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RETURN AND VOLATILITY SPILLOVERS IN HONG KONG FINANCIAL MARKETS

Key Points:

- *This paper studies the return and volatility spillovers between the stock market, the Exchange Fund Notes market and the Hong Kong dollar forward exchange market.*

- *Based on a bivariate GARCH model that specifies exogenous influences in the conditional mean and variance equations, this study examines the source and magnitude of the return and volatility spillover between financial markets.*

- *The estimation results suggest that while the pattern of return spillover is not clear, there is some evidence of volatility transmissions between selected financial markets in Hong Kong. In terms of the economic impact, however, most of these spillovers are minimal.*

- *When financial markets are turbulent, the return spillover from the forward exchange market to the stock market and the volatility transmission from the forward exchange market to the Exchange Fund Notes market can be substantial. As such, close monitoring of the fluctuations in the forward exchange market is warranted.*

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I. INTRODUCTION

Financial market volatility affects real economic activity and the proper functioning of financial markets. It is therefore an important subject for policy makers who are responsible for market stability. In previous studies, we have presented the stylised facts of asset volatility in Hong Kong financial markets and the linkages between them (RM15/2003 and RM19/2003). This paper addresses spillover effects across different financial assets.

The spillover or contagion effect across financial assets has been the focus of much interest from academics and financial market regulators in recent years. Many of the empirical and theoretical studies on the relationship between different assets concentrate on the spillovers between economies.[1] Few studies examine the spillover between financial markets within an economy.[2] This study aims to augment the understanding of the spillover transmission in financial markets within an economy by examining both the return and volatility spillovers between the stock market, the Exchange Fund Notes market and the Hong Kong dollar forward exchange market.

There are several reasons for studying the transmission of return and volatility across various financial markets in Hong Kong. To investment professionals, the study on the volatility spillover and correlation between returns in different markets can provide information useful for asset allocation and risk management purposes. To policy makers, the results may be useful for assessing financial market stability and to help monitor risk. For instance, if volatility spillovers are significant between markets, a shock emanating from one market may have a destabilising impact on other markets. This could amplify the extent and magnitude of the original shock and may threaten the financial system.[3] As such, it is important that policy makers understand the return and volatility spillovers between financial markets.

To determine the spillover of returns and volatility between financial markets, a bivariate GARCH model that allows for exogenous influences of one market on

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1 For example, Lin et al. (1994) focus on equity markets, while Engle et al. (1990) and Fleming and Lopez (1999) concentrate on the foreign exchange market and the US Treasury market respectively.

2 A few examples include Fleming et al. (1998), Darbar and Deb (1999) for the US, and Ebrahim (2000) for Canada.

3 Yu and Fung (2003) show that the correlation between volatility movements of local financial markets is positive in general. This positive relationship tends to be stronger during crises, suggesting that the benefit of risk diversification by investing in different domestic financial markets is limited. Furthermore, based on a regime switching ARCH model, Fung and Yu (2003) find strong volatility co-movement between Hong Kong financial markets, and the average of a stay in a high-volatility state for a pair of financial markets is found to be between five and seven weeks. For a major shock such as the Asian financial crisis, the duration is at least six months.

the others is specified. Estimation results from this specification provide information on both the source and magnitude of the spillovers.

The paper is organised as follows. Section II introduces the bivariate GARCH model and discusses its specification in detail. Section III examines the financial market data and in particular the characteristics of the return and volatility of each asset in this study. Empirical results on the spillover effect from the bivariate GARCH model are presented and discussed in section IV. Conclusions are provided in the final section.

II. Model Specification

Earlier studies on the transmission of volatility relied on the so-called two-stage univariate GARCH approach. Under this approach, two GARCH models, a base model and a spillover model, are specified for each market under study. To examine the spillover effect from market A to market B, the base model of market A is estimated first in order to obtain a time series of squared residuals. This series is then treated as the volatility term and included in the spillover model of market B in the subsequent estimation. An alternative approach is based on multivariate GARCH models which take into account the observation that many financial variables share and react to the same information set or shocks. Thus, the covariance terms between markets conditional on the information set or shocks will generally be non-zero.[4]

In this study, a bivariate GARCH model (which is the simplest example of a multivariate GARCH model) is employed and modified to estimate the return and volatility spillovers between financial markets in Hong Kong.[5] Let $y_{i,t}$ represents the

[4] Issues of computational feasibility and high dimensionality arise when estimating multivariate models. A model with a large number of parameters is often intractable in empirical estimation.

[5] In a simple bivariate GARCH model, the conditional mean equations under an AR(1) framework are

$$y_{1,t} = w_{10} + w_{11} y_{1,t-1} + \varepsilon_{1,t}$$
$$y_{2,t} = w_{20} + w_{22} y_{2,t-1} + \varepsilon_{2,t}$$

where the residual terms are distributed as N (0, H_t). In a diagonal representation, the 2 x 2 conditional variance-covariance matrix H_t under a GARCH (1,1) specification is given by

$$H_t = \begin{bmatrix} h_{11,t} \\ h_{12,t} \\ h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} \\ c_{12} \\ c_{22} \end{bmatrix} + \begin{bmatrix} \alpha_{11} & 0 & 0 \\ 0 & \alpha_{12} & 0 \\ 0 & 0 & \alpha_{22} \end{bmatrix} \begin{bmatrix} \varepsilon^2_{1,t-1} \\ \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon^2_{2,t-1} \end{bmatrix} + \begin{bmatrix} \beta_{11} & 0 & 0 \\ 0 & \beta_{12} & 0 \\ 0 & 0 & \beta_{22} \end{bmatrix} \begin{bmatrix} h_{11,t-1} \\ h_{12,t-1} \\ h_{22,t-1} \end{bmatrix}$$

or

$$h_{11,t} = c_{11} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11} h_{11,t-1}$$
$$h_{22,t} = c_{22} + \alpha_{22}\varepsilon^2_{2,t-1} + \beta_{22} h_{22,t-1}$$
$$h_{12,t} = c_{12} + \alpha_{12}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{12} h_{12,t-1}$$

return from a financial market i at time t. In a two-market case, the conditional return spillover under a first-order autoregressive AR(1) framework is defined as:

$$y_{1,t} = w_{10} + w_{11} y_{1,t-1} + w_{12} y_{2,t-1} + \varepsilon_{1,t}$$
$$y_{2,t} = w_{20} + w_{22} y_{2,t-1} + w_{21} y_{1,t-1} + \varepsilon_{2,t} \qquad (1)$$

where the error terms $\begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix}$ are distributed as N (0, H_t). From equation 1, the return spillover from another market is measured by the parameters w_{12} and w_{21}.

The conditional variance-covariance matrix H_t of the error terms is used to capture the volatility spillover between markets. In this study, the matrix H_t is structured as:

$$h_{11,t} = c_{11} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11} h_{11,t-1} + \gamma_{11}\varepsilon^2_{2,t-1}$$
$$h_{22,t} = c_{22} + \alpha_{22}\varepsilon^2_{2,t-1} + \beta_{22} h_{22,t-1} + \gamma_{22}\varepsilon^2_{1,t-1} \qquad (2)$$
$$h_{12,t} = c_{12} + \alpha_{12}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{12} h_{12,t-1} + \gamma_{12} h_{12,t-1}$$

Under this specification, one period lagged shocks in one market are included in the conditional variance equation of the other and the volatility spillover is measured by the parameters γ_{11} and γ_{22}.[6] The parameters in this bivariate GARCH model are estimated by numerically maximising the log likelihood function using the Broyden, Fletcher, Goldfarb and Shanno (BFGS) algorithm.[7]

The use of the bivariate GARCH model with the return and volatility spillovers specified in the conditional mean and variance equations has several advantages over the two-stage approach. First, the bivariate model takes into account cross-market dynamics.[8] Secondly, there are efficiency gains as parameters are estimated concurrently based on the same information set. Thirdly, compared to other approaches, the spillover effect can be directly estimated from the specification of the transmission mechanism in this model.[9]

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[6] Similar specifications have been applied by Alaganar and Bhar (2001) among others to the Australian equity market.

[7] The BFGS algorithm is described in Press et al. (1988).

[8] The use of a bivariate model is common in spillover studies. Despite its popularity, it should be noted that the bivariate model can only estimate two markets at a time. Thus, cross-market dynamics from a third market cannot be captured by this model.

[9] While the specification in this setup is easy to interpret, it cannot ascertain whether the shock in one market is directly caused by the volatility of another market or due to other common shocks. In addition, the possibility of structural breaks or regime switches in the volatility process is not accounted for in the model. Therefore, the final results from the analysis should be interpreted with caution.

III. THE DATA AND PRELIMINARY ANALYSES

Weekly data for the stock market return (represented by the log differences of the Hang Seng Index), the holding return for 10-year Exchange Fund Notes and the percentage change of 12-month Hong Kong dollar forward exchange rate per US dollar are used.[10] The data set for the Exchange Fund Notes spans from November 1996 to March 2003, while that of other markets starts from January 1990.

Table 1 presents descriptive statistics for the data. In general, all the series are skewed and have fat tails. The significant Jarque-Bera statistics reject the hypothesis that the data are normally distributed. Test statistics from the augmented Dickey-Fuller (ADF) unit root test indicate that all the series are stationary. The Q statistic stems from a Ljung-Box test for autocorrelation with lags up to the 6th order. The significant Q (6) and Q^2 (6) statistics provide evidence of serial correlation in the level and in the squared level respectively. These suggest the presence of autoregressive conditional heteroskedasticity (ARCH) in all the series and justify the use of an AR(1) term in the conditional mean equation.

[10] The approximation for the weekly holding period return for Exchange Fund Notes is based on Shiller (1979). For bonds selling at or near par value, Shiller suggests an approximate expression for the *n*-period holding period return $H_t^{(n)}$, where $H_t^{(n)} = (R_t^{(n)} - \gamma_n R_{t+1}^{(n-1)})/(1-\gamma_n)$, $\gamma_n = \gamma(1-\gamma^{n-1})/(1-\gamma^n)$, $\gamma = 1/(1+\overline{R})$, $R_t^{(n)}$ is the yield to maturity and $\overline{R}$ is the mean value of the yield to maturity.

Table 1. Summary Statistics for the Weekly Returns of Hong Kong Financial Markets

	Stock Market (in % return)	**Exchange Fund Notes Market** (in % return)	**Forward Exchange Market** (in % change)
Mean	0.16	0.20	0.00
Maximum	13.92	5.68	2.92
Minimum	-19.92	-8.91	-2.41
Std.Dev.	3.67	1.48	0.30
Skewness	-0.39	-0.81	1.60
Kurtosis	5.65	9.69	32.33
Jarque-Bera	222.14	662.62	25,391.34
ADF statistics	-25.89*	-17.72*	-28.00*
Q (6)	7.90	12.18^{+}	28.85*
Q^2 (6)	20.56*	28.34*	111.25*
Observations	700	336	700

Notes: * denotes coefficient significant at the 5% level. $^{+}$ denotes coefficient significant at the 10% level. The Jarque-Bera statistic has a χ^2 distribution with two degrees of freedom under the null hypothesis of normally distributed errors. The critical value of χ^2 (2) at the 5% level is 5.99. The critical ADF value at the 5% level is –2.87. Q (6) and Q^2 (6) are the Ljung-Box statistics based on the levels and the squared levels of the time series respectively up to the 6th order. Both statistics are asymptotically distributed as χ^2 (6). The critical value of χ^2 (6) at the 5% and the 10% level is 12.59 and 10.64 respectively.

Table 2 gives the estimation results under a univariate GARCH specification. The estimated coefficients of ARCH (α) and GARCH (β) effects are highly significant for each asset. The sum of ARCH and GARCH coefficients ($\alpha + \beta$) is close to or larger than one, suggesting that shocks to the conditional variance are highly persistent. This implies that disturbances that occurred in the distant past continue to have impact on current volatility. In the next section, the model is extended to a bivariate GARCH specification in order to examine the spillover effect between the markets.

Table 2. Parameter Estimates of a Univariate GARCH Model

Model: $y_t = w_0 + w_1 y_{t-1} + \varepsilon_t$, $\varepsilon_t \sim N(0, \sigma_t^2)$
$\sigma_t^2 = c_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$

	Stock Market	**Exchange Fund Notes Market**	**Forward Exchange Market**
w_0	0.303*	0.177*	-0.006
	(0.124)	(0.068)	(0.006)
w_1	0.021	0.058	-0.165*
	(0.039)	(0.074)	(0.080)
c_0	0.273	0.096	0.001
	(0.158)	(0.072)	(0.001)
α_1	0.078*	0.068*	0.493
	(0.031)	(0.034)	(0.303)
β_1	0.905*	0.890*	0.638*
	(0.035)	(0.051)	(0.114)
$\alpha_1 + \beta_1$	0.983	0.958	1.131
Log Likelihood	-1,860	-579	367
Q (6)	7.64	4.32	3.21
Q^2 (6)	2.17	0.85	1.21

Notes: Numbers in parentheses are standard errors. * denotes coefficient significant at the 5% level. Q (6) and Q^2 (6) are the Ljung-Box statistics based on the standardised residuals and the squared standardised residuals respectively up to the 6^{th} order. Both statistics are asymptotically distributed as χ^2 (6). The critical value of χ^2 (6) at the 5% level is 12.59.

IV. ESTIMATION RESULTS

The bivariate GARCH model is modified to incorporate the return and volatility spillovers as specified in equations 1 and 2. Table 3 presents the estimation results and a summary of the spillover analysis is reported in Table 4. Specification tests in terms of the Q (6) and Q^2 (6) statistics indicate that the series are adequately modeled without any serial correlation or ARCH effect.

Table 3. Parameter Estimates of the Bivariate GARCH Model with Return and Volatility Spillovers

Model: $y_{1,t} = w_{10} + w_{11} y_{1,t-1} + w_{12} y_{2,t-1} + \varepsilon_{1,t}$

$$y_{2,t} = w_{20} + w_{22} y_{2,t-1} + w_{21} y_{1,t-1} + \varepsilon_{2,t}, \quad [\varepsilon_{1,t} \ \ \varepsilon_{2,t}]' \sim N\left(0, \begin{pmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{pmatrix}\right)$$

$$h_{11,t} = c_{11} + \alpha_{11}\varepsilon^2_{1,t-1} + \beta_{11} h_{11,t-1} + \gamma_{11}\varepsilon^2_{2,t-1}$$

$$h_{22,t} = c_{22} + \alpha_{22}\varepsilon^2_{2,t-1} + \beta_{22} h_{22,t-1} + \gamma_{22}\varepsilon^2_{1,t-1}$$

$$h_{12,t} = c_{12} + \alpha_{12}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \beta_{12} h_{12,t-1} + \gamma_{12} h_{12,t-1}$$

	Stock – Exchange Fund Notes	**Forward Exchange – Exchange Fund Notes**	**Stock – Forward Exchange**
w_{11}	-0.018	-0.020	-0.060
	(0.069)	(0.070)	(0.042)
w_{12}	0.389	-0.002	-1.720*
	(0.205)	(0.007)	(0.377)
w_{22}	0.085	0.039	-0.196*
	(0.070)	(0.081)	(0.048)
w_{21}	-0.044*	0.034	-0.001
	(0.017)	(0.324)	(0.001)
α_{11}	0.148	0.809*	0.057*
	(0.098)	(0.071)	(0.021)
α_{22}	0.257*	0.384*	0.521*
	(0.075)	(0.076)	(0.017)
β_{11}	0.322	0.503*	0.917*
	(0.176)	(0.019)	(0.032)
β_{22}	0.615*	0.403*	0.651*
	(0.075)	(0.059)	(0.009)
γ_{11}	0.009	0.001*	0.522
	(0.279)	(0.000)	(0.934)
γ_{22}	-0.006	1.465*	0.000*
	(0.004)	(0.705)	(0.000)
Log likelihood	-899	214	-156
$Q_1(6)$	2.61	3.68	2.78
$Q_2(6)$	0.71	4.22	6.98
$Q_1^2(6)$	6.76	1.42	3.11
$Q_2^2(6)$	0.49	1.44	1.75

Notes: Estimates of the constant and covariance terms are not reported in the table. Numbers in parentheses are standard errors. * denotes coefficient significant at the 5% level. Q (6) and Q^2 (6) are the Ljung-Box statistics based on the standardised residuals and the squared standardised residuals respectively up to the 6th order. Both statistics are asymptotically distributed as $\chi^2(6)$. The critical value of $\chi^2(6)$ at the 5% level is 12.59.

Table 4. Summary Results from the Bivariate GARCH Model with Return and Volatility Spillovers (from Table 3)

Source Market	Recipient Market	Return Spillover (w_{12}, w_{21})	Volatility Spillover (γ_{11}, γ_{22})
From	**To**		
Exchange Fund Notes	Stock	No	No
Stock	Exchange Fund Notes	Yes*	No
Exchange Fund Notes	Forward	No	Yes*
Forward	Exchange Fund Notes	No	Yes*
Forward	Stock	Yes*	No
Stock	Forward	No	Yes*

Note: * denotes coefficient significant at the 5% level.

In general, the return from one market does not have any significant impact on that of another market as most of the estimated coefficients for measuring the spillover effect (w_{12} and w_{21}) are either economically or statistically insignificant. The only case in which a return spillover is significant is found between the forward exchange market and the stock market.[11] As shown in Table 3, the return of the forward exchange market is found to have a negative impact on the stock market in the next period. Thus, a weakening of the Hong Kong dollar forward exchange rate in the current period may lead to a fall in the stock market in the next week.[12] Regarding the magnitude of the impact, a one percent increase in the Hong Kong dollar forward exchange rate is estimated to cause the stock market to decline by 1.7% over the following week. Under normal circumstances, the weekly Hong Kong dollar forward exchange rate is not expected to change drastically. It is therefore unlikely that the forward exchange market would have any material impact on the stock return.[13]

There are three cases of statistically significant volatility spillover between financial markets. From Table 3, all of these spillover effects (which are captured by γ_{11} and γ_{22}) are positive, indicating that shocks to one market increase the conditional

[11] Although the stock market return is also found to have a statistically significant effect on that of the Exchange Fund Notes market, its economic impact is limited. From the estimated coefficient, a 1% rise in the stock market return this week is associated with a 0.04% fall in the Exchange Fund Notes market return in the coming week. In the most extreme case when the Hong Kong stock market fell by almost 20% in a week (the largest weekly % drop in the data, as given by the minimum value in Table 1), the return on the Exchange Fund Notes might increase by less than 1% in the following week.

[12] Since common shocks are not incorporated into the model and the reaction of the money market may also has an impact on both the forward exchange and stock markets, this cause-effect relationship should be interpreted with caution and taken as an indication only.

[13] In Table 1, the mean return in the forward exchange market is 0.003% in the study period. However, under the most extreme case when the Hong Kong dollar forward exchange rate could rise by 2.9% (the maximum weekly % change of the forward exchange market) during the Asian financial crisis, the change might cause the stock market to drop by almost 5% over the following week.

variance of another in the next period. Nevertheless, in terms of the economic impact, the volatility spillover between these markets appears to be minimal. The only exception is the one from the forward exchange market to the Exchange Fund Notes. In this case, a 1% increase in the volatility of the forward exchange market is estimated to raise that of the Exchange Fund Notes by 1.5%. During turbulent times when the forward exchange market may fluctuate significantly, the volatility transmitted to the Exchange Fund Notes market can thus be substantial.[14]

IV. CONCLUSION

It is important for policy markets to understand the dynamics of financial market spillovers. The analysis in this paper contributes to this subject by assessing the return and volatility spillovers between financial markets in Hong Kong. In particular, based on data from the stock market, the forward exchange market and the Exchange Fund Notes market, the analysis sheds light on the source and magnitude of such spillovers.

Estimation results from a modified bivariate GARCH model indicate that the return spillover effect between Hong Kong financial markets is generally not found to be clear cut. However, under an extreme case such as the Asian financial crisis, the impact from the forward exchange market to the stock market can be substantial. On the other hand, while there is some evidence of volatility transmission between selected financial markets, the economic impact of most of these spillovers is limited. The only exception is the link between the forward exchange market and the Exchange Fund Notes market for which the impact is estimated to be significant. Subject to the limitations of the model, the analysis suggests that close monitoring of the fluctuations in the forward exchange market is warranted.

[14] In Yu and Fung (2003), the volatility of the forward exchange market could be as high as 0.9% during the Asian financial crisis. This could raise the volatility of the Exchange Fund Notes market by an additional 1.4%.

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