Asian Economic and Financial Review
ISSN(e): 2222-6737
ISSN(p): 2305-2147
DOI: 10.18488/journal.aefr.2019.97.824.835
Vol. 9, No. 7, 824-835

URL: www.aessweb.com

A COMPARISON OF THE ECONOMIC VOLATILITY SPILLOVER EFFECT OF HONG KONG WITH CHINA AND USA

Eric M.T. Wong

Division of Business and Management, United International College, Beijing Normal University-Hong Kong Baptist University, 2000 Jintong Road, Tangjiawan, Zhuhai, Guangdong Province, China.
Email: ericmtwong@uic.edu.hk Tel: +86-756-3620404

Article History
Received: 23 April 2019
Revised: 27 May 2019
Accepted: 1 July 2019
Published: 24 July 2019

Keywords
Economic integration
Economic indicators
Volatility spillover
MGARCH
Exchange rate system
Anchor currency.

JEL Classification:
F150, F360, F440, F450.

ABSTRACT

Hong Kong has been part of China now for over twenty years. The economic activities between the two regions are more integrated due to policies for enhancing trade and finance, location convenience and fast economic growth in China. This article examined the economic integration between Hong Kong and China in terms of the volatility spillover effect of four economic indicators, namely real GDP growth rate, inflation rate, M2 supply and the three-month interbank offer rate. We used the Bivariate Multivariate GARCH model. As the USA has been the biggest trade partner of Hong Kong, the economic effect of the USA on Hong Kong was also analyzed. We found that the economic volatility of China significantly spills over to Hong Kong while there is less evidence found for a spillover effect from the USA. As the Hong Kong Dollar is still strictly pegged with the US Dollar, this paper provides evidence for the evaluation of Hong Kong's monetary policy on the exchange rate system.

Contribution/ Originality: This study contributes to the literature by examining the economic integration between Hong Kong and China in terms of the volatility spillover effect of four economic indicators, namely real GDP growth rate, inflation rate, M2 supply and the three-month interbank offer rate.

1. INTRODUCTION

This study examined the volatility spillover of the fundamental economic indicators between Hong Kong and China. As the two economies become more integrated, instead of measuring the cyclical effect in the business cycle, it is also valuable to measure whether there is co-movement in the volatility. Hong Kong has adopted a fixed exchange rate system for over 30 years.

Linking the Hong Kong Dollar with the US dollar implies the importance and influence of the US's monetary policy on Hong Kong. Because of this, if Hong Kong and the USA have different business cycles, by adopting the fixed exchange rate system, an inappropriate monetary policy will also be adopted and used. It has worked well for the past 30 years.

However, the political and therefore economic structures of Hong Kong, United States and China have changed in recent years. Hong Kong's economic structure is becoming more integrated with China. Therefore, re-examining the business cycle between Hong Kong, China and USA is necessary. This article evaluated the volatility co-movement of the business cycle in terms of a set of selected economic indicators among those regions.

2. LITERATURE REVIEW

In the research of GDP volatility, the GARCH model is an effective tool. Past researchers have used the MGARCH model on the real GDP growth rate to study the volatility spillover effect among countries. Fang *et al.* (2008) developed a GARCH model with a structural break. The model was used to estimate the real GDP growth of Canada, Germany, Italy, Japan, the United Kingdom and the United States. The conditional variances among those countries were declining and its effect on how real GDP growth affects volatility was tested.

Beirne *et al.* (2010) set up a Trivariate VAR GARCH-M model on stock market return. This was developed to detect the spillover effect in mean, volatility and GARCH-in-Mean among different parts of the world. They found that the mean spillover effect was common in Asia and Latin America. The spillover in variance was common in emerging European markets.

Antonakakis and Badinger (2012) applied a BEKK-MGARCH model to investigate the existence of real GDP growth and output spillover between G7 countries. There was positive mean and volatility spillover effects among most of the G7 countries. Hai *et al.* (2013) formed an EGARCH model to explore the existence of asymmetric volatility in real GDP growth rates in Singapore, Hong Kong and Taiwan. They found that evidence of asymmetry and persistence existed in the volatility of real GDP growth rates. Results were more significant with structural break points in volatility included.

Harvie *et al.* (2013) used data for the period of 1912-2008. They identified three groups from twelve countries with real GDP co-movements. The multivariate GARCH model was used to measure the volatility spillover effect among those groups. The growth volatility in Japan and South Korea were more influenced by its past volatility, while others were more influenced by other groups.

Janiga-Ćmiel (2013) have applied the MGARCH model to the real GDP growth rate in different countries. Most of the selected European countries were correlated with real GDP growth, except Poland. In this paper, the author extends these approaches to analyzing the volatility spillover effects between Hong Kong, China and the USA.

3. METHODOLOGIES

A. Measuring the Effect of Economic Shocks

If the economic instability of a country can affect other countries, it is considered to have a spillover effect. The spillover effect can be discovered in countries where there are close economic interactions. A spillover effect in the volatility of the economic indicators is an important measurement of how rigorous the change in one country can affect other countries. To measure the spillover effect in volatility, the method of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) was used in this study. This method is powerful in modeling time series data with changing volatility. This characteristic often appears in econometric time series. We estimated the GARCH models using four economic indicators, namely GDP growth rate, change of inflation rate, change of interest rate and money supply growth rate. Once we built the model the volatility spillover effect was measured.

B. Multivariate BEKK-GARCH Model

The univariate GARCH model proposed by Engle (1982) can only capture the variability of one dependent variable. The conditional variance equation can therefore only cover the volatility created by the dependent variable itself. Using the univariate GARCH model therefore cannot account for or explain all observed changes in time series data analysis. It cannot explain the cause of the volatility change of a variable. In practice, researchers want to know the cause of volatility changes of a dependent variable and also examine whether there are volatility co-movements or spillover effects between different variables. This led to the development of multivariate GARCH model.

The developers of the multivariate GARCH model are Bollerslev *et al.* (1988); Engle and Kroner (1995) due to their contributions on vectorized GARCH (VECH), Constant Conditional Correlation GARCH (CCC) and BEKK-GARCH (BEKK stands for researchers of this model-Baba, Engle, Kraft and Kroner).

There are several variations of the multivariate GARCH model as the multivariate model is not a natural extension of the univariate model. In the multivariate model, there is a (n x n) conditional covariance matrix, which complicates the system by involving many parameters that has little economic value for interpretation. This allows researchers to add specifications to the multivariate model to limit the number of parameters, and to achieve different purposes.

The VECH model was the first established multivariate GARCH model. It inspired later research but has two major weaknesses. The model requires n(n+1)/2+(p+q)(n4+2n3+n2)/4 parameters in the estimation process which creates an issue for the practical computation process. The huge number of parameters also means there is no guarantee of positive conditional covariance results.

Bollerslev (1990) created another variation of the multivariate GARCH model in which the conditional correlation is assumed to be constant. This simplified the model estimation process allowing it to be estimated in practice. The assumption of positive conditional covariance was also satisfied by this approach. However, critics of the CCC GARCH model argue that the assumption of constant conditional variance could not be always satisfied. This weakness limits the practical usability of CCC GARCH model.

The BEKK approach is a more dynamic approach to the interaction between time series. Although it requires more parameters than CCC, it provides more analytical aspects on the dynamics of the series. As discussed by Giles and Li (2015) the spillover effect between different markets is not captured by the DVEC model. The BEKK model can capture the response of one country's volatility to other countries and is often used to analyze the spillover effect of volatility. To reduce the number of parameters in the estimation process, a more restricted version of BEKK model called Diagonal-BEKK model is often used, as reviewed by Harvie *et al.* (2013).

As cited by Giles and Li (2015); Engle and Kroner (1995) mentioned that "In most cases, the GARCH(1,1) specification is particular popular…it is the leading model for almost of returns…it is quite robust and does most of the work in almost all cases". Therefore, we used the Diagonal-BEKK GARCH (1,1) model to detect the spillover effects in volatility between Hong Kong, China and the USA in this study.

C. The Model

The multivariate GARCH system in compact form:

$$\begin{aligned} &y_t = B'x_t + \varepsilon_t, \\ &\varepsilon_t \mid I_{t-1} \sim f\left[0, H\right], \\ &H_t = g\left(H_{t-1}, H_{t-2}, \ldots, \varepsilon_{t-1,}\varepsilon_{t-2,} \ldots\right) \end{aligned}$$

Where B is a (k x n) matrix of unknown parameters

x_t is a (k x 1) vector of endogenous and exogenous explanatory variables included in the available information set, I_{t-1},

f(.) is the conditional multivariate density function of the innovation process and g(.) is a function of the lagged conditional covariance matrices and the innovation process.

In this research, the mean equation y_t is defined as an autoregressive process.

$$y_t = c + \sum_{i=1}^{n} y_{t-i} + \varepsilon_t$$

This is to capture the autoregressive nature of the variables. The lagged terms will be determined by ACF and PACF autocorrelation tests. The GARCH effect for each variable is then represented by the conditional error term ε_t.

The innovation process can be written as

$$\varepsilon_t = H_t^{1/2} z_t$$

Where z_t is an (n x 1) independently and identically distributed vector process such that $E(z_t)=0$ and $E(z_t z_t')=I$. The specification of the covariance matrix H is restricted to be Diagonal-BEKK(p,q).

$$H_t = CC' + \sum_{i=1}^{q}(A_i \varepsilon_{t-i} \varepsilon'_{t-i} A'_i) + \sum_{j=1}^{p}(B_j H_{t-j} B'_j)$$

Where A_0 is a lower triangular matrix with (n(n+1)/2) parameters and A_i and B_j are specified as diagonal matrix. The bivariate DBEKK-GARCH variance-covariance matrix is

$$H_t = CC' + \begin{bmatrix} a_{11} & 0 \\ 0 & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1}\varepsilon_{1,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & 0 \\ 0 & b_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} b_{11} & 0 \\ 0 & b_{22} \end{bmatrix}$$

Expanding the above matrix, the conditional variance of each variable and the conditional co-variance between variables can be expressed by the following equations.

$$\begin{aligned} h_{11t} &= c_{11} + a_1 a_1 \varepsilon_{1,t-1}^2 + b_1 b_1 h_{11,t-1} \\ h_{12t} &= c_{12} + a_1 a_2 \varepsilon_{1,t-1} \varepsilon_{2,t-1} + b_1 b_2 h_{12,t-1} \\ h_{22t} &= c_{22} + a_2 a_2 \varepsilon_{2,t-1}^2 + b_2 b_2 h_{22,t-1} \end{aligned} \qquad (1)$$

The co-variance equation h_{12} represents the co-movement of volatility between country 1 and country 2, which is the volatility spillover effect. The co-volatility spillover is estimated by the sum of the cross products of A and B respectively. If there is co-volatility spillover effect, a_1, a_2, b_1, b_2 should show significance in h_{12t}.

Each economic indicator was paired into two bivariate systems, namely Hong Kong-China and Hong Kong-USA. By using system estimation in Eviews 8, we estimated the bivariate-GARCH model. The standardized error provided in Eviews was used as diagnostic checking for the significance of each parameter. With the estimation on the variance-covariance matrix, the spillover of volatility between the countries was detected.

4. DATA COLLECTION AND PROCESSING

The data for Hong Kong and the USA were downloaded from the Reuters DataStream terminal. Data for China were collected from the Wind terminal and the government's websites. As there is no official data for the real GDP in China, it has to be calculated or transformed from the quarterly announced nominal GDP. We adopted the transformation approach and the real GDP generated by the Renmin University of China. Data from between 1989 and 2014 were used in the analysis.

Monthly year on year data for the CPI were collected. The data were then transformed into the inflation rates for the three regions. For the M2 supply, quarterly data were collected. For the interest rate, the three-month daily interbank offer rate was adopted. This interest rate is sensitive to the market movement but not as noisy or volatile as the overnight or 1-month market interest rate.

The long-term market interest rate was not considered a proper indicator because the fixed exchange rate system in Hong Kong ensured the co-movement of the long-term market interest rate. As China reformed the exchange rate determination system in mid-2005, we used data from 2005 to 2014 for all the indicators.

Table-1. Data frequency and time period.

Data	Hong Kong - China	Hong Kong – USA
Real GDP growth rate	Quarterly (1989-2012)	Quarterly (1989-2013)
Inflation rate	Monthly (2005-2014)	Monthly (2005-2014)
M2 supply	Quarterly (2005-2014)	Quarterly (2005-2014)
Interest rate (3 months interbank offer rate)	Daily (2006-2014)	Daily (2006-2014)

Source: All data are downloaded from Thomson Reuters DataStream except that China's unemployment rate is downloaded from Wind Terminal.

Table-2. Cross-sectional data of Hong Kong, China and USA as at 2014.

Data	Hong Kong	China	USA
Real GDP Growth rate	0.025	0.074	0.024
Inflation rate	0.044	0.021	0.01
M2 growth rate	0.121	0.12	0.0408
Interest rate (3 months Interbank Offer Rate)	0.0038 (HIBOR)	0.051 (SHIBOR)	0.0026 (LIBOR)

Source: All data are downloaded from Thomson Reuters DataStream except that China's unemployment rate is downloaded from Wind Terminal.

A. Determining the Lagged Length of the Mean AR Equation

To set up the MGARCH model, the lagged term for each variable in the mean equation was necessary. Preliminary observations were provided by the ACF and PACF diagrams. After the preliminary checking with the ACF and PACF diagrams, the selected lagged terms were put into the mean equation as independent variables. The standard error and p-value was then provided for diagnostic checking. Diagnostic checking of significance was then conducted in each series and the results are listed in Appendix 1 of this article.

1. Mean AR Equations of the Real GDP Growth Rate

$$y_{rgdphk,t} = c + y_{t-2} + y_{t-4} + y_{t-5} + y_{t-7} + \varepsilon_t$$
$$y_{rgdpch,t} = c + y_{t-1} + y_{t-2} + y_{t-3} + y_{t-4} + \varepsilon_t$$
$$y_{rgdpus,t} = c + y_{t-2} + \varepsilon_t$$

From the mean equation, the real GDP growth rates in Hong Kong and China seemed more stable. This can be explained by the fact that China has experienced a long period of high economic growth rate over the past 30 years. The economic growth in the USA has been over a shorter time trend. Current economic growth in the USA can only be affected by the growth rate in the past two quarters. In other words, the economic cycle in China and Hong Kong is longer. It often lasts for one to two years. In the USA, its economic cycle of growth is shorter and often lasts for two quarters.

2. Change in Inflation Rate

$$y_{rinfhk,t} = c + y_{t-4} + y_{t-12} + \varepsilon_t$$
$$y_{rinfch,t} = c + y_{t-1} + y_{t-2} + y_{t-12} + \varepsilon_t$$
$$y_{rinfus,t} = c + y_{t-1} + y_{t-12} + \varepsilon_t$$

Since the data frequency of inflation rate was monthly, the lagged term of twelve monthly successfully captured this seasonal effect. There was a quarterly seasonal effect in Hong Kong while China and the USA each have a one month lag in the inflation rate.

3. Change in Interest Rate

$$y_{rinthk,t} = c + y_{t-1} + \varepsilon_t$$
$$y_{rintch,t} = c + y_{t-1} + y_{t-3} + y_{t-4} + \varepsilon_t$$
$$y_{rintus,t} = c + y_{t-1} + y_{t-2} + y_{t-3} + y_{t-5} + y_{t-6} + \varepsilon_t$$

Hong Kong had the shortest lagged term in change of interest rate. Its interest rate had very short memory of one day. In China and the USA, the lagged terms were extended to four to six days. The change of interest rate was not as rigorous as in Hong Kong. As Hong Kong is a small and open economy and adopts the fixed exchange rate, its interest rate is highly sensitive to the external market environment. The rigorousness of the change in interest rate reflected this situation.

4. Money Supply Growth Rate

$$y_{rmshk,t} = c + y_{t-2} + \varepsilon_t$$
$$y_{rmsch,t} = c + y_{t-3} + y_{t-12} + \varepsilon_t$$
$$y_{rmsus,t} = c + y_{t-1} + \varepsilon_t$$

China's policy duration on money supply growth rate is long. It has a yearly seasonal effect, which means that its policy is coherent. The money supply growth rate was only one month lagged in the USA. This is because the monetary policy in the USA is determined by the Federal Reserve every six weeks. As its policy may change every six weeks, the lagged term of one month truly reflects the policy adjustments.

B. Testing for GARCH Effect with Lag 1 in Each Economic Indicator

After the determination of AR lagged terms, the residual of each mean equation was tested for the existence of the ARCH effect in Lag 1. Eviews 8 provided the LM test and the Portmanteau test for the GARCH effect. The results are presented in Table 3 below.

Table-3. Test results for GARCH effect.

Variable	Portmanteau test/ LM test	Test statistic	Distribution	P-value	Significance
		Real GDP growth rate			
rgdphk	F-statistic	25.11566	Prob. F(1,101)	0	***
	Obs*R-squared	20.51222	Prob. Chi-Square(1)	0	***
rgdpch	F-statistic	10.76179	Prob. F(1,103)	0.0014	***
	Obs*R-squared	9.932931	Prob. Chi-Square(1)	0.0016	***
rgdpus	F-statistic	7.242882	Prob. F(1,106)	0.0083	***
	Obs*R-squared	6.907553	Prob. Chi-Square(1)	0.0086	***
		Change of inflation rate			
rinfhk	F-statistic	23.77922	Prob. F(1,319)	0	***
	Obs*R-squared	22.26836	Prob. Chi-Square(1)	0	***
rinfch	F-statistic	9.528101	Prob. F(1,319)	0.0022	***
	Obs*R-squared	9.309768	Prob. Chi-Square(1)	0.0023	***
rinfus	F-statistic	3.855881	Prob. F(1,319)	0.0504	**
	Obs*R-squared	3.833716	Prob. Chi-Square(1)	0.0502	**
		Change of Interest Rate			
rinthk	F-statistic	52.18827	Prob. F(1,1625)	0	***
	Obs*R-squared	50.62659	Prob. Chi-Square(1)	0	***
rintch	F-statistic	39.41396	Prob. F(1,2054)	0	***
	Obs*R-squared	38.70954	Prob. Chi-Square(1)	0	***
rintus	F-statistic	52.40656	Prob. F(1,1416)	0	***
	Obs*R-squared	50.60758	Prob. Chi-Square(1)	0	***
		Money Supply Growth Rate			
rmshk	F-statistic	10.25092	Prob. F(1,112)	0.0018	***
	Obs*R-squared	9.559068	Prob. Chi-Square(1)	0.002	***
rmsch	F-statistic	4.938848	Prob. F(1,103)	0.0284	**
	Obs*R-squared	4.804378	Prob. Chi-Square(1)	0.0284	**
rmsus	F-statistic	8.680028	Prob. F(1,113)	0.0039	***
	Obs*R-squared	8.203509	Prob. Chi-Square(1)	0.0042	***

(***/ ** / * refers to 0.01, 0.05 and 0.10 significance level respectively).

From the ARCH tests, there was significant evidence to prove that the real GDP growth rate in Hong Kong, China and the USA follows the ARCH effect. This means that the volatility in the real GDP growth rate was clustered and that sometimes the fluctuation in real GDP growth rate was more volatile while sometimes the growth rate was steady. This result matched the findings from the literature reviewed. It showed that the quarterly real GDP growth rate follows the ARCH effect and that the MGARCH model can be built between these three countries.

In the change in inflation rate, Hong Kong and China both exhibited the ARCH effect at the 0.01 level of significance. In contrast, the USA still demonstrates the ARCH effect, but at the 0.05 level of significance.

For the testing of the ARCH effect, all three countries exhibited ARCH effect.

There was significant evidence for the ARCH effect in the change in the interest rate between the three countries. The significance level was smaller than 0.01 which means that the interest rate is very sensitive to news and market movement. There are periods of high volatility and periods of stability. The data used for the interest rate is the three-months daily interbank rate, which was regarded as short-term market interest. It is highly responsive to the demand and supply of fund in the market. The existence of volatility clustering matched findings from other research.

Given the test result, the MGARCH model was built so that the relationship of the interest rate between the countries could be analysed for the volatility spillover effect.

Hong Kong and the USA both exhibit evidence of the ARCH-1 effect in the money supply growth rate at the 0.01 level of significance. As Hong Kong has no proactive monetary policy on money supply, its money supply totally depends on the inflow and outflow of foreign currency. This is highly market oriented. As the HKD is linked with the USD, the money supply in the USA has some effect on Hong Kong's money supply. As detected in the previous section, they are co-integrated. From the ARCH test, they also have a volatility clustering effect. Therefore, the MGARCH model can be used to detect the volatility co-movement between these two countries.

China also exhibited the ARCH-1 effect at the 0.05 level of significance. It showed that the money supply growth rate in China is also market driven. The money supply policy depends on the market environment.

Since all countries demonstrated the ARCH effect in the money supply growth rate, the MGARCH model could be built to detect the volatility spillover effect.

5. RESULTS AND DISCUSSION

The coefficients and diagnostic checking for significance for each pair of bivariate DBEKK-GARCH models were estimated using Eviews 8 (make system function). Some detected lagged terms in the previous step became insignificant in this MGARCH model and were removed.

We used the Bivariate DBEKK-GARCH in this research. For each economic indicator with a significant ARCH effect, Hong Kong was paired with China and the USA respectively to estimate the MGARCH model. The existence of volatility co-movement was diagnostically checked with the standard error function provided by Eviews 8.

Referring to the co-variance equation h_{12} in Equation 1, the significance and estimations of the coefficients a_1, a_2, b_1, b_2 are listed in Table 4 and Table 5 below. If all four estimations were positive and significant, then equation h_{12} would be significant. It fulfilled the assumption of positivity in variance covariance.

Table-4. Result of the volatility spillover effect between Hong Kong and China.

Hong Kong – China	Coefficient	Value	Std. error	z-Statistic	Prob.	Sig.
Log Real GDP	a_1	0.673247	0.148616	4.530096	0	***
	a_2	0.394382	0.071581	5.509615	0	***
	b_1	0.52275	0.213699	2.446199	0.0144	**
	b_2	0.891726	0.028686	31.08541	0	***
Inflation rate	a_1	0.534948	0.098212	5.44685	0	***
	a_2	-0.044404	0.068445	-0.648755	0.5165	Fail
	b_1	0.116421	0.57842	0.201274	0.8405	Fail
	b_2	0.991344	0.003858	256.9747	0	***
3-month Interbank Offer Rate	a_1	0.415871	0.004548	91.44428	0	***
	a_2	3.226755	0.014101	228.8253	0	***
	b_1	0.936851	0.000998	938.9007	0	***
	b_2	0.249875	0.005443	45.90571	0	***
M2 supply	a_1	0.177287	0.088838	1.99563	0.046	**
	a_2	0.60111	0.186358	3.22556	0.0013	***
	b_1	1.009807	0.018521	54.52115	0	***
	b_2	0.706699	0.170375	4.147902	0	***

Source: All data are downloaded from Thomson Reuters DataStream except that China's unemployment rate is downloaded from Wind Terminal and processed by Eviews 8.

Table-5. Result of the volatility spillover effect between Hong Kong and USA.

Hong Kong - USA	Coefficient	Value	Std. Error	z-Statistic	Prob.	Sig.
Log Real GDP	a_1	0.67606	0.143416	4.713975	0	***
	a_2	0.449146	0.108636	4.134397	0	***
	b_1	0.582894	0.200567	2.906234	0.0037	***
	b_2	-0.338695	0.622299	-0.544264	0.5863	Fail
Inflation rate	a_1	0.519635	0.094596	5.493213	0	***
	a_2	0.272034	0.043902	6.196387	0	***
	b_1	-0.199164	0.378733	-0.525869	0.599	Fail
	b_2	0.959682	0.013005	73.79481	0	***
3-month Interbank Offer Rate	a_1	0.359286	0.002934	122.4455	0	***
	a_2	0.768206	0.012113	63.42238	0	***
	b_1	0.953373	0.000648	1471.726	0	***
	b_2	0.843847	0.003243	260.2053	0	***
M2 supply	a_1	0.364741	0.08205	4.445354	0	***
	a_2	0.801575	0.121956	6.57265	0	***
	b_1	0.89513	0.048938	18.29093	0	***
	b_2	0.090773	0.555231	0.163487	0.8701	Fail

Source: All data are downloaded from Thomson Reuters DataStream except that China's unemployment rate is downloaded from Wind Terminal and processed by Eviews 8.

1. GDP Growth Rate

For the Hong Kong-China pairing for the real GDP growth rate, all coefficients in the mean equations were significant at 0.01 level. It was concluded that there is volatility co-movement in the real GDP growth rate between Hong Kong and China.

For the MGARCH model built between Hong Kong and the USA, all coefficients in the mean equations were significant. However, in the conditional variance co-variance equation, b_2 was not significant. It implied that there is no GARCH effect in the co-variance equation h_{12}. This result provided significant evidence that Hong Kong and the USA do not demonstrate any volatility co-movement in the real GDP growth rate.

The result provides a very important conclusion: that the volatility co-movement in the real GDP growth rate is only exhibited between Hong Kong and China, but not between Hong Kong and the USA.

2. Change in Inflation Rate

In the variance co-variance matrix, only a_1 and b_2 were significant. Comparing this estimation to Equation 1, it followed that Hong Kong exhibited the GARCH(1,0) and China exhibited the GARCH(0,1) effect. We also focused on the h_{12} equation. The result showed the insignificance of both the ARCH and GARCH terms. Therefore, there as no evidence to show the existence of any volatility co-movement in terms of the change in the inflation rate between Hong Kong and China.

For the Hong Kong-USA pairing, from the MGARCH model, both coefficients a_1 and a_2 demonstrated a significance at the 0.01 level. It suggested that the volatility in the inflation change rate in Hong Kong appears to have a GARCH effect. However, the insignificance of b_1 implied that there is no volatility spillover between Hong Kong and the USA. The MGARCH model on measuring volatility co-movement between Hong Kong and USA therefore did not need to be created.

In brief, both the Hong Kong-China and Hong Kong-USA pairings could not provide sufficient evidence for any volatility spillover effects relating to the change in the inflation rate. This suggested that the inflation rate change in the three locations had no spillover effects on other countries.

3. Change in Interest Rate

For the Hong Kong-China pairing, from the level of significance of a_1, a_2, b_1 and b_2, the MGARCH model was successfully created. It showed that Hong Kong and China's data both provide evidence of the GARCH effect and a cross correlation between their volatility. Therefore, there is volatility co-movement in the interest rate between Hong Kong and China. Mutual trade (including visible and invisible trade) between Hong Kong and China is very intense. The volatility of changed in short-term market interest rate reflects this situation. The market clearing calendar date effect also has some influence. Some financial products share the same date of maturity in Hong Kong and China. There is a certain level of financial market synchronization in Hong Kong and China's market, e.g. Hong Kong-Shanghai Connect and AH Shares. The co-movement in the volatility of market interest rate was a predictable result.

For the Hong Kong-USA pairing, from the above estimation of the MGARCH model, there was also evidence of the co-movement of volatility in the market interest rate between Hong Kong and the USA. It was shown in the significance of all variables in the variance co-variance equations.

There was an interesting finding in the difference between the COV1_2(-1) (same as b_1b_2) coefficients in the covariance equation h_2 in both pairs. Although both Hong Kong-China and Hong Kong-USA pairings exhibited a valid result, the size of the coefficient was quite different. In the Hong Kong-China pair, it was 0.2341. In the Hong Kong-USA pair, it was 0.8045.

The effect of volatility co-movement was much higher in the Hong Kong-USA pairing because of the fixed exchange rate policy adopted between Hong Kong and the USA. The market interest rate in Hong Kong follows that of the USA. If there are changes in the interest rate in USA, Hong Kong's must react to balance any arbitrary action. The figure showed that around 80% of Hong Kong's short-term interest rate volatility movement follows the USA while around 20% of Hong Kong's follows China. This sensibly captured the financial market action.

4. Change in Money Supply Growth Rate

For the Hong Kong-China pair, in the variance co-variance equations, all estimations were significant at the 0.01 level except for a_1 at the 0.05 level of significance. We concluded that the volatility of money supply growth rate is co-moved between Hong Kong and China. The reason is similar to that for the interest rate. Hong Kong and China are becoming closer in trade and other business activities. Due to the convenience in geographic location and the openness in China's capital market, liquidity flows have surged enormously in the past years. While Hong Kong has no independent monetary policy, the money supply in Hong Kong only depends on the currency board system. It means that when there is inflow of foreign currency into Hong Kong, the money supply will be increased by the same amount of the HKD. Therefore, the monetary policy in China largely affects the money supply in Hong Kong when the economic activities between these two countries are rigorous. This empirical result reflects the economic situation between Hong Kong and China. In the Hong Kong-USA pairing, the result was not as satisfactory as in the Hong Kong-China pairing. The estimation of b_i was not significant, leading to the failure to model the GARCH effect in the USA's money supply growth rate itself and its cross GARCH with Hong Kong. Therefore, no DBEKK-GARCH model could be significantly set up on the money supply growth rate between Hong Kong and the USA.

As a result, the contrast between the two pairs of MGARCH model provides important evidence that the volatility spillover effect in the money supply growth rate is revealed only in the Hong Kong-China pairing but not in the Hong Kong-USA pairing. It proved that China has exerted a large volatility spillover effect on Hong Kong's money supply.

6. CONCLUSIONS

The volatility spillover effects for the five economic indicators are listed in Table 6 below.

Table-6. Summary of the result of volatility co-movement (spillover) between countries.

Economic Indicators	Hong Kong-China	Hong Kong-USA
Real GDP growth rate	Yes	No
Change in inflation rate	No	No
Change in market interest rate	Yes	Yes
Money supply growth rate	Yes	No

Source: All data are downloaded from Thomson Reuters DataStream except that China's unemployment rate is downloaded from Wind Terminal and processed by Eviews 8.

For the measurements between Hong Kong and China, the real GDP growth rate, change of market interest rate and money supply growth rate all show volatility co-movement. It reflects that the volatility of the economic growth rate of both countries is affecting each other. This is because China is the biggest trade partner of Hong Kong and the export and import industry contributes 25% of Hong Kong's GDP. Over 60% of Hong Kong trade is determined by China, and the econometric analysis reflected this important relationship between Hong Kong and China. The result of the short-term market interest rate showed an interesting finding. The three-month interbank offer rate is determined by the market demand and supply for money. It is affected by short-term business and financial activities. Since China is Hong Kong's biggest business partner in both the real sector and financial sector, it is clear that Hong Kong and China are forming a bigger Chinese economic region. Hong Kong is acting as China's fund raising market. Therefore, their short-term movement is inter-related. This relationship reflected the co-movement of volatility. The result of money supply was valuable. Hong Kong has no active monetary policy. The money supply in Hong Kong is 100% affected by the inflow and outflow of foreign currency. If there is money inflow, more HKD will be issued, and vice versa. There is evidence of volatility spillover from China to Hong Kong, but not in the Hong Kong-USA pairing. It therefore showed that the money supply in China affects Hong Kong both in the short-term and long-term, while the USA's money supply has no short-term effect on Hong Kong.

From the empirical findings, it was concluded that there is more economic integration between Hong Kong and China than between Hong Kong and the USA. More variables were found to have a volatility spillover effect between Hong Kong and China. This research is valuable for policy researchers on formulating the economic development policy and monetary policy of Hong Kong. In particular, Hong Kong's current fixed exchange rate system in pegging the Hong Kong Dollar with the US Dollar may need to be re-evaluated in its suitability under Hong Kong's current economic structure.

Funding: This study received no specific financial support.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

REFERENCES

Antonakakis, N. and H. Badinger, 2012. International spillovers of output growth and output growth volatility: Evidence from the G7. International Economic Journal, 26(4): 635-653.Available at: https://doi.org/10.1080/10168737.2011.631025.

Beirne, J., G.M. Caporale, M. Schulze-Ghattas and N. Spagnolo, 2010. Global and regional spillovers in emerging stock markets: A multivariate GARCH-in-mean analysis. Emerging Markets Review, 11(3): 250-260.Available at: https://doi.org/10.1016/j.ememar.2010.05.002.

Bollerslev, T., 1990. Modelling the coherence in short-run nominal exchange rates: A multivariate generalized ARCH model. Review of Economics and Statistics, 72(3): 498-505.Available at: https://doi.org/10.2307/2109358.

Bollerslev, T., R. Engle and J. Wooldridge, 1988. A capital asset pricing model with time-varying covariances. Journal of Political Economy, 96(1): 116-131.Available at: https://doi.org/10.1086/261527

Engle, R., 1982. Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. Econometrica: Journal of the Econometric Society, 50(4): 987-1007.Available at: https://doi.org/10.2307/1912773.

Engle, R. and K. Kroner, 1995. Multivariate simultaneous generalized ARCH. Econometric Theory, 11(1): 122-150.Available at: https://doi.org/10.1017/s0266466600009063.

Fang, W., S.M. Miller and C. Lee, 2008. Cross-country evidence on output growth volatility: Nonstationary variance and GARCH models. Scottish Journal of Political Economy, 55(4): 509-541.Available at: https://doi.org/10.1111/j.1467-9485.2008.00464.x.

Giles, D. and Y. Li, 2015. Modelling volatility spillover effects between developed stock markets and Asian emerging stock markets. International Journal of Finance & Economics, 20(2): 155-177.Available at: https://doi.org/10.1002/ijfe.1506.

Hai, V.T., A.K. Tsui and Z. Zhang, 2013. Measuring asymmetry and persistence in conditional volatility in real output: Evidence from three East Aisan tigers using multivariate GARCH approach. Applied Economics, 45(20): 2909-2914.Available at: https://doi.org/10.1080/00036846.2012.687098.

Harvie, C., A. Valadkhani and I. Karunanayake, 2013. Global output growth and volatility spillovers. Applied Economics, 45(5): 637-649.Available at: https://doi.org/10.1080/00036846.2011.608648.

Janiga-Ćmiel, A., 2013. Detecting shocks in the economic development dynamics of selected countries. Leaves of Economic Stetinensis, 13(2): 120-133.Available at: https://doi.org/10.2478/foli-2013-0018.

APPENDICES

Appendix-1. Significance of the Lagged Length of Each Variable in the Mean Equation of the MGARCH model.

Economic Indicators	Lagged Terms	Coefficient	Std. Error	t-Statistic	Prob.	Significance
			Real GDP growth rate			
Hong Kong (RHK)	C	0.01143	0.002806	4.072928	0.0001	***
	RHK(-2)	-0.308722	0.065085	-4.743341	0	***
	RHK(-4)	0.640344	0.065084	9.838749	0	***
	RHK(-5)	-0.259788	0.064952	-3.999695	0.0001	***
	RHK(-7)	-0.278254	0.064919	-4.286174	0	***
China (RCH)	C	0.033042	0.010481	3.15253	0.0021	***
	RCH(-1)	-0.215032	0.064978	-3.309322	0.0013	***
	RCH(-2)	-0.209891	0.064565	-3.250824	0.0016	***
	RCH(-3)	-0.214679	0.064646	-3.320846	0.0012	***
	RCH(-4)	0.746423	0.064193	11.62777	0	***
USA (RUS)	C	0.004204	0.000808	5.200063	0	***
	RUS(-2)	0.344687	0.091157	3.781225	0.0003	***
			Change of Inflation Rate			
Hong Kong (RHK)	C	-0.004522	0.03695	-0.122381	0.9027	
	RHK(-4)	0.144174	0.048367	2.980808	0.0031	***
	RHK(-12)	-0.517708	0.04808	-10.76764	0	***
China (RCH)	C	-0.013195	0.042211	-0.312591	0.7548	
	RCH(-1)	0.364926	0.051103	7.141035	0	***
	RCH(-2)	0.239356	0.050928	4.699895	0	***
	RCH(-12)	-0.293489	0.043748	-6.708595	0	***
US (RUS)	C	-0.005733	0.017048	-0.336255	0.7369	
	RUS(-1)	0.358738	0.043328	8.279588	0	***
	RUS(-12)	-0.498164	0.042727	-11.6592	0	***
			Change of Interest Rate			
Hong Kong (RHK)	C	-0.000954	0.000612	-1.558797	0.1192	
	RHK(-1)	0.272326	0.022749	11.97078	0	***
China (RCH)	C	0.000104	0.000178	0.584665	0.5588	
	RCH(-1)	0.496166	0.019754	25.1169	0	***
	RCH(-3)	0.109675	0.022456	4.883885	0	***
	RCH(-4)	0.068267	0.022018	3.100568	0.002	***
USA (RUS)	C	-0.000279	0.000272	-1.024931	0.3056	
	RUSA(-1)	0.407604	0.02619	15.56321	0	***
	RUSA(-2)	0.051028	0.028985	1.76051	0.0785	*
	RUSA(-3)	0.081116	0.027417	2.958647	0.0031	***
	RUSA(-5)	0.076159	0.028201	2.700557	0.007	***
	RUSA(-6)	0.153114	0.029944	5.113371	0	***
			Money Supply Growth Rate			
Hong Kong (RHK)	C	0.010141	0.001916	5.291408	0	***
	RHK(-2)	-0.202302	0.091567	-2.209338	0.0292	**
China (RCH)	C	0.004279	0.001776	2.409501	0.0177	**
	RCH(-3)	0.172728	0.086856	1.988669	0.0494	**
	RCH(-12)	0.475909	0.088919	5.352187	0	***
USA (RUS)	C	0.001943	0.000503	3.865356	0.0002	***
	RUS(-1)	0.448753	0.083223	5.392145	0	***

(***/ ** / * refers to 0.01, 0.05 and 0.10 significance level respectively).
The prefix of the variable name rgdp, rinf, rint and rms represents the four returns of the economic indicators real GDP growth rate, change of inflation rate, change of unemployment rate, change of interest rate and money supply growth rate respectively; the suffix hk, ch and us represents Hong Kong, China and USA respectively.