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Correlation dynamics in East Asian financial markets

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Abstract

This paper examines the dynamic relationship between stock returns and exchange rate changes using daily data from January 3, 1994–September 27, 2013 for six East Asian countries: Indonesia, Malaysia, the Philippines, Singapore, South Korea and Thailand. We estimate conditional correlations using the multivariate GARCH-DCC model in order to disclose the relationship between stock markets and foreign exchange markets. This is important for understanding financial stability. The estimation results reveal time varying correlations in the pre and post Asian crisis and the Global Financial Crisis periods for all countries. The correlations are stronger when the crisis intensifies. The degree of interdependence between both markets reflects a mutually markets response to shocks and changes in policy.

Keywords: stock market, foreign exchange market, currency crisis, dynamic conditional correlation, interdependence

JEL-code: C32, F31, F37, G15

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1 Introduction

Over the last decades, financial stability has been at the top of the agenda of many central banks and financial supervising authorities around the world. The dramatic increase in the number of financial crises and the serious adverse economic and social effects in the wake of the crises seems to be one of the main reasons. Although there is still no widely accepted definition of financial stability, many economists confirm that some degree of asset price stability is required for a condition of financial stability (Allen and Wood, 2006; Dattels et al., 2010; IMF, 2012). Interrelations between asset markets reflect the process of pricing and transferring risk that have a potential to undermine financial stability. Moreover, identifying interrelations between asset markets sheds light on some widely debated spillovers to the financial system amplified and transferred by shocks.

In this paper, we focus on interrelations between the returns on the stock market and the market for foreign exchange in six East Asian countries in the period before, during and after the Asian financial crises in the period 1997–1998 and the Global Financial Crisis in 2008–2009 that originated in the United States. Since the growing significance of the Asian share in world trade and capital mobility, and the rapid growth in their domestic market capitalization over the past few decades (see Kohsaka, 2004), Asian financial markets has prompted researchers, policy makers as well as analysts to carry out detailed analysis of the relationship between the stock market and the exchange rate market. The importance of modeling currency and equity markets simultaneously is supported by Dungey and Martin (2007), Lin (2012) and Tsai (2012). Rapidly increasing international equity investments creates a higher supply and demand for currencies, leading to some degree of interdependence between both markets. The wide fluctuations in the value of the currencies heightened the interest in the potential vulnerability of internationally active firms to foreign exchange risk. Moreover, positive spillovers of volatility between both markets may increase the international portfolio risk faced by international investors. This reduces the opportunities from international diversification and disturbs the asset allocation decisions. Therefore,

the relationship between stock and foreign exchange markets is important to investigate especially in the case of highly volatile and unstable markets, that are typical of emerging economies.

In an effort to shed light on how conditional correlations between the stock market and the foreign exchange market evolve over time we employ the class of multivariate GARCH models developed by Engle (2002). This dynamic conditional correlation (DCC) model has a number of advantages over alternative models. Unlike most studies in the literature that estimate the contemporaneous relationship among time series, this model enables us to explore the dynamic relationship between the financial markets. An additional advantage is that we do not have to split the sample in non-crisis and crisis periods as in most static models of contagion. Nor do we have to impose restrictions on the conditional variance system—as in Caporale et al. (2005)—in order to identify the model. In addition, many straightforward multivariate extensions of the univariate GARCH model are often not parsimonious since the number of parameters to be estimated is increasing rapidly as the number of assets included grows. This is a serious shortcoming of these models, but of the DCC model. To our knowledge there are only a few studies using the DCC model to investigate the links between the stock market and the foreign exchange market in the Asian countries. An example is Kuper and Lestano (2007) who focus on Thailand and Indonesia only. This paper extends their analysis to more East Asian countries.

The remainder of the paper is organized as follows. The next section discusses the theoretical and empirical studies on the relationship between exchange rate fluctuations and stock returns. Section 3 briefly discusses the multivariate GARCH and DCC models. Section 4 presents the properties of stock and foreign exchange rate markets data in our sample. Estimation results are presented in Section 5. The implications are discussed in Sections 6 and 7. Section 8 summarizes the main conclusions.

2 A survey of the literature

2.1 Theoretical studies

The association between the movements in exchange rates and stock prices has long been an unresolved issue in the finance literature.¹ Theoretical models arrive at different conclusions about the causality between the two financial markets and the sign of their correlations. The portfolio balance model, developed by Branson (1983), Frankel (1983) and others, expects the stock prices to effect exchange rates. An increase in stock returns due to higher stock prices raises domestic wealth, which in turn leads to higher domestic demand for money and interest rates. The higher interest rates encourage capital inflows, leading to an appreciation of the domestic currency. This finding is supported by Gavin (1989) and Zapatero (1995).²

An alternative explanation for the relationship between stock prices and exchange rates is provided by the so-called traditional approach, like the model of Dornbusch and Fischer (1980). In this view, exchange rates affect stock prices positively. A depreciation of the domestic currency increases international competitiveness and therefore improves the current account. Consequently, rising real output in turn positively influences the profitability and the value of firms, and therefore their stock prices. The response of stock prices to fluctuations in the exchange rate depends on their degree of exposure to exchange rate risks through channels like the degree of openness both in international trade and international capital mobility, the degree of foreign competition for firms with no international business activity and the degree of competition for factors of production (Dominguez and Tesar, 2001). Some theoretical studies using exchange rate exposure models reach the same conclusion as Dornbusch and Fischer (1980). For instance, Hekman (1985) proposes a present value based financial valuation model for multinational firms, in which the exchange rate is a leading indicator of the stock price.

¹There are many papers that focus on, for instance, asset markets only. Recent examples are Hartmann et al. (2004) and Crouzille et al. (2008).

²Gavin (1989) provides a model in which stock market innovations have an impact on the exchange rate, while Zapatero (1995) shows that the volatility of the exchange rate is explained by the volatility of the indices of stock markets in fully integrated markets.

Sercu and Vanhulle (1992) explore the impact of exchange rate volatility on the market value of firms and conclude that an increase in exchange rate volatility has a positive effect on the market value of firms. Finally, Pavlova and Rigobon (2007) develop a model to show that asset prices and exchange rates interact with each other. They are able to characterize the transmission mechanism and the dynamic behavior of asset prices and exchange rates.

The events of the emerging market financial crisis of the 1990s motivated many economists to explain how exchange rate movements can affect emerging market firms through the foreign-currency debt on their balance sheets. Bordo with various co-authors studied financial crises from a macroeconomic viewpoint. Examples are Bordo and Schwartz (1996) and Bordo and Eichengreen (1999), Bordo et al. (2001) and Bordo (2003). Aghion et al. (2000, 2001, 2004) argue that if domestic firms hold a lot of foreign currency dominated debt, then output reacts negatively to an increase in the debt burden induced by a sharp currency depreciation. A deterioration of the net worth of firms—which resulted in many bankruptcies and loan defaults—is a primary cause of a sharp decline in lending and economic contraction. Moreover, countries with a less developed financial system are more prone to an output decline after an exchange rate shock. Calvo (2001, 2002) and Cristina and Jonathan (2010) reach similar conclusions, but they emphasize that the prevalence of foreign-currency liabilities in emerging markets limits the desirability of flexible exchange rates.

2.2 Empirical studies

In line with theoretical expectations, empirical research on the existence of a relationship between stock prices and exchange rates appears conflicting, and is mixed at best. An extensive range of empirical studies employ various statistical and econometric methods to provide evidence for a link between the two financial markets. These studies use different time spans, different frequencies of data, different geographical coverage, and different levels of the analysis: firm level, industry level or national level. In this overview we focus on research applied to Asian countries.

Some recent studies use the concept of Granger causality and cointegration techniques to examine interactions between stock and foreign exchange markets in Asia. Granger et al. (2000), among others, apply unit root tests and cointegration models to determine the appropriate Granger-causal relations between stock prices and exchange rates using recent data for nine East Asian countries. During tranquil periods, that is before and after the Asian financial crisis 1997-1998, the results reveal no definitive pattern of interaction between the two markets. However, there exists an interaction between the two markets during Asian crisis. In the case of South Korea, changes in the exchange rates lead that in stock prices. The reverse direction is found for Hong Kong and the Philippines. The other markets (Malaysia, Singapore, Thailand, and Taiwan) are characterized by bi-causal interactions. Using a similar methodology and sample of countries, Ramasamy and Yeung (2005) reach slightly different conclusions. Their results show that stock prices affect the exchange rates for Japan, Malaysia, Singapore, Thailand and Taiwan. The reverse causality occurs in South Korea and the Philippines. Hong Kong is the only country that shows a bi-causal relationship between stock prices and exchange rates. Using Granger causality in panel setting for five Asian countries (Indonesia, Malaysia, Philippines, Singapore and Thailand), Liang et al. (2013) find that exchange rates to stock prices are negatively related, and that causality runs from exchange rates to stock prices.

In the literature on foreign exchange rate exposure, empirical studies by Dominguez and Tesar (2001) and Chue and Cook (2008) apply a two-factor regression specification with instrumental variables to examine the relationship between excess stock returns and the change in the exchange rates. Using a wide range of firm level data for 15 emerging markets, Chue and Cook (2008) reveal that emerging market firms are mostly negatively exposed to exchange rate changes during the turbulent episodes of the Asian crisis. This negative exposure disappears shortly after the crisis. Focusing on non-US industrialized countries, Dominguez and Tesar (2001) confirm that a depreciation of the Thai Baht generally led to a decrease in the value of the share of firms in Thailand. Using the same methodology, Parsley and Popper (2006) focus on the exchange rate exposure of stock returns to vari-

ous foreign currencies (US dollar, Euro, UK Pound and Japanese Yen) under pegged and non-pegged exchange rate arrangements. Their results show that in Malaysia, the Philippines, and Thailand many firms exhibit a statistically significant exposure to the dollar with a peg. Under a peg, a certain number of firms in all nine countries in the sample show a significant exposure to fluctuations in the Yen. Without a peg, only Taiwanese firms show a notable exposure to the Yen. There is seemingly less exposure against the Euro and the Pound with or without a currency peg. A recent study by Bartram and Bodnar (2012), using cross-sectional regression in 37 developed and emerging markets including Asia, reveal that a relationship between exchange rate exposure and stock returns exists conditionally on the realized change in the exchange rate itself. The relation is more significant amongst emerging market firms.

Unlike Granger et al. (2000), Caporale et al. (2002) focus on causal links among variances by means of multivariate GARCH (Generalized Autoregressive Heteroskedasticity) model in four East Asian countries. They find that in the pre-crisis sample stock prices lead exchange rates negatively in Japan and South Korea and positively in Indonesia and Thailand. After the onset of the 1997 East Asian crisis the spillover effects are found to be bi-directional in the latter two countries. Muller and Verschoor (2007) use a univariate GARCH model to investigate whether the equity value of individual Asian internationally active firms are affected by exchange rate changes. They conclude that the overall extent of exchange rate exposure is not sample dependent, a depreciating (appreciating) Asian currency against foreign currencies has a net negative (positive) impact on stock returns. Using vector autoregression and multivariate GARCH models, recent study by Zhao (2010) focuses on identifying the source and magnitude of spillovers between the real effective exchange rate and the stock price in China. He concludes that spillovers and direct relationships between the foreign exchange and stock markets are weak. Another study by Kuper and Lestano (2007) use the multivariate GARCH with DCC (dynamic conditional correlations) specification to analyze the relationship between three financial markets: the stock market, the money market, and market for foreign exchange in Indonesia and Thailand.

They disclose a negative interdependence between stock markets and foreign exchange markets. In this paper the same methodology is used to study the relationship between these markets for a broader selection of East Asian countries.

3 Multivariate GARCH and DCC models

In this paper we are interested in the correlation between stock returns and exchange rates accounting for asset price volatility. Volatility plays a central role in asset pricing and many other areas of finance. The univariate autoregressive conditional heteroskedasticity (ARCH) model proposed by Engle (1982)—generalized by Bollerslev (1986) to the Generalized ARCH (GARCH) model—is one of the most important tools to model time-varying volatilities. There are a number of review articles on (G)ARCH modeling. A general review can be found in Bollerslev et al. (1992), Bera and Higgins (1993), Bollerslev et al. (1994); its performance to describe the conditional variance is discussed in Hansen and Lunde (2005); and its widespread finance applications are reviewed in Pagan (1996) and Bollerslev (2001). Since the univariate GARCH models have proved to be successful in capturing many properties of volatility, the model has been extended to multivariate GARCH (MVGARCH) in number of ways. We refer to Bauwens et al. (2006) and Silvennoinen and Teräsvirta (2008) for a survey on the most important developments in multivariate GARCH modeling.

Many variants of MVGARCH modeling use conditional correlations rather than conditional covariances as described above. Transforming the conditional variance matrix to conditional correlation models is specified in a hierarchical way (see Engle and Sheppard, 2001). First, one selects a model for each conditional variance. A large number of parametric specifications for conditional variance have been put forward in the literature. For instance, other than a conventional GARCH model, one may specify different GARCH model in terms of (a)symmetric volatility phenomenon, error distribution specification, mean equation specification, and numerical optimization algorithm. Second, the conditional correlation matrix is estimated based on the

conditional variances. Using a GARCH process for the conditional variance system corrects for the heteroskedasticity bias.³

This dynamic conditional correlation, or DCC, model has convenient practical advantages as is argued in the introduction: the model guarantees that the time dependent conditional correlation matrix is positive definite for each point in time. Moreover, the number of parameters grows only linearly and therefore the model is relatively parsimonious. A recent application of this model to the cross-border relationship in individual markets and on the relationship between financial markets within each country, can be found in, among others, Kearney and Poti (2006), Lee et al. (2006), Kuper and Lestano (2007), Diamandis (2008), and Durai and Bhaduri (2011). Cappiello et al. (2006) generalize the MVGARCH-DCC model in order to capture conditional asymmetries in correlation. Their model is quite general to include all previous cases, however, to impose the positive definiteness is computationally demanding.

4 Data and properties

The aim of the paper is to explore the interdependency between stock returns and exchange rate changes before, during and after the Asian crises of the late 1990s and the Global Financial Crisis (GFC) in 2008-2009.⁴ The two crises have brought about strains on world financial markets across the board. We focus on the stock market and the market for foreign exchange—Dungey and Martin (2007) argue that it is important to model these markets simultaneously—in six Asian countries: Indonesia, Malaysia, the Philippines, Singapore, South Korea and Thailand. These countries have in common that the rates of GDP growth before the Asian crisis were high, and that they have

³The parameter estimates of this two-stage DCC estimator are consistent and asymptotic normal. See Engle and Sheppard (2001) and McAleer et al. (2008) for a detailed proof. Appendix A provides a brief specification of the DCC model, based on Engle and Sheppard (2001).

⁴Other financial crises occurred during sample period, i.e. Russia in August 1998, the USA in September 1998 (with the near-collapse of the U.S. hedge fund Long-Term Capital Management), Brazil towards the end of 1998 and early 1999, and Turkey and Argentina in 2001 (Dungey et al., 2007). These crises marginally affected Asian markets.

been affected by the Asian crisis. We use the exchange rates (value of the national currency per US dollar) and the Dow Jones global price indices in terms of the US dollar. Our choice of the exchange rates is supported by the fact that the US is one of the most important trading partners of the Asian market. We excluded Hong Kong because the HK dollar has been pegged to the US dollar since October 1983.

All data is obtained from Thomson-Datastream. The sample period is from January 3, 1994 to September 27, 2013. We only include trading days (Monday–Friday), excluding holidays. This produces 5,510 observations. The sample period is selected to include the Asian financial crisis 1997-1998 and the GFC in 2008-2009. We prefer daily data over low frequency data because low frequency data obscures transient responses to innovations that may last for a few days only. Moreover, daily data are more adequate for capturing the effects of rapid capital movements. Figures 1 and 2 plot the levels and the returns of the stock market and the foreign exchange market series, respectively. Continuously compounded stock returns and exchange rate changes are calculated as the difference of the natural logarithms for two consecutive trading days. In terms of the exchange rate regime, all economies maintained a stable relationship with the US dollar or gradually depreciated the home currency against the US dollar until moving to a managed float system against a basket of currencies. During the Asian financial crisis, the graphs indicate pronounced depreciations for all currencies. The outbreak of the financial crisis forced most countries to switch to a floating exchange rate regime. An exception is the Malaysian Ringgit that maintained its peg to the US dollar. The GFC also results in an increase in exchange rate depreciation, although the magnitude has been much less than the Asian crisis. Similar falls in stock prices during the Asian crisis are witnessed in Figures 1 and 2. In general, stock markets in all countries were stable until 1996 when the Thai market started to deteriorate. In the following period, all market returns plunged as the financial crisis shook the economies in the region. The magnitude of the negative effect of the Asian crisis in 1997-1998 is huge as Figures 1 and 2 clearly shows. Although the markets have made a modest recovery after the crisis, the market returns remained below the 1990s level.

Following the GFC, the figures show that all Asian stock markets declines during 2008, particularly at the time just after the investment bank Bear Stearns failed (March 16, 2008) and Lehman Brothers collapsed (September 16, 2008). The crisis had a negative effect on the Asian stock markets but the degree is smaller compared to the effect of the Asian crisis in the 1990s.

Table 1: Descriptive statistics for the relative changes in the foreign exchange rates and stock market prices; January 3, 1994–September 27, 2013.

	Mean	Std. dev.	Skewness	Kurtosis	Jarque-Bera
<i>Exchange rate changes</i>					
Indonesia	3.30×10^{-4}	0.01	1.98	78.92	124,005.00
Malaysia	3.70×10^{-5}	0.01	18.03	1012.37	219,000.00
Philippines	8.69×10^{-5}	0.01	1.28	106.86	231,583.00
Singapore	-4.85×10^{-5}	0.00	-0.41	14.08	26,465.15
South Korea	5.51×10^{-5}	0.01	-0.75	104.36	204,787.00
Thailand	3.95×10^{-5}	0.01	0.91	56.18	607,362.10
<i>Stock market returns</i>					
Indonesia	-5.45×10^{-5}	0.03	-0.87	32.70	189,921.90
Malaysia	7.30×10^{-6}	0.02	0.77	43.57	353,548.90
Philippines	2.53×10^{-5}	0.02	0.17	16.46	38,910.66
Singapore	2.30×10^{-5}	0.01	0.00	17.29	43,829.80
South Korea	6.50×10^{-5}	0.02	0.16	17.30	43,915.40
Thailand	-3.99×10^{-5}	0.02	0.13	10.48	12,032.38

Note: The critical value of the Jarque-Bera statistic with two degrees of freedom is 5.99.

Table 1 reports descriptive statistics for the stock market prices and the exchange rates. All stock markets have low positive average daily returns, except Thailand and Indonesia. The table implies that the changes in the exchange rates and the stock returns exhibit high dispersion (measured as the absolute value of the percentage coefficient of variation): the coefficient of variation exceeds 3,000% in absolute value for the changes in the series. The skewness coefficients indicate that most of the series are positively skewed. The stock market return series and the changes in the exchange rates for all countries are leptokurtic (peaked relative to the normal distribution and fat tails). Consequently, all series display strong evidence of non-normality as is also illustrated by the Jarque-Bera statistic.

Figure 1: Foreign exchange rates and stock market prices; January 3, 1994–September 27, 2013.

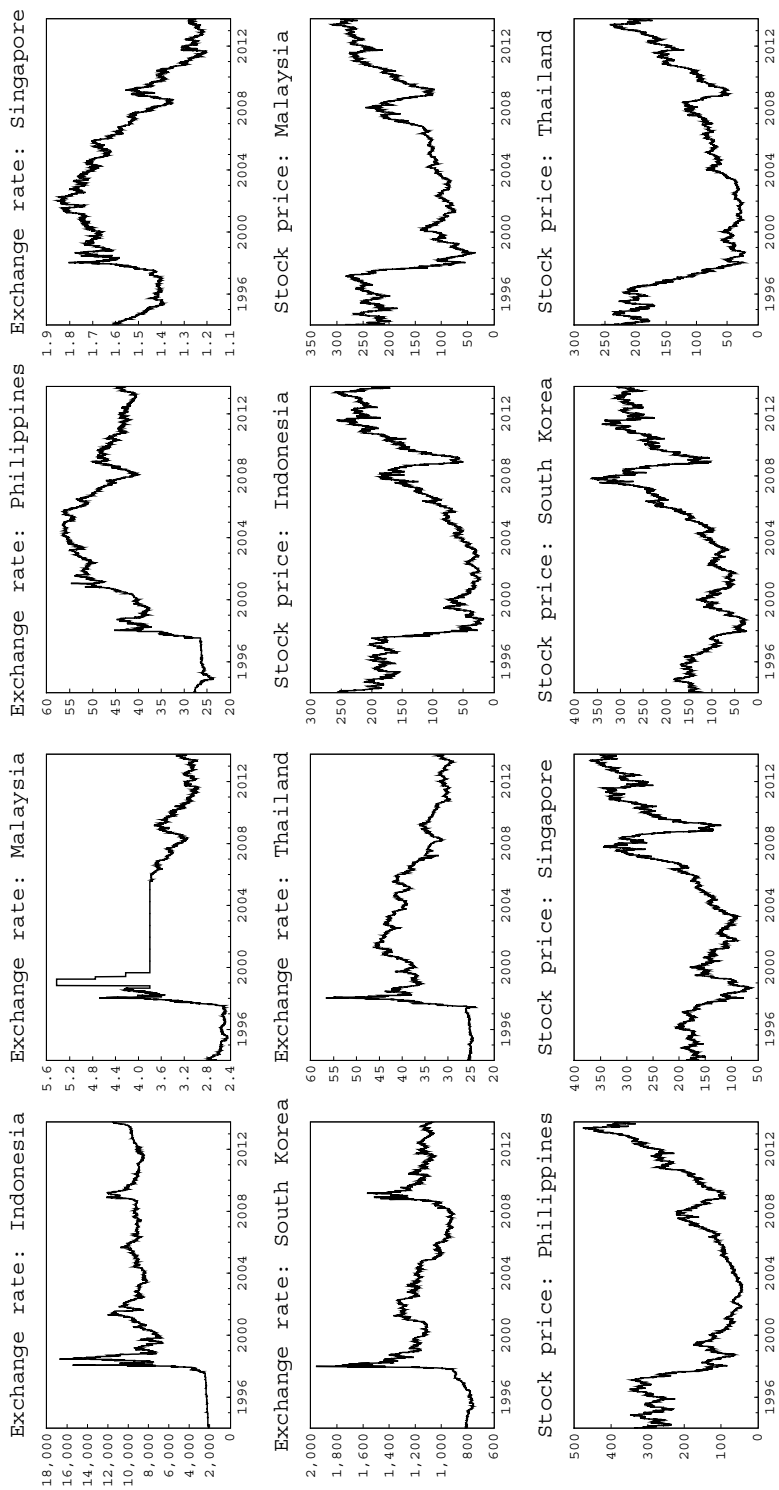


Figure 2: Relative changes in the exchange rate and stock market returns; January 3, 1994–September 27, 2013.

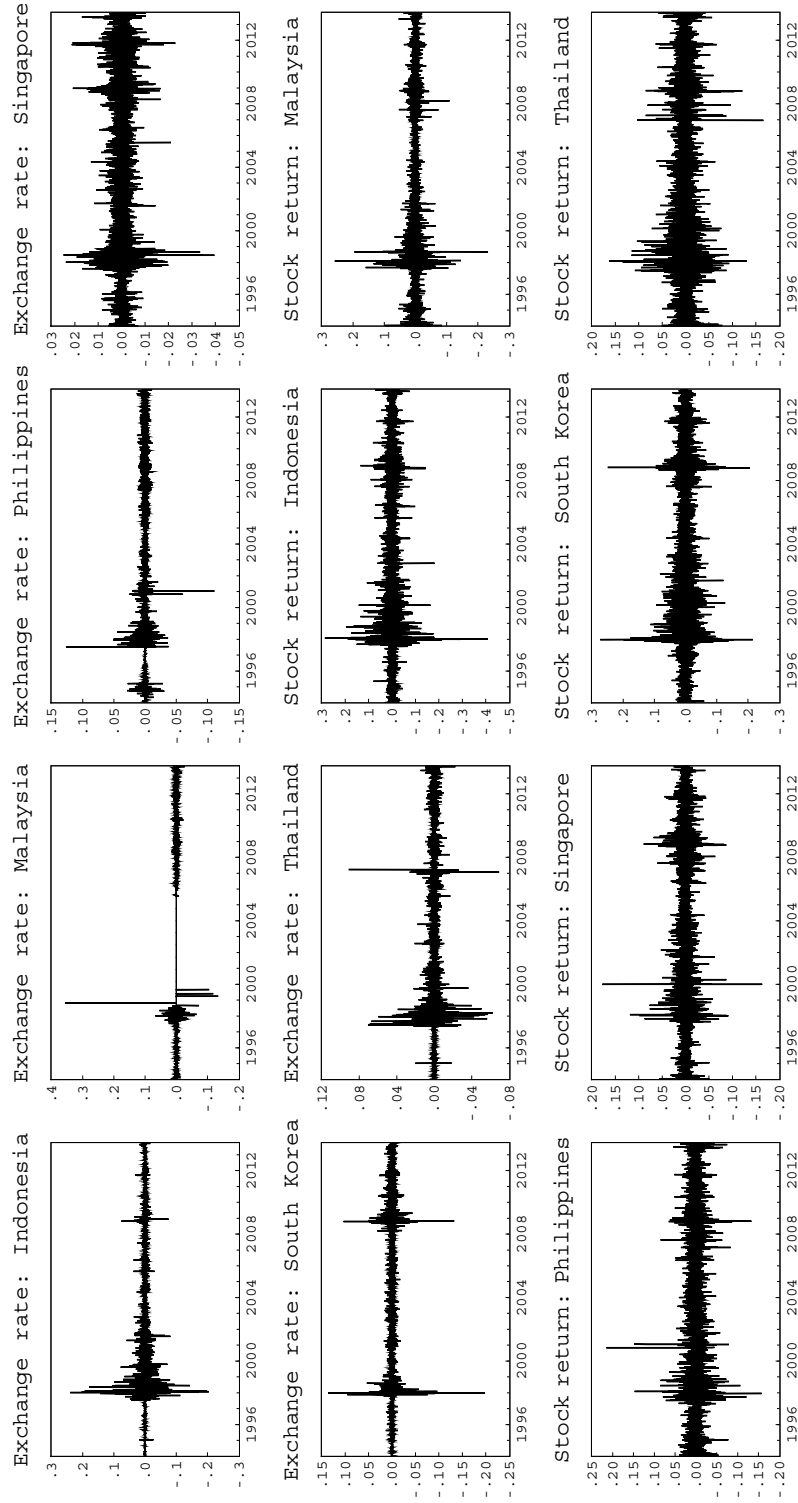


Table 2: Serial correlation and ARCH effect tests for the changes in the foreign exchange rates and the stock market returns; January 3, 1994–September 27, 2013.

	Ljung-Box Q-statistics				ARCH-LM	
	series		squared series		test	
	12 lags	24 lags	12 lags	24 lags	12 lags	24 lags
<i>Exchange rate changes</i>						
Indonesia	255.54	329.88	4,333.50	7,294.30	1,264.97	1,718.46
Malaysia	34.24	63.49	0.06	0.01	0.06	0.10
Philippines	132.62	165.93	64.43	105.55	53.76	72.74
Singapore	46.90	72.68	1,899.11	2,920.70	826.92	912.77
South Korea	524.03	713.09	3,842.00	5,086.20	1,399.30	1,482.70
Thailand	116.14	192.48	787.81	1,163.20	368.27	514.39
<i>Stock market returns</i>						
Indonesia	212.82	264.51	2,403.70	4,207.60	1,176.89	1,459.25
Malaysia	144.33	211.83	1,776.20	2,328.40	850.22	970.22
Philippines	156.41	179.33	293.72	445.16	180.51	219.60
Singapore	50.68	83.49	120.15	1,444.00	845.30	871.26
South Korea	155.33	191.50	3,160.90	4,916.00	1,173.55	1,204.15
Thailand	87.29	130.49	1,778.90	2,543.90	794.22	850.27

Note: The Ljung-Box Q-statistic tests the null hypothesis of no autocorrelation; ARCH-LM (Lagrange multiplier) tests the null hypothesis of conditional homoskedasticity. All these test statistics are χ^2 -distributed with the degrees of freedom equal to the number of lags. The critical values at the 5% level for these tests with 12 and 24 lags are 21.03 and 36.42, respectively.

Figure 2 shows that fluctuations tend to cluster together separated by periods of relative tranquility. This seems consistent with the volatility clustering phenomenon where large stock returns tend to be followed by large returns and small returns by small returns leading to contiguous periods of volatility and stability. If this is true, then an autocorrelation test should be taken into account. Table 2 reports test results of serial correlation and ARCH effects for all series at 12 and 24 lags. The Ljung-Box Q-statistics at 12 and 24 lags are computed for both the series and squared series. The results of the Q tests show that there is significant autocorrelation in the residuals. This is seen as evidence for linear and nonlinear dependencies. Linear dependencies may be caused by some form of market inefficiency or market structure, and nonlinear dependencies may lead to autoregressive conditional heteroskedasticity. The ARCH tests also indicate that the null hypothesis of

no autoregressive conditional heteroskedasticity is rejected at the 5% significance level.⁵

5 Estimation results

In this section, we analyze the association between stock returns and exchange rate changes in Indonesia, Malaysia, the Philippines, Singapore, South Korea, and Thailand using the multivariate GARCH and DCC approach discussed in Section 3. We focus on the relationship between financial markets within each country. The parameters of the multivariate GARCH and DCC models are estimated in a two-step procedure. In the first step we estimate a univariate GARCH(1,1) model⁶ for each asset with an AR(2) filter in the mean equation to remove serial correlation in the return series.⁷

The AR(2) model for the mean equation takes the form

$$r_t = \varphi_0 + \varphi_1 r_{t-1} + \varphi_2 r_{t-2} + u_t,$$

where r_t are changes in the exchange rate or stock market returns. Using the standardized residuals obtained from the univariate GARCH(1,1) models in the first step, the parameters describing the correlation between asset returns are estimated from the DCC(1,1) dynamic correlation structure (see Appendix A).

The estimated coefficients and t -values for the univariate GARCH(1,1) with AR(2) and DCC(1,1) models are presented in Table 3. The last two

⁵The Malaysian exchange market is an exception in these tests: the Q-test in levels shows autocorrelation, while the Q-test in squared series reveals the opposite; and the ARCH-test suggests no ARCH effect in both financial markets. The pegged exchange rate system in Malaysia following Asian crisis may be responsible for these test outcomes.

⁶Hansen and Lunde (2005) conclude that the relatively simple GARCH(1,1) performs extremely well compared to the more advanced alternative models in terms of in-sample performance as well as its predictive ability.

⁷We set lags up to five and check what value of order minimizes the AIC (Akaike Information Criterion) and SC (Schwarz criterion) criteria. The SC suggests that we choose order of one whereas the AIC suggests a longer lag length of two. We retain to the AR(2) model. In addition, coefficient of r_{t-2} is significantly different from zero, suggesting we do need at least two lags of r .

Table 3: Estimation results of the GARCH(1,1) model with an AR(2) filter and the DCC(1,1) model

	AR(2)		GARCH(1,1)		Wald test F -values		
	φ_0	φ_1	φ_2	ω			
<i>Exchange rates</i>							
Indonesia	8.11×10^{-5} (2.89)	0.074 * (7.37)	-0.0332 ** (-3.14)	4.69×10^{-8} (21.90)	0.07 *** (63.74)	0.92 *** (413.23)	465.14 ***
Malaysia	1.69×10^{-6} *** (0.13)	0.045 *** (1.55)	-0.0001 * (-0.01)	1.91×10^{-5} *** (14.72)	0.15 *** (9.12)	0.59 *** (20.53)	277.69 ***
Philippines	-6.33×10^{-5} * (-0.86)	0.005 * (0.28)	-0.0509 *** (-2.88)	2.52×10^{-6} *** (35.51)	0.15 *** (22.62)	0.76 *** (108.74)	791.75 ***
Singapore	-8.98×10^{-5} *** (-2.60)	-0.003 *** (-0.22)	-0.0310 *** (-2.19)	5.46×10^{-8} *** (7.17)	0.06 *** (19.71)	0.93 *** (314.45)	4.95 **
South Korea	-6.01×10^{-5} *** (-1.35)	0.026 * (1.81)	0.0070 ** (0.49)	1.77×10^{-7} *** (17.49)	0.11 *** (31.49)	0.88 *** (295.83)	28.22 **
Thailand	-5.61×10^{-6} * (-0.17)	0.046 ** (3.30)	-0.0018 ** (-0.13)	2.91×10^{-7} *** (10.81)	0.14 *** (41.38)	0.84 *** (256.92)	113.75 ***
<i>Stock market returns</i>							
Indonesia	5.94×10^{-4} *** (2.81)	0.140 *** (9.38)	0.0176 * (1.23)	5.32×10^{-6} *** (11.77)	0.12 *** (24.37)	0.87 *** (213.48)	9.77 ***
Malaysia	4.32×10^{-4} *** (3.65)	0.142 *** (9.77)	0.0286 * (2.16)	1.64×10^{-6} *** (13.74)	0.10 *** (22.33)	0.89 *** (215.60)	10.90 ***
Philippines	6.49×10^{-4} *** (3.64)	0.145 * (9.54)	0.0084 *** (0.55)	8.45×10^{-6} *** (10.39)	0.11 *** (18.79)	0.86 *** (121.39)	35.27 ***
Singapore	2.72×10^{-4} *** (2.07)	0.067 *** (4.73)	0.0137 * (0.94)	1.66×10^{-6} *** (7.55)	0.09 *** (18.15)	0.89 *** (94.11)	6.18 **
South Korea	5.87×10^{-4} *** (2.75)	0.062 *** (4.72)	-0.0036 * (-0.25)	2.38×10^{-6} *** (5.37)	0.07 *** (16.01)	0.91 *** (216.25)	6.24 **
Thailand	6.57×10^{-4} ** (3.39)	0.084 *** (5.75)	0.0671 *** (4.58)	8.94×10^{-6} *** (14.12)	0.12 *** (24.11)	0.85 *** (205.42)	25.10 ***
DCC(1,1)					0.02 *** (11.51)	0.95 *** (22.38)	20.10 ***

Note: The AR(2) takes the form $r_t = \varphi_0 + \varphi_1 r_{t-1} + \varphi_2 r_{t-2} + u_t$, where r_t is changes in the exchange rate or stock market returns. t -values are given between brackets. The mark *, **, and *** denote a significant rejection of the null hypothesis at 10%, 5%, and 1% level, respectively.

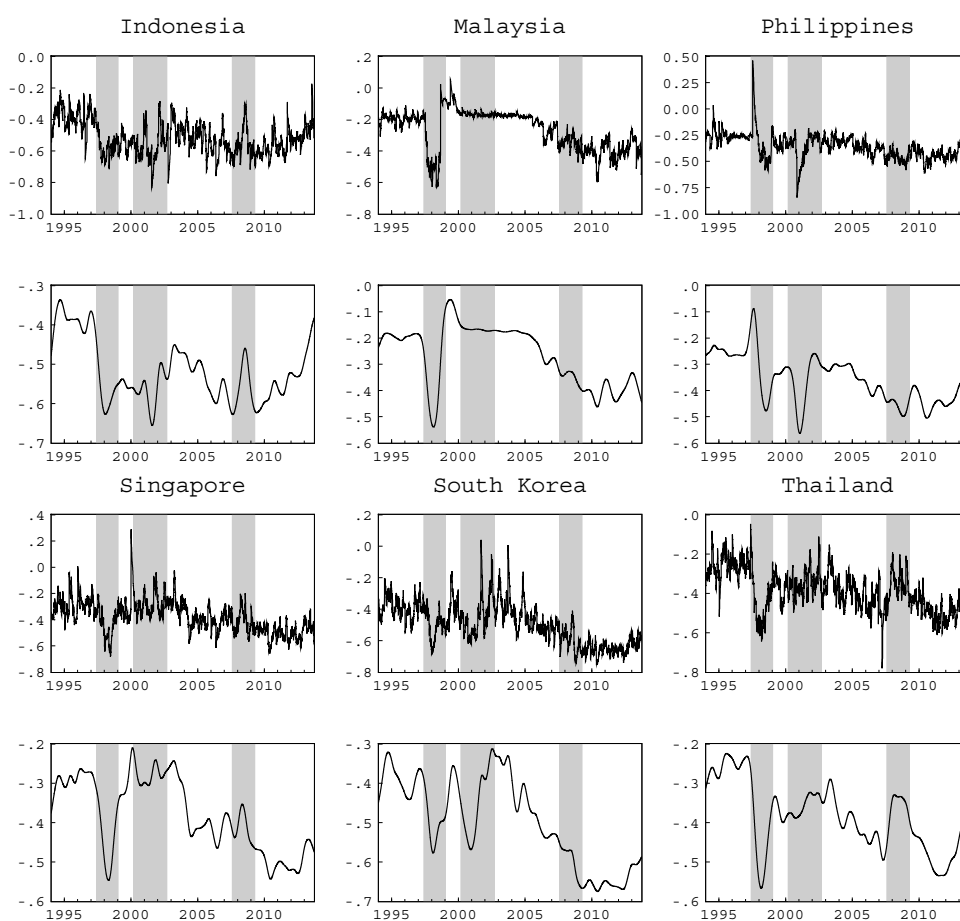
rows in Table 3 present the estimates of the DCC(1,1) parameters. The parameter estimates of the GARCH (1,1) and DCC(1,1) models are statistically significant at 1%. The estimates of β are larger than those of α and the sum $\alpha + \beta$ is very close to unity but significantly smaller than unity. This evidence is supported by Wald test that hypothesis of $\alpha + \beta = 1$ is rejected. This implies that the conditional variance processes is stable and highly persistent, but not leading to either non-stationary or have an infinite variance. The patterns in the conditional variance coefficients are not substantially different for the six Asian countries. The Ljung-Box Q-statistics and the ARCH-LM test in Table 4 show—with some exceptions⁸—no evidence of autocorrelation and autoregressive conditional heteroskedasticity up to order 24 in the standardized residuals. Given the results of the Q tests, we may conclude that the GARCH(1,1) model with an AR(2) filter model is quite successful in capturing volatility clustering. Overall, we can conclude that the volatility models are properly specified.

5.1 Discussion

Figure 3 shows the conditional correlations of stock market returns and changes in the exchange rates for each country. For sake of exposition, we applied the Hodrick-Prescott filter to obtain a smooth estimate of the conditional correlations. The shaded areas in this figure indicates the period of the Asian financial crisis and the GFC. The correlation coefficients are clearly time varying, with relatively high negative values throughout the sample period for all countries. Two crisis episodes mark declining trend of correlations, i.e. the Asian crisis and the GFC, and in between the episodes, the 2001 recession in the United States contributes marginally to the downward trend. Table 5 provides dates in which negative correlations hit its peak values during the episodes of crises and recession. The figure reveals that at the start of the Asian crisis the correlations start to trend downwards for all countries, except for the Philippines. The correlations are stronger during the period

⁸The exceptions are the Q tests for the residuals for the foreign exchange rate changes in Indonesia and Thailand for 1, 12 and 24 lags, for stock returns for Thailand for 1 lag, and for Malaysia and Singapore for 12 lags and 24 lags.

Figure 3: Dynamic conditional correlations between stock market and foreign exchange market



Note: The smoothed line depicts the Hodrick-Prescott filter of the estimates of dynamic conditional correlations reflected by the volatile line. The shaded area indicates the period of the Asian financial crisis: June 2, 1997 to December 31, 1998; the 2001 recession: March 10, 2000 to August 30, 2002; and the GFC: August 1, 2007 to March 31, 2009. The choice of the crisis period is based on official time lines for the Asian crisis dated by Baig and Goldfajn (1999) and Nagayasu (2001); the 2001 recession by Scherbina (2013) and for the GFC by Federal Reserve Board of St. Louis (2009) and Filardo et al. (2010).

Table 4: Serial correlation and ARCH effect tests for the filtered series of the changes in foreign exchange rates and the stock market returns; January 3, 1994–September 27, 2013.

	Ljung-Box Q-statistics						ARCH-LM		
	residuals			squared residuals			residuals		
	1 lag	12 lags	24 lags	1 lag	12 lags	24 lags	1 lag	12 lags	24 lags
<i>Exchange rates</i>									
Indonesia	21.64	54.76	89.18	0.19	21.26	29.14	0.18	19.17	27.57
Malaysia	0.01	3.69	9.91	0.01	0.01	0.02	0.01	0.01	0.02
Philippines	1.63	11.59	14.33	0.01	0.02	1.29	0.02	0.02	1.28
Singapore	3.54	20.84	34.76	0.27	6.86	13.39	0.25	6.78	13.51
South Korea	3.51	20.28	31.99	2.99	13.62	29.15	3.01	13.33	25.49
Thailand	6.23	60.59	78.08	0.22	2.53	9.82	0.21	2.50	9.83
<i>Stock market returns</i>									
Indonesia	9.97	19.43	32.14	1.68	16.77	26.39	1.62	16.39	25.31
Malaysia	6.08	29.42	40.94	0.05	7.29	11.11	0.06	7.11	11.32
Philippines	1.79	20.9	35.24	0.05	1.27	2.06	0.06	1.27	2.08
Singapore	1.67	31.52	44.77	3.55	6.13	10.4	3.54	6.02	10.23
South Korea	2.04	17.8	23.06	0.05	6.73	13.94	0.05	6.72	14.17
Thailand	5.01	20.81	36.01	3.45	18.5	25.52	3.40	17.92	21.10

Note: The diagnostics are computed for the standardised residuals. The Ljung-Box Q-statistic tests the null hypothesis of no autocorrelation; the ARCH-LM (Lagrange multiplier) tests the null hypothesis of conditional homoskedasticity. Both test statistics are χ^2 -distributed with degrees of freedom equal to the number of lags. The critical values at the 5% level for these tests with 1, 12, and 24 lag(s) are 3.84, 21.03 and 36.42, respectively.

of the Asian crisis. Indonesia reaches the highest negative correlation with a value of -0.72, followed by South Korea (-0.69), Singapore (-0.68), Thailand (-0.64), Malaysia (-0.62), and the Philippines (-0.58). For all countries, the correlations show a jump in the early stage of the crisis episode. Figure 3 also reveals a stronger downward trend of negative correlations in 2001 especially for Indonesia, South Korea, and Philippines, with the highest negative values of -0.66, -0.59, and -0.56, respectively. This trend is mainly characterized by the 2001 recession initially been most visible in the United States associated with the bursting of the information technology (IT) bubble resulting in the sharp declines in most major stock market indices and drops in business investment around the world. The attack of September 11, 2001 on the World Trade Center affected financial markets, directly and indirectly, deepening the recession. Malaysia, Singapore, and Thailand appeared to be somewhat insulated from the adverse shocks of the 2001 recession. At the start of the GFC, correlations deteriorate for all countries. While the initial

shock of the Asian crisis had its epicenter in Southeast Asia, the origins of the GFC lay outside the region. Figure 3 witnesses the intensification of the GFC spillovers to Asia. South Korea reaches the highest negative correlation with a value of -0.75, followed by Indonesia (-0.70), Singapore (-0.57), the Philippines (-0.57), Thailand (-0.51), and Malaysia (-0.47).

Linear regressions with AR(1) errors with the dynamic correlations as dependent variable and as explanatory variables three separate crisis period binary dummies (for the Asian crisis period, the IT bubble period, and the GFC), and three post-crisis period dummy variables (with values of one between the crisis periods) reveals that the correlations over time are stronger (more negative). In the period after the Asian crisis the correlations strengthen, especially for Indonesia and Thailand. In the period that marks the burst of IT bubble the correlations again are stronger for Indonesia and Thailand, and get even stronger after the 2001 recessions. During the GFC again the correlations are stronger (except for Malaysia), and increase further since March 3, 2009. All these shifts in the mean of the dynamic correlation coefficients are significant at the 1% significance level.

The extreme negative correlations during the crisis years reflect an escalation of a deeper regional foreign exchange risk exposure toward Asian firms. Our results reflected in Figure 3 are supported by foreign exchange rate exposure studies, Muller and Verschoor (2007) and Lin (2011), among others. Muller and Verschoor (2007) conclude that among 941 internationally active firms in East Asia that have significant exposure effects to the US dollar during the outbreak of the Asian financial crisis 1997-1998, 830 firms have negative exposure meaning that a depreciating Asian currency against the US dollar has a net adverse impact on their stock returns. The cross-countries distribution of exchange rate exposure reveals that all countries have a negative exposure.⁹ For exchange rate exposure during GFC periods, Lin (2011) reveals that a significant and asymmetric exposure is detected for the Asian emerging markets. More specifically, South Korea shows the highest incidence of exposure followed by Indonesia, Philippines, and Thailand.

⁹Muller and Verschoor (2007) use the same sample of countries as in this paper, including Hong Kong.

Table 5: Peak value of correlations; January 3, 1994–September 27, 2013.

	Asian financial crisis		2001 recession		GFC	
	Correlation	Date	Correlation	Date	Correlation	Date
Indonesia	-0.72	May 14, 1998	-0.66	November 13, 2001	-0.70	December 10, 2008
Malaysia	-0.62	October 7, 1998	-0.18	February 28, 2001	-0.47	December 19, 2008
Philippines	-0.58	September 9, 1998	-0.56	January 26, 2001	-0.57	January 9, 2009
Singapore	-0.68	June 18, 1998	-0.31	September 6, 2001	-0.57	October 29, 2008
South Korea	-0.69	December 31, 1998	-0.59	April 23, 2001	-0.75	October 31, 2008
Thailand	-0.64	March 16, 1998	-0.35	January 9, 2001	-0.51	August 28, 2007

Note: The choice of the crisis period is based on official time lines for the Asian crisis dated by Baig and Goldfajn (1999) and Nagayasu (2001); the 2001 recession by Scherbina (2013) and for the GFC by Federal Reserve Board of St. Louis (2009) and Filardo et al. (2010).

These results are consistent with ours. Moreover, if we compare the correlation coefficients between the two crises, the length of the downward trend of negative correlations in the GFC are longer than in the Asian crisis. All countries experience more sudden declining jumps in correlations during the Asian crisis compared to the GFC (see also Cheung et al., 2008). This implies that the spillovers from the recession and financial turmoil in the United States and Europe are too strong to be avoided by all Asian countries, despite the fact that the region are more resilient during the GFC compared to the Asian crisis. The pattern of the conditional correlations presented in Figure 3 reflects a reaction of the stock markets and the foreign exchange markets to changes in the underlying conditions in the markets caused by shocks and policy changes. We address this issue in detail below by focusing on the Asian crisis and the GFC since the two crises have worldwide spillovers. In Section 7 we exam the implications of changing correlations amongst financial asset returns for international portfolio selection.

6 Shocks and policy responses

In this section we describe the causes of the Asian crisis in the late 1990s and the GFC in the late 2000s, and we analyze how the crises developed, and what the policy responses were. We also relate these events to the relationship between the stock market and the foreign exchange market implied by the dynamic correlations shown in Figure 3.

6.1 The Asian financial crisis

The negative correlations between the stock market and foreign exchange market during the period before the Asian crisis is related to the Asian miracle. The world capital markets over invested in the Asian economies. This investment boom represented a significant positive shock to these economies, contributing to asset price increases, especially in the stock market. Corsetti et al. (1999) conclude that, despite the liberalization of internal and external financial control in the 1990s that triggered this boom, most of the Asian

economies pursued a policy of an effective peg to the US dollar in order to facilitate and maintain external financing of domestic investments. The peg reduced the currency risk premium charged by international investors. When the US dollar strengthened, the value of the Asian currencies per US dollar soared in 1996. This domestic currency appreciation eroded competitiveness in the traded-goods sector causing a shift in the composition of capital inflows from foreign direct investment to more liquid portfolio investment. The financial institutions in Asia were not capable in intermediating this increased capital inflow into productive capacity, but the capital inflow rather exacerbated the underlying structural weaknesses of domestic financial systems. Such a system is fragile and vulnerable to real and financial shocks.

The stronger correlations during the crisis indicate heavy losses in the stock markets and massive currency depreciation. Furman and Stiglitz (1998) argue that the heavy losses on the stock markets reflect the effects of the currency depreciation and higher domestic interest rates on highly leveraged firm and financial sector balance sheets. At least two factors play a role in deepening the Asian financial crisis in 1997-1998. These are the private investor's expectations about the economic situation and the policy actions. As a result of the exchange rate appreciation in 1996, Asian export growth deteriorated rapidly. Moreover, the world prices of Asian key exports began to fall which resulted in negative terms of trade shocks. Expectations of firm's earnings were revised downward, and nearly all stock markets in developing Asia began to drop sharply. Foreign speculators began to withdraw their funds in search for higher returns elsewhere. This capital outflow depleted international reserves in the countries with strictly pegged exchange rates. Most of the Asian currencies came under downward pressure. The main immediate concern was to sustain the peg in the face of a large current deficit, high short-term foreign debt, a collapse of property prices, and an erosion of international competitiveness. Asian monetary authorities intervened in the exchange market by selling international reserves at pegged rates and raised the interest rates temporarily. The latter policy is a reflection of the IMF policy recommendation. This measure was taken to reduce the downward pressure on the currency. The already weak financial sector and the loss in confidence

of domestic and foreign agents in the ability of central banks to maintain the peg much longer, pushed most of the Asian exchange rates on the edge of collapse. In turn, the substantial currency depreciation fed back to the stock market. Expectations of financial and non-financial corporate failures built up as the foreign currency denominated debt rose fast in terms of domestic resources (Eichengreen and Hausmann, 1999). Consequently, investors in the stock market panicked and rushed to sell their holdings, causing stock prices to fall further and international lenders to reject to roll over maturing loans.

The Asian financial crisis was costly both in terms of lost output and the fiscal outlays to shore up the fragile financial sector. The crisis not only forced the IMF and the G-7 to decide on how to respond to a request for help, but also called for a regional initiative to promote financial and exchange rate stability. Through the IMF's rescue package programs, some East Asian countries, especially Indonesia, the Philippines, South Korea, and Thailand, requested international financial assistance to limit the impact of the crises. On the other hand, Malaysia—where the IMF program was not followed—pursued a policy of capital controls and fixed the exchange rate to reduce foreign exchange exposure of domestic financial markets. The IMF's initial response supported by domestic policy adjustment for mitigating the crisis hinged substantially upon restoring confidence to the economies. The IMF claimed that financial markets stabilized and the exchange rates began to recover (see IMF, 1998, 2003). Despite criticism by many economists¹⁰ about the IMF's program to limit the crisis, Figure 3 clearly shows that the negative interdependence between the stock market and the foreign exchange market becomes lower toward the end of 1998.

¹⁰See Furman and Stiglitz (1998) and Radelet and Sachs (1998), among others, for a critique on the effectiveness of the IMF's immediate response to the Asian financial crisis. The critique lead to initiatives to reassess the IMF's role and function, but also to propose crisis resolutions for international financial architecture. Frankel and Roubini (2001) and Roubini and Setser (2004) provide a detailed description of these proposals. Others propose to form entirely new institutions or mechanisms initiated by a regional forum to prevent and resolve crises, like the Asian Monetary Fund initiated by Japan and the Chiang Mai Initiative. See Nasution (2005) and Kohsaka (2004).

6.2 The Global Financial Crisis

Many different perspectives have been put forward in the literature on the development of the GFC, the strength of the spillover effects, and the challenges for policy. However, many studies agree on the time lines of the crisis development.¹¹ There are three stages of the crisis. The first stage ranging from August 1, 2007 to September 15, 2008 is marked by initial financial turmoil originating from the collapse of the investment bank Bear Stearns and the suspension of the funds of BNP Paribas. With these events, the so-called US subprime mortgage crisis became apparent with a considerable increase in mortgage defaults and foreclosures. As credit markets came to a halt, the perceived credit risk and liquidity risk led financial agents, investors and banks, to prefer more safe assets, like short-term US Treasury bills, over credit or lending. The subsequent stage (September 16, 2008 until December 31, 2008) is associated by sharp financial deterioration signaled by the bankruptcy of Lehman Brothers and by global finance freezing up. The final stage (January 1, 2009 until March 31, 2009) of worsening macroeconomic performance, is characterized by vigorous policy interventions all over the world to stabilize the financial system. There are multiple factors that have led to a full-fledged economic crisis from the financial crisis. These factors are in particular global macroeconomic imbalances, poor risk management practices, weak financial regulation and supervision, and ill-prepared government responses.

Although the crisis originated in the US, its effects are global. As a by-product of the GFC some European countries faced sovereign debt servicing difficulties requiring financial assistance from the IMF, the ECB and the EU (see Boonman et al., 2013). In the aftermath of the sovereign debt crisis the financial system in the Eurozone turned out to be undercapitalised leading to a recession. The GFC also had serious implications for the emerging markets (see also Yiu et al., 2010). Compared with the EU, the impact of US spillovers on Asia may feed via different channels. The International Mon-

¹¹See Federal Reserve Board of St. Louis (2009), Filardo et al. (2010), and Financial Crisis Inquiry Commission (2011) for the chronology of the GFC.

etary Fund (2008) and Kim et al. (2009) point at economic openness and business cycle links between emerging Asia and the US. These studies conclude that Asia's trade and financial links with the US remain intense, and moreover, that financial links have become even stronger over time. In addition, the Asian business cycle is more correlated with the US business cycle. Although the growth of intra-regional trade's share in total Asian exports is higher compared to the US¹², the US still remains the main Asia's export destination for final goods. Therefore, growth of US demand appears to be a main factor for Asian export growth. For emerging Asia, the crisis is not one of low credit but of falling demand in the US markets. Increased Asian financial openness since the 1990s with financial deregulation and capital account liberalization, makes Asia's stock markets tend to track changes in the US market very closely. The stronger financial integration with the US has increased Asia's cross-border holdings of US financial assets. Moreover, growing foreign involvement in local capital markets increased the vulnerability of Asian financial markets to swings in the US market. This led to spillovers of the global financial crisis to the Asian regional market. The process of deleveraging during the crisis—in which many US financial institutions have difficulties in securing liquidity, forcing them to sell foreign currency denominated assets and repatriate the proceeds—led to a substantial liquidation of assets in emerging Asian markets and considerable capital outflows (Didier et al., 2012). These processes have resulted in abrupt declines in stock and other asset prices across Asia. The sell-off of local currencies accompanying the sudden changes in capital outflows resulted in depreciating Asian currency, especially the South Korean (see also Figure 1 above). Time-varying correlations between stock returns and changes in exchange rate exhibited in Figure 3 corroborate these facts. Downward patterns of negative correlations

¹²This evidence may support the decoupling hypothesis in which growing regional integration through growing intra-regional trade, investment, and financial linkages, makes emerging Asia to be more resilient from the effects of the GFC. Dooley and Hutchison (2009) reveal that emerging markets appeared to be largely insulated and decoupled from the GFC in the first stage of the GFC. In subsequent stages emerging markets are dragged down by the full-fledged deterioration of the US financial system and the real economy.

between the two asset markets in all Asian countries during the GFC episode illustrate that Asia is not immune to the crisis.

Nonetheless, some studies (International Monetary Fund, 2008, Didier et al., 2012, Gourinchas and Obstfeld, 2012, and Frankel et al., 2013, among others) conclude that the Asian exposure and losses to the GFC to date are low and that it is not plausible that the crisis leads to systemic banking crises and sovereign defaults. In spite of the financial market turbulence and weakness in exports, Asian economic growth perform soundly. The relative resilience of the Asian economies to the effects of the GFC has many causes. First, most Asian economies have strengthened their external position and their banking system since the aftermath of the Asian crisis as a result of combination of factors: well-capitalized balance sheets, low loan-to-deposit ratios coupled with little off-balance-sheet financing, and better regulation and supervision reinforced by more prudent practices by financial intermediaries. These factors explain why depositors did not run the banks when the financial environment in the US and in Europe deteriorated sharply. In relation to the external position, many Asian countries run current account surpluses partly due to major terms-of-trade improvements and sound structure of external assets and liabilities. Another reason behind the Asian resilience is the ability to conduct countercyclical monetary and fiscal policies allowing Asian economies to some extent counteract the GFC shock. Most Asian countries reduced interest rates via inflation targeting and improved the fiscal stance via designing and executing fiscal packages to cushion the effects of the global shock. A final strength of most emerging Asian countries has been the role of the flexible exchange rate regime adopted since the Asian crisis. This makes central banks more credible and increased the ability to reduce interest rates and to minimize the risks of currency mismatch via deepening local-currency financial instruments and debt markets. The strength of the Asian financial system and their sound macroeconomic policies explains part of the post-crisis Asian economic performance in which the countries recover fast. This is supported by Figure 3 that shows that the negative correlations between stock and exchange rate rebound after the crisis.

7 International Portfolio Investment

A key feature of portfolio selection is the correlation structure of the assets in the portfolio, and these correlations tend to change over time which is accommodated in DCC models in which correlations are updated in GARCH recursions. Accurate forecasts of volatilities and correlations are therefore critical, and GARCH models and DCC models are powerful instruments in international asset allocation (see Della Corte et al., 2011). The Black-Litterman model would imply that in crisis periods—in which correlations increase—the expected return of the portfolio increases assuming that the weights of the assets in the portfolio do not change. However, modern portfolio theory breaks down both in case of non-normality, and in crisis periods the weights of the assets in the portfolio do change.¹³

In this paper the portfolio is limited to stocks and currency. Longin and Solnik (1995) and Kearney and Lucey (2004) argue that deepening international financial integration tends to be associated with rising across border correlations between financial markets. High international capital mobility—due to interest rate differentials and deeper domestic financial development signaling a higher degree of financial integration—may affect the relationship between stock returns and exchange rates and, thereby, benefits from diversification between the two assets for international investors. When international investors are offered higher stock returns, then this may increase the value of the currency. This argument is line with Branson (1983) and Frankel (1983) (see also Section 2). Moreover, Moore and Wang (2014) conclude that international competitiveness of commodities may influence the relationship between stock returns and exchange rates. Changes in exchange rates affects exports, which in turn may affect the market value of firms and stock prices. This is in line with Dornbusch and Fischer (1980) as discussed in Section 2.

Figure 3 reveals that correlations between stock market and exchange rate market are negative for all countries throughout the sample period. These

¹³The impact of the changes in returns and volatilities in turbulent times in international asset allocation may be analyzed by calculating Sharpe ratios using four moment statistics in a Modified VaR (Favre and Galeano, 2003). However, this is beyond the scope of this paper.

negative values of correlation are intensified during the Asian and Global financial crisis, and the 2001 recession (see Table 5). Reduced international competitiveness may be responsible for the negative correlations between the stock market and the exchange rate market. The depreciation of the exchange rate degenerates price competitiveness worsening the current account, and lowers real output, and current and future cash flows of firms. Ultimately, stock prices fall. This effects become stronger in the presence of a financial crisis in which a free fall of the exchange rate occurs, or capital outflows are lowered in case of a fixed exchange regime as operated by Malaysia following the Asian financial crisis. In addition, in well-developed financial markets like Singapore, the linkage between the stock market and the foreign exchange markets may be sensitive to international capital mobility and financial market deepening. In this case, a rise in interest rate differential leads to a higher negative correlation between stock returns and exchange rate. In countries like Thailand, the Philippines and Malaysia, there are still some obstacles that prevent capital mobility and free movement of exchange rates. Asset portfolios in these countries may be less sensitive to correlations between the stock market and the foreign exchange rate market. Thus, there are limited opportunities and benefits for international investors and markets in the region to allocate capital more efficiently.

Table 6 provides descriptive statistics for the dynamic conditional correlations (DCCs) between stock market and foreign exchange markets over the entire sample period, and for both the financial crisis-recession and tranquil periods. Table 6 reveals that in most countries on average the range (maximum minus minimum) of DCC values is high in turmoil periods compared to tranquil periods. The GFC period is an exception. Entering turmoil periods the maximum values increase gradually, while the minimum values of the correlations show jump-like behavior. In addition, skewness and excess kurtosis values for the correlations indicate that the distribution of correlations over time is not normal, which is supported by Jarque-Bera test. These findings are confirmed by Figure 3 that shows that DCCs during turmoil periods are more volatile than in the tranquil periods. The correlations between markets considered in this paper strongly vary over time. This implies the

Table 6: Descriptive statistics of dynamic conditional correlations between stock market and foreign exchange market for the period January 3, 1994–September 27, 2013 and crisis and non-crisis periods

	Entire Sample Period					Pre Asian Financial Crisis						
	IND	MAL	PHI	SIN	KOR	THA	IND	MAL	PHI	SIN	KOR	THA
Mean	-0.52	-0.27	-0.36	-0.38	-0.50	-0.39	-0.39	-0.20	-0.26	-0.29	-0.39	-0.25
Maximum	-0.17	0.05	0.46	0.29	0.04	-0.05	-0.21	-0.11	0.04	0.01	-0.20	-0.05
Minimum	-0.84	-0.63	-0.85	-0.68	-0.75	-0.78	-0.65	-0.31	-0.38	-0.48	-0.55	-0.52
Std. Dev.	0.11	0.12	0.12	0.12	0.13	0.11	0.07	0.03	0.05	0.08	0.07	0.06
Skewness	0.34	-0.59	0.88	0.56	0.48	0.07	-0.46	-0.43	1.27	0.77	0.11	-0.20
Kurtosis	2.76	2.59	9.48	4.32	3.06	2.66	3.75	3.53	7.88	3.81	2.74	4.39
Jarque-Bera	108.55	338.37	9665.44	648.30	200.37	28.60	51.63	38.11	1117.34	113.23	4.17	76.92
	Between Asian Financial Crisis–2001 recession											
Mean	-0.58	-0.38	-0.31	-0.45	-0.50	-0.46	-0.55	-0.10	-0.33	-0.28	-0.41	-0.36
Maximum	-0.42	0.02	0.46	-0.20	-0.33	-0.15	-0.42	0.05	-0.16	0.29	-0.16	-0.24
Minimum	-0.72	-0.63	-0.58	-0.68	-0.69	-0.64	-0.66	-0.18	-0.43	-0.44	-0.57	-0.51
Std. Dev.	0.07	0.19	0.23	0.11	0.09	0.11	0.05	0.05	0.06	0.15	0.10	0.06
Skewness	0.18	0.67	1.52	-0.09	-0.32	0.76	0.02	0.70	0.53	1.93	0.63	-0.47
Kurtosis	2.38	1.94	4.91	2.35	2.25	3.19	2.51	3.43	2.52	5.95	2.65	2.33
Jarque-Bera	8.88	50.08	223.15	7.81	16.99	40.05	3.05	28.05	17.59	305.74	22.16	17.52
	2001 recession, Mar 10, 2000–Aug 30, 2002											
Mean	-0.57	-0.17	-0.38	-0.29	-0.45	-0.35	-0.53	-0.21	-0.35	-0.37	-0.45	-0.40
Maximum	-0.28	-0.12	-0.19	-0.04	0.04	-0.11	-0.29	-0.15	-0.20	-0.02	0.01	-0.15
Minimum	-0.84	-0.19	-0.85	-0.43	-0.62	-0.50	-0.81	-0.41	-0.53	-0.61	-0.64	-0.78
Std. Dev.	0.10	0.01	0.15	0.08	0.14	0.07	0.09	0.06	0.07	0.09	0.11	0.09
Skewness	0.44	0.90	-1.26	0.79	1.21	0.72	-0.25	-1.47	-0.39	0.36	1.16	-0.35
Kurtosis	3.34	3.72	3.97	3.07	4.01	3.52	3.00	4.23	3.05	3.72	4.71	4.79
Jarque-Bera	23.63	101.17	195.55	67.30	184.14	62.30	13.14	543.89	31.95	56.00	442.91	198.19
	Post Global Financial Crisis											
Mean	-0.55	-0.35	-0.47	-0.42	-0.60	-0.35	-0.54	-0.40	-0.43	-0.50	-0.65	-0.48
Maximum	-0.30	-0.23	-0.33	-0.20	-0.41	-0.19	-0.17	-0.25	-0.23	-0.32	-0.53	-0.25
Minimum	-0.72	-0.47	-0.58	-0.57	-0.75	-0.51	-0.70	-0.60	-0.61	-0.66	-0.75	-0.61
Std. Dev.	0.10	0.04	0.05	0.09	0.08	0.07	0.08	0.06	0.06	0.06	0.04	0.06
Skewness	0.86	0.00	0.39	0.58	0.29	0.18	0.97	-0.41	-0.17	-0.12	0.30	0.55
Kurtosis	3.10	2.99	2.67	2.65	2.53	2.42	4.90	3.69	2.80	2.78	3.02	3.71
Jarque-Bera	53.30	0.00	13.17	26.62	10.04	8.62	362.58	56.28	7.78	5.17	17.26	82.98

Note: IND, MAL, PHI, SIN, KOR, and THA stands for Indonesia, Malaysia, Philippines, Singapore, South Korea, and Thailand.

relevance of the DCCs when evaluating the effectiveness and stability of asset diversification. For all countries we report negative values of the correlations changing substantially during turmoil periods, and correlations that are less volatile in tranquil periods. This implies a reduced benefit from portfolio diversification between stock markets and foreign exchange markets in turmoil periods. Moreover, this implicitly shows that Asian markets are relatively well integrated.

8 Conclusion and policy implication

In this paper we use daily data of stock returns and exchange rate changes of six East Asian, namely Indonesia, Malaysia, the Philippines, Singapore, South Korea and Thailand, in order to analyze the dynamic relationships between stock markets and foreign exchange markets. We implement the multivariate GARCH model with the DCC specification proposed by Engle (2002). The model is general enough to describe the data used for estimating dynamic conditional correlations. The correlations between stock returns and exchange rate changes are negative and change over time, the correlations become stronger particularly during the episodes of the Asian crisis and the GFC. However, downward patterns of negative correlations are more pronounced in the episodes of the Asian crisis than the GFC. Sound macroeconomic policies and healthier financial sectors make the stock and foreign exchange markets better prepared to cope with the effects of the GFC compared to devastating effects of the Asian crisis. The correlations also show that most Asian countries are able to recover faster during the GFC in comparison to the post-crisis recovery performance after the Asian crisis. This paper also reveals that overall negative correlations between stock market and foreign exchange market implicitly indicate limited opportunities for investors to reach a higher degree of risk diversification and a lower probability of asymmetric shocks. In addition, international investors benefit from asset diversification is reduced from tranquility periods to turmoil periods

The policy implications of our findings are important, as they suggest that exchange rate policies should not be implemented without taking into

account the repercussions on the stock market, and vice versa. Monitoring the trade and financial channels of internationally active (non)financial firms over time has to be considered. This strengthens transparency and accountability of financial markets by achieving the most favorable prudential or supervisory standards. Combined with a prudent exchange rate policy, this would help to minimize volatility in the stock prices as well as the erratic movements of the currency values. More complex trade-offs between higher growth and other positive spillover effects, and increased sensitivity to adverse global shocks, requires stronger cooperation between financial and macroeconomic policies at both the regional and global level to avoid aggravating cross-border strains and to contribute to higher co-movement of output in increasingly more integrated global trade and financial markets.

Appendix A. The DCC model

The MVGARCH-DCC model employs r_t as a $k \times 1$ vector of the rate of returns of k assets conditional on information available at $t - 1$ denoted as Φ_{t-1} . r_t is assumed to be conditional multivariate normally distributed with zero mean and covariance matrix H_t . The returns can be the residuals from a filtered time series as is the case in our model. The model can thus be written as:

$$r_t | \Phi_{t-1} \sim N(0, H_t),$$

$$H_t \equiv D_t R_t D_t,$$

where R_t is the $k \times k$ time-varying correlation matrix, containing conditional correlations and D_t is a $k \times k$ diagonal matrix with the time-varying standard deviations with $\sqrt{h_{it}}$ on the i^{th} diagonal. D_t can be obtained from a univariate GARCH model

$$h_{it} = \omega_i + \sum_{p=1}^{P_i} \alpha_{ip} r_{it-p}^2 + \sum_{q=1}^{Q_i} \beta_{iq} h_{it-q},$$

where ω_i is the constant value; non-negativity and stationarity of the variances are applied for $i = 1, 2, \dots, k$; and $\sum_{p=1}^{P_i} \alpha_{ip} + \sum_{q=1}^{Q_i} \beta_{iq} < 1$. H_t will meet the condition of positive definite for all t since all restrictions of the GARCH model are fulfilled.

The proposed dynamic correlation structure is:

$$Q_t = \left(1 - \sum_{m=1}^M \alpha_m - \sum_{n=1}^N \beta_n\right) \bar{Q} + \sum_{m=1}^M \alpha_m (\epsilon_{t-m} \epsilon'_{t-m}) + \sum_{n=1}^N \beta_n Q_{t-n},$$

where $\epsilon_t = D_t^{-1} r_t$ is the matrix of standardized noise; Q_t is the covariance matrix of ϵ_t ; and \bar{Q} is the unconditional correlations matrix of covariance of ϵ_t .

The dynamic correlation coefficient matrix R_t can be expressed as

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1},$$

where Q_t^* is a diagonal matrix which has as its elements the square root of the elements of the diagonal of the matrix of covariances Q_t . The elements of matrix R_t which is positive definite are $\rho_{ijt} = q_{ijt} / \sqrt{q_{iit}q_{jtt}}$.

The log-likelihood of the DCC estimator, conditional on the parameters of the GARCH model, can be written as:

$$QL = -\frac{1}{2} \sum_{t=1}^T \left(k \log(2\pi) + 2 \log(|D_t|) + \log(|R_t|) + \varepsilon_t' R_t^{-1} \varepsilon_t \right).$$

There are two components in the log-likelihood function which are the sum of one volatility part containing only terms in D_t and the sum of one correlation part comprising only terms in R_t . Only the last two terms influence parameter selection in the DCC model. This makes the log-likelihood function easily to be estimated in two stages and results in consistent estimators.

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