that analyse particular issues regarding some Asian markets			
Yong, Ziaei and Szulczyk (2021)	Analyze the impact of Covid-19 in the stock markets of Malaysia and Singapore	TGARCH model	Univariate model with Leverage Effects
Zehri (2021)	Analyze the extreme risk spillovers from the US stock market to the Asian stock markets of China, Japan, Hong Kong and South Korea	GARCH-Copula CoVaR model	Multivariate model with Symmetric Effects
Zhang, et. al. (2022)	Analyze the contagion effects of jump risk across the Asian markets of China, Hong Kong, Japan, South Korea, Singapore, Thailand and Taiwan	TGARCH model	Univariate model with Leverage Effects

Source: Authors´ own elaboration.

Table 1 shows that the studies have similarities modeling the stock market series. Most of them assume the univariate modeling approach and the TGARCH specification of the conditional variance. The first assumption implies that the dynamics and the volatility of each series are relatively independent of the other series. The second assumption implies that the series of returns experiment leverage effects and that they do not have a long memory. Thus, negative informational shocks have a larger effect on volatility than positive ones and the impacts of these shocks are not time persistent.

We should point out that the studies above may be questionable under methodological grounds. Usually, the selection criteria for ARCH/GARCH models relies on goodness-of-fit estimations. Franco and Zakoian (2019), among others, recommend estimating several types of models for the same time-series and comparing their goodness-of-fit estimations to choose the one that best fits the data. However, with the exception of the study of Szczygielski, et. al. (2021), none of the studies that describe and analyze the Asian markets follow such recommendation. The studies simply postulate that the models considered are adequate.

In this context, we should recognize that there is no consensus regarding which may be the best goodness-of-fit criterion for selecting a regression model. The criteria for selecting models impose different tradeoffs between the goodness-of-fit and the complexity of the assessed models (Gujarati, Porter and Pal, 2021). Furthermore, the estimators do not always agree on which may be the model with the best goodness-of-fit. Thus, there is not always a straightforward decision regarding the most adequate model to fit a time series.

Here we follow the methodological recommendations of Franco and Zakoian (2019) to study the dynamics and volatilities of six East Asian stock market indices during the COVID-19 pandemic. Particularly, for each stock market series, we estimate five types of univariate ARCH/GARCH models for each series of returns. We also estimate three different goodness-of-fit estimators for each model. Then, based on the goodness-of-fit estimations and a majority rule, we select the model that best fits each series. Subsequently, we proceed with the description and the analysis of the series of returns.

We conclude this literature review emphasizing the need to improve our understanding of the dynamics and volatilities of the series of returns of the East Asian indices during the COVID-19 pandemic. Particularly, we believe that such understanding may provide insights regarding the medium-run direction of the Asian and the global economies. In this context, we should recall that China, Hong Kong, Japan, South Korea and Taiwan contribute approximately with 27 percent of global GDP. Thus, their importance for global economic development is not negligible. Indeed, these considerations motivate this study.

Methodological Issues

In this section, we focus on the methodological issues regarding the investigation of the dynamics and volatilities of the East Asian stock markets during the COVID-19 pandemic. Particularly, we indicate the stock market data, the statistics, the tests, the ARCH/GARCH models and the goodness-of-fit estimators. We also focus on the assumptions that characterize the models used to describe the series of stock market returns. Furthermore, we describe how we select the models that best fits the set of series of returns. The study of the features of the series relies on the estimations associated to such models.

The study relies on six series of stock market indices. These indices are the Shangai Composite (SSEC), the Shenzen Component (SZSE), the Hang Seng (HIS), the Nikkei 225 (N225), the KOSPI (KS11), and the Taiwan Weighted (TWII). These indices are considered as representative of the stock markets of China (SSEC, SZSE), Hong Kong (HIS), Japan (N225), South Korea (KS11) and Taiwan (TWII). Particularly, given that the first alert regarding the COVID-19 was spread in December 30, 2019; we use daily closing prices of the indices for the period between January 2nd, 2020 and December 16th, 2021.

Here, we follow the traditional accounting convention to express the returns of the East Asian stock markets in terms of daily growth rates. Thus, if we express the price index i on day t as P_{it}, we express the daily return of the index i on day t as $r_{it} = \left(\frac{P_{it} - P_{it-1}}{P_{it-1}} \right) * 100$. Thus, the sample of stock market data includes six series of price indices and six series of stock market returns. The series of price indices includes 485 daily observations, while the series of returns include 484 observations. Particularly, this investigation relies on the series of returns due to statistical convenience.

Methodologically, the study relies on descriptive statistics, pairwise correlations, ARCH/GARCH models, statistical tests and goodness-of-fit estimators. We use the descriptive statistics to describe the series of stock market returns. We use the pairwise correlations to assess the relationships between the series. We use the ARCH/GARCH models to describe the dynamics, volatilities and properties of the series of returns during the COVID-19 pandemic. Specifically, we estimate five univariate models of the APARCH, EGARCH, FIGARCH, GJR-GARCH and TGARCH types (see Appendix).

ARCH/GARCH models depend on the assumptions regarding the conditional mean and variance and the distribution of the standardized residuals. Here, the models assume a constant mean and a normal density distribution. They differ only on the specification of the conditional variance. Particularly, the models that assume the APARCH, EGARCH, GJR-GARCH and TGARCH specifications, postulate that the volatility of a series exhibit leverage effects. The models that assume the FIGARCH specification, by contrast, postulate that the volatility exhibits symmetric effects.

We support the econometric analysis with several statistical tests and goodness-of-fit assessments. Specifically, we use Jarque-Bera normality tests, Phillips-Perron unit-root tests, ARCH-LM tests and significance tests. For simplicity, we assess the null hypotheses with the p-values associated to the test statistics. The goodness-of-fit assessments rely on estimates of the Logarithm of Likelihood, the Akaike Information Criterion and the Bayesian Information Criterion. The estimates are used to assess the models that best describe the dynamics and volatilities of the series of returns.

Finally, we describe and analyze the series of stock market returns based on the features that characterize the models with best goodness-of-fit. We select the ARCH/GARCH model that best fits each series of returns using the goodness-of-fit estimations and a majority rule. Subsequently, we study the series of returns considering the features that characterize the models selected. Particularly, we focus on the effects that the volatility of the series exhibits due to informational shocks; but also, on the persistence of informational shocks on the volatility of the series.

Statistical Analysis

This section includes the statistical analysis of the series of returns for the East Asian stock market indices during the COVID-19 pandemic. The analyzed series and the estimation results are shown graphically and summarized in tables for simplicity. Particularly, Figure 1 shows the six series of stock market returns. Table 2 shows the descriptive statistics and the Jarque-Bera normality tests for the series. Table 3 shows the pairwise correlations of the series of returns and their associated significance tests. Finally, Table 4 shows the Philips-Perron unit-root tests for the series.

Figure 1 suggests that the series of East Asian returns may be described and analyzed with ARCH/GARCH models. Specifically, the figure shows that the series is characterized by non-linearities, excessive volatilities, volatility clusters and non-constant volatilities. Furthermore, the figure shows that the series of returns do not necessarily have common dynamics nor volatilities. Thus, the figure suggests that the dynamics of the East Asian stock markets were relatively independent of each other during the COVID-19 pandemic. Moreover, the figure implies that it was possible to diversify risks with assets of the region.

Figure 1. Series of returns of the East Asian stock market indices

Notes: The series express the daily returns of the stock market indices for the period between January 3rd, 2020 and December 16th, 2021.
Source: Authors´ estimations with stock market indices obtained from the Yahoo Finance database.

Table 2. Descriptive statistics and Jarque-Bera tests associated to the series of returns

Country	Index	Mean	Std. Deviation	Var. Coefficient	Skewness	Kurtosis	Jarque-Bera	P-value
China	SSEC	0.0391	1.1143	28.4622	-0.7225	6.6821	920.5532	0.0000
China	SZSE	0.0790	1.4797	18.7201	-0.7972	3.0652	235.0303	0.0000
Hong Kong	HSI	-0.0308	1.3773	-44.7231	-0.3232	1.5574	56.5866	0.0000
Japan	N225	0.0565	1.4208	25.1384	0.2253	4.3307	373.9918	0.0000
South Korea	KS11	0.0763	1.4662	19.2134	0.0024	6.7910	928.7484	0.0000
Taiwan	TWII	0.0899	1.2182	13.5504	-0.4160	4.9341	495.4627	0.0000

Notes: The series express the daily returns of the stock market indices for the period between January 3rd, 2020 and December 16th, 2021.
Source: Authors´ estimations.

Table 2 confirms some of the previous findings. Particularly, it shows that the TWII index had the highest return levels and the lowest volatile returns; while the opposite occurred with the HSI index. The table also shows that most of the series are left-skewed and leptokurtic. Furthermore, the table shows that none of the series are normally distributed. Thus, the findings confirm that the dynamics of the stock markets were different during the analyzed period. Particularly, they suggest that the stock market of Hong Kong was the most harmed during the pandemic; while the opposite occurred with market of Taiwan.

Table 3. Pairwise correlations of the series of returns and associated significance tests

Index	SSEC	SZSE	HSI	N225	KS11	TWII
SSEC	**1.0000**					
SZSE	**0.9100** ***	**1.0000**				
	0.0000					
HSI	**0.0880** **	**0.0280**	**1.0000**			
	0.0112	*0.5987*				
N225	**0.0350** *	**0.0650** **	**-0.1000** ***	**1.0000**		
	0.0598	*0.0196*	*0.0074*			
KS11	**0.0340** *	**0.0330**	**0.4400** ***	**-0.1800** ***	**1.0000**	
	0.0627	*0.3869*	*0.0000*	*0.0027*		
TWII	**0.0130**	**0.0270**	**-0.027**	**0.2000** ***	**-0.0180**	**1.0000**
	0.4359	*0.9235*	*0.1627*	*0.0000*	*0.1506*	

Notes: The series express the daily returns of the stock market indices. Pairwise correlations are denoted in bold. P-values associated to the significance tests are denoted in italics. One, two and three asterisks indicate significance levels of 10, 5 and 1 percent, respectively.
Source: Authors´ estimations.

Table 3 shows that most of the correlations are low (less than 0.80) and that some of them are not significant. However, it also shows that the series of returns of the Chinese markets, SSEC and SZSE, have a high, positive and significant correlation. The table also shows that the series of returns of the N225 index is the only one that has significant correlations with the other series. Thus, the table confirms that the East Asian stock markets, with the exception of the ones of China and Japan, did not have common dynamics or common volatilities during the COVID-19 pandemic.

Table 4 shows that all the series of stock market returns are stationary, i.e. they do not have unit-roots. This finding is important to justify the convenience of using ARCH/GARCH models to describe and analyze the series. When the series are stationary, their statistical properties do not change over time. Moreover, they allow us to avoid the estimation of spurious regressions. However, we should point out that stationarity is not a sufficient condition to use the ARCH/GARCH models. All the series of returns must have conditional heteroscedasticity in the residuals.

Table 4. Phillips-Perron tests for the series of returns

	PP Statistic		Lags	Order of Integration
SSEC	-21.683	***	18	0
SZSE	-21.563	***	18	0
HSI	-23.835	***	18	0
N225	-21.250	***	18	0
KS11	-22.940	***	18	0
TWII	-21.738	***	18	0

Notes: The series express the daily returns of the stock market indices. The null hypothesis of the Phillips-Perron (PP) test is that there is a unit root. The PP test estimations include a linear trend and a constant as external regressors. The number of lags is estimated with basis on the Bayesian Information Criterion (BIC). One, two and three asterisks denote significance levels of 10, 5 and 1 percent, respectively.
Source: Authors´ estimations.

The main findings suggest that the dynamics of the East Asian stock markets were relatively independent of each other during the pandemic. Specifically, they suggest that: 1) The series of returns exhibited non-linearities, excessive volatilities, volatility clusters, non-constant volatilities and non-normal distributions; 2) the stock market of Hong Kong was the most harmed during the pandemic; while the opposite occurred with the market of Taiwan; and, 3) the markets analyzed, with the exceptions of the ones dealing with China and Japan, did not have common dynamics or common volatilities during the COVID-19 pandemic.

Modeling Analysis

This section includes the modeling analysis of the series of returns for the East Asian stock market indices. Like in the previous section, the estimation results are summarized in tables. Particularly, Table 5 shows the ARCH-LM tests of the series of returns. Table 6 shows the estimations of goodness-of-fit criteria of all the models used to describe the series of returns. Table 7 specifies the ARCH/GARCH models with best goodness-of-fit criteria for the series of returns. Tables 8, 9 and 10, show, respectively, the estimations of the FIGARCH, GJR-GARCH and the APARCH models used to describe and analyze the series of returns.

Table 5. ARCH-LM tests for the series of returns

	LM Statistic	**P-value**
SSEC	26,995.07	0.0000
SZSE	31,237.98	0.0000
HSI	13,240.87	0.0000
N225	48,662.65	0.0000
KS11	81,729.23	0.0000
TWII	110,886.80	0.0000

Notes: The series express the daily returns of the stock market indices. The null hypothesis of the ARCH LM test is that the series exhibit no ARCH effects. The decision criterion rejects the null hypothesis under a significance level of five percent.
Source: Authors´ estimations.

Tables 5 and 6 confirm that the series of returns can be described and analyzed with models of the ARCH/GARCH family. Specifically, Table 5 shows that all the ARCH-LM tests reject the null hypothesis that there is no conditional heteroscedasticity in the residuals; i.e., they confirm the existence of ARCH effects. Table 6 shows that, with the exception of the Chinese series, SSCE and SZSE, there are no straightforward conclusions regarding the models that may have the best goodness-of-fit. The absence of straightforward conclusions justifies the use of the majority rule for choosing the models with the best goodness-of-fit.

Table 6. Goodness-of-fit criteria of the ARCH/GARCH models used to describe the series of returns

	APARCH(1,1,1,1)	EGARCH(1,1,1)	FIGARCH(1,1,1)	GJR-GARCH(1,1,1)	TGARCH(1,1,1)	Model With Best Goodness-of-Fit
			Log Likelihood Criterion			
SSEC	-702.75	-703.27	-698.65	-702.79	-703.08	FIGARCH
SZSE	-847.62	-847.70	-846.99	-847.81	-847.69	FIGARCH
HSI	-827.78	-829.03	-828.61	-828.10	-828.66	APARCH
N225	-794.58	-798.91	-802.52	-795.02	-796.57	APARCH
KS11	-773.67	-776.56	-777.89	-773.70	-776.41	APARCH
TWII	-716.56	-719.02	-729.31	-723.45	-718.76	APARCH
			Akaike Information Criterion			
SSEC	1417.50	1416.53	1407.31	1415.58	1416.16	FIGARCH
SZSE	1707.23	1705.41	1703.97	1705.61	1705.37	FIGARCH
HSI	1667.56	1668.06	1667.21	1666.20	1667.31	GJR-GARCH
N225	1601.16	1607.81	1615.05	1600.05	1603.14	GJR-GARCH
KS11	1559.35	1563.13	1565.77	1557.39	1562.82	GJR-GARCH
TWII	1445.11	1448.04	1468.63	1456.90	1447.53	APARCH
			Bayesian Information Criterion			
SSEC	1442.59	1437.44	1428.22	1436.49	1437.07	FIGARCH
SZSE	1732.33	1726.32	1724.88	1726.52	1726.28	FIGARCH
HSI	1692.76	1689.06	1688.21	1687.20	1688.32	GJR-GARCH
N225	1626.28	1628.74	1635.98	1620.98	1624.07	GJR-GARCH
KS11	1584.58	1584.15	1586.79	1578.42	1583.84	GJR-GARCH
TWII	1470.24	1468.98	1489.57	1477.84	1468.47	GJR-GARCH

Notes: The table shows the three groups of goodness-of-fit estimations associated to the models that describe the series of returns. For simplicity, each row shows the set of estimations associated to a particular group and series. The set of estimations includes the goodness-of-fit estimations for the five models assessed. The last column indicates the model with the best goodness-of-fit for a series accordingly to a specific criterion.
Source: Authors´ estimations using the ARCH Toolbox developed for Python.

Table 7 shows the ARCH/GARCH models with best goodness-of-fit for the series of returns of the East Asian stock markets according to the majority rule. Thus, and under this rule, the FIGARCH (1,1,1) model is the one that best describes the series of returns of the Chinese indices, i.e., the SSEC and SZSE indices. The GJR-GARCH (1,1,1) model is the one that best describes the returns of the indices of Hong Kong, Japan and South Korea; respectively, the HIS, N225 and KS11 indices. The APARCH (1,1,1,1) model is the one that best describes the returns of the index of Taiwan; i.e., the TWII index.

Table 7. ARCH/GARCH models with best goodness-of-fit for the series of returns

	SSEC	SZSE	HSI	N225	KS11	TWII
Models With Best Goodness-of-Fit Accordingly to the Majority Rule						
Model	FIGARCH(1,1,1)	FIGARCH(1,1,1)	GJR-GARCH(1,1,1)	GJR-GARCH(1,1,1)	GJR-GARCH(1,1,1)	APARCH(1,1,1,1)

Notes: The ARCH/GARCH model reported for each series is the one that has the best goodness-of-fit accordingly to two or three model-selection criteria (see Table 6).
Source: Authors´ estimations.

Table 8 shows the estimations of the FIGARCH (1,1,1) model. These estimations are the best ones to describe and analyze the series of returns of the Chinese indices (SSEC and SZSE). Statistically, the estimation results suggest that the volatility of the series of returns exhibit symmetric effects and that the Chinese series have a long memory. The first feature implies that informational shocks of the same magnitude, positive or negative, had identical effects on the volatility of the returns. The second feature implies that the impacts of the informational shocks on the volatility were time persistent.

Table 8. Estimations for the FIGARCH (1,1,1) model for the series of returns

Parameter		SSEC	SZSE	HSI	N225	KS11	TWII
ω	Coef.	0.0569	0.0004	0.1633	0.1863	0.0701	0.0038
	P-value	0.4080	0.9950	0.0821	0.2520	0.6210	0.9510
ϕ_1	Coef.	0.2532	0.3333	0.0000	0.3451	0.0000	0.0000
	P-value	0.3740	0.4180	1.0000	0.361	1.0000	1.0000
δ_1	Coef.	0.2234	0.3334	0.3073	0.2015	0.4406	0.3651
	P-value	0.0068	0.0816	0.0015	0.0895	0.0048	0.0471
β_1	Coef.	0.2261	0.5273	0.2358	0.2920	0.0906	0.2824
	P-value	0.3750	0.2920	0.1950	0.4090	0.9120	0.1540

Notes: The ARCH/GARCH models assume a constant mean and a normal distribution. P-values are estimated based on a t-Student distribution. Table 7 shows that the FIGARCH model is the best one to describe and analyze the series of returns associated to the SSEC and SZSE indices.
Source: Authors´ estimations using the ARCH Toolbox developed for Python.

Table 9 shows the estimations of the GJR-GARCH (1,1,1) model. These estimations are the best ones to describe and analyze the series of returns of the indices of Hong Kong (HIS), Japan (N225) and South Korea (KS11). Particularly, the estimation results suggest that the series exhibit leverage effects and that the series do not have a long memory. The first feature implies that the volatilities of the markets of Hong Kong, Japan and South Korea were relatively more sensitive to "bad" news than to "good" news. The second feature implies that the impacts of the informational shocks on the volatility were not time persistent.

Table 9. Estimations for the GJR-GARCH (1,1,1) model for the series of returns

Parameter		SSEC	SZSE	HSI	N225	KS11	TWII
ω	Coef.	0.1705	0.1613	0.1112	0.1528	0.1743	0.2270
	P-value	0.2020	0.2670	0.4380	0.0705	0.0074	0.2460
α_1	Coef.	0.1319	0.0903	0.0127	0.0274	0.1156	0.0000
	P-value	0.156	0.0228	0.7100	0.5490	0.0410	1.0000
γ_1	Coef.	0.1840	0.1313	0.1083	0.2204	0.3177	0.2509
	P-value	0.4000	0.4790	0.1160	0.0051	0.0095	0.1330
β_1	Coef.	0.6525	0.7757	0.8686	0.7797	0.6321	0.6863
	P-value	0.0008	0.0000	0.0000	0.0000	0.0000	0.0004

Notes: The ARCH/GARCH models assume a constant mean and a normal distribution. P-values are estimated accordingly to a t-Student distribution. Table 7 shows that the GJR-GARCH model is the best one to describe and analyze the series of returns associated to the HSI, N225 and KS11 indices.
Source: Authors´ estimations using the ARCH Toolbox developed for Python.

Table 10 shows the estimations of the APARCH (1,1,1,1) model. These estimations are the best ones to describe and analyze the series of returns of the Taiwan index (TWII). Particularly, the estimations suggest that the series exhibit leverage effects and that the series may not necessarily have a long memory. Thus, the estimation results suggest that the volatility of the market Taiwan was more sensitive to "bad" news than to "good" news. However, they also suggest that impacts of informational shocks on the volatility of the series were unlikely to be time persistent.

Table 10. Estimations for the APARCH (1,1,1,1) model for the series of returns

Parameter		SSEC	SZSE	HSI	N225	KS11	TWII
ω	Coef.	0.1685	0.1354	0.1025	0.3629	0.1745	0.0703
	P-value	0.1920	0.3180	0.0442	0.8160	0.0088	0.1100
α_1	Coef.	0.2201	0.1639	0.0057	0.0818	0.2491	0.0903
	P-value	0.0664	0.0521	0.5440	0.695	0.0001	0.0092
γ_1	Coef.	0.2307	0.2463	0.9997	0.2703	0.3197	0.9078
	P-value	0.3110	0.2560	0.7630	0.6060	0.0102	0.0000
β_1	Coef.	0.6591	0.7853	0.8889	0.6113	0.6317	0.8732
	P-value	0.0004	0.0000	0.0000	0.5630	0.0000	0.0000
δ_1	Coef.	1.8226	1.5896	3.4410	4.0000	2.0037	0.6239
	P-value	0.0969	0.0578	0.5410	0.7200	0.0001	0.0012

Notes: The ARCH/GARCH models assume a constant mean and a normal distribution. P-values are estimated based on a t-Student distribution. Table 7 shows that the APARCH model is the best one to describe and analyze the series of returns associated to TWII index.
Source: Authors´ estimations using the ARCH Toolbox developed for Python.

Tables 8,9 and 10 show that the volatility processes have significant differences. Specifically, they show that: 1) the Chinese series of returns exhibit symmetric effects and that the series have a long memory; 2) the series of returns of Hong Kong, Japan and South Korea exhibit leverage effects and that the series do not have a long memory; and, 3) the series of returns of Taiwan exhibit leverage effects and that the series may not necessarily have a long memory. Thus, the main differences in the volatilities refer to the effects and the persistence of the informational shocks on the volatility of the series.

The findings of the modeling analysis show that the volatilities of the East Asian markets were different during the pandemic. The differences refer to the effects and the persistence of the informational shocks on the volatility of the series. In this context, the analysis shows that the best models to describe the series of returns are: 1) The FIGARCH (1,1,1) for the series associated to the Chinese indices; 2) the GJR-GARCH (1,1,1) for the series associated to the indices of Hong Kong, Japan and South Korea; and, 3) the APARCH (1,1,1,1) for the series associated to the index of Taiwan.

Conclusions and Discussion

We have studied the dynamics and volatilities of six series of returns representative of the East Asian stock markets during the COVID-19 pandemic. We have studied the markets of China, Hong Kong, Japan, South Korea and Taiwan. We have described and analyzed the series of stock market returns using statistical and modeling analyses. The analyses have used descriptive statistics, pairwise correlations, five types of univariate ARCH/GARCH models, three goodness-of-fit estimators and several statistical tests. We have used daily indices for the period between January 2nd, 2020 and December 16th, 2021.

The findings of the statistical analysis suggest that the dynamics of the stock markets were relatively independent of each other during the pandemic. Specifically, they suggest that: 1) The series of returns exhibited non-linearities, excessive volatilities, volatility clusters, non-constant volatilities and non-normal distributions; 2) the stock market of Hong Kong was the most harmed during the pandemic; while the opposite occurred with the market of Taiwan; and, 3) the markets analyzed, with the exceptions of the ones related to China and Japan, did not have common dynamics or common volatilities during the COVID-19 pandemic.

The findings of the modeling analysis confirm that the volatility processes of the series of returns were different. The differences refer to the effects and the duration of the impacts of shocks on the volatility of the series. In this context, the analysis shows that the best models to describe the series during the pandemic were: 1) The FIGARCH (1,1,1) for the series associated to the Chinese indices; 2) the GJR-GARCH (1,1,1) for the series associated to the indices of Hong Kong, Japan and South Korea; and, 3) the APARCH (1,1,1,1) for the series associated to the index of Taiwan.

These findings have implications for understanding the direction of Asian and global economies. Specifically, the analyses of the series of returns suggest that the expectations for economic recovery are different for each East Asian economy. Particularly, they suggest that Taiwan has the best expectations and that Hong Kong has the worst. Furthermore, the evidence of leverage effects and non-long run memories, suggest that Japan, Hong Kong, South Korea and Taiwan will remain relatively vulnerable to "bad" news. However, the results also suggest that the impact of such shocks would not be persistent.

The expectations of performance of the Chinese economy are fundamental for global economy. In this context, the results of the modelling analysis provide some insights regarding such performance. Specifically, the evidence of symmetric effects and long run memories in both markets, suggest that the economy will remain relatively stable against informational shocks. However, the results also suggest that the impact of shocks will be persistent along time. Thus, it would be reasonable to expect the negative economic effects of the pandemic to be long-lasting.

How good are the expectations for the Chinese economy? Here, we should point out that the results of the statistical analysis provide mixed evidence. According to the SZSE index, the expectations of China are only below the ones regarding Taiwan. However, according to the SSEC index, the expectations of China are only above the ones dealing with Hong Kong. In this context, we should point out that the SZSE index is dominated by stocks of state-controlled firms; while the SSEC includes diverse stocks. Thus, it could be that the expectations for China based on the SSEC index may be the most realistic ones.

We should emphasize that the East Asian stock markets had different dynamics and volatilities during the pandemic. This finding has implications for economic growth. According to our results, with the exception of Hong Kong, the East Asian economies have positive expectations. Moreover, they suggest that Taiwan and South Korea will have the best performances of the region. However, they also suggest that China will grow by relatively modest levels. Thus, it is likely that the long-term effects of the pandemic may include increases of inequality among and within the East Asian economies.

Finally, we should point out that this study suggests some ideas to develop further research. Specifically, further studies should include data series related to COVID-19 (cases, deaths, vaccinations, etc.). Intuitively, given the relevance of informational shocks, these studies may be useful to explain the dynamics and volatilities of the series of returns. More importantly, they may be useful for improving public policy, investment and risk management decisions. In this context, we hope to encourage the development of further studies on the relationships between the performance of the stock markets and the population health of Asia.

Appendix

Here, we show the variance specifications of the ARCH/GARCH models estimated. For estimation purposes, all the models assume that the error terms follow a normal distribution

Table A1. ARCH/GARCH models used in the study.

Model	Specification of the Conditional Variance	Reference	Modeling assumptions
APARCH (Asymmetric Power ARCH)	$\sigma_t^{\delta}=\omega+\sum_{i=1}^{p}\alpha_i(\square\square_{t-1}\square-\gamma_i I_{[0>i]}\square_{t-i})^{\delta}+\sum_{j=1}^{q}\beta_j\sigma_{t-j}^{\delta}$	Ding, Granger and Engle (1993)	Univariate model with Leverage Effects
EGARCH (Exponential GARCH)	$ln\sigma_t^2=\omega_0+\sum_{i=1}^{p}\alpha_i(\square\square_{t-i}\square+\gamma_i\square_{t\text{-}i})+\sum_{j=1}^{q}\beta_j\ln\sigma_{t-j}^2$	Nelson (1991)	Univariate model with Leverage Effects
FIGARCH (Fractionally Integrated GARCH)	$h_t=\omega+[1-\beta L-\phi L(1-L)^{\delta}]\square_t^2+\beta h_{t-1}$	Baillie, Bollerslev and Mikkelsen (1996)	Univariate models with Symmetric Effects
GJR-GARCH (GJR-GARCH)	$\sigma_t^2=\omega+\sum_{i=1}^{p}\alpha_i\square_{t-i}^2+\gamma_k\square_{t-k}^2 I\square_{t-1<0}\square+\sum_{j=1}^{q}\beta_j\sigma_{t-j}^2$	Glosten, Jagannathan and Runkle (1993)	Univariate model with Leverage Effects
TGARCH (Threshold GARCH)	$\sigma_t=\omega+\sum_{i=1}^{p}\alpha_i\ {}_{t-1}+\sum_{k=1}^{k}\gamma_k\ {}_{t-k}I\ {}_{t-k<0}+\sum_{j=1}^{q}\beta_j\sigma_{t-j}$	Zakoian (1994)	Univariate model with Leverage Effects

Source: Authors´ own elaboration.

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