International Comovement of Equity Markets and Foreign Exchage

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Abstract

With this article, we contribute to the analysis of comovement of equity markets and foreign exchange rates using a large international data set covering the most important markets. We measure the mutual influence on the levels by correlation, linear regression, vector autoregression, and Granger causality as well as the dynamic in the comovement behavior by means of DCC-GARCH. We find significant negative as well as positive comovement. Moreover, we observe that comovement measured by linear dependence tends to be much more stable in developing economies than in the leading economies. On the other hand, we generally do not find significant regional clusters of comovement behavior.

Key words:

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1. Introduction

In increasingly globally active financial markets, the aspect of comovement between currencies and international portfolio holdings becomes an issue of paramount importance (Johnson and Soenen, 2009). Negligance of which might easily counteract portfolio management objectives. Consequently, in a world of global equity investments, exchange rates are just as relevant for portfolio returns as the equity returns themselves. Moreover, the foreign exchange market actually represents the largest asset class in the world.[3] It is the aim of this work to contribute with a thorough econometric analysis of comovement between equity markets and foreign exchange, whose results can immediately benefit the investor.

Visual examination of equity market and exchange rate plots reveals many similarities. All markets and exchange rates are affected to some extent by global developments. As an example, we present the development of the euro zone in Figure 1. In the first years of examination, the dot-com bubble, the subsequent crash, and recovery therefrom dominate the picture. The following years are mostly characterized by equity market growth, which peaks with the United States real estate bubble. The collapse of the bubble is then succeeded by recovery and turbulent times afterwards. A certain Comovement is visually detectable to some extent. However, comovement characteristics differ greatly between different markets. Moreover, comovement is more evident in some periods than in others.

In his seminal work on portfolio theory, Markowitz (1952) suggests that

[3]See, for example, Galati and Melvin (2004).

minimization of risk can be achieved through diversification. In an extension of the original idea, Sharpe (1964) considers the presence of undiversifiable, systematic risk in his popular capital asset pricing model. Asset excess returns depend to some extent on the market excess returns linearly. That is, he considers comovement between assets and some market where comovement is expressed as correlation. More generally, Ross (1976) introduces the sensitivity of asset prices to n economic factors. Consequently, the arbitrage pricing theory acknowledges price comovements with further factors.

Comovement in terms of asset price dependencies is a common and well-studied phenomenon. Common economic factors, which influence expected discounted returns, serve as primary explanation. However, plenty of research suggests that there is asset price comovement in excess of what any economic explanatory factors could account for. Campbell et al. (2001) notice that, even though comovement in the United States had decreased somewhat during the decades prior to their study, it is still beyond that measurable by the covariance. This excess comovement is commonly explained by investor sentiment and irrational "herd behavior".

The most intuitive measures of comovement are based on correlation. Nevertheless, defining comovement is not trivial. There is plenty of research about comovement but no common understanding of the term. Baur (2003) notes that there is no clear and unambiguous definition of comovement and no unique measure associated with it. Campbell et al. (2001) define it as the part of stock price variation that cannot be explained by market or industry movements. It is not clear from the start which methodology suits the purpose best. Hence, in our analysis of comovement between stocks and foreign exchange prices, we will use several different measures.

To introduce the reader to the matter as well as present the state of research, we provide section 2. Each model used in our study will be presented in detail. The data consisting of 30 equity indices and 30 exchange rates series will be introduced in chapter 4. Section 5 will present the results. To conclude, section 6 will summarize.

2. Literature

The academic literature related to the term comovement is manifold. However, to the best of our knowledge, the term appears in an economic context, only, and mostly in the field of finance where it is used to describe the coherence between financial asset prices or asset returns. The bulk of the comovement literature in this context concentrates on equity with particular focus on international markets, fundamentals, individual stocks, or stocks and other securities.

By far, most research focuses on comovement of equity prices or returns. In particular, comovement of international equity markets on a regional or global scale is thoroughly studied.

Being among the first to go into this direction, Agmon (1972) finds support for the hypothesis that share price comovement in the United States, United Kingdom, Germany, and Japan behave as if there were only one common capital market. Panton et al. (1976) find different degrees of similarity of return comovement between twelve major international equity markets. Evidence that comovement is not simply equivalent to fundamentals is provided, for example, by Shiller (1989) who reports evidence of stock price comovement between the United States and United Kingdom stock prices in excess of what dividend comovement would suggest.

It is commonly observed that comovement changes in time. Using a common factor model, Morana and Beltratti (2008) document that volatility comovement between the US, UK, German, and Japanese markets, respectively, have become more pronounced, in the period 1973–2004. Bollerslev (1990) documents rising comovement between five nominal European U.S.

dollar exchange rates following the inception of the European Monetary System. To do so, he uses the constant correlation multivariate GARCH model. They find volatility components strongly correlated between the currencies. Moreover, they find a much higher likelihood for their model than for the CC-GARCH model. Though not focussing on volatility comovement, Johnson and Soenen (2009) suggest that a higher share of imports by Germany from other EU countries as well as fluctuations and increased volatility in the exchange rate have negative effects on stock market comovement.

There is research that suggests that comovement increases during periods of turmoil at the financial markets. Especially the black Monday in 1987, the 1994 Mexican peso crisis, the Asian financial crisis of 1997, and the collapse of the dot-com bubble in 2000 are well examined considering changes of asset price comovements. Wen-Chung and Hsiu-Ting (2008) suggest that comovement between stocks in high-tech industries is stronger than in traditional industries and stronger in bull than in bear markets. This is a well known fact. Building on Veldkamp (2006) and Brockman et al. (2010), Höchstötter et al. (2010) analyze the impact of news on stock return comovement. Defining a measure of news comovement, they find that stock return comovement is to some extent driven by the degree of commonality in firm specific news.

Lee and Kim (1993) document a strengthening of comovement after the 1987 stock market crash. Brooks and Del Negro (2004) applying analysis of variance and mean absolute deviations of coefficients in a cross-sectional regression model cannot reject the hypothesis that the rise in comovement during the period between 1985 and 2002 was only temporary due to the stock market IT bubble. As explanation of rising comovement, Connolly et al. (2007) regarding United States and European equity markets find that comovement is stronger in uncertain time periods. This is in agreement with the view presented Höchstötter et al. (2010) and Brockman et al. (2010), for example.

Research on comovement between stock returns and economic fundamental values such as inflation, interest rate, etc. is also very common. For example, Karolyi and Stulz (1996) do not find evidence that US macroeconomic announcements, foreign exchange shocks, and treasury bill returns have influence on return correlations between US and Japanese market returns.

There has also been research on comovement of stock returns and bond yields and, to a lesser extent, on comovement between equity returns and returns of different kinds of securities, such as asset backed securities or among bond yields. For example, Shiller and Beltratti (1992) document negative correlation between stock prices and bond yields in the US and the UK between 1871 and 1989. Jobst (2006) examine comovement between asset-backed securities and stocks using a vector autoregressive model.

Using regression analysis, Ammer et al. (2011) study the comovement between emerging market and non-emerging market stock and bond markets in the period 1992–2009. Their study suggests that longer period emerging market bond and stock prices have on average moved in the same direction as the prices of non-emerging market risky assets. However, they also find evidence that the responsiveness of emerging market asset prices to movements in U.S. high-yield corporate bond spreads has declined over the past decade.

We conclude this section with the literature mostclosely related to ours.

Granger et al. (2000) point out the contrasting theories of the "traditional" approach, i.e. currencies lead stocks, and the "portfolio" approach, i.e. stocks lead currencies negatively correlated. Using daily Asian data between 1986 and 1998, support of the traditional approach is found in South Korea while the portfolio approach is supported in Hong Kong. In the other Asian markets, the relationships are bidirectional. Based on monthly Swedish data in the period 1993-98, Hatemi-J and Irandoust (2002) prove that stocks unidirectionally Granger cause exchange rates. With the aid of a friction and Tobin model, Hashimoto and Ito (2004) analyze Asian stocks and currencies in the period 1997-99. They find that the Hong Kong stock market was significantly affected by the Indonesian, Korean, and Thai currency depreciations. Dimitrova (2005) focussing on the US and UK 1990 and 2004 finds weak evidence of currency depreciation caused by an upward trend in the stock market. Aydemir and Demirhan (2009) using data from Turkey between 2001 and 2008 find evidence of a bidirectional causal relationship between exchange rates and stock prices.

3. Methodology

3.1. Covariance, Correlation, and Linear Regression

Since covariance, Pearson correlation, and the concept of linear regression are well-known, we simply state a few details. For series of length T, we use the unbiased covariance estimate with standard error

$$\hat{\sigma}_{Cov} = Cov(x, y) \cdot \sqrt{\frac{2}{T-1}}$$

as established by Ahn and Fessler (2003). For the assessment of the goodness-of-fit of the regression, in addition to the R^2, we also use the adjusted coefficient of determination

$$\bar{R}^2 = 1 - (1 - R^2)\frac{T-1}{T-p-1}$$

where p is the total number of regressors in the linear model excluding the constant term.

3.2. Vector Autoregression and Granger Causality

To test whether one can predict equity market movements by foreign exchange movements or the converse, the time series are tested for Granger causality. According to Granger (1969), x causes y if x contains information that helps predict y above and beyond the information contained in past values of y alone. This technique can be found often in the context of comovement as, for example, by Jang and Sul (2002) or D'Ecclesia et al. (2006).

Granger causality is analyzed in a vector autoregression model of the form

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} A_{11}(L) & A_{11}(L) \\ A_{21}(L) & A_{22}(L) \end{bmatrix} \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} + \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \end{bmatrix}$$

The $y_{it}, i = 1, 2$ denote the endogenous variables, c_i denote constants, and ϵ_i denote independent disturbances at time t. The model parameters $A_{ij}(L)$ take the form $\sum_{k=1}^{l} a_{ijk} L^k$, where L is the lag operator defined by $L^k y_t = y_{t-k}$, and l is the lag length.

The choice of lag length can be crucial. Thornton and Batten (1984) show that Granger causality tests can come to converse results, if conducted with different lag lengths. For an objective selection of lag length, the Bayesian Information Criterion (BIC) of Schwarz (1978)

$$BIC = \log \hat{\sigma}_\epsilon^2 + \frac{1 + 2l + m}{T} * \log T.$$

is employed where m is the number of exogenous instantaneous variables.

To test for Granger causality based on T observations, the sum of squared residuals of the models (including contemporaneous as well as l lagged observations) before and after inclusion of the corresponding causal series are compared applying the F-statistic

$$F = \frac{\frac{RSS_1 - RSS_2}{l}}{\frac{RSS_2}{T - (1 + 2l + m)}}$$

where RSS_1 and RSS_2 denote the residual sums of squares with and without consideration of x_t, respectively.

3.3. Geweke's Measure for Linear Dependence

Geweke (1982) proposes additional linear measures, which are occasionally employed with respect to comovement analysis, predominantly for the detection of the influence of fundamentals on comovement. It is assumed that for the two time series x_t and y_t, there are autoregressive representations, such that:

$$x_t = \sum_{s=1}^{\infty} e_{1s} x_{t-s} + u_{1t}, \qquad \Sigma_1 = Var(u_{1t})$$
$$y_t = \sum_{s=1}^{\infty} g_{1s} x_{t-s} + v_{1t}, \qquad \mathrm{T}_1 = Var(v_{1t})$$

and vector autoregressive representations of the form

$$x_t = \sum_{s=1}^{\infty} e_{2s} x_{t-s} + \sum_{s=1}^{\infty} f_{2s} y_{t-s} + u_{2t}, \qquad \Sigma_2 = Var(u_{2t})$$
$$y_t = \sum_{s=1}^{\infty} g_{2s} x_{t-s} + \sum_{s=1}^{\infty} h_{2s} y_{t-s} + v_{2t}, \qquad \mathrm{T}_2 = Var(v_{2t}).$$

According to Geweke's work, linear feedback from y to x is measured as follows:

$$F_{y \to x} = \ln \left(|\Sigma_1| \,/\, |\Sigma_2| \right) \tag{1}$$

and linear feedback from x to y symmetrically:

$$F_{x \to y} = \ln \left(|\mathrm{T}_1| \,/\, |\mathrm{T}_2| \right). \tag{2}$$

The residual vectors u_{2t} and v_{2t} are both serially uncorrelated, but can be correlated with each other contemporaneously. The covariance matrix Υ of the vector autoregression residual series therefore is

$$\Upsilon = Var \begin{pmatrix} u_{2t} \\ v_{2t} \end{pmatrix} = \begin{bmatrix} \Sigma_2 & C \\ C' & \mathrm{T}_2 \end{bmatrix}.$$

This leads to Geweke's measure of instantaneous feedback

$$F_{x \cdot y} = \ln \left(|\mathrm{T}_2| \cdot |\Sigma_2| \,/\, |\Upsilon| \right). \tag{3}$$

Geweke proposes the following measure for linear dependence

$$F_{x,y} = \ln \left(|\Sigma_1| \cdot |\mathrm{T}_1| \,/\, |\Upsilon| \right) F_{x,y} = F_{y \to x} + F_{x \to y} + F_{x \cdot y}.$$

as the sum of the three types of linear feedback (1), (2), and (3) established above.

Hence, the measure considers (instantaneous) linear regression and vector autoregression aspects. Geweke was the first one to point out the decomposition such that linear dependence is the sum of linear feedback from x to y, linear feedback from y to x, and mutual instantaneous linear feedback.

3.4. Dynamic Conditional Correlation GARCH (DCC-GARCH)

It is well known that financial time series tend to feature heteroscedasticity. However, the dependence structure between equity markets and foreign exchange is dynamic. Based on the initial autoregressive conditional heteroscedasticity models by Engle (1982) and Bollerslev (1986), the multivariate dynamic conditional correlation (DCC-GARCH) model can feature both, conditional (co-)variances and conditional correlations. For example, Balasubramanyan (2004) apply vector autoregression and the DCC-GARCH model to stock returns in the US, UK, and Japanese markets and find time varying correlation with asymmetric volatility comovement and spillover effects.

As presented by Engle III and Sheppard (2001), it is assumed that the filtered returns from k assets are conditionally multivariate normal with conditional covariance matrix H_t composed of a $k \times k$ diagonal matrix of conditional standard deviations h_{it} on the diagonal and a matrix R_t containing the conditional correlations

$$
\begin{aligned}
H_t &= D_t R_t D_t \\
D_t &= \operatorname{diag}\left\{\sqrt{h_{i,t}}\right\}
\end{aligned}
$$

The log-likelihood of this estimator can be written

$$
\begin{aligned}
L &= -\frac{1}{2}\sum_{t=1}^{T}\left(k\log(2\pi) + \log(|H_t|) + r_t' H_t^{-1} r_t\right) \\
&= -\frac{1}{2}\sum_{t=1}^{T}\left(k\log(2\pi) + \log(|D_t R_t D_t|) + r_t' D_t^{-1} R_t^{-1} D_t^{-1} r_t\right) \\
&= -\frac{1}{2}\sum_{t=1}^{T}\left(k\log(2\pi) + 2\log(|D_t|) + \log(|R_t|) + \epsilon_t' R_t^{-1} \epsilon_t\right)
\end{aligned}
$$

where are the standardized residuals $\epsilon_t = D_t^{-1} r_t \sim N(0, R_t)$. The elements of D_t are univariate GARCH models, such that

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

for $i = 1, 2, \ldots, k$ with $\sum_{p=1}^{P_i} \alpha_{ip} + \sum_{q=1}^{Q_i} \beta_{iq} < 1$ and restrictions for non-negativity of variances.

The DCC-GARCH model is able to capture dynamic covariances as well as correlations. The dynamic correlation structure is:

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

with

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

where ϵ_t are the standardized residuals, as described above. Q_t is the conditional covariance matrix of the standardized residuals and $\bar{Q}$ is the unconditional covariance of the standardized residuals. Q_t^* is a diagonal $k \times k$ matrix composed of the square root of the diagonal elements of Q_t:

$$Q_t^* = \begin{bmatrix} \sqrt{q_{11}} & 0 & 0 & \cdots & 0 \\ 0 & \sqrt{q_{22}} & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & \sqrt{q_{kk}} \end{bmatrix}.$$

Elements of R_t are of the form $\rho_{ijt} = \frac{q_{ijt}}{\sqrt{q_{ii} q_{jj}}}$. Engle III and Sheppard (2001) show that R_t is positive definite if a number of parameter restrictions are satisfied for all asset series $i \in [1, \ldots, k]$ and they develop a procedure for estimation which this work relies on.

Engle III and Sheppard (2001) develop a test for constant correlation of residuals of two univariate GARCH processes, i.e. $H_0 : R_t = \bar{R}$. First of all, univariate GARCH processes are estimated and residuals are standardized. Then the correlation of the standardized residuals is estimated. The vector of standardized residuals is now jointly standardized by the symmetric square root decomposition of the estimated correlation. The outer product of the resulting residuals is then regressed on a constant and lagged outer products. Under the null, all of the lagged parameters and the constant should be zero.

4. Data

For an analysis of comovement between equity markets and foreign exchange, the selection of data suffers from a trade-off between available number of free floating exchange rates and time series length. Less strict requirements on time series length imply availability of more free floating exchange rates.

This work focuses on equity market and exchange rate comovement from January 1999 on due to two main reasons. Firstly, 1999 was the year of the introduction of the EUR currency. From its beginnings on, it was the world's second most traded currency and it should have an appropriate weight in this study. Secondly, the number of exchange rates, which are free floating, did not substantially increase since 1999. Most of the monetary regime changes took part before that time.

The authors are indebted to the Chair of Financial Engineering and Derivatives (2011) at the Karlsruhe Institute of Technology for providing access to the Bloomberg data repository. Data consist of exchange rates and MSCI Country Indices of 30 countries. The countries have been selected due to availability of a country index and their exchange rate regime. Countries with managed floating with no predetermined path for the exchange rate and countries with independently floating exchange rate arrangements, as stated in the reports of the IMF (2004) and the IMF (2009), have been considered, if a country index is available at the time of writing.

Most of the world's leading currencies fulfill the floating requirement noted above. Of the 33 currencies that contribute more than 0.1% to the global foreign exchange market turnover, only HKD, RUB, DKK, HUF, CNY, and SAR do not or did not have floating exchange rates for most of the period of concern. HKD, CNY, and SAR have arrangements where the USD serves as exchange rate anchor. The RUB has a fixed peg arrangement to a composite of currencies and the DKK is pegged to the EUR. The HUF is freely floating now but it did have a flexible peg to the EUR until 02/25/2008 (MNB, 2008) and therefore is not examined.

All currency exchange rates examined are local currency/USD. All MSCI Country Indices are performance indices, which means they indicate equity price returns and dividend yields. The indices are capitalization-weighted and free float adjusted. All indices are denominated in local currency. Data consist of daily observations for all trading days. Each day, the last prices of the respective markets are taken. For foreign exchange, which is traded 24 hours a day in the interbank market, the last prices in New York at 17:00 ET (23:00 ECT) are considered relevant. At this time, all equity markets regarded are closed and there is no overlapping. Only the following currencies have pricing hours limited to local market hours: Brazilian real (last price at 23:00 ECT), Chilean peso (19:30 ECT), Colombian peso (20:00 ECT), Egyptian pound (14:30 ECT), Indonesian rupiah (11:00 ECT), Israeli shekel (22:00 ECT), Indian rupee (13:30 ECT), South Korean won (8:00 ECT), Malaysian ringgit (11:00 ECT), Peruvian nuevo sol (20:30 ECT), Philippine peso (11:00 ECT), Pakistani rupee (14:30 ECT), Turkish lira (23:00 ECT), and New Taiwan dollar (10:00 ECT).

Examining the comovement between country indices and foreign exchange is favorable to examining the comovement of single stocks and foreign exchange rates for different reasons. Country Indices are not only easier to handle in terms of data processing. The MSCI Country Indices also give a general overview by comprising every listed stock in the respective market. They cover all sectors and are not affected by mergers and acquisitions or stock splits. Moreover, there is no apparent downside of using country indices in a general work like this one.

The use of MSCI Country Indices comes with several advantages in terms of comparability, since the indices are all generated by the same methodology. Daily data is available for all markets of interest and is examined in the period 01/01/1999–06/30/2011 with the exception of the markets of the United Kingdom, Brazil, Turkey, and Malaysia. In the United Kingdom daily country index data is only availably for the period 05/30/2002–04/29/2011. Brazil's currency has been independently floating only from 01/18/1999 on (Meirelles, 2009) and Turkey's from 02/28/2001 on (Görmez and Yilmaz, 2007). Malaysia's managed floating exchange rate regime was not in place until 05/21/2005 (BNM, 2005).

Since all currency exchange rate are equal to the local currency's value in USD, it is not meaningful to study the comovement between the USD, which of course always has the value 1, and United States equities. Instead, comovement is examined between the United States equity market and a weighted average of a basket of exchange rates. More precisely, the exchange rates USD/EUR (weighting 0.405), USD/JPY (0.235), USD/GBP (0.160), USD/AUD (0.077), USD/CHF (0.064), and USD/CAD (0.060) make up the composite exchange rate, for which comovement of United States equities and foreign exchange is evaluated. Weightings are according to the respective average proportions in USD of foreign exchange turnover in accordance with the Bank of International Settlement's central bank surveys of 2001, 2004, 2007, and 2010 (BIS, 2010). The currencies selected are the six most frequently traded currencies in exchange for USD. In the period regarded they make up 80% of the foreign exchange of USD. Also, these six respective markets and the United States market will be referred to as “major” markets from here on, all other markets are considered “minor”.

5. Results

The methods established above are applied to each country separately, considering equity market and exchange rate returns. For the United States, the composite exchange rate USD/CMP is used instead of a single exchange rate. Results for Egypt and Pakistan are not meaningful because of strong non-market manipulation and therefore are not discussed.

5.1. Correlation Analysis and Linear Regression

As can be seen from Table 1, correlation analysis reveals that equity markets and foreign exchange rates are not independent. However, results are mixed. There are positive correlations as well as negative ones. With Egypt and Pakistan left out, the markets with positive correlation outnumber the ones with negative correlation 25 to 3. The average correlation is slightly positive with a value of 0.17. The absolutely strongest positive correlation of 0.43 is obtained for the Turkish market. The strongest negative correlation of -0.13 is given by Switzerland.

There are three markets with negative correlations to the corresponding exchange rates, namely the United States market, the Japanese Market and the Swiss market. Interpretation for negative correlation of Japan and Switzerland with their respective exchange rates is not trivial. Both exchange rates appreciate strongly during the regarded period. This is also true for the Swiss equity market.

A reasonable explanation is that some currencies serve as a “safe haven” for investors in uncertain times. As equity markets decline, investors re-allocate their funds into allegedly save currencies. Moreover, Japan’s and

Switzerland's balances of trade traditionally show a surplus, which points out the relative dependency on exports of these countries. Weak currencies of course strengthen the competitiveness. In the case of the United States, the economy has had a trade deficit during the whole period of concern explaining the negative relationship during strong market periods.

All other markets show positive correlation with their respective exchange rates of varying magnitude. The Euro Zone market shows, with a value of 0.02, the least absolute correlation of all markets regarded (leaving out Pakistan). Other major markets, such as Australia and especially Canada show relatively strong positive correlation with their exchange rates, just like most minor markets.

Beside the fact that the major markets have comparably small correlations, economic development does not have a unique influence on the correlation. For example, the two emerging markets of South Africa and Turkey display correlation close to zero as well as, on the other hand, very high correlation. Geographical proximity is also not relevant. The South East Asian markets of Thailand and Malaysia for example show quite different correlations. However, it is apparent that correlation in the Americas markets is comparably high with an average correlation of 0.29.

To demonstrate the effect on the portfolio risk, in Table 2 we display Markowitz's risk measure of portfolios consisting of two assets, for each market, one being the local currency and the other an equity investment copying the respective MSCI index. The table exhibits risk without correlation effects, risk with correlation effects, and the percentage change.

On average, investments are more than 6% riskier if correlations are considered. The greatest increase is above 16% in the case of a foreign investment in Turkey. On the other hand, negative correlation between Swiss equity market returns and CHF/USD exchange rate returns actually reduce risk for foreign investments in Switzerland. The change in risk is directly related to the correlation between the two assets.

Tables 3 and 4 display the results of linear regression analysis with equity market and exchange rates as dependent variables, respectively. The constant terms are not particularly meaningful and in many case statistically insignificant.

All regression coefficients, except for the Euro Zone market, are significant, as t-statistics prove.[4]

The β coefficients are generally higher in regressions of equity markets on exchange rates than vice versa due to higher equity market volatility.

In accordance with the correlation coefficients, only the United States', the Japanese, and the Swiss equity market and exchange rate coefficients are negative. Minor markets tend to have greater regression coefficients. Canada and Australia stick out from the major markets with comparably high regressions coefficients. On the other hand, the markets in the Czech Republic, South Africa, Israel, New Zealand, and Thailand have relatively weak linear ties between their equity markets and exchange rate returns.

5.2. Vector Autoregression and Granger Causality

For each equity market and corresponding exchange rate, a vector autoregessive model as in equation 3.2 is employed. Without Egypt and Pakistan,

[4]Regression analyses for Egypt and Pakistan are not discussed due to known reasons.

there are 28 relevant vector autoregressions left. Since each vector contains two variables, there are 56 regression models overall. According to the BIC criterion, in 52 out of 56 relevant regressions, the preferable lag length is $l = 1$ compared to lengths of $2, 3, 4, 5$, and 10. Therefore, all vector autoregressions are conducted with $l = 1$.

Estimation results are presented in Table 5 and 6. For every vector autoregression, there are two regression functions, one for each dependent variable. For each regression, the first lags (lag1) of both equity market (country) and exchange rate (FX) returns serve as independent variables. In Table **??**, we present the Granger test results.

The results of vector autoregression analysis and Granger causality tests are mixed. The vector autoregressive model fit in terms of R^2 is better than the linear regression model fit in eight out of 56 cases. For five of the seven models for the major markets, the fit is better than for the corresponding linear regression models. This means that the vector autoregressive models perform particularly better for the major markets since five out of eight R^2 improvements overall do occur here. These are the two vector autoregressions of the Euro Zone and Japan as well as the equity market vector autoregression of Australia.

When interpreting these results, one has to consider the time shifts between the different markets. The exchange rate trading day ends for most currencies at 5pm EST (New York). This is fourteen hours after closing of the Tokyo Stock Exchange in Japan. Therefore, in the Japanese case, exchange rate returns of time time t contain more advanced information than equity market returns of time t. The same is true for most currencies to some extent. Even currencies which are only traded locally contain more advanced information because interbank trading outlasts exchange trading. Nevertheless, exchange rate returns of time $t-1$ precede the equity exchange opening on day t in any case. Therefore, they may be used to predict returns on day t.

The Granger causality results vary as seen in Tables 7 and 8. Only some series show Granger causality while others display Granger causality for one dependent variable and not for the other. Again, in some cases, only lagged values of the dependent variable Granger cause the process, in some cases only the independent variable does.

Regarding the 28 relevant vector autoregressive models with equity market returns as dependent variable (Table 7), at a significance level of 5%, 14 of them show significant auto causation and 19 show significant exchange rate return causation. Of the 28 vector autoregressive models with the exchange rate returns as dependent variable (Table 8), 14 show significant auto causation and 6 show significant equity market return causation. Thus, overall, exchange rate returns are more influential in terms of Granger causation than equity market returns.

5.3. Geweke Measure

For computability, 20 lags were used. The instantaneous feedback measures are different from the instantaneous measures presented above in so far that vector autoregressive effects are subtracted.

The Geweke measures consolidate the results above, as one can see in table 9. They tend to exhibit strong linear dependence for the same equity markets and exchange rates which exhibit strong correlation or Granger causality. In addition to that, the analysis contributes a differentiated view on linear dependence, since lagged and instantaneous factors are singled out. The analysis underlines once again that by tendency, the instantaneous linkages between equity markets and exchange rates are stronger than single lagged linkages. In 19 out of 28 relevant relationships, this is true. In the other nine cases, a single lagged feedback is stronger, mostly currency feedback. Moreover, currency feedback is generally stronger than market feedback. This underlines the results from Granger causality analysis, that lagged currency market returns are more influential on equity market returns than vice versa.

5.4. Dynamic Conditional Correlation GARCH

First, for each univariate series, Engle's test for ARCH effects (Engle, 1982) and a Kolmogorov-Smirnov test for normality of model residuals has been performed, and resulting *p*-values are displayed in Table 10 (equities) and 11 (exchange rates), respectively.[5]

Notably, no equity return series fulfills the assumption of residual normality. The Kolmogorov-Smirnov test for normality is rejected at the 5% significance level in every single case. The results for the exchange rate return series are not as clear cut. Nevertheless, normality is rejected for the large majority. In 23 out of 28 cases, the Kolmogorov-Smirnov test rejects a normal distribution at the 5% significance level.

The tests for no ARCH effects confirm the presence of volatility clustering. Only in one case, it is not possible to reject the hypothesis of no ARCH effects

[5]Computations in this subsection are based on Matlab code provided by `http://www.kevinsheppard.com/wiki/UCSD_GARCH`.

at the 5% significance level. The tests for constant correlation on the other hand are somewhat ambiguous. Constant correlation can only be rejected in eight cases at the 5% significance level.

All univariate GARCH models have in common that the constant terms ω are very small compared to the unconditional variance. Unconditional variances have magnitudes of 10^{-5} to 10^{-4}, whereas the ωs have magnitudes of only 10^{-7} to 10^{-6}. The ω coefficient is significantly smaller than the α coefficient in every case. Therefore, lagged returns have greater impact on volatility than the unconditional term. Still, ω is significantly different from zero in most cases. Especially the univariate GARCH exchange rate return models hold significant constant terms.

However, most influential is the autoregressive term of the volatility model. The β coefficient is larger than the ω and α coefficients for every series. The β is responsible for a long memory property of the conditional variance process. Many series have a β close to one and therefore exhibit very long memory.[6]

For all pairs of equity market and exchange rate return data, bivariate estimation of the DCC(1,1)-GARCH(1,1) model has been conducted. The results are displayed in Table 12.[7] Moreover, the results of the test for dynamic correlation and the log likelihood at the optimum are displayed. For the DCC, a simple first order model with lag lengths $P = 1, Q = 1$ is selected in accordance with Engle (2002). The BIC results for the univariate

[6] The coefficient β can of course not be equal to or greater than one, since this would imply a unit root and therefore infinite variance.

[7] Even though returns are not normal, quasi-maximum likelihood as mentioned in (Engle, 2002) provides for consistent estimators.

GARCH models vary. The criterion actually suggests a GARCH(0,1) model in most cases. However, the transient factor α of the prior period returns is meaningful, in some cases. For consistency, the DCC(1,1)-GARCH(1,1) model is selected throughout. Then, elements $q_{i,j,t}$ of Q_t in equation 3.4 take the following form for equity return series $y_{1,t}$ and exchange rate return series $y_{2,t}$

$$q_{i,j,t} = (1 - \alpha - \beta)\, \bar{q}_{i,j} + \alpha\, (\epsilon_{i,t-1}\epsilon_{j,t-1}) + \beta q_{i,j,t-1}$$

for $i, j \in \{1, 2\}$. The constant term $\bar{q}_{1,2}$ is the unconditional correlation between the standardized returns. Therefore, for general i and j,

$$\rho_{i,j,t} = \frac{q_{i,j,t}}{\sqrt{q_{i,i,t} q_{j,j,t}}}.$$

For the conditional correlation processes, the α are close to zero, whereas the β are mostly close to one. Thus, correlation processes tend to have very long memory. This tendency is more pronounced than in the univariate conditional volatility models. Although the α are small in each case, they are still mostly significant at a 5% level.[8]

Regarding the major markets, results are mixed, once again. The hypothesis of constant correlation is rejected for the United States market, the Euro Zone market, and the Canadian market at the 5% level. For Australia, Japan, and Switzerland, the hypothesis of constant correlation cannot be rejected. Of the developing markets, in our sample, only Chile and South Africa have significant instability in their respective correlations between equity returns

[8]The corresponding t-values are obtained using equation (33) in Engle (2002).

and exchange rates. So, it appears as if comovement as measured by correlation is of particularly stable nature in developing countries. A hypothesis would be that this is the results since neither of them provides currency safe havens nor are their markets self-sustainable enough to be less dependent on the international currency exchange rates.

6. Conclusion

We saw that comovement was detected in many cases. Several different methodologies of comovement measurement were applied often yielding mixed results. Therefore, the importance of the sensitivity of comovement to the measurement technique was emphasized.

Correlations between equity market and exchange rate returns were shown to have impact on the risk foreign investors are exposed to. In particular, we demonstrated that according to the Markowitz's measure, risk will be 6% higher on average, if this study's correlations are considered.

This study provided a comprehensive approach to document comovement between equity markets and foreign exchange on a global scale. It focused on the most common techniques used in available comovement research to analyze comovement at level scale as well as the inherent dynamics.

It appeared that regional clusters had not necessarily influence on the level of comovement between foreign exchange rates and equity returns except for, maybe, in Latin America.

Moreover, we challanged the assumption that the relationships between equity markets and foreign exchange are stable. Fundamentals change, monetary policies change, investors change. Why should the relationship between equity market and exchange rate returns not change? We found that this relationship was particularly instable in developed economies compared to developing economies.

Furthermore, the examination period can be extended for some currencies back to the collapse of the Bretton Woods system in 1971.

In international investmnts, the comovement of equity and foreign exchange rates play an essential role for risk assessment.

7. Appendix

Short form	Meaning
AUD	Australian dollar
ARCH	autoregressive conditional heteroscedasticity
BRL	Brazilian real
CAC	French stock market index
CAD	Canadian dollar
CHF	Swiss franc
CLP	Chilean Peso
COP	Colombian Peso
CMP	Weighted composite of EUR, JPY, GBP, AUD, CHF, CAD
CZK	Czech koruna
DCC	dynamic conditional correlation
DEM	Deutsche Mark
EGP	Egyptian pound
EMEA	Europe, Middle East, and Africa
EUR	Euro
FRF	French franc
GARCH	generalized autoregressive conditional heteroscedasticity
GBP	Pound sterling
IDR	Indonesian rupiah
ILS	Israeli new shekel
INR	Indian rupee
JPY	Japanese yen
KRW	South Korean won
MXN	Mexican peso
MYR	Malaysian ringgit
NOK	Norwegian krone
NZD	New Zealand dollar
PEN	Peruvian nuevo sol
PHP	Philippine peso
PKR	Pakistani rupee
PLN	Polish złoty
SEK	Swedish krona
SGD	Singapore dollar
THB	Thai baht
TRY	Turkish lira
TWD	New Taiwan dollar
ZAR	South African rand

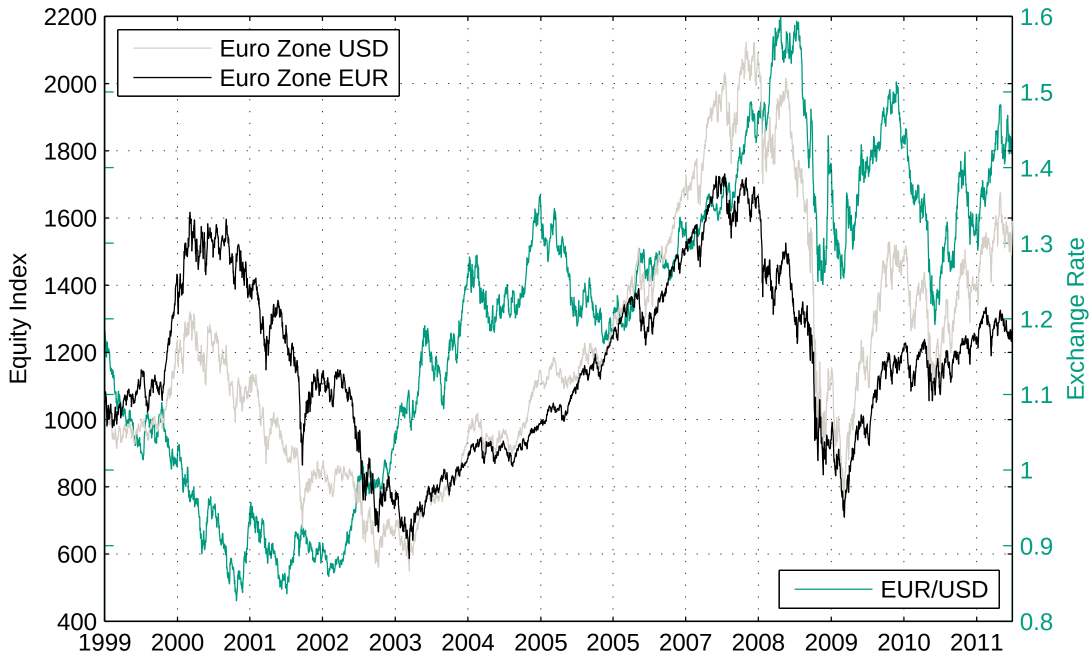

Figure 1: MSCI Euro Index Performance and EUR/USD Exchange Rate

Market	Covariance (10^{-5})		Correlation
Australia	1.72	(0.04)	0.19
Brazil*	8.43	(0.21)	0.42
Canada	2.48	(0.06)	0.33
Chile	1.51	(0.04)	0.23
Colombia	2.27	(0.06)	0.22
Czech Republic	1.40	(0.03)	0.11
Egypt	-0.19	(0.00)	-0.02
Euro Zone	0.20	(0.00)	0.02
India	1.94	(0.05)	0.32
Indonesia	4.49	(0.11)	0.26
Israel	0.76	(0.02)	0.11
Japan	-0.64	(0.02)	-0.07
Korea	3.70	(0.09)	0.25
Malaysia*	1.09	(0.04)	0.30
Mexico	3.50	(0.09)	0.36
New Zealand	0.65	(0.02)	0.07
Norway	3.07	(0.08)	0.24
Pakistan	-0.02	(0.00)	-0.00
Peru	1.22	(0.03)	0.22
Philippines	1.67	(0.04)	0.24
Poland	3.32	(0.08)	0.22
Singapore	0.70	(0.02)	0.16
South Africa	1.47	(0.04)	0.10
Sweden	2.96	(0.07)	0.22
Switzerland	-1.11	(0.03)	-0.13
Taiwan	1.10	(0.03)	0.24
Thailand	1.08	(0.03)	0.13
Turkey*	11.00	(0.30)	0.43
United Kingdom*	0.86	(0.02)	0.11
United States	-0.86	(0.02)	-0.12
Average	1.99		0.17

Table 1: Covariance and Correlation between equities and currencies. Standard errors of covariance in parentheses (10^{-5})

Market	With correlation (10^{-2})	No correlation (10^{-2})	Change in %
Australia	1.37	1.49	8.84
Brazil*	2.17	2.50	15.31
Canada	1.42	1.59	11.59
Chile	1.22	1.33	9.74
Colombia	1.61	1.75	8.36
Czech Republic	1.79	1.87	4.27
Egypt	1.86	1.85	-0.54
Euro Zone	1.59	1.60	0.78
India	1.81	1.91	5.79
Indonesia	2.08	2.29	9.85
Israel	1.46	1.51	3.53
Japan	1.58	1.53	-2.63
Korea	2.10	2.27	8.06
Malaysia*	1.00	1.10	10.39
Mexico	1.64	1.84	12.26
New Zealand	1.35	1.40	3.51
Norway	1.79	1.95	9.16
Pakistan	1.92	1.92	-0.05
Peru	1.90	1.96	3.33
Philippines	1.55	1.66	6.71
Poland	1.90	2.07	8.77
Singapore	1.40	1.45	3.50
South Africa	1.75	1.83	4.71
Sweden	1.88	2.03	8.01
Switzerland	1.40	1.32	-5.85
Taiwan	1.67	1.74	3.84
Thailand	1.86	1.92	3.05
Turkey*	2.51	2.92	16.13
United Kingdom*	1.44	1.50	4.05
Average	1.69	1.8	6.02

Table 2: Markowitz risk of portfolio of currency position and MSCI index position considering (with correlation) and neglecting (no correlation) correlation effects, respectively.

Dependent Variable	Independent Variable	Constant (10^{-4})		Coefficient	
Australia	AUD/USD	2.64	(1.45)	0.23	(10.94)
Brazil	BRL/USD	8.11	(2.86)	0.66	(26.38)
Canada	CAD/USD	2.25	(1.05)	0.72	(19.66)
Chile	CLP/USD	6.15	(3.46)	0.38	(13.55)
Colombia	COP/USD	9.99	(4.05)	0.43	(12.61)
Czech Republic	CZK/USD	5.67	(2.03)	0.21	(6.22)
Egypt	EGP/USD	7.85	(2.51)	-0.07	(-1.13)
Euro Zone	EUR/USD	0.75	(0.30)	0.05	(1.19)
India	INR/USD	6.83	(2.29)	1.62	(18.86)
Indonesia	IDR/USD	8.08	(2.55)	0.54	(15.57)
Israel	ILS/USD	2.87	(1.20)	0.30	(6.32)
Japan	JPY/USD	-0.21	(-0.08)	-0.14	(-3.83)
Korea	KRW/USD	5.19	(1.56)	0.66	(14.89)
Malaysia	MYR/USD	3.73	(1.68)	0.71	(12.45)
Mexico	MXN/USD	7.27	(2.95)	0.82	(21.69)
New Zealand	NZD/USD	1.63	(0.90)	0.09	(4.15)
Norway	NOK/USD	3.31	(1.21)	0.50	(14.32)
Pakistan	PKR/USD	7.61	(2.38)	-0.00	(-0.09)
Peru	PEN/USD	7.63	(2.38)	1.38	(12.78)
Philippines	PHP/USD	2.43	(0.97)	0.78	(14.32)
Poland	PLN/USD	3.02	(1.05)	0.41	(12.86)
Singapore	SGD/USD	2.75	(1.16)	0.72	(9.48)
South Africa	ZAR/USD	6.34	(2.76)	0.11	(5.57)
Sweden	SEK/USD	2.53	(0.87)	0.47	(12.71)
Switzerland	CHF/USD	0.86	(0.41)	-0.23	(-7.62)
Taiwan	TWD/USD	1.00	(0.36)	1.41	(13.98)
Thailand	THB/USD	4.44	(1.42)	0.48	(7.23)
Turkey	TRY/USD	9.01	(2.31)	0.84	(24.68)
United Kingdom	GBP/USD	1.94	(0.73)	0.23	(5.23)
United States	USD/CMP	0.68	(0.30)	-0.27	(-6.68)

Table 3: Linear regression estimates. Dependent variable: Equities. t-statistics in parentheses.

Dependent Variable	Independent Variable	Constant (10^{-4})		Coefficient	
AUD/USD	Australia	1.26	(0.85)	0.15	(10.94)
BRL/USD	Brazil	-2.14	(-1.19)	0.27	(26.38)
CAD/USD	Canada	0.95	(0.98)	0.15	(19.66)
CLP/USD	Chile	-0.82	(-0.77)	0.14	(13.55)
COP/USD	Colombia	-1.48	(-1.18)	0.11	(12.61)
CZK/USD	Czech Republic	1.47	(1.04)	0.05	(6.22)
EGP/USD	Egypt	-1.68	(-1.81)	-0.01	(-1.13)
EUR/USD	Euro Zone	0.64	(0.56)	0.01	(1.19)
INR/USD	India	-0.56	(-0.96)	0.06	(18.86)
IDR/USD	Indonesia	-1.23	(-0.80)	0.13	(15.57)
ILS/USD	Israel	0.50	(0.56)	0.04	(6.32)
JPY/USD	Japan	1.05	(0.89)	-0.03	(-3.83)
KRW/USD	Korea	-0.15	(-0.12)	0.10	(14.89)
MYR/USD	Malaysia	0.89	(0.93)	0.13	(12.45)
MXN/USD	Mexico	-1.58	(-1.47)	0.15	(21.69)
NZD/USD	New Zealand	1.27	(0.84)	0.06	(4.15)
NOK/USD	Norway	0.58	(0.44)	0.12	(14.32)
PKR/USD	Pakistan	-1.69	(-1.59)	-0.00	(-0.09)
PEN/USD	Peru	0.14	(0.28)	0.03	(12.78)
PHP/USD	Philippines	-0.51	(-0.64)	0.08	(14.32)
PLN/USD	Poland	0.36	(0.24)	0.12	(12.86)
SGD/USD	Singapore	0.78	(1.44)	0.04	(9.48)
ZAR/USD	South Africa	-0.97	(-0.48)	0.08	(5.57)
SEK/USD	Sweden	0.47	(0.34)	0.10	(12.71)
CHF/USD	Switzerland	1.55	(1.29)	-0.08	(-7.62)
TWD/USD	Taiwan	0.28	(0.59)	0.04	(13.98)
THB/USD	Thailand	0.39	(0.47)	0.03	(7.23)
TRY/USD	Turkey	-3.56	(-1.78)	0.22	(24.68)
GBP/USD	United Knigdom	0.28	(0.22)	0.05	(5.23)
USD/CMP	United States	-0.57	(-0.58)	-0.05	(-6.68)

Table 4: Linear regression estimates. Dependent variable: Currencies. *t*-statistics in parentheses.

Dependent Variable	R^2	σ_e	Country (lag1)	t-statistic	p-value	FX (lag1)	t-statistic	p-value	constant	t-statistic	p-value
United States	0.0058	0.0002	-0.076752	-4.362355	0.000013	-0.007196	-0.173860	0.861986	0.000090	0.391615	0.695368
Euro Zone	0.0005	0.0002	-0.022358	-1.275635	0.202176	0.015211	0.395834	0.692253	0.000079	0.310158	0.756461
Japan	0.0535	0.0002	0.002399	0.140344	0.888397	-0.485039	-13.518939	0.000000	0.000015	0.062962	0.949800
United Kngdom	0.0042	0.0002	-0.065157	-3.157163	0.001613	0.014391	0.330541	0.741020	0.000212	0.792839	0.427951
Australia	0.0550	0.0001	-0.087473	-5.040957	0.000000	0.286602	13.534395	0.000000	0.000281	1.559976	0.118863
Switzerland	0.0038	0.0001	0.004564	0.258584	0.795973	-0.107245	-3.450689	0.000566	0.000067	0.315975	0.752042
Canada	0.0083	0.0002	-0.068543	-3.713433	0.000208	0.190300	4.685304	0.000003	0.000323	1.431315	0.152436
Sweden	0.0018	0.0003	-0.026351	-1.468339	0.142109	0.083467	2.172172	0.029915	0.000290	0.969021	0.332607
Norway	0.0008	0.0003	-0.024667	-1.364876	0.172387	0.046139	1.242386	0.214184	0.000387	1.371770	0.170230
Poland	0.0193	0.0003	0.005525	0.310436	0.756249	0.256331	7.728928	0.000000	0.000313	1.073762	0.283009
Turkey	0.0085	0.0005	-0.009710	-0.457702	0.647203	0.187379	4.526627	0.000006	0.000756	1.762040	0.078176
South Africa	0.0124	0.0002	0.068124	3.890539	0.000102	0.093219	4.650755	0.000003	0.000591	2.573934	0.010099
Czech republic	0.0055	0.0003	0.034315	1.951943	0.051031	0.123316	3.542325	0.000402	0.000563	2.009951	0.044519
Israel	0.0010	0.0002	0.031173	1.766295	0.077440	-0.017368	-0.365121	0.715045	0.000297	1.238324	0.215685
Egypt	0.0102	0.0003	0.094334	5.397872	0.000000	-0.116111	-1.965943	0.049390	0.000702	2.249279	0.024562
New Zealand	0.0130	0.0001	-0.012451	-0.712910	0.475952	0.137443	6.539171	0.000000	0.000159	0.873815	0.382283
Korea	0.0102	0.0004	-0.032361	-1.796742	0.072469	0.273476	5.769822	0.000000	0.000536	1.566987	0.117215
Singapore	0.0034	0.0002	0.002876	0.162139	0.871206	0.252563	3.249708	0.001167	0.000316	1.322581	0.186068
India	0.0045	0.0003	0.044506	2.388992	0.016952	0.195836	2.051341	0.040315	0.000632	2.016383	0.043844
Taiwan	0.0041	0.0003	0.004567	0.253016	0.800272	0.371016	3.473950	0.000520	0.000135	0.467672	0.640050
Malaysia	0.0228	0.0001	0.081988	3.108521	0.001915	0.243445	3.946433	0.000083	0.000393	1.701821	0.088990
Thailand	0.0086	0.0003	0.063683	3.618711	0.000301	0.227251	3.403933	0.000672	0.000429	1.362084	0.173266
Philippines	0.0290	0.0002	0.076271	4.280759	0.000019	0.430417	7.559673	0.000000	0.000216	0.842306	0.399679
Indonesia	0.0146	0.0003	0.075837	4.202972	0.000027	0.157256	4.221087	0.000025	0.000740	2.263534	0.023668
Pakistan	0.0085	0.0003	0.091836	5.246329	0.000000	-0.012389	-0.234721	0.814440	0.000690	2.161660	0.030717
Mexico	0.0137	0.0002	0.056745	3.041229	0.002375	0.193128	4.497486	0.000007	0.000656	2.498584	0.012518
Brazil	0.0014	0.0003	0.040087	2.064547	0.039046	-0.011554	-0.377981	0.705470	0.000771	2.465719	0.013726
Chile	0.0270	0.0001	0.168063	9.445537	0.000000	-0.035860	-1.211538	0.225777	0.000513	2.839474	0.004547
Colombia	0.0300	0.0002	0.177204	10.003444	0.000000	-0.061738	-1.765966	0.077496	0.000805	3.224344	0.001275
Peru	0.0031	0.0004	0.056958	3.168326	0.001547	-0.118464	-1.045059	0.296074	0.000780	2.371932	0.017753

Table 5: Vector Autoregression Models. Dependent Variable = Equity

Dependent Variable	R^2	σ_e	Country (lag1)	t-statistic	p-value	FX (lag1)	t-statistic	p-value	constant	t-statistic	p-value
USD/CMP	0.0120	0.0000	-0.046946	-6.296959	0.000000	-0.016614	-0.947333	0.343539	-0.000057	-0.585320	0.558373
EUR/USD	0.0005	0.0000	0.008920	1.116061	0.264478	-0.010145	-0.578894	0.562701	0.000063	0.547235	0.584255
JPY/USD	0.0072	0.0000	0.030926	3.708845	0.000212	-0.050301	-2.873657	0.004084	0.000113	0.952194	0.341069
GBP/USD	0.0033	0.0000	0.007907	0.808234	0.419037	0.052867	2.561631	0.010480	0.000038	0.298520	0.765332
AUD/USD	0.0020	0.0001	-0.006464	-0.442503	0.658155	-0.042018	-2.357002	0.018482	0.000182	1.201463	0.229659
CHF/USD	0.0039	0.0000	0.013471	1.344064	0.179021	-0.055107	-3.122516	0.001809	0.000159	1.313552	0.189090
CAD/USD	0.0021	0.0000	0.011969	1.422250	0.155050	-0.047143	-2.545907	0.010945	0.000146	1.415486	0.157022
SEK/USD	0.0011	0.0001	0.012821	1.529407	0.126261	-0.024518	-1.365875	0.172073	0.000075	0.534385	0.593112
NOK/USD	0.0007	0.0001	-0.009034	-1.027211	0.304397	-0.015452	-0.855026	0.392600	0.000110	0.804200	0.421340
PLN/USD	0.0031	0.0001	-0.009844	-1.022392	0.306672	0.056811	3.166060	0.001559	0.000074	0.471787	0.637110
TRY/USD	0.0031	0.0001	0.013188	1.210167	0.226321	-0.061308	-2.883204	0.003968	-0.000230	-1.044318	0.296432
ZAR/USD	0.0033	0.0001	-0.018218	-1.185556	0.235884	-0.051516	-2.928672	0.003428	-0.000034	-0.166512	0.867764
CZK/USD	0.0007	0.0001	-0.013071	-1.468777	0.141990	0.001769	0.100371	0.920056	0.000187	1.321220	0.186521
ILS/USD	0.0005	0.0000	0.007329	1.118715	0.263344	0.009119	0.516476	0.605557	0.000059	0.666584	0.505085
EGP/USD	0.0249	0.0000	-0.001555	-0.302926	0.761966	-0.157704	-9.092812	0.000000	-0.000198	-2.163057	0.030610
NZD/USD	0.0001	0.0001	0.009300	0.636853	0.524265	-0.001758	-0.100030	0.920327	0.000136	0.898707	0.368875
KRW/USD	0.0037	0.0001	0.004919	0.716099	0.473981	-0.062927	-3.481068	0.000506	0.000032	0.242760	0.808207
SGD/USD	0.0008	0.0000	0.004711	1.162057	0.245297	-0.021936	-1.234938	0.216943	0.000092	1.676934	0.093651
INR/USD	0.0047	0.0000	0.014052	3.864161	0.000114	-0.023085	-1.238817	0.215505	-0.000025	-0.408752	0.682749
TWD/USD	0.0037	0.0000	0.008994	2.947471	0.003227	-0.044604	-2.470413	0.013547	0.000034	0.702013	0.482721
MYR/USD	0.0024	0.0000	0.003090	0.270853	0.786540	-0.050753	-1.902188	0.057333	0.000154	1.537471	0.124383
THB/USD	0.0222	0.0000	0.022362	4.856376	0.000001	-0.133647	-7.650850	0.000000	0.000048	0.587743	0.556746
PHP/USD	0.0034	0.0000	-0.000815	-0.144296	0.885276	-0.057466	-3.184159	0.001465	-0.000035	-0.427112	0.669326
IDR/USD	0.0040	0.0001	0.025582	2.912167	0.003614	0.022969	1.266412	0.205456	-0.000039	-0.246076	0.805639
PKR/USD	0.1405	0.0000	0.007418	1.372510	0.170000	-0.374182	-22.959979	0.000000	-0.000238	-2.418983	0.015619
MXN/USD	0.0013	0.0000	0.002991	0.366630	0.713919	-0.037390	-1.991376	0.046523	-0.000056	-0.485956	0.627031
BRL/USD	0.0010	0.0001	-0.004562	-0.369516	0.711767	0.010867	0.559156	0.576094	0.000003	0.015322	0.987777
CLP/USD	0.0052	0.0000	0.012323	1.139304	0.254660	0.064333	3.575543	0.000355	-0.000004	-0.039119	0.968798
COP/USD	0.0011	0.0001	0.013700	1.504200	0.132627	-0.025898	-1.440794	0.149739	-0.000055	-0.431975	0.665788
PEN/USD	0.0011	0.0000	0.004643	1.626738	0.103890	-0.022794	-1.266542	0.205410	0.000040	0.763914	0.444497

Table 6: Vector Autoregression Models. Dependent Variable = Currency.

		F-value	p-value		F-value	p-value
1	United States	19.0301	0.0000	New Zealand	0.5082	0.4760
2	USD/CMP	0.0302	0.8620	NZD/USD	42.7608	0.0000
3	Euro Zone	1.6272	0.2022	Korea	3.2283	0.0725
4	EUR/USD	0.1567	0.6923	KRW/USD	33.2909	0.0000
5	Japan	0.0197	0.8884	Singapore	0.0263	0.8712
6	JPY/USD	182.7617	0.0000	SGD/USD	10.5606	0.0012
7	United Kingdom	9.9677	0.0016	India	5.7073	0.0170
8	GBP/USD	0.1093	0.7410	INR/USD	4.2080	0.0403
9	Australia	25.4112	0.0000	Taiwan	0.0640	0.8003
10	AUD/USD	183.1799	0.0000	TWD/USD	12.0683	0.0005
11	Switzerland	0.0669	0.7960	Malaysia	9.6629	0.0019
12	CHF/USD	11.9073	0.0006	MYR/USD	15.5743	0.0001
13	Canada	13.7896	0.0002	Thailand	13.0951	0.0003
14	CAD/USD	21.9521	0.0000	THB/USD	11.5868	0.0007
15	Sweden	2.1560	0.1421	Philippines	18.3249	0.0000
16	SEK/USD	4.7183	0.0299	PHP/USD	57.1487	0.0000
17	Norway	1.8629	0.1724	Indonesia	17.6650	0.0000
18	NOK/USD	1.5435	0.2142	IDR/USD	17.8176	0.0000
19	Poland	0.0964	0.7562	Pakistan	27.5240	0.0000
20	PLN/USD	59.7363	0.0000	PKR/USD	0.0551	0.8144
21	Turkey	0.2095	0.6472	Mexico	9.2491	0.0024
22	TRY/USD	20.4903	0.0000	MXN/USD	20.2274	0.0000
23	South Africa	15.1363	0.0001	Brazil	4.2624	0.0390
24	ZAR/USD	21.6295	0.0000	BRL/USD	0.1429	0.7055
25	Czech Republic	3.8101	0.0510	Chile	89.2182	0.0000
26	CZK/USD	12.5481	0.0004	CLP/USD	1.4678	0.2258
27	Israel	3.1198	0.0774	Colombia	100.0689	0.0000
28	ILS/USD	0.1333	0.7150	COP/USD	3.1186	0.0775
29	Egypt	29.1370	0.0000	Peru	10.0383	0.0015
30	EGP/USD	3.8649	0.0494	PEN/USD	1.0921	0.2961

Table 7: Granger Test: Dependent Variable = Equity. F-values refer to inclusion of equity (odd line number) and currency (even line number)

line		F-value	p-value		F-value	p-value
1	United States	39.6517	0.0000	New Zealand	0.4056	0.5243
2	USD/CMP	0.8974	0.3435	NZD/USD	0.0100	0.9203
3	Euro Zone	1.2456	0.2645	Korea	0.5128	0.4740
4	EUR/USD	0.3351	0.5627	KRW/USD	12.1178	0.0005
5	Japan	13.7555	0.0002	Singapore	1.3504	0.2453
6	JPY/USD	8.2579	0.0041	SGD/USD	1.5251	0.2169
7	United Kingdom	0.6532	0.4190	India	14.9317	0.0001
8	GBP/USD	6.5620	0.0105	INR/USD	1.5347	0.2155
9	Australia	0.1958	0.6582	Taiwan	8.6876	0.0032
10	AUD/USD	5.5555	0.0185	TWD/USD	6.1029	0.0135
11	Switzerland	1.8065	0.1790	Malaysia	0.0734	0.7865
12	CHF/USD	9.7501	0.0018	MYR/USD	3.6183	0.0573
13	Canada	2.0228	0.1551	Thailand	23.5844	0.0000
14	CAD/USD	6.4816	0.0109	THB/USD	58.5355	0.0000
15	Sweden	2.3391	0.1263	Philippines	0.0208	0.8853
16	SEK/USD	1.8656	0.1721	PHP/USD	10.1389	0.0015
17	Norway	1.0552	0.3044	Indonesia	8.4807	0.0036
18	NOK/USD	0.7311	0.3926	IDR/USD	1.6038	0.2055
19	Poland	1.0453	0.3067	Pakistan	1.8838	0.1700
20	PLN/USD	10.0239	0.0016	PKR/USD	527.1607	0.0000
21	Turkey	1.4645	0.2263	Mexico	0.1344	0.7139
22	TRY/USD	8.3129	0.0040	MXN/USD	3.9656	0.0465
23	South Africa	1.4055	0.2359	Brazil	0.1365	0.7118
24	ZAR/USD	8.5771	0.0034	BRL/USD	0.3127	0.5761
25	Czeh Republic	2.1573	0.1420	Chile	1.2980	0.2547
26	CZK/USD	0.0101	0.9201	CLP/USD	12.7845	0.0004
27	Israel	1.2515	0.2633	Colombia	2.2626	0.1326
28	ILS/USD	0.2667	0.6056	COP/USD	2.0759	0.1497
29	Egypt	0.0918	0.7620	Peru	2.6463	0.1039
30	EGP/USD	82.6792	0.0000	PEN/USD	1.6041	0.2054

Table 8: Granger Test: Dependent Variable = Currency. F-values refer to inclusion of equity (odd line number) and currency (even line number)

Market	Currency Feedback	Market Feedback	Instant. Feedback	Linear Dependance
Australia USD	0.0715	0.0070	0.0433	0.1218
Brazil USD*	0.0294	0.0824	0.2240	0.3357
Canada USD	0.0218	0.0115	0.1140	0.1473
Chile USD	0.0245	0.0082	0.0531	0.0859
Colombia USD	0.0269	0.0076	0.0481	0.0826
Czech republic USD	0.0198	0.0152	0.0113	0.0463
Egypt USD	0.0168	0.0020	0.0009	0.0197
Euro Zone USD	0.0133	0.0053	0.0005	0.0190
India USD	0.0084	0.0067	0.1067	0.1219
Indonesia USD	0.0361	0.0656	0.0685	0.1702
Israel USD	0.0055	0.0068	0.0116	0.0239
Japan USD	0.0622	0.0307	0.0070	0.0998
Korea USD	0.0382	0.0172	0.0711	0.1264
Malaysia USD*	0.0142	0.0080	0.1036	0.1257
Mexico USD	0.0296	0.0340	0.1358	0.1994
New Zealand USD	0.0223	0.0074	0.0061	0.0358
Norway USD	0.0149	0.0108	0.0593	0.0851
Pakistan USD	0.0043	0.0314	0.0000	0.0358
Peru USD	0.0246	0.0423	0.0432	0.1101
Philippines USD	0.0332	0.0218	0.0674	0.1224
Poland USD	0.0599	0.0064	0.0481	0.1144
Singapore USD	0.0258	0.0116	0.0301	0.0675
South Africa USD	0.0201	0.0208	0.0119	0.0528
Sweden USD	0.0060	0.0061	0.0490	0.0611
Switzerland USD	0.0170	0.0083	0.0174	0.0427
Taiwan USD	0.0091	0.0096	0.0604	0.0790
Thailand USD	0.0199	0.0306	0.0182	0.0686
Turkey USD*	0.0363	0.0784	0.2252	0.3400
United Kingdom USD*	0.0111	0.0126	0.0129	0.0366
United States	0.0064	0.0191	0.0155	0.0409

Table 9: Geweke test results.

Variable	ARCH test p-value	KS test p-value	ω	t-statistic	p-value	α	t-statistic	p-value	β	t-statistic	p-value
United States	0.0000	0.0000	0.000001	2.473094	0.013446	0.068491	7.213253	0.000000	0.924635	90.333138	0.000000
Euro Zone	0.0000	0.0001	0.000002	3.139366	0.001708	0.091926	6.734647	0.000000	0.900413	67.652124	0.000000
Japan	0.0000	0.0000	0.000004	3.363596	0.000778	0.095224	7.032574	0.000000	0.885699	60.018371	0.000000
United Kingdom	0.0000	0.0021	0.000001	2.691239	0.007169	0.097226	6.386812	0.000000	0.899397	62.027536	0.000000
Australia	0.0000	0.0001	0.000001	2.776173	0.005532	0.078951	5.652093	0.000000	0.914995	65.181342	0.000000
Switzerland	0.0000	0.0001	0.000002	3.681437	0.000236	0.106020	7.375475	0.000000	0.878703	57.650235	0.000000
Canada	0.0000	0.0000	0.000001	2.212894	0.026974	0.059166	5.588318	0.000000	0.936737	80.331673	0.000000
Sweden	0.0000	0.0006	0.000002	2.550940	0.010789	0.074016	5.544405	0.000000	0.921203	66.865560	0.000000
Norway	0.0000	0.0000	0.000005	4.304598	0.000017	0.106233	7.405011	0.000000	0.870797	52.508556	0.000000
Poland	0.0000	0.0041	0.000002	2.088591	0.036822	0.051934	6.026162	0.000000	0.942092	91.534046	0.000000
Turkey	0.0000	0.0103	0.000006	1.857986	0.063280	0.065963	3.619244	0.000301	0.921885	39.398936	0.000000
South Afrika	0.0000	0.0032	0.000004	3.716371	0.000206	0.093048	6.705810	0.000000	0.883200	51.846879	0.000000
Czeh Republic	0.0000	0.0003	0.000007	4.515278	0.000007	0.113148	7.703484	0.000000	0.858631	55.715306	0.000000
Israel	0.0000	0.0000	0.000001	2.232631	0.025641	0.047126	3.877478	0.000108	0.944594	67.021685	0.000000
Egypt	0.0000	0.0000	0.000005	2.094132	0.036326	0.048080	4.094234	0.000043	0.937802	57.411329	0.000000
New Zealand	0.0000	0.0032	0.000001	1.653123	0.098402	0.049839	3.149117	0.001652	0.945541	53.166774	0.000000
Korea	0.0000	0.0000	0.000001	1.965729	0.049415	0.058791	4.611229	0.000004	0.939990	76.472073	0.000000
Singapore	0.0000	0.0001	0.000001	2.917253	0.003555	0.100440	7.424085	0.000000	0.896139	66.619509	0.000000
India	0.0000	0.0000	0.000008	2.889450	0.003885	0.147452	5.070426	0.000000	0.834088	25.829411	0.000000
Taiwan	0.0000	0.0000	0.000002	2.547873	0.010884	0.056801	6.115703	0.000000	0.937942	95.950563	0.000000
Malaysia	0.0001	0.0001	0.000001	2.202295	0.027792	0.113747	3.911512	0.000096	0.879097	33.270050	0.000000
Thailand	0.0000	0.0000	0.000013	1.391709	0.164106	0.069288	4.117361	0.000039	0.887808	22.686609	0.000000
Philippines	0.1334	0.0000	0.000025	2.372386	0.017732	0.103138	3.491096	0.000487	0.783538	14.925315	0.000000
Indonesia	0.0000	0.0000	0.000012	2.449157	0.014372	0.097827	4.286395	0.000019	0.870298	27.069018	0.000000
Pakistan	0.0000	0.0000	0.000013	2.880657	0.003995	0.190816	4.944352	0.000001	0.783721	20.161465	0.000000
Mexico	0.0000	0.0002	0.000002	2.475505	0.013356	0.064781	5.760028	0.000000	0.928053	73.266823	0.000000
Brazil	0.0000	0.0023	0.000006	2.875435	0.004061	0.067783	5.839674	0.000000	0.911164	55.237208	0.000000
Chile	0.0000	0.0001	0.000003	4.422426	0.000010	0.122229	7.578913	0.000000	0.845325	44.052045	0.000000
Colombia	0.0000	0.0000	0.000015	4.256186	0.000021	0.246865	6.325954	0.000000	0.685742	14.328981	0.000000
Peru	0.0000	0.0000	0.000005	2.309838	0.020960	0.084103	3.674148	0.000243	0.902941	36.935965	0.000000

Table 10: ARCH tests of equities. t-statistics are obtained from QML inference.

Variable	ARCH test p-value	KS test p-value	ω	t-statistic	p-value	α	t-statistic	p-value	β	t-statistic	p-value
USD/CMP	0.0000	0.0421	0.000000	3.638635	0.000278	0.032556	7.456173	0.000000	0.962714	244.705613	0.000000
EUR/USD	0.0000	0.0602	0.000000	0.101979	0.918780	0.031078	7.424629	0.000000	0.967123	31.466714	0.000000
JPY/USD	0.0000	0.0016	0.000001	2.983806	0.002868	0.041660	4.416452	0.000010	0.942475	76.127626	0.000000
GBP/USD	0.0000	0.1264	0.000000	2.804525	0.005080	0.038815	6.139296	0.000000	0.955351	163.725852	0.000000
AUD/USD	0.0000	0.0011	0.000001	3.246509	0.001180	0.058718	6.256042	0.000000	0.929157	89.154047	0.000000
CHF/USD	0.0000	0.0195	0.000000	2.746358	0.006059	0.025187	5.720566	0.000000	0.970719	222.012605	0.000000
CAD/USD	0.0000	0.2437	0.000000	0.456476	0.648078	0.047567	7.388079	0.000000	0.949318	63.537893	0.000000
SEK/USD	0.0000	0.5199	0.000000	2.945561	0.003247	0.035634	5.793848	0.000000	0.957637	138.800186	0.000000
NOK/USD	0.0000	0.2324	0.000000	2.989306	0.002817	0.036276	5.901373	0.000000	0.956706	139.787397	0.000000
PLN/USD	0.0000	0.0003	0.000001	2.943234	0.003271	0.073978	6.322209	0.000000	0.909940	63.392856	0.000000
TRY/USD	0.0000	0.0000	0.000003	2.804760	0.005072	0.143228	4.528249	0.000006	0.835537	24.783313	0.000000
ZAR/USD	0.0000	0.0002	0.000001	2.065076	0.038995	0.093439	6.365933	0.000000	0.906559	69.345637	0.000000
CZK/USD	0.0000	0.0090	0.000000	2.650412	0.008078	0.035140	6.042188	0.000000	0.960739	159.942832	0.000000
ILS/USD	0.0000	0.0000	0.000000	2.724355	0.006477	0.089084	4.511997	0.000007	0.896021	44.166754	0.000000
EGP/USD	0.9331	0.0000	0.000000	0.019618	0.984350	0.007961	5.703314	0.000000	0.992037	764.930422	0.000000
NZD/USD	0.0000	0.0013	0.000001	3.429130	0.000613	0.052935	5.999981	0.000000	0.930495	80.074251	0.000000
KRW/USD	0.0000	0.0000	0.000000	3.364255	0.000776	0.087258	7.129748	0.000000	0.904115	76.836664	0.000000
SGD/USD	0.0000	0.0056	0.000000	7.919328	0.000000	0.037037	5.203648	0.000000	0.953508	123.717261	0.000000
INR/USD	0.0000	0.0000	0.000000	7.958819	0.000000	0.194967	6.619066	0.000000	0.805031	33.566517	0.000000
TWD/USD	0.0000	0.0000	0.000001	3.124741	0.001795	0.170267	3.367003	0.000769	0.782147	17.213518	0.000000
MYR/USD	0.0000	0.0006	0.000000	1.219626	0.222794	0.108724	7.063267	0.000000	0.891274	56.626273	0.000000
THB/USD	0.0000	0.0000	0.000000	3.729119	0.000195	0.138281	5.692744	0.000000	0.855015	38.889400	0.000000
PHP/USD	0.0000	0.0000	0.000000	2.164380	0.030508	0.151937	5.530097	0.000000	0.848061	30.638600	0.000000
IDR/USD	0.0000	0.0000	0.000002	1.473782	0.140637	0.268913	2.149703	0.031652	0.731085	6.421298	0.000000
PKR/USD	0.0000	0.0000	0.000007	0.789835	0.429682	0.480047	0.911609	0.362043	0.519951	8.138568	0.000000
MXN/USD	0.0000	0.0000	0.000001	3.576389	0.000353	0.091895	6.046496	0.000000	0.885496	48.043390	0.000000
BRL/USD	0.0000	0.0007	0.000002	3.644665	0.000272	0.163943	8.002612	0.000000	0.831056	44.883659	0.000000
CLP/USD	0.0000	0.0001	0.000000	2.758634	0.005837	0.043678	3.453893	0.000560	0.953480	70.219602	0.000000
COP/USD	0.0000	0.0000	0.000001	2.215592	0.026789	0.137576	3.045124	0.002345	0.854740	19.619027	0.000000
PEN/USD	0.0000	0.0000	0.000000	1.897481	0.057853	0.350824	4.235569	0.000023	0.649174	8.107365	0.000000

Table 11: ARCH tests of currencies. t-statistics are obtained from QML inference.

Variable 1	Variable 2	constant correlation test p-value	log-likelihood	α	t-statistic	p-value	β	t-statistic	p-value
United States	USD/CMP	0.0004	22804.9720	0.024933	4.737021	0.000002	0.972737	154.374414	0.000000
Euro Zone	EUR/USD	0.0130	21794.0461	0.026449	1.745176	0.081049	0.968572	67.257085	0.000000
Japan	JPY/USD	0.8632	21466.2057	0.003215	2.665932	0.007716	0.996241	633.676105	0.000000
United Kingdom	GBP/USD	0.0661	16500.4536	0.008548	2.210283	0.027181	0.990954	214.425633	0.000000
Australia	AUD/USD	0.8786	22219.5712	0.002707	1.667594	0.095493	0.996037	329.522991	0.000000
Switzerland	CHF/USD	0.6977	22136.8729	0.023592	3.655249	0.000261	0.963912	87.280253	0.000000
Canada	CAD/USD	0.0347	23033.2271	0.018353	2.932761	0.003383	0.979574	134.426350	0.000000
Sweden	SEK/USD	0.0001	20655.7329	0.013116	3.656845	0.000259	0.985463	242.262881	0.000000
Norway	NOK/USD	0.0012	21020.5990	0.007564	3.834365	0.000128	0.991825	448.009500	0.000000
Poland	PLN/USD	0.7862	20243.7190	0.006641	2.826439	0.004736	0.992621	351.730110	0.000000
Turkey	TRY/USD	0.5819	15734.1036	0.017254	2.268275	0.023391	0.920364	35.049087	0.000000
South Afrika	ZAR/USD	0.0098	20405.6138	0.020622	3.720393	0.000202	0.976525	144.269154	0.000000
Czeh Republic	CZK/USD	0.0776	20710.2695	0.007418	1.638162	0.101485	0.989878	125.787155	0.000000
Israel	ILS/USD	0.9662	22795.3992	0.004705	1.391012	0.164317	0.992089	132.111918	0.000000
Egypt	EGP/USD	0.9875	22243.5142	0.002925	3.202209	0.001377	0.996446	1211.711878	0.000000
New Zealand	NZD/USD	0.8957	21753.5798	0.016871	1.260499	0.207580	0.763327	3.174199	0.001517
Korea	KRW/USD	0.1483	21415.4704	0.012670	2.512453	0.012038	0.981594	100.972594	0.000000
Singapore	SGD/USD	0.3974	24313.3780	0.006242	2.233228	0.025602	0.992244	228.012161	0.000000
India	INR/USD	0.1496	23595.9765	0.020445	2.528454	0.011505	0.974483	91.405143	0.000000
Taiwan	TWD/USD	0.8124	23904.1003	0.014654	0.927779	0.353592	0.979325	35.888088	0.000000
Malaysia	MYR/USD	0.8961	12012.6906	0.007004	0.095343	0.924055	0.000002	0.000000	1.000000
Thailand	THB/USD	0.6814	22450.1416	0.008376	3.094875	0.001986	0.988326	188.055599	0.000000
Philippines	PHP/USD	0.7106	22721.2390	0.012391	2.189886	0.028603	0.955216	65.655084	0.000000
Indonesia	IDR/USD	0.5622	20523.1650	0.026487	2.956980	0.003129	0.926656	53.520340	0.000000
Pakistan	PKR/USD	0.8959	21728.9333	0.022854	1.022735	0.306510	0.563175	4.047020	0.000053
Mexico	MXN/USD	0.1600	22068.2212	0.020029	4.285942	0.000019	0.976893	164.944392	0.000000
Brazil	BRL/USD	0.9239	19933.9772	0.022969	2.951775	0.003182	0.968348	71.490368	0.000000
Chile	CLP/USD	0.0000	23010.2989	0.053273	3.750714	0.000179	0.887584	25.693772	0.000000
Colombia	COP/USD	0.0660	21906.3176	0.048393	3.732851	0.000193	0.902047	26.779399	0.000000
Peru	PEN/USD	0.0726	24227.3462	0.007214	2.977111	0.002931	0.991228	274.074646	0.000000

Table 12: DCC-GARCH estimates and constant correlation test results. t-statistics are obtained from equation (33) in Engle (2002).

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