Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-022-01470-4 OPEN

Investments in the Asian water sector: an analysis based on the DCC-GARCH model

Rajibur Reza [1], Gurudeo Anand Tularam [2], Xiyang Li [3]✉ & Bin Li [1]

The availability of potable water is a challenging issue for many Asian countries where economies are still expanding and the population is growing. It is not difficult to observe that water scarcity will become far worse, sooner rather than later. In this study, we investigate the relationships among water indices in five Asian markets (namely China, Hong Kong, Japan, Philippines and Singapore) for the sample period 2005–2018 using the DCC-GARCH model. The empirical results confirm that volatility spillover exists among all the five water indices and there are persistent positive volatility effects. Further, we find that portfolio diversification is possible and benefits may be gained due to the contrasting correlations between pairs of these water indices. The findings of this study may be useful to academics, researchers, policymakers and major water investors worldwide in further comprehending the challenges faced by the Asian water market.

[1] Department of Accounting, Finance, and Economics, Griffith University, Nathan Campus, Brisbane, QLD, Australia. [2] The Centre for Planetary Health and Food Security, Griffith University, Nathan Campus, Brisbane, QLD, Australia. [3] Department of Accounting, Business School, Soochow University, Suzhou, China. ✉email: xiyangli@suda.edu.cn

Introduction

Although water is an essential commodity for survival, 2.2 billion people around the world still have no access to fresh water (United Nation Water, 2019). The amount of fresh water has been decreasing mostly due to climate change-related effects. Rainfall patterns have been changing and pollution such as those caused by floods and agricultural runoff have risen over time (Tularam and Properjohn, 2011; Tularam and Reza, 2018). It seems that climate change and its related consequences affect the long-term supply of potable water (Lancaster-Brooks, 2002; Gleick, 2006; Tularam and Reza, 2017). Potable water availability can be a challenging issue for many countries, especially some Asian countries (Roca et al., 2015; Tularam and Marchisella, 2014; Wild et al., 2007), where the economies are growing and the population is still rapidly increasing (Gleick, 1993). Therefore, the potable water-related problems may become far worse, sooner than later, in Asia (Brown et al., 2007; Tularam and Properjohn, 2011; Tularam and Marchisella, 2014).

Across Asia, approximately 783 million people are unable to readily access fresh drinking water[1]. The population growth rate in Asia and the Pacific is 1.0% (UNESCO, 2011). In Asia and the Asia Pacific about 43% of the population is currently living in urban areas and the Asia-Pacific urban proportion has risen by 29% in the past two decades, more than any other regions worldwide (UNESCO, 2011).

China is one of the most water-stressed countries in the world (Sullivan et al., 2008) with almost 22% population. More than 400 out of 663 cities in China have been suffering from water shortages, with 110 long classified as "severe" (KPMG, 2012). China's water consumption is still on the rise and is expected to be around 1068 billion tons by 2030 (Brown et al., 2007). A large amount of investment is needed if the Chinese water industry is to perform well in the future. The current investment is probably concentrated on capital and water infrastructure only (Olstein et al., 2009). For there to be sufficient funds in the sustainment of the sector, the private sector will need to be a key player, so its participation is crucial. Not surprisingly, the water investment in the Chinese private water sector appears to be a "hot topic", and for this reason, China has made plans to allow possible business opportunities by foreign water utilities (Lee, 2007; Hutterer, 2008).

Roca and Tularam (2012) identify China and Japan as the two significant water equity markets in Asia. In fact, the Chinese and Japanese water markets are expected to have development rates of over 8–10% in the years to come. Some statistics show that the investment profitability of Asian-based water sectors are higher than the US water industry. The Asian water sector has investment opportunities for others in that Asia has been experiencing steady growth over the past ten years.

However, in most cases, the Asian water sector has been maintained and controlled by government agencies, in that the water provision and sanitation services up to 1997 were provided by public companies. Also, in the past, there has been little appetite or interest in private investment opportunities in the Asian water industry (Grace et al., 2007). One exception is the Philippines, which is the first Asian country where the water sector is partially privatized; this was done by taking support from the World Bank and Asian Development Bank and carrying out a significant water privatization project in the world in 1997 (Brown et al., 2007; Grace et al., 2007). Singapore has also moved in this direction, and the water industry in the area has become much stronger in that the number of water companies has tripled since 2006[2]. The five Asian water markets (namely, China, Hong Kong, Japan, the Philippines and Singapore) are currently experiencing growing private sector participation and this will allow further market opportunity. Essentially, the private sector can help provide financial, managerial and modern technological capacity to solve most water supply problems; that is, privatization tends to be the solution for water problems in most cases (Kessides, 2004). In sum, to address future Asian water problems, it is essential to seek larger private investments for the water industry.

In 2015, 16% of the world's population was served by the private water companies and this is predicted to be as high as 20% in 2025 (Pinsent Masons, 2009; RobecoSAM, 2015). The increase in interest has led to a more diverse water market. The Asian water market is particularly dominated by large multinational water companies, but there are signs of financial openings for local investors, who have captured some of the water market share (Jin et al., 2019). A worldwide interest in the water market has yet to be reflected in the Asian region, notwithstanding the high forecasted growth for the region.

Globally, private water sector also requires a large amount of funds for the water investment, which has been estimated to be around US$600 billion (Roca and Tularam, 2012). The infrastructure of the Asian regions needs around US$260 billion[3]. To facilitate the investing process so that large investments are possible, more in-depth knowledge of the correlations among the major Asian water-sector market indices is crucial. There is a need for water investors to better predict international portfolio diversification benefits, for example. The nature of the individual country's water-sector market index, in fact, shows that the investment in the Asian water sector may provide high yields. This will help the private investors invest in water within their portfolios of water asset class especially if the investment allows the enhancement of diversification benefits (Jin et al., 2015a; Roca and Tularam, 2012). Diversification benefit is a desirable metric in financial portfolio calculations and aids in decision making for water investors in the process of determining whether investors may gain hedge benefits and/or profit from investing in the Asian water industry.

In terms of determining possible benefits in portfolio analysis, the use of the dynamic conditional correlation (DCC) method is common in the literature. Econometric methods such as DCC have been used to study the shock transmissions, the volatility spillover effects, diversification, and the dynamics of conditional relationships between financial assets (Peri et al., 2017). Despite the DCC-generalized autoregressive conditional heteroscedasticity (DCC-GARCH) model being the more powerful method of examining diversification and dynamics of conditional relationships, there is much less work done using this method to study the diversification benefits and dynamic relationships amongst the Asian water-sector market indices.[4]

In this study, five Asian markets are investigated pertaining to the private water industry: namely China, Hong Kong, Japan, the Philippines and Singapore. The DCC-GARCH model is applied to determine correlations over time that can in turn be incorporated into portfolio modeling. In so doing, we examine the performance of the water sector in five Asian markets.

The contributions of this paper to the literature are threefold. Firstly, this is one of the few studies that investigates the dynamic relationships among the global water indices including Asian water indices. Secondly, to the best of our knowledge, no prior studies have examined the country-wise water indices in Asia with the diversification benefits of water investments. Thirdly, the results of this study would be beneficial to water-focused investors as well as to the Asian regulators in terms of containing contagion risk, thus assisting investors and institutions in making important investment decisions.

According to portfolio diversification theory, the lower (higher) the correlation of the Chinese water index with other

Asian water indices, the larger (smaller) the diversification benefit to be obtained. Our results indicate that the correlations of the Chinese water index with other Asian water indices are low. Our GARCH results suggest that volatility spillover exists among the five Asian water indices. Further, DCC-GARCH results show that the Chinese water index influences the other Asian water indices. Thus, Chinese water investors now have the opportunity to diversify into other Asian countries' water sector to achieve additional hedging benefits.

Literature review

Hedging investment funds has led to studies involving portfolio diversification implications, and the formula for variance of investment funds within a portfolio relies on variance of investments that in turn depend on correlations. Rather than using constant correlations, the use of dynamic conditional correlation relationships (correlations that can change over time) has become crucial for the calculation/prediction of the range of profits from investments. For this and other reasons, there is much research work still being done in the understanding of the relationships among equity indices, mutual funds and exchange traded funds (ETFs) including bond indices; and these in turn have become one of the main issues in hedging of funds (see, e.g., Joy et al., 1976; Longin and Solnik, 1995; Dean and Faff, 2001; Jithendranathan, 2005; Billio et al., 2006; Chiang et al., 2007; Kuper and Lestano, 2007; Asai, McAleer, 2009; Gupta and Donleavy, 2009; Li, 2009; Lafuente and Ordonez, 2009; Tularam et al., 2010; Gallali and Kilani, 2010; Gupta and Guidi, 2012; Bouri, 2013; Ahmad et al., 2014; Nagayev et al., 2016; Sclip et al., 2016; Hassan et al., 2018; Joyo and Lefen, 2019; Niyitegeka and Tewari, 2020).

By applying the DCC-GARCH model (Engle, 2002), previous studies have identified the significance and crucial importance of the dynamic conditional correlation relationships of financial markets and the potential benefits of hedging motivations especially in the international diversification case.

Unfortunately, despite its importance to water finance and investment, a smaller list of studies has investigated the risk and returns of investing in water stocks, water indices, water funds, water ETFs and water equity markets (see, e.g., Buckland and Fraser, 2000; Morana and Sawkins, 2000; Antoniou et al., 2000; Buckland and Fraser, 2001; Geman and Kanyinda, 2007; Roca and Tularam, 2012; Buckland and Williams, 2013; Buckland et al., 2015; Jin et al., 2014, 2015a, 2015b and 2019; Roca et al., 2015; Tularam and Reza, 2016; Fiorelli and Mele, 2017; Reza et al., 2017, 2018 and 2021; Vandone et al., 2018; Ibikunle and Martí-Ballester, 2020; Piñeiro-Chousaa et al., 2020). Specifically, only four studies (Roca et al., 2013; Gilroy et al., 2013; Jin et al., 2015a; Zeneli, 2016) have investigated the correlations of water with stocks and bonds for the portfolio diversification within the water investments.

Roca et al. (2013) and Jin et al. (2015a) both use the World Water Index (WOWAX) to represent water as an investment asset. Roca et al. (2013) find that WOWAX has low correlation with MSCI World Index (MSCIWI) and Barclays Global Aggregate Index (BGAI). Hence, investors on WOWAX can gain diversification benefits from investing on MSCIWI and BGAI. Jin et al. (2015a), applying Markowitz (1952) approach, find that the WOWAX has the capacity to provide potential diversification benefits to investors on other traditional assets, i.e., MSCIWI and BGAI.

Gilroy et al. (2013) base their analysis on Palisades Global Water Index—an investable water equity index. They find that Palisades Global Water Index has high positive correlation with the MSCIW, and slightly negative correlation with bonds. But, by applying Markowitz (1952) approach, Gilroy et al. (2013) fail to note any potential diversification benefits with the Palisades Global Water Index. Zeneli (2016) selects the S-Network Global Water Index (S-Net) as a representative of water stock and finds that returns of other traditional stock are less and negatively correlated with the S-Net returns. Hence, portfolio diversification benefits are possible with the S-Net.

The study by Peri et al. (2017) is one study that examines the dynamic relationships among the water, energy and food sectors by adopting a volatility perspective using VARMA with the DCC. Their results show that correlations between the water, energy and food sectors are time-varying and that volatility spillover exists. It is noted that useful correlations exist using the DCC-GARCH model so that the appropriate diversification implications may be sought.

The dynamic nature of the DCC-GARCH model is a useful tool in determining the possibility of hedging portfolios based on diversification benefits for return calculations and thus decision making in large investments. The DCC-GARCH model, which is more parsimonious and flexible than other GARCH models such as the BEKK-GARCH model, often provides better fitting and forecasting performances (Huang et al., 2010). It also enables researchers to analyze interdependence among markets or variables by estimating the time-varying conditional correlation (Engle, 2002)—which was not available until the introduction of the DCC-GARCH model. However, studies using the DCC-GARCH method concerning the Asian water indices are lacking somewhat and therefore, our paper attempts to close this important gap in the literature.

Our paper proposes the following two testable hypotheses:

H_1: The Asian water indices exhibit persistent volatility.

H_2: There are dynamic conditional relationships among the Asian water indices.

Data. This study utilizes Datastream (DS) Water Index daily datasets concerning the water markets of China, Hong Kong, Japan, the Philippines and Singapore. The data are obtained from Refinitiv Datastream for the sample period from April 1, 2005 to April 30, 2018. We have selected the Chinese, Hong Kong, Japanese, Philippines and Singaporean markets not only because of the completeness of data required but also because these countries are the most important in the region in terms of size and impact. These water markets are related to financial markets in general and this helps investors engage in the private water sector in terms of indices, managed funds and ETFs. The individual water-sector market index covers private water firms, which account for 75% to 80% of the market capitalization (Roca and Tularam, 2012).

Figure 1 shows the Asian water indices' time-series price movements. The daily returns of Asian water indices are transformed by the following formula: $R_t = \ln(\text{Price}_t/\text{Price}_{t-1}) \times 100$.

Methodology. The purpose of this study is to investigate the dynamic relationships among five Asian water indices and their volatility and returns using the DCC-GARCH model. Univariate time-series methods are thus developed in this section. Figure 2 provides a flowchart summarizing the research description and how each method answers the specific hypothesis.

A DCC model is a nonlinear combination of univariate GARCH models where the multivariate conditional variance is estimated through the univariate GARCH model for each market (Huang et al., 2010; Tularam et al., 2010). There are two steps in the estimation. First, the residuals can be obtained from the estimation of the DCC model; second, the parameters for the conditional correlation are calculated by using the transformed residuals obtained from the first step (Huang et al., 2010; Tularam et al., 2010). Following Orskaug (2009) and Tularam et al. (2010), the DCC-GARCH model, first introduced by Engle and Sheppard (2001), can be specified as:

$$H_t = D_t R_t D_t \tag{1}$$

where $H_t = n \times n$ matrix of conditional variances at time t; $D_t = n \times n$ diagonal matrix of conditional standard deviations from univariate GARCH models with $\sqrt{\hbar_{it}}$ on the i^{th} diagonal and $R_t = n \times n$ conditional correlation matrix of a_t at time t.

By taking the substitution $H_t = D_t R_t Dt$, we obtain the log-likelihood of this estimator as follows:

$$\begin{aligned}\log(L(Q)) &= -\tfrac{1}{2}\sum_{t-1}^{t}\left(k\log(2\pi)+\log([\mathrm{H}_t])+\varepsilon_t^T H_t^{-1}\varepsilon_t\right)\\ &= -\tfrac{1}{2}\sum_{t-1}^{t}\left(k\log(2\pi)+\log([D_t R_t D_t])+\varepsilon_t^T D_t^{-1}R_t^{-1}D_t^{-1}\varepsilon_t\right)\\ &= -\tfrac{1}{2}\sum_{t-1}^{t}\left(k\log(2\pi)+2\log([D_t])+\log[R_t])+\varepsilon_t^T D_t^{-1}R_t^{-1}D_t^{-1}\varepsilon_t\right)\end{aligned} \tag{2}$$

where $\varepsilon_t \sim N$ (0, R) is a residual, standardized by its conditional standard deviation.

We follow Orskaug (2009) and Tularam et al. (2010) to use the elements in the diagonal matrix D_t as univariate GARCH models so that we can rewrite it as follows:

$$\hbar_{it} = \omega_{i0} + \sum_{\mathrm{q}=1}^{\mathrm{Q_i}}\omega_{\mathrm{iq}}\gamma^2_{\mathrm{i,t-q}} + \sum_{\mathrm{p}=1}^{\mathrm{P_i}}\lambda_{\mathrm{ip}}\hbar_{\mathrm{i,t-p}} \tag{3}$$

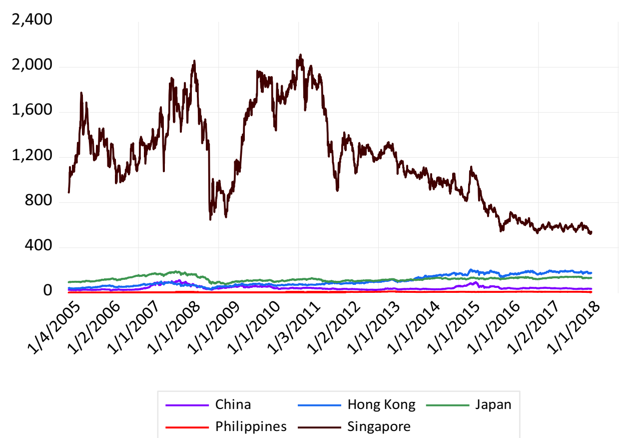

Fig. 1 Price movement of five Asian water market indices, 2005–2018.

for $i = 1, 2, \ldots, k$ with the conditions for the univariate GARCH model restrictions (non-negativity and stationarity) being imposed.

Thus, we can write the elements of D_t, the standard deviations from univariate GARCH model as follows:

$$\mathrm{D}_t = \begin{vmatrix} \sqrt{\hbar_{11}} & 0 & 0 & \cdots & 0 \\ 0 & \sqrt{\hbar_{2t}} & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & & \vdots \\ 0 & 0 & 0 & \cdots & \sqrt{\hbar_{nt}} \end{vmatrix} \tag{4}$$

R_t is the conditional correlation matrix of the standardized disturbances $\in_t$, i.e.,

$$\in_t = D_t^{-1}\alpha \sim \mathrm{N}(0, \mathrm{R})$$

Since R_t is a correlation matrix it is symmetric.

$$R_t = \begin{vmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \cdots & \rho_{1n,t} \\ \rho_{12,t} & 1 & \rho_{23,t} & \cdots & \rho_{2n,t} \\ \rho_{13,t} & \rho_{23,t} & 1 & \ddots & \vdots \\ \vdots & \vdots & \ddots & \ddots & \rho_{n-t,n,t} \\ \rho_{1n,t} & \rho_{2n,t} & \cdots & \rho_{n-t,n,t} & 1 \end{vmatrix} \tag{5}$$

The elements of $H_t = D_t R_t D_t$ is

$$|H_t|_{ij} = \sqrt{\hbar_{it}\hbar_{it}}\rho_{it} \tag{6}$$

where $\rho_{ii} = 1$. To ensure both of these requirements in the DCC-GARCH model are satisfied, R_t is decomposed into:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \tag{7}$$

$$Q_t = (1 - \alpha - \beta)\bar{Q} + \alpha \in_{t-1}\in_{t-1}^T + \beta Q_{t-1} \tag{8}$$

where $\bar{Q}_t = Cov|\in_t\in_t^T| = E|\in_t\in_t^T|$ is the unconditional covariance matrix of the standardized errors $\in_t$ and $\bar{Q}_t$ can be estimated as:

$$\bar{Q}_t = \frac{1}{T}\sum_{t=1}^{T}\in_t\in_t^T \tag{9}$$

The parameters α and β are scalars, and Q_t^* is a diagonal matrix with the square root of the diagonal elements of Q_t at the

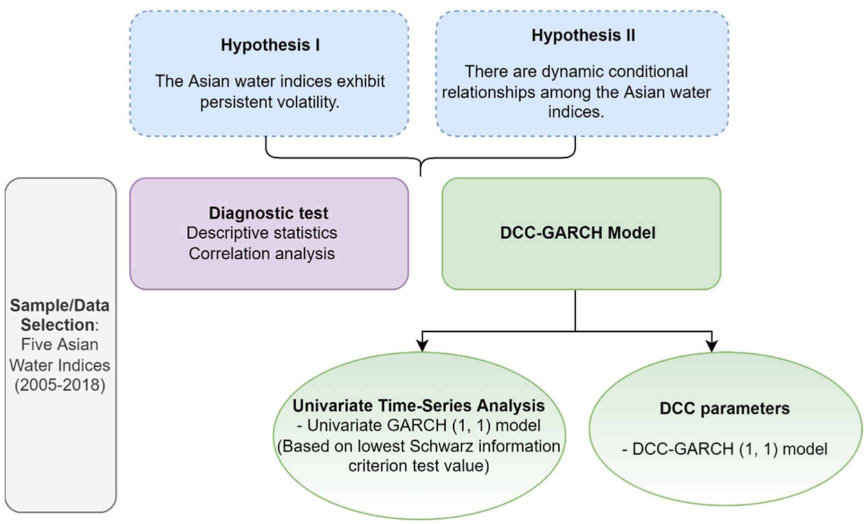

Fig. 2 Research methodology for the dynamic relationships among five Asian water indices.

diagonal.

$$Q_t^* = \begin{vmatrix} \sqrt{q_{11t}} & 0 & 0 & \dots & 0 \\ 0 & \sqrt{q_{22t}} & \cdot & \dots & 0 \\ \vdots & \vdots & \vdots & & \vdots \\ 0 & 0 & 0 & \dots & \sqrt{q_{nnt}} \end{vmatrix} \quad (10)$$

Q_t^* scales the elements in Q_t to ensure the second requirement, $|\rho_{ijt}| = |\frac{q_{ijt}}{q_{iit} q_{ijt}}| \le 1$, satisfied.

We include GARCH process with normally distributed errors and follow Tularam et al.'s (2010) dynamic correlation structure, and propose a dynamic correlation model, which is:

$$Q_t = \left(1 - \sum_{m=1}^{M} \alpha_{m-} \sum_{n=1}^{N} \beta_n\right)\bar{Q} + \sum_{m=1}^{M} \alpha_m \left(\in_{t-m} \in_{t-m}^t\right) + \sum_{n=1}^{N} \beta_n Q_{t-n} \quad (11)$$

where Q is the unconditional covariance of the standardized residuals.

Empirical results

Descriptive statistics. In Table 1, our results show that stock returns are positive in all markets except Japan. The highest mean return (0.061) is in Hong Kong, whereas Japan has the lowest mean return (−0.010), followed by the Philippines (0.042), China (0.008) and Singapore (0.007). The market with the highest risk is Japan (4.16126), followed by China (2.404), Singapore (2.207), Hong Kong (2.195) and the Philippines (1.902). These results are summarized as graphs in Fig. 3.

Table 1 Descriptive statistics.

Variables	Obs	Mean	Std. Dev.	Min	Max
China	3412	0.008	2.404	−19.398	9.479
Hong Kong	3412	0.061	2.195	−12.483	18.355
Japan	3412	−0.010	4.161	−58.746	92.989
Philippines	3412	0.042	1.902	−16.705	14.107
Singapore	3412	0.007	2.207	−28.207	17.156

This table reports the descriptive statistics for water indices in five Asian markets: China, Hong Kong, Japan, the Philippines and Singapore. Data are obtained from the Thomson Reuters DataStream database. The daily returns of Asian water indices are transformed to the form of $R_t = \ln(\text{Price}_t/\text{Price}_{t-1}) \times 100$. The prices of these indices are calculated based on US dollars.

Correlation matrix. Table 2 shows the correlation results amongst the five Asian water indices. The correlation matrix shows mixed results (positive or negative correlations) among China, Hong Kong, Japan, the Philippines and Singapore. It is noted that both the Hong Kong and Philippines water indices are positively correlated with the Chinese water index, whereas the Japanese and Singaporean indices are negatively correlated with the Chinese one. The Hong Kong water index is positively correlated with the Singaporean water index. However, the Japanese and Philippines water indices are negatively correlated with the Hong Kong water index. The Japanese water index is negatively correlated with the Philippines and Singapore water indices. The Philippines water index is also negatively correlated with the Singapore water index. When the correlation is somewhat low or negative, there is some scope for hedging in the market and water investors are likely to gain diversification benefits within a portfolio of investments or assets. Our analysis shows that the five Asian water indices are, at times, negatively correlated with each other. Correlation results are summarized as graphs in Fig. 4.

DCC-GARCH model. In this study, we have applied the DCC-GARCH model (Engle, 2002) to examine the return correlations between five Asian water indices (see Table 3). The Schwarz Information Criterion (SIC) is used to determine the optimal DCC-GARCH specifications. Table 3 presents the SIC results. In our case, the DCC-GARCH (1, 1) specification has the lowest SIC value and is thus adopted for the estimation.

Table 4 presents the univariate GARCH (1, 1) model estimation results for the five Asian water index returns based on Eq. (5). The estimates of volatility equations in the GARCH (1, 1) model show that all the parameters, i.e., ω—the unconditional volatility, α—the ARCH and β—the GARCH effects are positive and significant.

The coefficients for our five Asian water indices are positive and significant. The unconditional volatility (ω) of Singapore has the highest coefficient (0.401), followed by the Philippines (0.087), Hong Kong (0.075), China (0.067) and Japan (0.033). The ARCH coefficients (α) for the five Asian water indices are positive at the 1% level of significance, suggesting today's volatility is highly related to yesterday's innovation for all these five water indices. The GARCH coefficients (β) for the five Asian

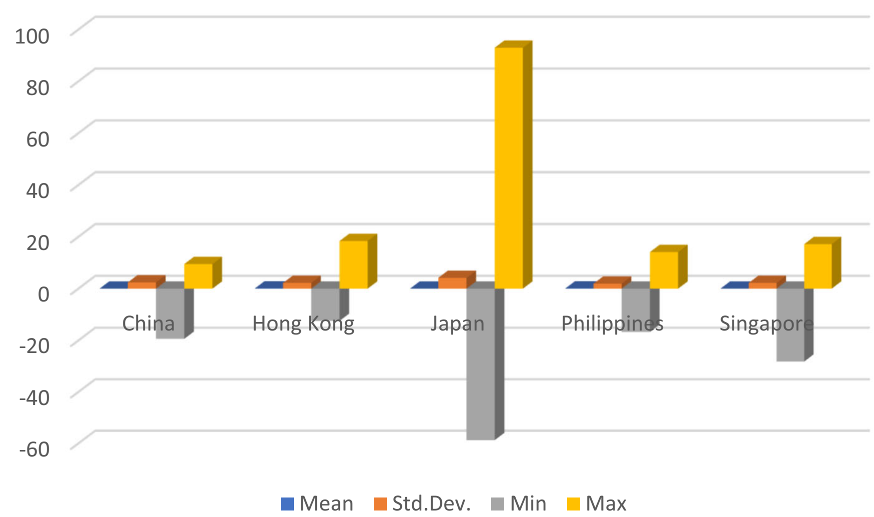

Fig. 3 Mean, standard deviation, maximum, and minimum of the price movement. Note: Mean, standard deviation, maximum, and minimum results are summarized as graphs here.

Table 2 Correlation matrix.

Variables	China	Hong Kong	Japan	Philippines	Singapore
China	1.000				
Hong Kong	0.005	1.000			
Japan	−0.032	−0.005	1.000		
Philippines	0.105	−0.010	−0.016	1.000	
Singapore	−0.017	0.227	−0.007	−0.006	1.000

This table reports the correlation results among five Asian water indices: China, Hong Kong, Japan, the Philippine, and Singapore.

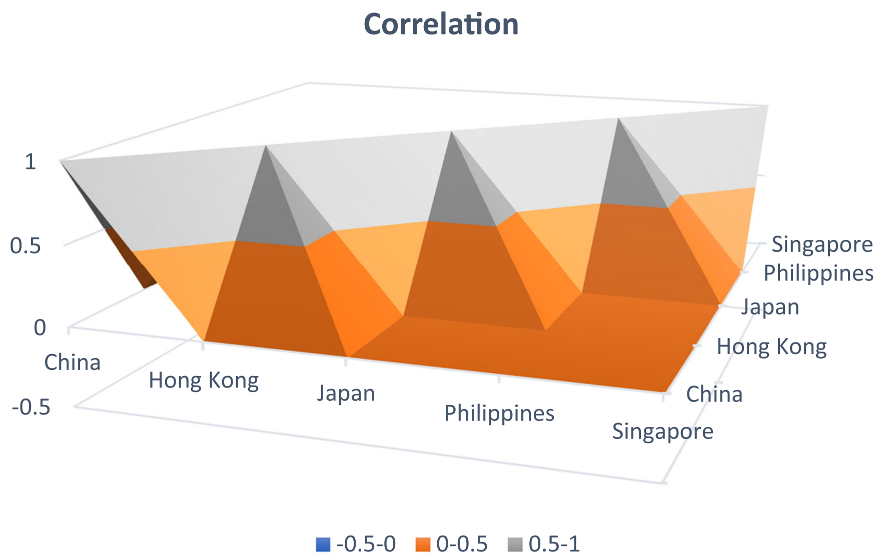

Fig. 4 Correlations among the Water Index Returns of China, Hong Kong, Japan, the Philippines, and Singapore.

Table 3 Optimal GARCH (p, q) specifications.

	p,1	p,2	p,3	p,4
1,q	1.868[a]	9.359	7.969	7.240
2,q	9.351	7.963	7.248	5.349
3,q	7.967	7.242	5.347	5.552
4,q	7.244	5.341	5.559	4.311

[a]Denotes lowest SIC value.

Table 4 Univariate GARCH model estimates.

Country	ω	α	β
China	0.067 (0.000)***	0.032 (0.000)***	0.953 (0.000)***
Hong Kong	0.075 (0.000)***	0.066 (0.000)***	0.916 (0.000)***
Japan	0.033 (0.000)***	0.161 (0.000)***	0.832 (0.000)***
Philippines	0.087 (0.000)***	0.089 (0.000)***	0.888 (0.000)***
Singapore	0.401 (0.000)***	0.175 (0.000)***	0.739 (0.000)***

Standard errors are presented in parentheses; ***Significant at the 1% level.

indices indicate a persistent effect, which are positive and significant for the five water indices. The ARCH and GARCH results confirm that volatility spillover exists among five water indices. These results support the hypothesis H_1.

Table 5 DCC parameters-DCC-GARCH (1, 1).

Parameters	Estimates	Significance
α	0.032	(0.000)***
β	0.953	(0.000)***

Standard errors are presented in parentheses; ***Significant at the 1% level.

The estimation results the DCC model obtained suggest that the dynamic conditional correlations may be useful in the analyses of the water sector. The results are synthesized in Table 5 and the results support the hypothesis H_2.

Figure 6 reports the nature of the Chinese water index and its influence in the Asian regional markets. The dynamic correlations between the water indices are rather similar to the values shown in Fig. 5. It is noted that all the dynamic correlation graphs show spikes at a similar point in time; they "build up" around 2008 and in late 2010, i.e., closely related to the ensuing global financial crisis (GFC) period. The co-movement of the Asian water indices is similar. Figure 5 shows that there is superimposition in all the DCCs of the five Asian water indices and the hedging or diversification benefits using other markets would probably be less during the GFC period.

Figures 5 and 6 both show that the Chinese and the other Asian water indices tend to fluctuate over time. However, correlation results are still within the range for benefits to be gained. Thus, hedging or portfolio diversification is possible. Figure 5 demonstrates that these five water markets provide portfolio diversification benefits to the water investors except the GFC period. Nonetheless, there may be increasing commonalities among five water indices in terms of the way water investors

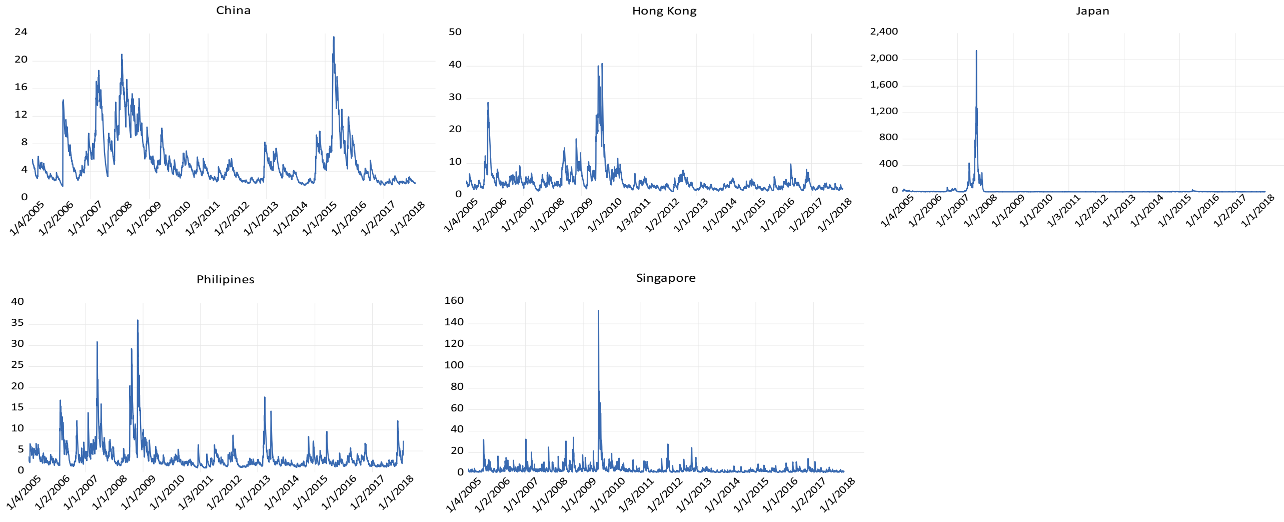

Fig. 5 Time-varying correlations of individual country Water Index Returns based on DCC-GARCH model.

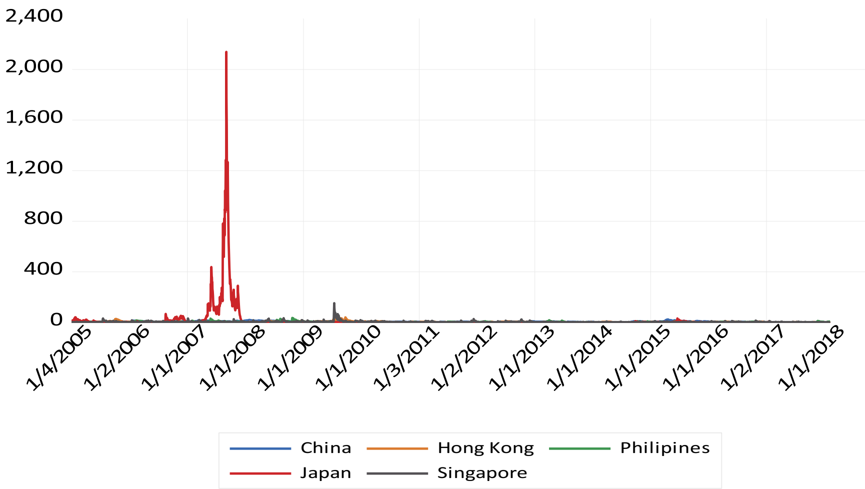

Fig. 6 Combined time-varying correlations of individual country Water Index Returns based on DCC-GARCH model.

behave in these markets, which may bring down the diversification benefits. To obtain better risk–return trade-off, investors in the Asian water markets may include some assets in other markets into their portfolios.

Discussion

Our study uses multivariate GARCH model to analyze the relationships among Asian water indices including their volatility effects and returns. The correlation results obtained show that the Japanese water index is negatively correlated with the Chinese and Hong Kong water indices; the Philippines index is negatively correlated with the Hong Kong one; and the Hong Kong and Singapore water indices are negatively correlated with the Chinese, Japanese and Philippines water indices. Clearly, this finding shows that there is a possibility for hedging in the market as well as for gaining diversification benefits within a portfolio. Water investors may indeed gain international portfolio diversification benefits.

The univariate GARCH (1, 1) model results (α and β) show that the Asian water indices capture the "extremely" high level of stock return volatility. These results are in line with Reza et al. (2018). However, these results contrast with Tularam and Reza (2016) who find that there is a lower systematic risk and a positive impact on the water ETFs investment returns.

The DCC results suggest positive dynamic conditional correlations that could be used in the analysis of the Asian water sector. Similar to previous studies on other sectors (such as electricity, SRI, etc.), this study explicitly accounts for international portfolio diversification benefits with the consideration of the volatility transmission mechanism.

Conclusion

We investigate the dynamic relationships between water indices in China and other Asian markets (Hong Kong, Japan, the Philippines and Singapore) for the period 2005–2018 using the dynamic DCC-GARCH model. Our study is motivated by a need to understand the possibility of diversification and dynamic hedging or balancing of portfolios based on the types of relationships that are noted among Asian water indices, and whether Asian water indices are diversified and desirable tools for water investment.

We find that the Chinese water index has a spike in correlations with the other four Asian water indices. Although we find fluctuations in the correlations of China with the other Asian markets, the correlations remain in appropriate bands for benefits in that the Chinese market is positively correlated with the Hong Kong and the Philippines markets, while the Japanese and Singaporean markets are negatively correlated with the Chinese one, suggesting possible hedging benefits. Note that the Japanese market is negatively correlated with those in Hong Kong, the Philippines and Singapore. Also, the Philippines market is negatively correlated with the Singaporean one. Clearly, there is an avenue for water investors not only to hedge but also to diversify in the Asian water sector.

The results of our research will be helpful to academics, researchers, policymakers and major water investors worldwide. Future research may focus on other factors that drive the relationships among global and Asian water-sector markets.

Data availability

The data used in this study are available from the Datastream, which is a commercial database owned by Refinitiv. Griffith University has the license to use the data from the Refinitiv Datastream for research purpose. As affiliated researchers of Griffith University, the authors obtained the data for this study.

Received: 11 May 2022; Accepted: 29 November 2022;
Published online: 16 December 2022

Notes

1 https://asiafoundation.org/2012/03/21/asia-the-worlds-driest-continent/
2 https://www.businessavenues.eu/sites/default/files/public/imce/contentmanagers/environment_and_water_industry_programme_office_2.pdf
3 https://www.who.int/water_sanitation_health/publications/global_costs/en/
4 Due to the limited scope of this paper, the benefit analysis will not be presented here. https://www.chinawaterrisk.org/opinions/china-water-investments-3-thoughts/

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Author contributions

All authors significantly contributed to the article and approved the submitted version. Contributed to the conception or design of the work: RR, GA, BL. Contributed to analysis and interpretation of data for the work: RR. Drafted the work or revised it critically for important intellectual content: RR, GA, XL, BL. Final approval of the version to be published: RR, GA, XL, BL. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: RR, GA, XL, BL.

Competing interests

The authors declare no competing interests.

Ethical approval

Not required for this study. This article does not contain any studies with human participants performed by any of the authors.

Informed consent

Not required for this study. This is because this article does not contain any studies with human participants performed by any authors.

Additional information

Correspondence and requests for materials should be addressed to Xiyang Li.