ANNALS OF ECONOMICS AND FINANCE **17-2**, 365–402 (2016)

What Makes a Safe Haven? Equity and Currency Returns for Six OECD Countries during the Financial Crisis*

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We estimate dynamic conditional correlations (DCCs) between equity and currency returns during the financial crisis using Engle's (2002) model. DCCs and their volatilities increased for all countries, increasing investors' risk aversion and leading to the "flight-to-quality". The US, Japan, and Switzerland have negative DCCs, making them "safe havens" that experienced capital inflows, whereas the UK, Australia, and Canada have positive DCCs. Stock and foreign exchange volatility indexes increase DCCs for countries without safe assets; however, they decrease DCCs for countries with safe assets. Higher country-specific risk, as measured by its TED spread, and CDS spread, means higher DCCs.

Key Words: GARCH; Dynamic conditional correlations; Safe haven; Flight to quality; Wealth effect; Substitution effect; Stock market volatility index; Foreign-exchange volatility index; Interest-rate differentials; TED spread; Credit-default swap spread.
JEL Classification Numbers: F31, G15.

* This study was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2014011487).

1529-7373/2016

1. INTRODUCTION

The interactions between equity and currency returns have extremely important implications for currency hedging, international portfolio management, and macro (especially monetary) policies. However, identifying these interactions and providing one coherent explanation for them has so far proven to be elusive. For example, Hau and Rey (2006) developed a theoretical model that showed a uniform negative relationship between equity and currency returns through order flows in the foreign-exchange market. However, Cho et al. (2012) provided empirical work in which currency returns were negatively correlated with stock returns in emerging markets, but positively correlated in developed markets. Building upon these and other studies, our model predicts that currency returns are negatively correlated with stock returns in safe-haven countries, those with safe assets (currencies or bonds), but positively correlated in countries without safe assets.

International portfolio rebalancing generates capital flows into and out of countries without safe assets in a pro-cyclical way that could create demand and supply in their respective currencies. More specifically, we provide evidence that currency returns affect overall risk asymmetrically, depending upon whether a country has a safe asset. We also show that these equity capital flows are more pronounced during down markets, resulting in strengthened correlations. By analyzing the interactions of equity and currency returns, we are able to show that during the US financial crisis (and down markets in general) correlations become stronger because of increased systemic market risk.

Because currency risk amplifies a portfolio's overall volatility and currency hedging is more beneficial with stronger positive correlations (Perold and Schulman, 1988), our findings have important implications for global currency hedging opportunities. Using the Bai-Perron (2003) test of unknown structural breaks, we divide the sample into pre-crisis, contagion, and post-crisis periods, and demonstrate that dynamic conditional correlations (DCCs) are significantly greater during the contagion phase of the crisis. Jo et al. (2014) using regime-switching causality tests have shown that currency returns lead equity returns when currency-market and equity-market volatilities are high, i.e., when systemic risk increases in the economy.

Finally, we use the dynamic conditional correlation with exogenous variables (DCCX) model of Kim et al. (2013) to find the channels of transmission between equity and currency markets. Contrary to previous studies, which failed to take into account the differences in the macroeconomic environment of each sovereign market, the DCCX model allows us to identify the global and country-specific factors that are significant for the safe-haven flows and that mattered for the different phases of the dynamic linkages between equity and currency returns for six OECD countries during the 2008 financial crisis. These DCCX estimations show that the Chicago Board Options Exchange volatility index (hereafter VIXUS), the 3-month US dollar/Euro volatility index (hereafter FXVUS), the country-specific LIBOR interest differential (hereafter the TED spread), and the credit-default swap spread of each country (hereafter CDS) are all important for the linkage of equity and currency returns.

This paper is organized as follows. In Section 2, we review the relevant previous literature that describes the interactions between equity and currency returns. Section 3 introduces the DCC-MGARCH model and discusses the DCC estimates obtained for the six OECD countries. Section 4 provides strengthened DCCs for the contagion period of the crisis and the results of the Markov-switching Granger causality tests. In Section 5, we analyze the determinants of DCCs using the DCCX model; Section 6 concludes.

2. LITERATURE REVIEW

Equity returns and currency returns can be correlated by equity portfolio investment[1] or order flows in foreign-exchange markets.[2] According to the traditional "flow approach" described by Dornbusch and Fisher (1980), the changes in the value of the domestic currency may affect the relative competiveness of export goods in international markets, thereby increasing stock prices, i.e., equity and currency returns have positive correlations. However, in the "portfolio-balance approach"[3] an increase in domestic stock prices causes local currency appreciation as investors rebalance their portfolios, so that changes in stock prices cause changes in the domestic currency. In a similar way, Friedman (1988), Gavin (1989), and Choudhry (1996) show that equity returns may give rise to changes in domestic money demand through substitution or wealth effects, thereby affecting the value of domestic currency. If the wealth effect dominates the substitution effect then the two returns may be positively correlated, whereas dominance of the substitution effect implies a negative correlation.

Brennan and Cao (1997) build a model of equity portfolio investment flows based on differences in informational endowments and show that host countries' equity returns are positively correlated with US investors' equity purchases; however, they could not find evidence that US equity flows are associated with exchange-rate changes. Hau and Rey (2006) developed a

[1]See, e.g., Brennan and Cao (1997), Froot et al. (2001), Griffin et al. (2004).
[2]See, e.g., Lyons (1995) and Evans and Lyons (2002).
[3]See, e.g., Branson (1983), Branson and Henderson (1985), and Frankel (1983).

model in which exchange rates, equity prices, and capital flows are jointly determined under incomplete foreign-exchange risk trading. They show that mean-variance-optimizing investors will pull out of a bullish foreign market to reduce increased exposure in foreign equity, resulting in negative correlations between equity and currency returns.

Empirical investigations on short-run and long-run dynamics between equity prices and exchange rates have been performed by Ajayi and Mougoue (1996), Phylaktis and Ravazzolo (2005), and Du and Hu (2012). Ajayi and Mougoue (1996) used an error-correction model (ECM) of stock prices and exchange rates for the "big-eight" countries and showed that currency depreciation has negative short-run and long-run effects on the stock price. Phylaktis and Ravazzolo (2005) studied the long-run and short-run dynamics between stock prices and exchange rates using cointegration methodology for a group of Pacific Basin countries over the period 1980-1998 and concluded that stock and foreign-exchange markets are positively related and that the US stock market acts as a conduit for these links. However, Du and Hu (2012) find that foreign-exchange volatility has no power to explain either the time-series or the cross-section of US stock returns.

The literature discussed above is closely related to that on safe havens, which, according to Jordan (2009) are countries with: political, institutional, and social and financial stability; low inflation; central banks that promote confidence; and "comfortable" amounts of official reserves, savings, and net foreign assets.[4] In a similar way, safe assets are defined by Ranaldo and Soederlind (2010) as those that provide "hedging benefits on average or in times of stress" (p. 387). Clearly the relationship between stock prices and exchange rates is an important part of whether these hedging benefits are ultimately achieved. Yet much of the research to date examines only one of these markets. For example, Campbell et al. (2010) investigate the role of foreign currency in a diversified investment portfolio over the period 1975 to 2005 for the seven major developed-market currencies. They assume the investor has an exogenous portfolio of equities or bonds and is interested in using foreign currency to minimize the risk of the total portfolio. They show that the Australian and Canadian dollars are both positively correlated with global and their own stock markets; whereas, the euro, Swiss franc, and the bilateral US-Canadian exchange rates are negatively correlated with the world equity market. The US dollar, euro, and Swiss franc are considered safe assets, benefitting from a flight to quality when "bad news" arrives or risk aversion increases. How-

[4] Jordan's work is discussed in McCauley and McGuire (2009, p. 87). These factors were the main reason why Switzerland is considered a safe haven according to Jordan, and although Japan shares many of these traits with Switzerland, low yields are the main reason why the Japanese yen and Swiss franc have been such important "funding" currencies.

ever, their estimation does not account for the heteroscedastic nature of equity and currency returns, nor do they cover the years affected by the US financial crisis.

Aslanidis and Casas (2013) use time-varying correlation estimators to examine what happens to a portfolio consisting of five major and two emerging-economies' currencies. They model structural changes in the currencies' relationships, finding that currencies like the Swiss franc, which protect wealth during adverse market conditions, are safe-haven currencies; the yen and the euro are similar. Currencies like the Australian dollar and the Brazilian real become attractive during boom periods of increased macroeconomic performance and higher interest rates. Correlations among the major currencies shifted to a higher level in the period 2002-2005; however, the correlations of the Japanese yen dropped around 2006 and then became negative.

Caballero and Krishnamurthy (2008) show that severe flight-to-quality episodes involve uncertainty about the market and an "uncertainty shock" during the economic turmoil makes investors move toward holding uncontingent and safe assets. Brunnermeier et al. (2009) provides evidence of a strong link between carry trade (CT) in a currency and its crash risk, i.e., investing in high interest-rate currencies while borrowing in low-interest currencies delivers negatively skewed returns. They also show that currency crashes are positively correlated with stock-market volatility and interest-rate differentials (the TED spread). Christiansen et al. (2011) use a regime-dependent pricing model to examine CTs, finding that a typical CT strategy has high exposure to the stock market and is mean-reverting when foreign exchange volatility is high. Thus, the CT performance is better explained by a time-varying systematic risk that increases in volatile markets. Bakshi and Panayotov (2013) find that currency volatility and, to a lesser extent, a liquidity measure can lead to greater predictability of CT payoffs. Focusing on the Japanese yen CT, Hutchison and Sushko (2013) identify a significant impact of macroeconomic surprises on foreign-exchange speculation, represented by the CT, with the cost of hedging as the transmission mechanism.[5] They also find a close link between risk reversals and speculative futures positions in Japanese yen.

Ranaldo and Soederlind (2010) find a systematic relation between risk increases, stock-market downturns, and the appreciation of safe-haven currencies (p. 386). The US dollar is not a safe-haven currency; rather, the Swiss franc and the Japanese yen have safe-haven attributes, appreciating against the US dollar when US stock prices decrease, and also moving in-

[5]Spronk et al. (2013) build a carry-trade model that includes carry traders, chartists, and fundamentalists. Their model helps to explain several currency empirical facts, including excess volatility, volatility clustering, and the negative relationship between market volatility and carry-trade activity.

versely with international equity markets and foreign-exchange volatility (p. 388). They also find that foreign-exchange risk (FX volatility) matters more than do other risk or liquidity measures (CBOE's VIX and the TED spread) in affecting exchange-rate returns.

Our model not only allows us to deal with the heteroscedasticity that Campbell et al. (2010) overlooked; it also enables structural breaks to be determined, which, along with differing macro environments, mean that a country cannot take its safe-haven status for granted. For example, we find that the Swiss franc loses its role as a safe-haven currency during the contagion phase of the US crisis. Also, unlike Ranaldo and Soederlind (2010), we find that the US dollar and Japanese yen are safe-haven currencies when the market is under extreme stress. Most importantly, as discussed by Lustig et al. (2011), we seek a "characteristics-based" explanation for what makes a safe haven: when confronted with a common global shock, what is different about those countries that are perceived to be less risky?

3. THE DYNAMIC CONDITIONAL CORRELATION (DCC)-MULTIVARIATE GARCH (MGARCH) MODEL AND ITS ESTIMATION

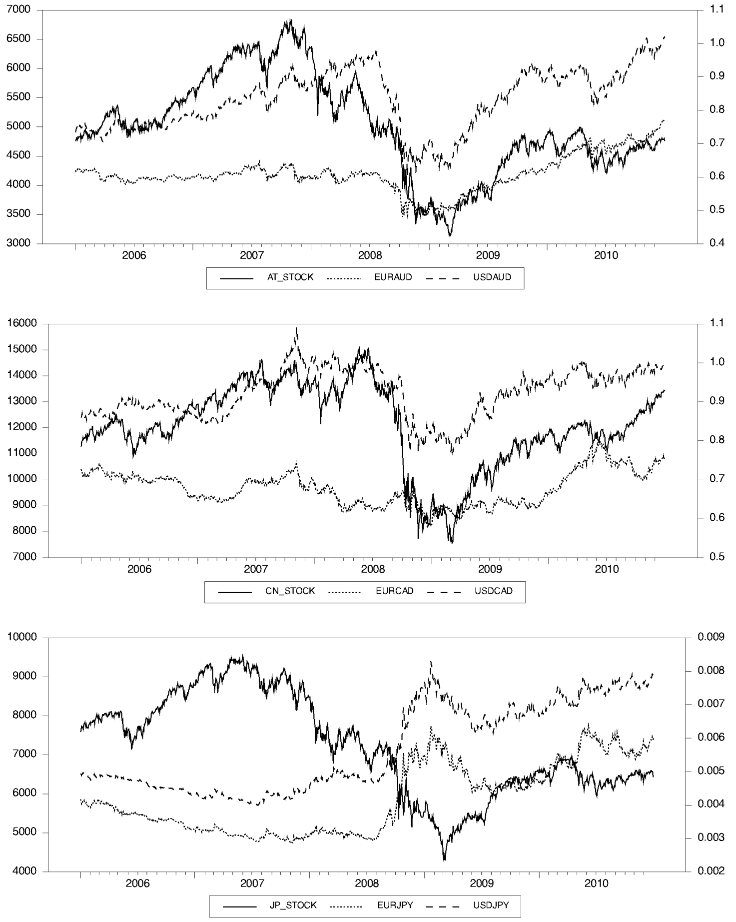
The DCC-MGARCH model has two advantages over traditional correlation analysis. First, Forbes and Rigobon (2002) show that heteroscedasticity can bias 'tests for contagion' when traditional correlation coefficients are used. The MGARCH model deals with the heteroscedasticity exhibited by the currency- and equity-return data. Second, the DCC-MGARCH model provides time-varying correlation coefficients, which can be extremely useful when patterns of capital flows change over time. Fratzscher (2012) shows that the signs of the estimated parameters change substantially during the crisis episode and the DCC-MGARCH model can successfully illustrate the changing patterns of correlation between equity and currency returns during the US financial crisis.

3.1. Data and Descriptive Statistics

We use daily data from Bloomberg and Datastream over the period January 2, 2006 to December 31, 2010 for six OECD countries: Australia, Canada, Japan, Switzerland, the UK, and the US. As shown in the Data Appendix, we have country-specific data on stock prices, exchange rates, interest rates (used for the TED spread), and (with the exception of Canada) credit-default swap spreads (CDS). The global shocks emanating from the US financial crisis are represented by the CBOE stock volatility index (VIXUS) and the foreign-exchange volatility index (FXVUS), which tracks changes in the 3-month US dollar-euro.

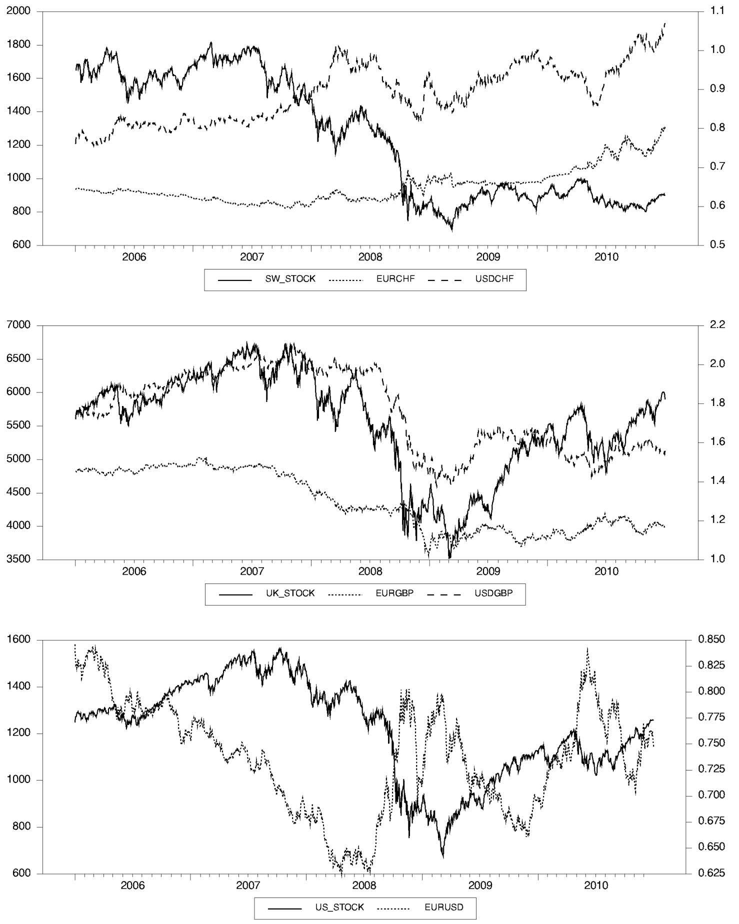
FIG. 1. Stock Market Index and Exchange Rate

Figure 1 shows stock market indices and exchange rate in USD and EUR for six OECD countries.



The exchange rates show the purchasing power of local currency in terms of the euro (EUR). Figure 1 plots each country's stock market index and exchange rate (in both USD and EUR); Figure 2 shows the dynamic conditional correlations (DCCs) in each country's stock and foreign-exchange markets. These figures reveal that, in all countries, the volatility of both stocks and exchange rates (in both USD and EUR) rose significantly during the 2008 US financial crisis period, raising the volatilities of their returns as well. Also, without exception, there are huge crashes in each country's

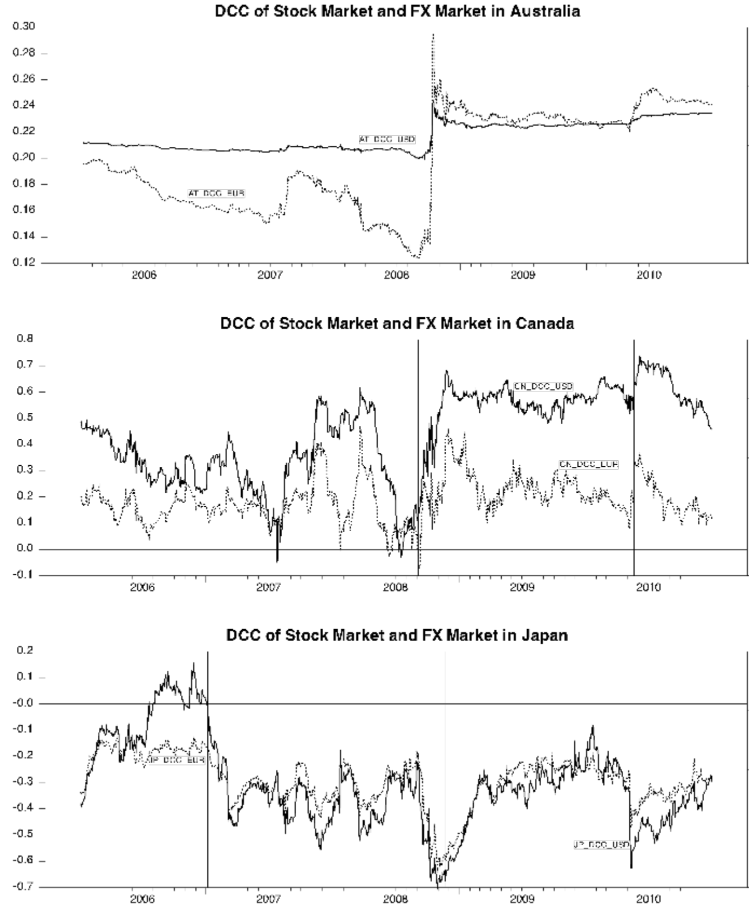
FIG. 1—*Continued*



stock index around the middle of 2008. However, Figure 1 shows that different countries' exchange rates had very different dynamics. While the USD, Japanese yen (JPY) and Swiss franc (CHF) appreciated against EUR during the US financial crisis, other currencies depreciated against EUR. However, the British pound (GBP) depreciated against EUR for a short time during the US crisis and then appreciated against the EUR with the evolution of the sovereign crisis in Europe. The most striking feature of the exchange-rate dynamics is the USD appreciation during the crisis (2008), which can be explained by its safe-haven property, the unwinding of the carry trade, and the US dollar shortage in the global banking system (Mc-

FIG. 2. Dynamic Conditional Correlations (DCCs) of Stock and FX Markets in Major Developed Countries

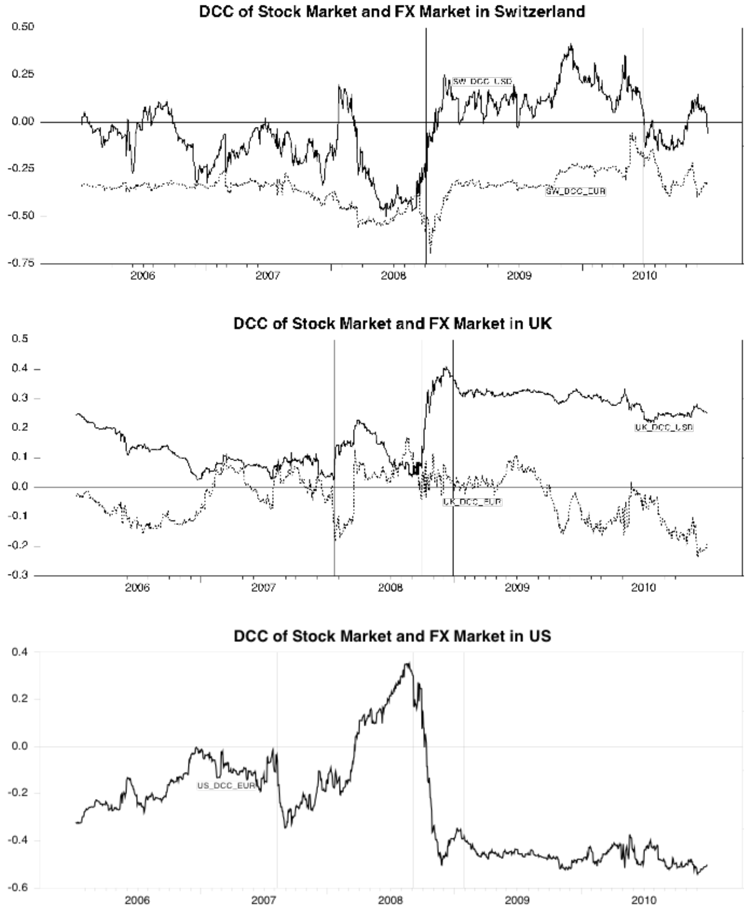
Figure 2 shows DCCs of Stock Market and FX Market in USD and EUR for six OECD countries.



Cauley and McGuire, 2008; Kohler, 2010). However, a large number of currencies that were not at the center of the turmoil depreciated (Kohler, 2010).

Table 1 presents descriptive statistics for currency returns in USD (Panel A) and EUR (Panel B), and stock-market returns (Panel C). Panels A and B show that the UK and the US have negative sample means in their currency returns of -0.7% and -1% respectively, whereas Japan has the

FIG. 2—*Continued*



maximum mean value of 3.6%. Volatility is highest in Australia (standard error of 1.104), but lowest in United Kingdom (standard error of 0.698). All countries' currency-return data reveal heteroscedasticity and are not normally distributed. Panel C shows that Canada has the highest mean stock-market returns (1.4%), whereas Japan has the lowest mean return (−4.7%). As for currency returns, all countries show heteroscedasticity in their stock-market return data.

TABLE 1.

Descriptive Statistics

Panel A. Currency Returns in USD						
	Australia	Canada	Japan	Switzerland	UK	US
Observations	1304	1304	1304	1304	1304	–
Sample Mean	0.025	0.012	0.036	0.026	−0.007	–
Standard Error	1.104	0.756	1.037	0.702	0.698	–
Skewness	−0.729***	−0.214***	0.691***	0.235***	−0.512***	–
Kurtosis (excess)	12.021***	2.400***	6.873***	2.562***	2.796***	–
JB Statistics	7967***	323***	2670***	368***	481***	–
LB Q Test (20)	68.36***	40.38***	61.71***	20.23	41.59***	–
ARCH LM Test (20)	31.35***	20.91***	18.49***	7.57***	16.92***	–
Panel B. Currency Returns in EUR						
	Australia	Canada	Japan	Switzerland	UK	US
Observations	1304	1304	1304	1304	1304	1304
Sample Mean	0.016	0.002	0.026	0.017	−0.017	−0.01
Standard Error	0.856	0.683	1.383	0.431	0.574	0.686
Skewness	−0.875***	−0.044	0.574***	−0.431***	−0.167**	−0.152**
Kurtosis (excess)	12.736***	2.225***	6.032***	8.056***	3.45***	2.256***
JB Statistics	8980***	269***	2048***	3566***	653***	281***
LB Q Test (20)	72.46***	26.64	64.87***	55.41***	35.92**	17.41
ARCH LM Test (20)	33.08***	7.48***	27.2***	9.5***	22.28***	14.52***
Panel C. Stock Market Returns						
	Australia	Canada	Japan	Switzerland	UK	US
Observations	1304	1304	1304	1304	1304	1304
Sample Mean	6.8E-05	0.014	−0.047	−0.013	0.004	0.001
Standard Error	1.334	1.457	1.605	1.317	1.447	1.546
Skewness	−0.446***	−0.675***	−0.205***	0.116*	−0.093	−0.236***
Kurtosis (excess)	4.170***	8.237***	7.068***	7.866***	7.324***	9.013***
JB Statistics	987***	3785***	2723***	3364***	2916***	4426***
LB Q Test (20)	19.54	78.1***	29.81*	71.72***	65.26***	78.36***
ARCH LM Test (20)	20.46***	40.24***	43.9***	31.45***	25.3***	33.94***

Table 1 reports the descriptive statistics. LB Q test is the Ljung-Box test for autocorrelation and the ARCH LM test is for heteroscedasticity. ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

3.2. Time-Series Properties of Equity and Currency Returns

Since our study focuses on the subprime mortgage crisis in 2008, which caused radical changes in financial markets, we use the Lagrangian multiplier (LM) unit-root test of Lee and Strazicich (2004) to account for the structural breaks in the data.[6] Table 2 shows that we cannot reject the null hypothesis of nonstationarity in the level of the exchange rate and stock indices in all countries, but we can reject the null hypothesis of nonstationarity in their first differences with 1% significance level. Thus, we conclude that the exchange rates and the stock indices in all countries are I(1) process.

TABLE 2.

Results of Unit-Root Tests

		Level		Log-Return	
	Country	Break Point	t-statistics	Break Point	t-statistics
USD Exchange Rate	Australia	2008:10:23	−2.035	2008:10:03	-40.620^{***}
	Canada	2008:11:19	−2.285	2008:10:28	-37.844^{***}
	Japan	2009:01:20	−2.744	2008:10:23	-35.403^{***}
	Switzerland	2008:03:25	−2.712	2008:12:16	-38.751^{***}
	UK	2009:01:19	−2.349	2009:01:19	-35.264^{***}
	US	–	–	–	–
EUR Exchange Rate	Australia	2008:10:14	−1.450	2008:10:07	-40.936^{***}
	Canada	2010:06:01	−1.881	2009:01:02	-36.882^{***}
	Japan	2009:01:19	−2.506	2008:10:23	-34.642^{***}
	Switzerland	2010:06:28	−1.076	2009:03:11	-38.347^{***}
	UK	2008:12:16	−1.891	2008:11:12	-34.706^{***}
	US	2010:06:03	−2.293	2009:03:17	-36.127^{***}
Stock Index	Australia	2008:10:09	−1.976	2008:10:09	-38.532^{***}
	Canada	2008:11:19	−2.043	2008:11:19	-39.773^{***}
	Japan	2008:10:24	−2.224	2008:10:13	-37.172^{***}
	Switzerland	2008:10:09	−2.143	2008:10:09	-37.041^{***}
	UK	2008:10:09	−2.120	2008:10:09	-39.464^{***}
	US	2008:11:28	−1.871	2008:11:19	-41.686^{***}

Table 2 reports the Perron unit-root test with a structural break (Perron, 2006). The model adopts innovational outlier, considering changes in constant. ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

To consider the long-term relationship between stocks and exchange rates in each country, Table 3 shows the cointegration test results using the methodology of Gregory and Hansen (1996), which is advantageous when

[6]We analyze each series' stationarity in a crash model (that allows for only a change in intercept) and break model (that includes changes in trend and intercept) as follows: $y_t = \alpha_0 + \alpha_1 t + \alpha_2 B_t + \alpha_3 B_t t + \beta y_{y-1} + \sum_{j=1}^{k} C_j \Delta y_{t-j} + e_t$ where t, B_t, are e_t time trend, the change in intercept, and error term, respectively. This equation describes the break model; without the fourth term, which denotes the change in trend, it would describe the crash model.

there are structural breaks.[7] For Australia, Canada, Japan, and the UK, the null hypothesis of no cointegration between the stocks and exchange rates is rejected by at least one of the three different specifications of the test. On the other hand, we cannot reject the null hypothesis for Switzerland or the UK and the US.

TABLE 3.

Results of Cointegration Tests

Panel A. USD Exchange Rate						
	Model C/T		Model C/S		Model C/T/S	
Country	Break Point	t-Statistics	Break Point	t-Statistics	Break Point	t-Statistics
Australia	2008:10:14	-5.429^{**}	2008:01:25	-4.773	2008:08:18	-6.25^{**}
Canada	2007:08:20	-4.716	2007:06:12	-5.302^{*}	2007:06:08	-5.544
Japan	2009:02:27	-5.102^{*}	2009:01:21	-4.111	2009:02:27	-6.708^{***}
Switzerland	2008:09:19	-4.187	2008:01:08	-4.311	2008:07:14	-4.393
UK	2010:02:11	-4.979	2008:10:27	-5.086	2009:06:04	-5.597
US	–	–	–	–	–	–
Panel B. EUR Exchange Rate						
	Model C/T		Model C/S		Model C/T/S	
Country	Break Point	t-Statistics	Break Point	t-Statistics	Break Point	t-Statistics
Australia	2010:02:19	-4.338	2009:08:06	-5.004	2008:09:24	-5.548
Canada	2010:02:23	-4.368	2010:02:05	-3.588	2009:10:26	-4.998
Japan	2010:03:10	-4.529	2009:09:28	-3.588	2008:11:20	-4.906
Switzerland	2010:04:01	-3.905	2009:08:06	-5.652^{**}	2008:10:24	-6.182^{**}
UK	2007:12:13	-4.55	2008:01:22	-4.846	2008:04:02	-5.171
US	2010:02:08	-4.124	2008:10:08	-4.257	2008:10:08	-4.839

Table 3 reports the Gregory-Hansen cointegration root test with a structural break. The optimal number of lags in each series is determined by AIC. ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively. C denotes constant; C/T denotes constant and trend; C/S denotes constant and slope; and C/T/S denotes constant, trend, and slope.

3.3. Dynamic Conditional Correlations (DCC)-MGARCH Model

Because both equity and currency returns exhibit heteroscedasticity in our sample period and may depend on their volatilities, we use the mul-

[7] Table 3 depicts the result of the cointegration test in the following equation: $y_{1t} = \mu_1 + \mu_2\varphi_{t\tau} + \beta t + \alpha_1 y_{2t} + \alpha_2 y_{2t}\varphi_{t\tau} + e_t$ where μ_1, μ_2, t, and e_1 are the intercept before the break, the change in the intercept at the break, time trend, and error term, respectively, and denotes the coefficient of level shift, the cointegrating slope before the break, the change in the slope, and time trend respectively. Depending on which term is included in the model, the results are divided into model C/T (constant and trend), C/S (constant and slope), and C/T/S (constant, trend, and slope). All models include LIBOR to control for international liquidity in the cointegrating system.

tivariate GARCH, MGARCH, model. Engel (2002) proposes the dynamic conditional correlations (DCCs) model to estimate conditional covariance in the MGARCH model. By reducing the number of parameters in the variance equations, this model allows us to derive time-varying correlations in volatilities between variables. The conditional covariance matrix in the DCC specification can be written as:

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

where $D_t = \mathrm{diag}(\sqrt{h_{i,t}})$ is andiagonal matrix and D_t, following the univariate GARCH(p, q) model, is defined as:

$$h_{i,t} = \omega_i + \sum_{p=1}^{P_i} \alpha_{ip}\varepsilon_{i,t-p}^2 + \sum_{q=1}^{Q_i} \beta_{iq} h_{i,t-q}, \tag{2}$$

and $R_t = \{\rho_{ij}\}_t$ is the time varying conditional correlation matrix:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}, \tag{3}$$

where $Q_t = (1-\sum_{m=1}^{M} \alpha_m - \sum_{n=1}^{N} \beta_n)\overline{Q} + \sum_{m=1}^{M} \alpha_m(\varepsilon_{t-m}\varepsilon'_{t-m}) + \sum_{n=1}^{N} \beta_n Q_{t-n}$, $\overline{Q}$ is the unconditional covariance of the $\varepsilon_{i,j}$ and $\varepsilon_{i,j}$, and $Q_t^* = \mathrm{diag}\{\sqrt{q_{i,i}}\}$ is a diagonal matrix containing the square root of the diagonal elements of Q_t. The correlation estimator of Q_t is:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}}, \quad \text{for} \;\; i, j = 1, 2, \ldots, n \text{ and } i \neq j. \tag{4}$$

For maximizing the log-likelihood function,

$$L = -\frac{1}{2}\sum_{i=1}^{T} [m \log(2\pi)] + 2\log|D_t| + \log|R_t| + \varepsilon_t' R_t^{-1} \varepsilon_t, \tag{5}$$

which allows us to estimate the DCC model.

We develop a DCC-MGARCH(1,1) model for equity and currency returns. The mean equations are defined in Eqs. (6) and (7):

$$STR_t = \gamma_0 + \sum_{j=1}^{K} \gamma_{1,j} STR_{t-j} + \sum_{j=1}^{K} \gamma_{2,j} FXR_{t-j} + \varepsilon_{1,t}, \tag{6}$$

$$FXR_t = \lambda_0 + \sum_{j=1}^{K} \lambda_{1,j} STR_{t-j} + \lambda_2 FXR_{t-1} + \varepsilon_{2,t}. \tag{7}$$

where STR_t and FXR_t are equity returns and currency returns, respectively, and $varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are the heteroscedastic error terms. In the conditional-variance equations, we allow the model to include asymmetric effects based on a GJR threshold-type formulation (Glosten et al., 1993) and EGARCH (Nelson, 1991). It is assumed that the volatility increases proportionally more following negative shocks than positive shocks. Thus, the conditional variance equations can be written as:

$$\ln h_{STR,t} = c_t + a_1(|\varepsilon_{1,t-1}| - d_1\varepsilon_{1,j-1}) + b_1 \ln h_{STR,t-1} \tag{8}$$

$$\ln h_{FXR,t} = c_2 + a_2(|\varepsilon_{2,j-1}| - d_2\varepsilon_{2,t-1}) + b_2 \ln h_{FXR,t-1} \tag{9}$$

where $h_{STR,t}$ and $h_{FXR,t}$ are volatility terms of equity returns and currency returns, respectively, and $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are from Eqs. (6) and (7). The third terms of Eqs. (8) and (9) imply asymmetric effects.

The estimation results of the DCC-MGARCH model are presented in Tables 4-A (in USD) and 4-B (in EUR). Panel A of both tables shows that currency risks (lagged currency returns in the equity return mean equation) are priced in equity returns for Japan and Australia. On the other hand, Table 4-B shows that portfolio risk (the lagged equity returns in the currency return mean equation) is priced in currency returns for the US and this implies that a change in excess equity return, which would lead to more or less investment flows into or out of the US, may cause a change in the exchange rate. From Panel B of both tables, we find that most of the coefficients for the squared errors (A) and lagged variances (B) are positively significant in both equity and currency variance equations for all countries, which validates the appropriateness of the DCC-GARCH(1,1) specification. Positive and significant coefficients of the squared errors support the idea that shocks from the currency (equity) market may boost the volatility in equity (currency) market. The large values of the estimated coefficients in the lagged own variance terms (the Bs) indicate that shocks have persistent impacts in both the equity and currency markets. Moreover, the positive and significant asymmetric terms (the Ds) in the conditional-variance equation for equity returns (currency returns) imply that negative shocks in equity returns (currency returns) may cause larger volatility than positive ones.

3.3.1. Safe-Haven Flows and Dynamic Conditional Correlations

Vayanos (2004) and Caballero and Krischnamurty (2008) claim that increased volatility and uncertainty during economic turmoil makes investors more risk averse and leads them to sell risky assets and purchase relatively safe assets (the so-called "flight-to-quality").[8] While international capital flows can explain the dynamics of sovereign exchange rates during the crisis and can signal their correlation with equity return, earlier studies emphasized capital flows between emerging economies and advanced economies[9] and little is known about the capital flows amongst advanced economies. One striking feature of the recent downturn was that capital flight was overwhelmingly to the US, and Euro area countries recorded net outflows (Pepinsky, 2012). In other words, rather paradoxically, during the Great Recession safe-haven flows went into the country at the epicenter of the crisis (Kohler, 2010). In this section, we investigate flight-to-quality capital flows among OECD countries during the recent episode of extreme market distress. In particular, we explore the changing basket of safe-haven assets and currencies during and after the US financial crisis.

A currency can be classified as a "safe-haven" currency if it appreciates with an increase in risk aversion and during stock-market downturns. Historical episodes illustrate that different currencies have enjoyed safe-haven status during previous severe market downturns. For example, Kaul and Sapp (2006) show that the US dollar was a safe-haven currency at the beginning of 2000 (McCauly and McGuire 2009, p. 86). Ranaldo and Soederlind (2010) show that periods of high risk-aversion are associated with a depreciation of the USD against the Swiss franc (CHF) and Japanese yen (JPY); a case in which CHF and JPY are safe havens. However, Cairns (2007) finds that the CHF, EUR, and JPY tend to strengthen against the USD when volatilities rise and that the USD tends to appreciate against a number of other emerging-market currencies, making the USD a safe haven relative to them. The performance of safe-haven currencies mirrors the losses of carry-trade speculation and supports the idea of a crash risk (Brunnermeier et al., 2009).

Table 5 presents the summary statistics for the DCCs between equity and currency returns. Australia (0.212 in USD and 0.198 in EUR) and Canada (0.444 and 0.190) have positive mean values of DCCs, implying that a decrease in equity price is, on average, associated with a depreciation of its domestic currency against the USD and EUR. However, DCCs for Japan (-0.305 and -0.291), Switzerland (-0.035 and -0.345), and the US (-0.256 in EUR) are negative on average, implying that an equity price decrease is associated with an appreciation of its domestic currency, on av-

[8]Vayanos' argument is based on a preference for liquidity and his liquidity premium is time-varying and increasing with market uncertainty measured by the implied volatilities of key financial variables.

[9]See, e.g., Fernandez-Arias (1994) and Fratzscher (2012).

TABLE 4A.

Estimation Results from the DCC-MGARCH Model for Currency Returns in USD

Panel A. Mean equations

	Australia	Canada	Japan	Switzerland	UK	US
Constant	0.038*	0.039*	0.020	0.041*	0.062**	–
	(1.698)	(1.776)	(0.695)	(1.754)	(2.544)	–
STR{1}	−0.141***	−0.064**	−0.096***	0.005	−0.070**	–
	(−5.292)	(−2.534)	(−3.528)	(0.191)	(−2.53)	–
STR{2}	–	−0.042*	–	–	–	–
	–	(−1.700)	–	–	–	–
FXR{1}	0.477***	0.120***	−0.445***	−0.076*	−0.021	–
	(16.592)	(3.336)	(−15.249)	(−1.905)	(−0.470)	–
FXR{2}	–	0.07**	–	–	–	–
	–	(1.991)	–	–	–	–
Constant	0.052***	0.021	−0.023	0.025	0.014	–
	(3.200)	(1.503)	(−1.51)	(1.629)	(0.937)	–
FXR{1}	−0.073***	−0.057**	−0.004	−0.058**	−0.013	–
	(−4.183)	(−2.397)	(−0.156)	(−2.172)	(−0.482)	–
STR{1}	–	0.022*	0.004	0.010	0.016	–
	–	(1.841)	(0.243)	(0.705)	(1.388)	–

Panel A shows the estimation results of mean equations ($STR_t = \gamma_0 + \sum_{j=1}^{K} \gamma_{1,j} STR_{t-j} + \sum_{j=1}^{K} \gamma_{2,j} FXR_{t-j} + \varepsilon_{1,t}$, $FXR_t = \lambda_0 + \sum_{j=1}^{K} \lambda_{1,j} STR_{t-j} + \lambda_2 FXR_{t-1} + \varepsilon_{2,t}$), where FXR_t is currency returns in USD. Panel B presents the estimation results of variance equations ($\ln h_{STR,t} = c_1 + a_1(|\varepsilon_{1,t-1}| - d_1\varepsilon_{1,t-1}) + b_1 \ln h_{STR,t-1}$, $\ln h_{FXR,t} = c_2 + a_2(|\varepsilon_{2,t-1}| - d_2\varepsilon_{2,t-1}) + b_2 \ln h_{FXR,t-1}$). The LB1 Q test is the Ljung-Box test for autocorrelation in the residuals of stock-price return equations and the LB2 Q test is for autocorrelation in the residuals of the currency-return equations. The likelihood-ratio (LR) test examines the cross effects between stock-price returns and currency returns in mean equations. t-statistics are in parentheses. ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

erage, against the USD and EUR. As discussed in Hau and Rey (2006, 302-303), our results for Australia and Canada agree with the "popular view" — that lower equity returns should be mirrored by a weakening currency; whereas, results for Japan, Switzerland and the US reflect the "alternative view" — that lower equity returns are associated with a diminished competitiveness for exporters due to a strengthening currency. With the exception of Switzerland, each country's estimates of DCCs between equity returns and currency returns are greater when exchange rates are expressed in USD than in EUR. At the same time, all estimated DCCs show heteroscedasticity and deviation from normality.

Figure 2 shows estimated DCCs for each country. Consistent with Table 5, the DCCs are mostly negative for the US, Japan, and Switzerland,

TABLE 4A—*Continued*

Panel B. Variance equations

	Australia	Canada	Japan	Switzerland	UK	US
C(1)	-0.142^{***}	-0.112^{***}	-0.101^{***}	-0.162^{***}	-0.169^{***}	–
	(−6.935)	(−47.372)	(−36.642)	(−44.525)	(−43.897)	–
C(2)	-0.160^{***}	-0.12^{***}	-0.144^{***}	-0.066^{***}	-0.101^{***}	–
	(−8.158)	(−51.44)	(−71.145)	(−57.465)	(−49.983)	–
A(1)	0.168^{***}	0.141^{***}	0.141^{***}	0.197^{***}	0.224^{***}	–
	(6.233)	(45.541)	(38.246)	(37.708)	(43.918)	–
A(2)	0.190^{***}	0.129^{***}	0.212^{***}	0.083^{***}	0.106^{***}	–
	(7.483)	(42.651)	(76.384)	(56.632)	(40.540)	–
B(1)	0.955^{***}	0.975^{***}	0.963^{***}	0.949^{***}	0.965^{***}	–
	(87.574)	(307.01)	(251.572)	(165.711)	(194.107)	–
B(2)	0.977^{***}	0.981^{***}	1.002^{***}	0.997^{***}	0.984^{***}	–
	(150.763)	(404.758)	(402.22)	(866.424)	(567.511)	–
D(1)	0.018^{***}	0.008^{***}	0.009^{***}	0.02^{***}	0.009^{***}	–
	(3.209)	(7.081)	(8.558)	(7.037)	(4.770)	–
D(2)	0.009^{**}	0.018^{***}	-0.027^{***}	0.000	0.016^{***}	–
	(2.536)	(3.035)	(−8.36)	(0.030)	(3.298)	–
Log Likelihood	−3529	−3126	−3755	−3182	−3227	–
LB1(10) Q Test (p-value)	0.1147	0.4729	0.8126	0.5738	0.9313	–
LB2(10) Q Test (p-value)	0.7222	0.2898	0.4858	0.3063	0.9918	–
LR Test ($H_0 : \gamma_2 = \lambda_2 = 0$)	275.288^{***}	18.517^{***}	232.646^{***}	4.229	2.149	–

deemed to be countries with safe assets or safe-haven currencies.[10] During a market downturn when equity prices fall significantly, increased risk aversion causes portfolio investment inflows into the US, Japan, and Switzerland resulting in an appreciation of their currencies.[11] At the same time, with the increase in market volatility, the unwinding of carry trades accelerated the appreciation of these funding currencies,[12] implying that substi-

[10]See, e.g., Bernanke et al. (2011) or Gourinchas and Jeanne (2012) for a discussion of safe assets.

[11]This is contrary to what Ranaldo and Soederlind (2010) claimed: that a period of high risk aversion is associated with a depreciation of the USD against both the JPY and CHF.

[12]See, e.g., McCauley and McGuire (2009), Brunnermeier et al. (2009), and the OECD (2008).

TABLE 4B.

Estimation Results from the DCC-MGARCH Model for Currency Returns in EUR

Panel A. Mean equations						
	Australia	Canada	Japan	Switzerland	UK	US
Constant	0.041	0.042*	0.004	0.053**	0.063**	0.068***
	(1.583)	(1.786)	(0.161)	(2.321)	(2.56)	(2.939)
STR{1}	−0.108***	−0.04	−0.085***	0.015	−0.078***	−0.06**
	(−3.748)	(−1.36)	(−3.256)	(0.537)	(−2.743)	(−2.079)
FXR{1}	0.435***	0.009	−0.334***	–	−0.085	0.006
	(11.269)	(0.229)	(−13.53)	–	(−1.604)	(0.164)
Constant	0.028*	0.01	−0.036	−0.008	−0.008	−0.026*
	(1.781)	(0.616)	(−1.446)	(−1.177)	(−0.724)	(−1.862)
FXR{1}	−0.013	−0.01	0.023*	−0.067**	0.011	−0.038
	(−0.474)	(−0.367)	(1.673)	(−2.356)	(0.448)	(−1.403)
STR{1}	−0.008	−0.015	−0.011	−0.004	0.003	−0.033***
	(−0.641)	(−1.121)	(−0.596)	(−1.349)	(0.349)	(−2.743)

Panel A shows the estimation results of mean equations ($STR_t = \gamma_0 + \sum_{j=1}^{K} \gamma_{1,j} STR_{t-j} + \sum_{j=1}^{K} \gamma_{2,j} FXR_{t-j} + \varepsilon_{1,t}$, $FXR_t = \lambda_0 + \sum_{j=1}^{K} \lambda_{1,j} STR_{t-j} + \lambda_2 FXR_{t-j} + \varepsilon_{2,t}$), where FXR_t is currency returns in EUR. Panel B presents the estimation results of variance equations ($\ln h_{STR,j} = c_1 + a_1(|\varepsilon_{1,t-1}| - d_1\varepsilon_{1,t-1}) + b_1 \ln h_{STR,t-1}$, $\ln h_{STR,t-1} = c_2 + a_2(|\varepsilon_{2,t-1}| - d_2\varepsilon_{2,t-1}) + b_2 \ln h_{FXR,t-1}$). The LB1 Q test is the Ljung-Box test for autocorrelation in the residuals of the stock-price return equations and the LB2 Q test is for autocorrelation in the residuals of the currency-return equations. The likelihood-ratio (LR) test examines the cross effects between stock-price returns and currency returns in mean equations. t-statistics are in parentheses. ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

tution effects[13] are stronger than wealth effects[14] for most of this period. Consistent with Campbell et al. (2010), for these countries, currencies provide a natural hedge since they tend to move in the opposite direction from the underlying equities. Since part of the loss from the underlying stock could be offset from the gains in the currency position, investors should not hedge the currency risk (Cho et al., 2012). However, if we focus on the early stage of the crisis in the US, DCCs are positive, implying that a huge decrease in equity returns dominated the wealth effect at the beginning of the crisis.

The unwinding of carry trades (McCauley and McGuire, 2009) and flight-to-quality (JPY, USD) are the two main reasons for the negative correla-

[13]See, e.g., Friedman (1988) and Choudhry (1996). When turbulent markets generate an excess return for the domestic currency, substitution from domestic equities to domestic currencies will occur, resulting in negative correlations between equity and currency returns.

[14]When equity prices fall, demand for the domestic currency falls, resulting in a depreciation of the domestic currency.

TABLE 4B—*Continued*

Panel B. Variance equations						
	Australia	Canada	Japan	Switzerland	UK	US
C(1)	-0.146^{***}	-0.12^{***}	-0.093^{***}	-0.154^{***}	-0.181^{***}	-0.126^{***}
	(−34.835)	(−7.411)	(−5.579)	(−40.436)	(−45.491)	(−60.722)
C(2)	-0.187^{***}	-0.092^{***}	-0.125^{***}	-0.113^{***}	-0.124^{***}	-0.085^{***}
	(−59.166)	(−6.154)	(−8.235)	(−137.341)	(−58.161)	(−54.042)
A(1)	0.179^{***}	0.153^{***}	0.129^{***}	0.192^{***}	0.233^{***}	0.169^{***}
	(35.277)	(6.939)	(5.737)	(34.329)	(42.088)	(53.796)
A(2)	0.21^{***}	0.099^{***}	0.173^{***}	0.166^{***}	0.125^{***}	0.104^{***}
	(51.885)	(4.509)	(8.001)	(118.256)	(46.278)	(50.691)
B(1)	0.95^{***}	0.972^{***}	0.967^{***}	0.954^{***}	0.967^{***}	0.977^{***}
	(127.887)	(135)	(115.907)	(188.217)	(201.337)	(471.88)
B(2)	0.972^{***}	0.986^{***}	0.992^{***}	0.999^{***}	0.986^{***}	0.995^{***}
	(299.581)	(140.174)	(207.136)	(3183.845)	(821.853)	(747.698)
D(1)	0.018^{***}	0.008^{***}	0.009^{***}	0.016^{***}	0.01^{***}	0.006^{***}
	(7.414)	(3.057)	(3.754)	(7.574)	(5.448)	(4.951)
D(2)	0.015^{***}	0.014	−0.003	-0.093^{***}	0.04^{***}	−0.003
	(4.044)	(0.692)	(−0.811)	(−8.083)	(4.573)	(−0.528)
Log Likelihood	−3278	−3236	−4169	−2265	−2930	−3113
LB1(10) Q Test (p-value)	0.6336	0.5157	0.6827	0.5088	0.9109	0.4785
LB2(10) Q Test (p-value)	0.9937	0.7506	0.6052	0.3564	0.9533	0.6012
LR Test ($H_0 : \gamma_2 = \lambda_1 = 0$)	127.40^{***}	1.32	184.01^{***}	1.82	2.67	7.55^{**}

tions in US, Japan, and Switzerland during the contagion phase of the financial crisis. When equity volatilities rise significantly, higher yields on investment currencies cause a depreciation of investment currencies against the USD, CHF or JPY, resulting in a fat tail of negative returns in the distribution of carry-trade returns (Gyntelberg and Remolona, 2007).

The pattern of DCCs for Switzerland and the UK depends on the currency used. While the CHF against the EUR shows negative DCCs between equity and currency returns throughout the sample period, the CHF against the USD shows mostly negative DCCs, but positive DCCs from the last quarter of 2008, caused by the USD appreciation in 2008.[15] During the contagion phase of the crisis, the CHF depreciated against the USD because of the sharp dollar appreciation caused by dollar shortage and overhedging, but it appreciated against other currencies because of the unwinding of carry trades and safe-haven flows (OECD, 2008; IMF, 2012). Thus,

[15]McCauley and McGuire, (2009) attributed this USD appreciation to the unwinding of carry trades and its shortage in the global banking system.

TABLE 5.

DCCs of Stock Returns and Currency Returns

Panel A. DCCs of Stock Returns and Currency Returns in USD						
	Australia	Canada	Japan	Switzerland	UK	US
Observations	1303	1303	1303	1303	1303	–
Sample Mean	0.212	0.444	−0.305	−0.035	0.245	–
Standard Error	0.000	0.165	0.166	0.184	0.000	–
Skewness	0.361***	−0.552***	0.419***	−0.319***	−0.414***	–
Kurtosis (excess)	−1.468***	−0.521***	0.123	−0.266*	−1.092***	–
JB Statistics	145.3***	80.8***	38.9***	25.9***	101.9***	–
LB Q Test (20)	24351***	22640***	22072***	21462***	25269***	–
ARCH LM Test (5)	67.51***	25.61***	7.63***	1.98*	105.51***	–
ARCH LM Test (20)	18.04***	9.88***	2.62***	1.22	41.38***	–
Panel B. DCCs of Stock Returns and Currency Returns in EUR						
	Australia	Canada	Japan	Switzerland	UK	US
Observations	1303	1303	1303	1303	1303	1303
Sample Mean	0.198	0.190	−0.291	−0.345	−0.034	−0.256
Standard Error	0.037	0.081	0.096	0.087	0.080	0.220
Skewness	−0.087	0.511***	−0.934***	−0.433***	−0.124*	0.762***
Kurtosis (excess)	−1.355***	0.914***	1.166***	1.153***	−0.943***	−0.165
JB Statistics	101.316***	102.166***	263.330***	112.915***	51.616***	127.709***
LB Q Test (20)	23826***	13358***	20559***	21366***	20160***	24512***
ARCH LM Test (5)	95.84***	6.25***	3.68***	4.72***	19.24***	16.78***
ARCH LM Test (20)	26.29***	3.37***	1.75**	4.26***	6.48***	11.09***

Table 5 presents the descriptive statistics for the DCCs for each country. The LB Q test is the Ljung-Box test for autocorrelation and the ARCH LM test is for heteroscedasticity. ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

when the market is in extreme turbulence the CHF loses its position as a safe-haven currency against the USD, resulting in positive correlation with equity returns. However, the CHF appreciated against the EUR during the same period, retaining its safe-haven currency status against the EUR. The DCCs of equity and currency returns confirm these findings when the exchange rate is denominated in EUR.

Turning to the UK, the DCCs of the UK are positive when the GBP is denominated in USD; however, if the GBP is in EUR then its DCCs are mostly negative, becoming positive after the US financial crisis. These findings imply that the GBP is not a safe-haven currency against the USD; however, consistent with Ronald and Soderland (2012), because the GBP appreciated against the EUR with the Eurozone sovereign crisis, it was a safe-haven currency against the EUR during this crisis. However, because the strength of its correlation (the absolute value of DCCs) is the weakest among the six countries, the GBP was the weakest safe-haven currency.

Australia and Canada have positive DCCs throughout the period. Because of the unwinding of carry trades, their currencies both depreciated against the EUR and the USD during the US financial crisis. This finding implies that, during the market downturns brought about by the extreme recession, increased risk aversion caused equity capital outflows from Australia and Canada since they are not considered safe havens. However, currency hedging is beneficial for them since hedging currency risk significantly improves the risk-return tradeoff.

Table 6 reports capital flows into the safe-haven countries, US, Japan, and Switzerland over the 2006-2010 period. It shows that the unusual strength of the USD against all currencies (except JPY) is mostly caused by investors' appetite for government bonds and US Treasuries rather than the USD per se. However, the international transaction data for Japan show that most of the capital flowing into it was in the form of financial derivatives and "other investments" rather than government bonds.[16]

4. CHANGING PATTERNS OF DYNAMIC CONDITIONAL CORRELATIONS AND VOLATILITIES

One very salient feature of Figure 2 is that DCCs increase abruptly (in absolute value) near the Lehman failure for most of the countries, regardless of denominating currencies. At the same time, it is worth investigating whether volatility increased during the contagion phase of the crisis. In this section, we investigate the time-varying patterns of DCCs and volatilities by considering unknown structural breaks in DCCs. First, we identify three different phases of crisis spillover — the before-crisis period, contagion period and herding period — using the Bai-Perron test (1998) of unknown structural breaks for each country's DCCs. Second, using the structural breaks found by the Bai-Perron test, we investigate the changing patterns of DCCs and volatilities by estimating the GARCH with dummy-variables model. Finally, we explain these time-varying patterns of DCCs and volatilities with the safe-haven flows of capital.

4.1. Structural Breaks in Dynamic Conditional Correlations

To investigate the changing phases of interactions between the stock and exchange markets during the US financial crisis, we estimate unknown

[16] "Other investments" include trade credits, loans, currency and deposits, and other assets/liabilities.

TABLE 6.

International Transactions in the US, Japan, and Switzerland

Panel A. US										
Items	2006		2007		2008		2009		2010	
	1	2	1	2	1	2	1	2	1	2
Net Portfolio Investment	65.2	220.4	213.9	131.3	50.4	711.9	−555.8	−79.7	7.4	79.5
Treasury	42	108.3	70.8	94.5	215.4	496.2	328.8	225.6	295	444.8
Currency	−2.3	4.5	−7.8	−2.9	−6.5	35.7	9.9	2.8	4.4	24
Panel B. Japan										
Items	2006		2007		2008		2009		2010	
	1	2	1	2	1	2	1	2	1	2
Net Portfolio Investment	11836.8	672.7	6390.9	5602.1	−8366.6	−15955	−17011	−4243.9	−7167.7	−9068.4
Financial Derivatives	156.7	126.8	−11.4	336.3	521.6	1934.7	100.2	848.6	324.6	701.5
Other Investment	−14533	−5857.3	−10480	−14157	731.3	18475.3	11051.9	574.5	−3133.9	3142.8
Panel C. Switzerland										
Items	2006		2007		2008		2009		2010	
	1	2	1	2	1	2	1	2	1	2
Net Portfolio Investment	−50.54	−3.00	−31.27	7.96	−26.28	−12.23	−42	9.94	6.54	24.43
Official Transaction, net	0.93	−1.32	0.92	−4.98	−1.53	−2.62	−32.14	−14.64	−142.8	4.99

Table 6 presents the net flow of international transactions in the US, Japan, and Switzerland. A positive value implies a financial inflow, whereas a negative value implies a financial outflow. Figures are in billions of dollars, billions of yen, and billions of Swiss francs, respectively. The darkened areas indicate the contagion phase of the crisis.

structural breaks of DCCs using the Bai-Perron test.[17] Tables 7-A and B present the estimation results of the Bai-Perron test for DCCs in both USD and EUR. These tables show that all countries have a structural break around September-October of 2008, which may have been caused by the Lehman failure in mid-September. Using those structural breaks in DCCs, we divide the sample into three distinctive sub-periods, i.e., the before-crisis period, the contagion period and the post-crisis adjustment period. For Japan, we find a break at January 5, 2007, following the 10.72% NIKKEI plunge on December 29, 2006. For the US, we find a break at August 9, 2007, the day the DJIA fell 400 points. Breaks at January 29, 2009 in the

[17]For this test, we use $y_t = c_j + \beta_j y_{t-1} + \varepsilon_t$, where $t = T_{j-1}+1, K, T_j, j = 1, K, m+1, T_1, K, T_m$ are the break points, and m is the number of breaks. We assume all the coefficients are subject to change over time. This method sequentially preceeds the test by increasing the number of breaks. In other words, if the test finds one structural break in the whole sample period then it repeats the same process in two subsamples, before and after the break. This recursive process continues until any subsamples do not have significant structural break. We set the number of maximum structural breaks as 6 and the shortest distance between two breaks as 60.

TABLE 7A.

Estimation Results from Structural Breaks for Currency Returns in USD

Country	# of Breaks	Break Point	Lower 95%	Upper 95%
Australia	3	2008:07:22	2008:06:13	2008:07:22
		2008:10:14	2008:10:13	2008:10:16
		2009:01:07	2009:01:07	2009:02:26
Canada	4	2008:05:01	2008:04:28	2008:05:26
		2008:09:04	2008:08:29	2008:09:19
		2010:05:20	2010:04:30	2010:05:24
		2010:08:30	2010:08:27	2010:09:27
Japan	4	2007:01:05	2006:08:24	2007:01:19
		2008:10:06	2008:05:12	2008:10:07
		2008:12:29	2008:12:26	2009:05:01
		2010:05:11	2010:05:10	2011:01:20
Switzerland	3	2008:03:14	2007:08:30	2008:03:26
		2008:10:03	2008:09:29	2008:10:08
		2009:10:07	2009:09:15	2010:08:18
UK	3	2008:07:07	2007:10:04	2008:07:08
		2008:10:22	2008:10:16	2008:10:24
		2009:05:29	2008:06:09	2009:06:12
US	3	2007:08:09	2007:07:30	2007:08:15
		2008:09:04	2008:08:14	2008:09:05
		2009:01:29	2009:01:16	2009:03:17

Table 7-A presents the results of the Bai-Perron tests for multiple structural breaks. The number of significant breaks in each DCC is determined by the Bayesian information criterion (BIC). ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

US and at January 7, 2009 in Australia match the dates the US Congress and Australian Senate approved their respective stimulus packages.

4.2. The GARCH with Time Dummy Variables Model

To check the validity of changing phases of correlations and volatilities during the market downturns, we use the GARCH with dummy variables model. To validate the changing phases of DCCs shown in the previous sections, we employ the GARCH(1,1) model with time dummy variables determined by the different structural breaks in Tables 7-A and 7-B. Because we are focusing on the US financial crisis, we drop the structural breaks that occurred before it. The model can be written as follows, in which Eq.

TABLE 7B.

Estimation Results from Structural Breaks for Currency Returns in EUR

Country	# of Breaks	Break Point	Lower 95%	Upper 95%
Australia	3	2008:07:22	2008:06:30	2008:07:23
		2008:10:14	2008:10:13	2008:10:15
		2009:01:13	2009:01:13	2009:05:04
Canada	2	2008:09:15	2008:08:19	2008:09:17
		2009:01:19	2009:01:16	2009:04:13
Japan	4	2007:01:05	2006:11:30	2007:02:14
		2008:10:06	2008:07:30	2008:10:07
		2008:12:01	2008:11:28	2009:02:18
		2010:05:06	2010:01:28	2010:05:07
Switzerland	3	2008:03:17	2008:02:11	2008:03:18
		2008:09:12	2008:08:08	2008:09:16
		2008:11:14	2008:11:13	2008:12:15
		2010:05:07	2010:02:10	2010:05:10
UK	4	2008:03:17	2008:03:12	2008:03:18
		2008:09:29	2008:07:25	2008:10:02
		2008:11:24	2008:11:18	2009:02:12
		2009:05:19	2009:05:15	2009:06:22
US	3	2007:08:09	2007:07:30	2007:08:15
		2008:09:04	2008:08:14	2008:09:05
		2009:01:29	2009:01:16	2009:03:17

Table 7-B presents the result of Bai-Perron tests for multiple structural breaks. The number of significant breaks in each DCC is determined by the Bayesian information criterion (BIC). ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

(10) is for the means and Eq. (11) is for the conditional variances:

$$\rho_t = \gamma_0 + \gamma_1 \rho_{t-1} + \sum_{k=1}^{n} \tau_{1,k} DM_k + \varepsilon_{\rho,t}, \tag{10}$$

$$h_{\rho,t} = c + \alpha \varepsilon_{\rho,t-1}^2 + \beta h_{\rho,t-1} + \sum_{k=1}^{n} \tau_{2,k} DM_k + \nu_{\rho,t}, \tag{11}$$

where $n = 4$ for Canada and Japan and 3 otherwise. DM_k is a time dummy variable for regime k.

4.3. Estimation of GARCH with Dummies

Tables 8-A and 8-B report the estimation results for the GARCH with dummy variables model when the exchange rate is denominated in USD and EUR, respectively. These tables show that, in most cases, the estimated coefficients for the dummy variables are highly significant, implying that interactions between equity and currency returns became stronger after the Lehman failure.

From the estimates of DM_1-DM_4, we can classify the six OECD countries into four distinct groups. For Australia and Canada, the estimates of the DCCs increase significantly after the US financial crisis. The estimated coefficients of the period dummy for the herding phase in the mean equation (Australia, DM_3) and that for the contagion phase in the mean equation (Canada, DM_1) are both positive and significant. It is also notable that the estimated coefficients of the dummy variables for the contagion phase in the variance equations (Australia, DM_2; Canada, DM_1) are positive and significant, implying that, during the contagion period, DCCs and market volatilities increase at the same time.

Switzerland exhibits a different pattern for different currency denominations. In terms of the EUR, estimates of the DCCs increase (in absolute value) sharply during the contagion phase of the crisis and then decrease (in absolute value) afterwards. The estimated coefficient of the contagion period dummy (DM_2) is negative and significant in the mean equation, but positive and significant for herding and the post-crisis adjustment periods (DM_3 and DM_4). However, in terms of the USD, the estimates of DCCs change from negative to positive, and this is confirmed by the positive and significant contagion and herding period's dummy variables (DM_2 and DM_3). However, as we saw for both Australia and Canada, the estimated coefficients for Switzerland's period dummy variables for the variance equation are positive and significant (DM_2) for both the USD and EUR denominations.

The UK also exhibits different patterns of DCCs for different currency denominations. In terms of the EUR, the estimated coefficient of the dummy variable for the post-crisis adjustment period (DM_4) is negative and significant in the mean equation and the estimated DCCs become negative as the Eurozone sovereign crisis develops. This is caused by the GBP appreciation against the Euro with the Euro sovereign crisis, implying that the GBP become a safe-haven currency against the EUR. However, in terms of the USD, the estimated coefficient of the dummy variable for the post-crisis adjustment period (DM_4) is positive and significant in the mean equation and the estimated DCCs remain positive even with the Euro sovereign crisis. If we look at the variance equation, the estimated dummy for the contagion phase increased significantly, implying high volatility during the period (DM_2) in both the USD and EUR denominations.

For Japan and the US, the estimated coefficients of the period dummies are all negative and significant and the largest estimate is the dummy for the contagion period (DM_2), implying that the DCCs increase (in absolute value) throughout the crisis period with the largest jump for the contagion period (DM_2) in the mean equation. At the same time, the contagion-period dummy (DM_2) in the variance equation is positive and significant, whereas that for the herding period is negative and significant. Thus, the DCCs of Japan and the US increase during the contagion period and they are accompanied by increased market volatilities, but volatilities decrease thereafter.

TABLE 8A.
Estimation Results of DCC with Time Dummy Variables for Currency Returns in USD

Panel A. Mean equations

	Australia	Canada	Japan	Switzerland	UK	US
Constant	1.46E-03***	3.04E-03***	−3.11E-04	−3.97E-03***	7.05E-04*	–
	(42.477)	(7.821)	(−0.223)	(−3.086)	(1.825)	–
RHO{1}	9.93E-01***	9.86E-01***	9.72E-01***	9.59E-01***	9.91E-01***	–
	(5840.181)	(1372.416)	(203.566)	(131.511)	(333.521)	–
DM_1	1.48E-04	1.63E-03	−9.17E-03***	−1.45E-02***	6.65E-05	–
	(0.257)	(1.126)	(−4.645)	(−4.94)	(0.084)	–
DM_2	4.13E-05	1.15E-02***	−2.08E-02***	1.43E-02***	5.60E-03***	–
	(0.322)	(3.445)	(−4.678)	(2.912)	(3.207)	–
DM_3	2.00E-04***	4.98E-03***	−7.96E-03***	1.01E-02***	2.11E-03***	–
	(16.553)	(9.489)	(−4.086)	(4.07)	(3.566)	–
DM_4	–	4.13E-03***	-1.06E-02***	2.09E-03	–	–
	–	(4.872)	(−4.194)	(0.882)	–	–

Panel A shows the estimation results of mean equations ($\rho_t = \gamma_0 + \gamma_1 \rho_{t-1} + \sum_{k=1}^{n} \tau_{1,k} TDM_t + \varepsilon_{\rho,t}$). Panel B presents the estimation results of variance equations ($h_{\rho,t} = c + \alpha\varepsilon_{\rho,t-1}^2 + \beta h_{\rho,t-1} + \sum_{k=1}^{n} \tau_{2,k} TDM_t + \nu_{\rho,t}$). The LR test in Panel C examines the joint significance of time dummy variables in mean equations, variance equation, and both equations. t-statistics are in parentheses. ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

Overall, with the exception of the UK, the DCCs increased significantly during the contagion phase of the US financial crisis and this was accompanied by increased market volatilities. This may reflect the fact that, with the unfolding of the US financial crisis, systemic risk for both the equity and currency markets increased and this increased common volatilities, as we witnessed in the dummies of the variance equation, drives up the correlations of the two asset markets (Alexander, 1995).

TABLE 8A—*Continued*

Panel B. Variance equations						
	Australia	Canada	Japan	Switzerland	UK	US
C	9.28E-09***	1.04E-04***	2.84E-04***	1.81E-04***	2.21E-06***	–
	(7.159)	(80.497)	(7.996)	(4.668)	(6.882)	–
A	4.65E-01***	1.02E-01***	2.15E-01***	7.43E-02***	2.12E-01***	–
	(9.912)	(15.196)	(5.307)	(3.995)	(10.786)	–
B	5.46E-01***	7.00E-01***	1.13E-01*	6.75E-01***	7.28E-01***	–
	(22.03)	(146.747)	(1.662)	(11.647)	(37.605)	–
DM_1	2.89E-05***	1.94E-05***	3.26E-05	−1.44E-05	1.39E-05***	–
	(114.628)	(3.489)	(0.88)	(−0.416)	(5.757)	–
DM_2	1.72E-07**	9.65E-05**	3.83E-04**	3.24E-04**	1.46E-05**	–
	(2.058)	(2.494)	(2.263)	(2.457)	(2.109)	–
DM_3	−1.61E-10	−7.72E-05***	−6.59E-05**	−1.52E-03***	−1.68E-07	–
	(−0.098)	(−42.931)	(−2.155)	(−2.774)	(−0.621)	–
DM_4	–	−7.46E-05***	−1.51E-05	1.49E-03***	–	–
	–	(−28.623)	(−0.363)	(2.73)	–	–
Log Likelihood	8720	3416	3277	2885	4955	–
LB1(5) Q Test (p-value)	0.9905	0.2667	0.4638	0.8154	0.7728	–
LB1(10) Q Test (p-value)	0.3688	0.2674	0.5861	0.2382	0.3474	–
Panel C. LR Test						
	Australia	Canada	Japan	Switzerland	UK	US
$H_0 : \sum_{k=1}^{n} \tau_{1,k} = 0$	278.33***	126.90***	30.80***	34.90***	17.07***	–
$H_0 : \sum_{k=1}^{n} \tau_{2,k} = 0$	13381.80***	2680.69***	16.96***	14.69***	41.03***	–
$H_0 : \sum_{k=1}^{n} \tau_{1,k} = \sum_{k=1}^{n} \tau_{2,k} = 0$	14813.33***	2807.59***	49.89***	48.29***	64.18***	–

5. DETERMINANTS OF DYNAMIC CONDITIONAL CORRELATIONS BETWEEN EQUITY AND CURRENCY RETURNS

5.1. DCCX Model and Explanatory Variables

The DCCs between equity and currency returns in Eq. (6) derived from the DCC-MGARCH model represent the size of the conditional correlation. In this setting, it is important to identify which factors determine this conditional correlation. Similar to the DCCX (DCC with exogenous variables) model of Kim et al. (2013), we estimate the determinants of the

TABLE 8B.

Estimation Results of DCC with Time Dummy Variables for Currency Returns in EUR

Panel A. Mean equations	Australia	Canada	Japan	Switzerland	UK	US
Constant	8.50E-04**	6.70E-03***	−4.87E-03***	−1.31E-02***	−9.35E-04**	−1.36E-03
	(2.283)	(4.448)	(−15.582)	(−90.106)	(−2.09)	(−1.483)
RHO{1}	9.95E-01***	9.56E-01***	9.67E-01***	9.64E-01***	9.86E-01***	9.88E-01***
	(461.043)	(118.607)	(900.862)	(2016.39)	(249.741)	(254.89)
DM_1	−1.28E-04	9.39E-03**	−5.23E-03***	−4.84E-03***	6.50E-04	3.11E-03**
	(−0.451)	(2.04)	(−8.029)	(−7.621)	(0.497)	(2.189)
DM_2	3.43E-04	1.83E-03	−1.83E-02***	−9.69E-03**	2.08E-03	−9.05E-03***
	(0.642)	(1.603)	(−6.759)	(−2.115)	(0.566)	(−2.822)
DM_3	4.51E-04***	–	−3.87E-03***	2.62E-03***	2.28E-04	−4.64E-03***
	(3.169)	–	(−7.416)	(6.829)	(0.346)	(−3.432)
DM_4	–	–	−5.97E-03***	2.53E-03**	−1.83E-03**	–
	–	–	(−7.705)	(2.123)	(−1.961)	–

Panel A shows the estimation results of mean equations ($\rho_t = \gamma_0 + \gamma_1\rho_{t-1} + \sum_{k=1}^{n} \tau_{1,k}TDM_t + \varepsilon_{\rho,t}$). Panel B presents the estimation results of variance equations ($h_{\rho,t} = c + \alpha\varepsilon^2_{\rho,t-1} + \beta h_{\rho,t-1} + \sum_{k=1}^{n} \tau_{2,k}TDM_t + \nu_{\rho,t}$). The LR test in Panel C examines the joint significance of time dummy variables in mean equations, variance equation, and both equations. t-statistics are in parentheses. ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

DCCs in the function shown below:

$$|\rho_{i,t}| = \frac{\exp(\beta' X_{it})}{1 + \exp(\beta' X_{i,t})}, \tag{12}$$

where $\rho_{i,t}$ and $X_{i,t}$ are the DCCs and the explanatory variables for the DCCs of each country. We take the absolute values of the DCCs because we are investigating the effect of exogenous variables on the strength of its comovement regardless of the direction. This logistic function is to circumvent the restriction on DCC, being $0 \le |\rho_{i,t}| \le 1$. The $(K \times 1)$ vector X_t also includes VIXUS, FXVUS, TED spread, and CDS.[18] Therefore, the random-effects model is defined as:

$$l(|\rho_{i,t}|) = \beta_0 + \beta_1 VIXUS_t + \beta_2 FXVUS_t + \beta_3 TED_{i,t} + \beta_4 CDS_{i,t} + u_i + e_{i,t} \tag{13}$$

where $l(|\rho_{i,t}|)$ is the transformed DCC, and u_i and $e_{i,t}$ are the country-specific effect and the error term that follows a white noise process, respectively.

[18]The data appendix provides a detailed description of all variables and their sources.

TABLE 8B—*Continued*

Panel B. Variance equations						
	Australia	Canada	Japan	Switzerland	UK	US
C	8.37E-08***	1.20E-04***	8.42E-05***	1.06E-05***	3.62E-05***	1.38E-04***
	(5.559)	(3.287)	(38.638)	(41.53)	(5.381)	(12.979)
A	2.84E-01***	1.11E-01***	2.83E-01***	1.43E-01***	1.73E-01***	1.34E-01***
	(10.023)	(3.796)	(20.479)	(29.278)	(5.877)	(4.733)
B	7.19E-01***	5.61E-01***	2.40E-01***	7.39E-01***	5.58E-01***	2.19E-01***
	(39.553)	(4.887)	(21.817)	(259.523)	(10.241)	(37.56)
DM_1	4.76E-07	5.18E-04**	4.41E-05***	6.14E-06***	4.47E-05***	9.35E-05***
	(1.552)	(2.406)	(12.076)	(3.302)	(3.36)	(4.05)
DM_2	9.91E-07*	9.53E-06	3.03E-04***	1.36E-04***	3.11E-04***	6.19E-04***
	(1.881)	(0.603)	(3.946)	(3.536)	(3.384)	(5.741)
DM_3	−4.43E-09	–	−9.52E-06***	6.92E-07	3.22E-06	−8.02E-05***
	(−0.305)	–	(−2.678)	(1.526)	(0.79)	(−7.128)
DM_4	–	–	1.53E-05*	5.17E-05***	1.64E-05***	–
	–	–	(1.92)	(14.758)	(2.139)	–
Log Likelihood	6924	3241	3771	4123	3866	3743
LB1(5) Q Test (p-value)	0.0425	0.833	0.4039	0.5057	0.3535	0.2035
LB1(10) Q Test (p-value)	0.1115	0.6884	0.1895	0.1345	0.5444	0.0152

Panel C. LR Test						
	Australia	Canada	Japan	Switzerland	UK	US
$H_0 : \sum_{k=1}^{n} \tau_{i,k} = 0$	10.35**	5.94	224.51***	113.7***	4.64	19.85***
$H_0 : \sum_{k=1}^{n} \tau_{2,k} = 0$	6.06	5.94	172.26***	243.54***	18.83***	135.18***
$H_0 : \sum_{k=1}^{n} \tau_{1,k} = \sum_{k=1}^{n} \tau_{2,k} = 0$	17.15***	12.16**	396.77***	357.24***	26.14***	168.77***

Fratzscher (2012) analyzes the effect on capital flows of a set of common global shocks and a set of country-specific shocks, concluding that global factors account for the global capital flow pattern during the crisis. In this section, we investigate the role of both global and country-specific shocks in affecting the DCCs between equity and currency returns. For global shocks, we include the stock-market volatility index of the US (VIXUS) and the foreign-exchange market volatility index of the US (FXVUS) since the recent global "great recession" originated in the US financial markets (Kanas, 2000; Fratzscher, 2012). For country-specific shocks, we include sovereign CDS (credit-default swap spreads) and country-specific TED spreads. The CDS measures country-specific risk and credit contagion (Longstaff et al., 2011; Jorion and Zhang, 2007). The country-specific TED spread is defined as the difference between the 3-month interbank interest rate and Libor, which measures a country's liquidity condition (Lashgari, 2000; Cheung et al., 2010).

5.2. Estimation of the DCCX Model

Before estimating the DCCX model, we divide the countries into two distinct groups: Panel A consists of Australia, Canada and the UK, the countries without safe-haven assets; and Panel B consists of the US, Japan, and Switzerland, the countries with safe-haven assets. Table 9 reports the estimation results of the DCCX model with random effects for both groups of countries (those without and those with safe assets) and for all countries (Panel C).

Global shocks, which are measured by the VIXUS and FXVUS indexes, increase the DCCs of equity and currency returns for countries without safe-haven assets, but decrease them for countries with safe-haven assets. Increased global volatility and risk aversion make investors rebalance their portfolio by selling risky assets and buying safe assets. In Australia, Canada, and the UK, as stock prices fell investors rebalanced their portfolios by buying safe-haven assets, resulting in capital outflows and depreciation of these countries' currencies. However, in the US, Japan, and Switzerland, as stock prices fell increased global volatilities and risk aversion caused capital to flow into these countries, resulting in appreciations of these countries' currencies (Caballero and Krishnamurthy, 2008). This finding is consistent with Fratzscher's (2012) hypothesis that the dynamics of capital flows were driven by safe-haven flows during the crisis.

Turning to the country-specific shocks in Table 9, an increased TED spread, our country-specific measure of liquidity, increases the DCCs of stock and currency returns for all countries since a high TED spread implies worsened liquidity and unwinding of the carry trade (Brunnermeier, 2009). Thus, an increased TED spread decreases equity prices and causes capital outflows for all countries, resulting in a depreciation of their currencies. This is consistent with the notion that an increased TED spread, or worsened liquidity, would lower the stock-market returns, which would then depreciate the domestic currency. In this way, the TED spread can strengthen the DCCs between stock-price and foreign-exchange returns.

Finally, the CDS has positive and significant association with the DCCs in Australia, Canada, and the UK, which is consistent with the findings of Bystrom (2005) that increased credit-default swap spreads associated with increased volatility in stock markets may strengthen the conditional corre-

TABLE 9.

Estimation Results from the DCCX Model

Panel A. The Countries without Safe Assets				
Dep. Variables: $l(\rho_{i,t})$	Australia, Canada, and UK			
	DCCs in USD term		DCCs in EUR term	
Variables	Coefficient	t-statistics	Coefficient	t-statistics
Constant	0.1920	(0.4986)	0.0605	(0.3618)
VIXUS{1}	0.0101***	(14.2790)	0.0034***	(5.8860)
FXVUS{1}	0.0081***	(3.3646)	0.0076***	(3.8022)
TED{1}	0.1495***	(38.4346)	0.0097**	(3.0281)
CDS{1}	0.0016***	(17.1449)	0.0000	(0.5480)
Panel B. The Countries with Safe Assets				
Dep. Variables: $l(\rho_{i,t})$	Japan, Switzerland, and US			
	DCCs in USD term		DCCs in EUR term	
Variables	Coefficient	t-statistics	Coefficient	t-statistics
Constant	0.0570	(0.1787)	−0.3173**	(−2.0932)
VIXUS{1}	−0.0159***	(−11.9959)	−0.0095***	(−13.8718)
FXVUS{1}	−0.0128***	(−2.8507)	−0.0138***	(−5.9516)
TED{1}	0.0134*	(1.8408)	0.0247***	(6.5822)
CDS{1}	0.0003	(0.7120)	−0.0000	(−0.0652)
Panel C. All Countries				
Dep. Variables: $l(\|\rho_{i,t}\|)$	All Countries			
	DCCs in USD term		DCCs in EUR term	
Variables	Coefficient	t-statistics	Coefficient	t-statistics
Constant	−1.4543***	(−4.5693)	−1.4745***	(−3.9699)
VIXUS{1}	0.026***	(12.0993)	0.0024	(1.195)
FXVUS{1}	−0.0151**	(−1.9937)	0.0225***	(3.2556)
TED{1}	0.1484***	(15.3438)	0.0633***	(7.1459)
CDS{1}	0.0028***	(7.8414)	−0.0015***	(−4.5443)
Panel D. Panel Cointegration				
	AT, CN, UK	JP, SW, US	All Countries	
Panel v-statistics (USD)	2.892***	42.661***	5.182***	
Panel v-statistics (EUR)	12.952***	22.698***	13.791***	

Table 9 presents the results of the DCCX model with random effects. VIXUS is the volatility index for the Chicago Board Options Exchange; $l(|\rho_{i,t}|)$ signifies the logistic transformation of the DCCs in the absolute value. FXVUS is the 3-month USD/EUR volatility index; TED is the interest rate of each country minus the 3-month LIBOR; and CDS is the credit-default swap spread in each country. Panel D presents the results of Pedroni test of panel cointegration (Pedroni, 2004). ***, **, and * represent the significance level of 1%, 5%, and 10%, respectively.

lation. In other words, an increased CDS decreases stock prices and leads to capital outflows from these non-safe-haven countries, depreciating their currencies. However, the CDS is insignificant for the safe-haven countries.

6. CONCLUSIONS

We have investigated the changing patterns of the dynamic correlations (DCCs) between equity and currency returns for six OECD countries from January 2006 to December 2010. First, using the DCC-MGARCH model, we estimated the dynamic conditional correlations of equity and currency returns. In the US, Japan, and Switzerland, safe-haven capital inflows mean that even when their stock prices are falling, their currencies appreciate, or the substitution effect dominates the wealth effect. However, countries that are not considered to be safe havens the UK, Canada, and Australia experienced capital outflows and positive correlations between their equity and currency returns, or the wealth effect dominates the substitution effect for these countries.

Second, using the GARCH with dummy-variables model, we confirm that DCCs between equity and currency returns and their volatilities became stronger during the contagion phase of the US financial crisis. Finally, using the DCCX model, we find that global shocks have an asymmetric impact on the DCCs of the two groups of countries. Both global volatility indexes (VIXUS and FXVUS) increase the DCCs of countries without safe-haven assets, but decrease the DCCS of countries with safe-haven assets. Our liquidity measure, the TED spread, increases the DCCs of both groups of countries; however, the credit-default swap spread is significant only for countries without safe-haven assets. In this way, we have catalogued some of the ways in which safe-haven countries respond differently to global risk; that is, we have identified the characteristics that lead to these countries being perceived as less risky than others.

Contrary to previous studies, which failed to take into account the differences in the macroeconomic environment of each sovereign market, we have identified the factors that mattered for the different phases of the dynamic linkages between equity and currency returns for these six OECD countries during the 2008 financial crisis. Our results provide investors and portfolio managers with a better way to guard their portfolios from future market turmoil and, consequently, improve their financial strategies. Furthermore, this study provides policymakers with insights into the transmission channels that affect the strength of time-varying correlations between the stock and foreign-exchange markets, thus allowing them to come up with preemptive and active responses against shocks before they can destabilize the financial market.

APPENDIX: DATA APPENDIX

Country	Item	Description	Source
Australia	Stock Index	All Ordinaries Index	Datastream
	Exchange Rate	USD/AUD	Datastream
	Interest Rate	3-month Australian Deposit	Bloomberg
	CDS	5-year Australia CDS in USD	Bloomberg
Canada	Stock Index	TSX Composite Index	Datastream
	Exchange Rate	USD/CAD	Datastream
	Interest Rate	3-month Canadian T-Bill	Datastream
	CDS	Not available	Bloomberg
Japan	Stock Index	Nikkei 225 Index	Datastream
	Exchange Rate	USD/JPY	Datastream
	Interest Rate	3-month Japanese T-Bill	Bloomberg
	CDS	5-year Japan CDS in USD	Bloomberg
Switzerland	Stock Index	Swiss Market Index	Datastream
	Exchange Rate	USD/CHF	Datastream
	Interest Rate	3-month Swiss Interbank	Datastream
	CDS	5-year Swiss CDS in USD	Bloomberg
UK	Stock Index	FTSE 100 Index	Datastream
	Exchange Rate	USD/GBP	Datastream
	Interest Rate	3-month UK T-Bill	Bloomberg
	LIBOR	3-month GBP LIBOR	Bloomberg
	CDS	5-year UK CDS in USD	Bloomberg
US	Stock Index	S&P 500 Index	Datastream
	Exchange Rate	EUR/USD	Datastream
	Interest Rate	3-month US T-Bill	Bloomberg
	CDS	5-year US CDS in EUR	Bloomberg
	Stock Volatility Index (VIXUS)	Chicago Board Options Exchange (CBOE) volatility index	Bloomberg
	FX Volatility Index (FXVUS)	3-month USD/EUR volatility index	Datastream

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