

Does Exchange Rate Risk Affect Exports Asymmetrically? Asian Evidence

by

WenShwo Fang,^a YiHao Lai,^b and Stephen M. Miller^{c,d}

^a *Department of Economics, Feng Chia University and the Overseas Chinese Institute of Technology, 100 WenHwa Road, Taichung, Taiwan*

^b *College of Business, Feng Chia University, 100 WenHwa Road, Taichung, Taiwan*

^c *College of Business, University of Nevada, Las Vegas, Nevada, USA*

stephen.miller@cmail.nevada.edu

(702)-895-3969 (voice), (702)-895-1354 (fax)

^d *Corresponding author*

Abstract

The effects of exchange rate risk have interested researchers, since the collapse of fixed exchange rates. Little consensus exists, however, regarding its effect on exports. Previous studies implicitly assume symmetry. This paper tests the hypothesis of asymmetric effects of exchange rate risk with a dynamic conditional correlation bivariate GARCH(1,1)-M model. The data include bilateral exports from eight Asian countries to the US. The empirical results show that real exchange rate risk significantly affects exports for all countries, negative or positive, in periods of depreciation or appreciation. For five of the eight countries, the effects of exchange risk are asymmetric. Policy makers need to consider the stability of the exchange rate in addition to its depreciation as a method of stimulating export growth.

JEL classification: C32; F14; F31; F41

Does Exchange Rate Risk Affect Exports Asymmetrically? Asian Evidence

I. Introduction

The relationship between exchange rate risk and exports has received considerable interest since the collapse of fixed exchange rates in the early 1970s. Ethier (1973) argues that exchange rate risk could lower exports due to profit risk. De Grauwe (1988), however, suggests that exporters might increase exports to offset potential revenue losses. Broll and Eckwert (1999) note that the price of an option to export increases with risk. Pozo (1992) uncovers a negative effect of exchange rate risk on UK exports to the US. Chowdhury (1993) and Arize (1995, 1996, 1997) find negative effects of exchange rate risk on US, European, and G7 exports. Weliwita, Ekanayake, and Tsujii (1999) and Fang and Thompson (2004) provide evidence of negative effects for developing countries of Sri Lanka and Taiwan. Arize, Osang, and Slottje (2000) and Arize, Malindretos, and Kasibhatla (2003) conclude that exchange rate risk generates a negative effect on LDC exports, using a moving sample standard deviation model. In contrast, Asseery and Peel (1991) find positive effects for multilateral exports except for the UK. Kroner and Lastrapes (1993) uncover positive effects for France, Germany, and Japan, but negative effects for the UK and the US. McKenzie and Brooks (1997) report positive effects for Germany and the US. Finally, Klaassen (2004) finds no effect of monthly bilateral US exports on other G7 countries.

While a variety of theoretical and empirical models attempt to isolate quantitatively important effects of exchange rate risk on exports, all work proceeds under the assumption of symmetric effects, meaning that no difference exists between the risk effects of exchange rate appreciation and depreciation. Tse and Tsui (1997) find that a depreciation shock produces a greater effect on future volatility in exchange rates than an appreciation shock of the same magnitude. Risk-averse exporters behave differently when facing different degrees of foreign

exchange market volatility. Thus, different risk effects emerge under conditions of exchange rate depreciation and appreciation. This paper tests the hypothesis of asymmetric effects of exchange rate risk on exports.

No empirical studies directly test whether exchange rate risk acts symmetrically or asymmetrically. Some inferences emerge from the research on export price adjustments to exchange rate changes (Krugman 1987, Sercu 1992, Knetter 1994, Kanas 1997, and Mahdavi 2000). These papers establish the hypothesis that the risk profile of economic exposure exhibits asymmetry. That is, changes in the export price differ between real depreciations and real appreciations. Our paper considers whether we observe different exchange rate risk effects on exports between depreciations and appreciations.

Whether asymmetric risk effects exist proves important to policy-makers. Conventional wisdom argues that depreciation increases exports, but exchange rate risk induced by the depreciation can hurt exports. Thus, market intervention to stimulate exports may fail, if the authorities ignore the effects of exchange rate risk. Fang and Thompson (2004) show that exports respond positively to depreciations and negatively to risk effects, but the net effect only adds noise to export fundamentals. The existence of asymmetric risk effects further complicates and increases the uncertainty of trade policy. Thus, successful trade policy requires a full understanding and control of exchange risk during periods of depreciation and appreciation.

To study the effects of exchange rate risk requires a measure of the unobservable exchange rate risk. Hodrick and Srivastava (1984) show that exchange risk is conditional and time varying. Moving standard deviations of the exchange rate maintain the hypothesis of homoskedasticity while serving as a proxy for heteroskedastic risk in Chowdhury (1993), Arize, Osang, and Slottje (2000), and Arize, Malindretos, and Kasibhatla (2003). This approach raises a logical inconsistency and could prove inadequate to capture exchange rate risk dynamics.

Generalized autoregressive conditional heteroskedasticity (GARCH) models can successfully model relationships between means and variances as in Bollerslev (1986, 1990), Engle et al. (1987), and Bollerslev et al. (1992). This paper specifies exchange rate risk as time-varying exchange rate volatility constructed with a GARCH (1, 1) process following Bollerslev (1986) such that a larger estimated conditional variance indicates more risk.

This paper contributes to the literature by using the bivariate GARCH-M model with dynamic conditional correlation (DCC) (Engle 2002) in measuring the exchange rate risk effect on exports and testing for asymmetry. Engle's DCC approach allows time-varying correlations between exports and the exchange rate. It differs from previous studies that implicitly assume a constant correlation. This paper uses monthly time-series data on bilateral exports from eight Asian countries -- Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, and Thailand -- to the US for 1979 to 2003. The majority of existing studies consider developed countries, but the eight Asian countries, except Japan, industrialized during this period. Klaassen (2004) suggests that one use developing countries to study the effect of exchange risk on exports. In Table 1, the US accounts for a substantial portion of exports from these Asian countries. The average US share of total exports over the sample ranges from 16 percent for Indonesia to 34 percent for the Philippines. The bilateral approach can avoid asymmetric responses across exchange rates in highly aggregated data, and then focus on the asymmetric effects of the exchange risk.

After testing for the time-series properties of the variables and identifying the GARCH or ARCH effects of the exchange rates, the empirical results of our bivariate GARCH-M model with DCC provides some evidence of the asymmetry hypothesis. In each country, positive depreciation effects exist along with negative or positive exchange risk effects in depreciations or appreciations. For five of the eight countries significant asymmetric effects of the exchange risk

on exports occur. The evidence supports the uncertainty of exchange rate policies designed to influence exports.

The rest of this paper is organized as follows. Section 2 specifies the analytical framework, which includes the main elements of the time-varying correlation bivariate GARCH-M model designed to test for the asymmetric hypothesis of the exchange risk. Section 3 describes data, analyzes the time-varying variances of exports and the exchange rates, and presents empirical results. Section 4 investigates the asymmetric effects of exchange rate risk on exports. Section 5 summarizes the empirical findings and provides concluding remarks.

II. The Bivariate GARCH-M Model and Testing for Asymmetric Effects

The nonstructural reduced-form export equation of Rose (1990), Pozo (1992), and Klaassen (2004) provides the building block for our empirical analysis of asymmetric effects of exchange rate risk on Asian exports to the United States. Real export revenue (x) depends on real foreign income (y), the real exchange rate (q), and real exchange rate risk (h_q). Real export revenue equals nominal export revenue in domestic currency deflated by the consumer price index (CPI). Foreign income, the US industrial production index, should produce a positive effect on exports. The real exchange rate, the domestic currency price of the US dollar times the ratio of US to domestic CPIs, should exhibit a positive effect on exports. The real exchange rate eliminates potential ambiguity from adjusting price levels. The effect of exchange rate risk proves uncertain theoretically and empirically.

To capture dynamic adjustments of the variables, the following eclectic bivariate GARCH-M-DCC model provides the framework for investigating and testing the asymmetric hypothesis.

$$\Delta x_t = a_0 + \sum_{i=1}^2 a_i \Delta x_{t-i} + \sum_{i=0}^2 b_i \Delta y_{t-i} + \sum_{i=0}^2 c_i \Delta l q_{t-i} + \sum_{i=0}^2 d_i h_{q,t-i}^{1/2} + \varepsilon_{x,t} \quad (1)$$

$$\Delta lq_t = s_0 + s_1 \varepsilon_{t-1} + \sum_{i=1}^2 \gamma_i MD_i + \varepsilon_{q,t} \quad (2)$$

$$\varepsilon_t | \Psi_{t-1} \sim Student - t(v) \quad (3)$$

$$h_{x,t} = \alpha_0 + \alpha_1 \varepsilon_{x,t-1}^2 + \alpha_2 h_{x,t-1} \quad (4)$$

$$h_{q,t} = \beta_0 + \beta_1 \varepsilon_{q,t-1}^2 + \beta_2 h_{q,t-1} + \sum_i^2 \lambda_i VD_i \quad (5)$$

$$D_t^2 = \begin{bmatrix} h_{q,t} & 0 \\ 0 & h_{x,t} \end{bmatrix} \quad (6)$$

$$\eta_t = D_t^{-1} \varepsilon_t \quad (7)$$

$$Q_t = \bar{\rho}_{sq}(1 - \theta_1 - \theta_2) + \theta_1 \eta_{t-1} \eta'_{t-1} + \theta_2 Q_{t-1} \quad (8)$$

$$R_t = diag\{Q_t\}^{-1} Q_t diag\{Q_t\}^{-1} \quad (9)$$

where $\Delta l x_t \equiv 100 \times (\ln x_t - \ln x_{t-1})$, $\Delta l y_t \equiv 100 \times (\ln y_t - \ln y_{t-1})$ and $\Delta l q_t \equiv 100 \times (\ln q_t - \ln q_{t-1})$. The lag structure of the mean equation of $\Delta l x_t$ is selected by the Schwartz Information Criteria (SIC). $h_{q,t}$ is time varying exchange rate volatility estimated by the GARCH(1,1) process. The presence of the square root of $h_{q,t}$, $h_{q,t}^{1/2}$, in the mean equation of $\Delta l x_t$ constitutes the multivariate GARCH-M model. ARMA components pick up serial dependence to ensure that $\varepsilon_{x,t}$ and $\varepsilon_{q,t}$ are white noise. The residual matrix, ε_t , conditional on the information set Ψ_{t-1} available at time $t-1$ follows a bivariate Student-t distribution with degrees of freedom v . MD_i and VD_i are dummy variables employed to capture extraordinary exchange rate changes in the mean and the variance equations for $\Delta l q_t$. $h_{x,t}$ measures the conditional variance of exports. Conditions, $\alpha_i > 0$, $\beta_i > 0$, $\lambda_i > 0$, $\alpha_1 + \alpha_2 < 1$ and $\beta_1 + \beta_2 < 1$, imply positive and stable conditional variances of $\varepsilon_{x,t}$ and $\varepsilon_{q,t}$. If α_2 or β_2 equal zero, the process reduces to an ARCH(1). The matrix D_t^2 contains $h_{x,t}$ and $h_{q,t}$ along the principle diagonal and thus, η_t

is the standardized residual matrix. Q_t is the covariance matrix of η_t , following a GARCH(1,1) process. $\bar{\rho}_{xq}$ is the unconditional correlation of exports and the exchange rates over the sample period. θ_1 and θ_2 must be positive and $\theta_1 + \theta_2 < 1$ to ensure that Q_t is positively defined and mean-reverting. R_t is the conditional correlation matrix composed of time-varying correlations. Equations (1) to (9) constitute the DCC estimator proposed by Engle (2002). If $\theta_1 = \theta_2 = 0$, then it reduces to the Bollerslev (1990) constant conditional coefficient estimator.

Let Φ denote the parameters in D_t^2 that includes all parameters in equations (1) to (5) and Θ denote the parameters in R_t that includes θ_1 and θ_2 . Then, the log likelihood function of multivariate t-distribution in the maximization procedure is

$$L(\Phi, \Theta) = \sum_{t=1}^T L_t(\Phi, \Theta)$$

where $L_t(\Phi, \Theta) = \ln \Gamma\left(\frac{\nu+2}{2}\right) - \ln \Gamma\left(\frac{\nu}{2}\right) - \ln[\pi(\nu-2)] - \frac{1}{2} \ln |D_t R_t D_t| - \frac{\nu+2}{2} \ln\left(1 + \frac{\eta_t' D_t^{-1} R_t^{-1} D_t^{-1} \eta_t}{\nu-2}\right)$ and $\Gamma(\bullet)$ represents the Gamma function.

The model focuses on the effects of exchange rate movements on exports and the reduced-form export equation includes depreciation and exchange rate risk as well as the rate of change of foreign income as explanatory variables. The signs, magnitudes, and significance of the estimated coefficients (c_i) in equation (1) provide a straightforward test of the relationship between exports and depreciation, where $\sum c_i > 0$ implies that depreciation improves exports. Also of interest are the signs, magnitudes, and significance of the estimated coefficients of the $h_{q,t}^{1/2}$ variable in equation (1). If exporters reduce their exports to minimize profit uncertainty

during periods of exchange rate fluctuations, then $\sum d_i < 0$. If, however, exporters intend to offset potential losses or use options markets as a hedge, then $\sum d_i > 0$. As the equation constrains the d_i s to remain constant for the exchange risk variable during both appreciations and depreciations, equation (1) implicitly assumes a symmetric response of the export revenue to the exchange rate risk.

To test for asymmetric effects, we test the hypothesis that d_i differs between appreciations and depreciations. Let $d_i = d_{1i} + d_{2i}D$, where the dummy $D=1$ for $\Delta lq_t < 0$ (i.e. an appreciation) and 0 for $\Delta lq_t \geq 0$ (i.e. a depreciation). Equation (1) becomes

$$\Delta x_t = a_0 + \sum_{i=1}^2 a_i \Delta x_{t-i} + \sum_{i=0}^2 b_i \Delta y_{t-i} + \sum_{i=0}^2 c_i \Delta lq_{t-i} + \sum_{i=0}^2 d_{1i} h_{q,t-i}^{1/2} + \sum_{i=0}^2 d_{2i} (D h_{q,t-i}^{1/2}) + \varepsilon_{x,t} \quad (1')$$

The estimated relations are as follows:

$$\text{Depreciation: } \Delta x_t = \hat{a}_0 + \sum_{i=1}^2 \hat{a}_i \Delta x_{t-i} + \sum_{i=0}^2 \hat{b}_i \Delta y_{t-i} + \sum_{i=0}^2 \hat{c}_i \Delta lq_{t-i} + \sum_{i=0}^2 \hat{d}_{1i} h_{q,t-i}^{1/2} + \varepsilon_{x,t}$$

$$\text{Appreciation: } \Delta x_t = \hat{a}_0 + \sum_{i=1}^2 \hat{a}_i \Delta x_{t-i} + \sum_{i=0}^2 \hat{b}_i \Delta y_{t-i} + \sum_{i=0}^2 \hat{c}_i \Delta lq_{t-i} + \sum_{i=0}^2 (\hat{d}_{1i} + \hat{d}_{2i}) h_{q,t-i}^{1/2} + \varepsilon_{x,t}$$

Thus, $\sum \hat{d}_{2i}$ measures the difference in the effects of the exchange rate risk between appreciations and depreciations. Equation (1') replaces equation (1) in estimating our bivariate GARCH-M model. Statistical evidence consistent with an asymmetric effect exists, if either the sum of the \hat{d}_{1i} , $\sum \hat{d}_{1i}$, or the sum of the \hat{d}_{1i} and \hat{d}_{2i} , $\sum (\hat{d}_{1i} + \hat{d}_{2i})$, (or both) significantly differs from zero and the difference between the two sums, $\sum \hat{d}_{2i}$, also differs significantly from zero. If both sums prove statistically insignificant, then the exchange rate risk causes no effect on exports.

III. Data and Empirical Results

For each of the eight countries, the bilateral export variable is monthly seasonally adjusted real export revenue for the US from January 1979 to April 2003 with a base year of 1995. All data

come from the *International Financial Statistics and Direction of Trade* of the IMF, except for Taiwan, where the data come from *AREMOS*. Table 2 reports preliminary statistics for log differences of exports and the real exchange rate. Every country experienced depreciation and export growth, on average. Thailand exhibits the highest average export growth at 1.031% with a depreciation of 0.196%. Indonesia exhibits the highest monthly depreciation at 0.336% and an export growth of 0.486%. Thus, depreciation positively associates with exports, on average.

Regarding unconditional risk measured by standard deviations, Indonesia exhibits the most volatile exchange rate and exports while Japan and Singapore exhibit the least volatile exports and exchange rates, respectively. Export volatility is higher than exchange rate volatility in every country. A general impression of volatility's effect on exports does not emerge from standard deviations and extreme values.

Skewness statistics reject Δx_t symmetry at the 5-percent level for Taiwan and Δq_t symmetry for every country, except Singapore and Taiwan. Kurtosis statistics for Δx_t and Δq_t imply that all series are leptokurtic with fat tails. Jarque-Bera tests reject normality for all variables and countries, suggesting the use of the Student-t distribution in model estimation.

The Ljung-Box Q-statistic tests for autocorrelation, where the number of lags (k) affects its power. Tsay (2002) suggests choosing $k = \ln(T)$ where T equals the number of observations (291), implying $k = 5.67$. Thus, the autocorrelations tests run to 6 lags. Ljung-Box Q-statistics indicate autocorrelation in Δx_t and Δq_t for all countries. Ljung-Box Q-statistics for squared Δx_t and Δq_t suggest time-varying variances for both series in all countries, except for Δq_t in the Philippines and Taiwan. An ARMA process for mean and variance equations captures the dynamic structure. In order to generate white-noise residuals, AR(2) and MA(1) processes are employed, respectively, for equation (1') and equation (2), the mean equation of Δx_t and of Δq_t , and GARCH(1,1) for equation (4) and equation (5), the two variance equations.

Valid inference in GARCH models requires stationary variables. After selecting lag lengths by the Schwartz Information Criterion (SIC), the augmented Dickey-Fuller (ADF) test shows that $\Delta l x_t$ and $\Delta l q_t$ are individually stationary [I(0)] series at the 5-percent level.

The correlation coefficient between the two monthly log differenced series ranges from 0.018 in Taiwan to 0.259 in the Philippines. Figure 1 shows the sample correlation coefficient using a moving window of 12 observations (i.e., 1 year). The horizontal line denotes the correlation coefficient. The correlation changes over time and, except for Japan, appear to increase in recent years for most countries, especially Indonesia and Korea. Engle (2002), Tsay (2002), and Tse and Tsui (2002) provide evidence that the estimation of a time-varying correlation GARCH model improves over that of a constant correlation model. This paper applies Engle's (2002) dynamic conditional correlation bivariate GARCH modeling approach. The bivariate GARCH model consists of two sets of equations. The first set of equations consists of a bivariate GARCH (1,1) model for the conditional variances in equations (1') to (5) and the second set, a GARCH (1,1) model for the correlation coefficient in equations (6) to (9).

Preliminary examination shows that the standard univariate GARCH(1,1) model for $\Delta l q_t$ performs adequately for Japan, Singapore, and Taiwan. Unstable variance processes emerge, however, in Indonesia, Korea, Malaysia, the Philippines, and Thailand because the Asian financial crisis that began in Thailand during July 1997 increased exchange market volatility immediately. Neglecting structural breaks may bias upward GARCH estimates of the persistence in variance, vitiating the use of GARCH to estimate the mean equation. Perron (1989, 1997) suggests identifying break points by examining data and using dummy variables to capture shifts in mean or variance processes. Figure 2 shows time plots of the eight exchange rates, marking the break dates.

One-time shocks appear as a single pulse in the depreciation series and as a mean shift in

volatility. Dummy variables enter the mean equation for Indonesia and Thailand and the variance equations for Indonesia, Korea, Malaysia, the Philippines, and Thailand. In the mean equations, the two dummies for Indonesia are $MD_1 = 1$ for $t = 1983:04$, $MD_2 = 1$ for $t = 1986:09$, and 0 otherwise; for Thailand, $MD_1 = 1$ for $t = 1981:07$, $MD_2 = 1$ for $t = 1984:11$, and 0 otherwise. In the variance equations, dummies for Indonesia are $VD_1 = 1$ for $t \geq 1997:07$, and 0 otherwise; for Korea $VD_1 = 1$ for $t \geq 1997:07$, and 0 otherwise; for Malaysia $VD_1 = 1$ for $1997:07 \leq t \leq 1998:12$, and 0 otherwise; for the Philippines $VD_1 = 1$ for $1983:01 \leq t \leq 1984:12$, $VD_2 = 1$ for $1997:07 \leq t \leq 1998:12$, and 0 otherwise; for Thailand $VD_1 = 1$ for $t \geq 1997:07$, and 0 otherwise. The 1997 Asian crisis raised exchange rate volatility in Indonesia, Korea, Malaysia, the Philippines, and Thailand. The Philippines also experienced another volatile period from 1983 through 1984.

The properties of the time varying variance and correlation in exports and exchange rates suggest the bivariate GARCH(1,1)-M model with dynamic conditional correlation specified in equations (1') to (9) to investigate the asymmetric effect of exchange rate risk. The general model is estimated first. Although neither autocorrelation nor heteroskedasticity exist, insignificant coefficients make it difficult to gauge the effect of the risk. Table 3 reports estimated coefficients and standard errors for a parsimonious version with insignificant variables deleted. The advantages of the parsimonious specification include higher precision of estimates from reduced multicollinearity, increased degrees of freedom, more reliable estimates, and greater power of tests. The insignificant likelihood ratio statistic, $LR(k)$, at the 5-percent level suggests no explanatory difference between the general and the parsimonious models for each country.

All estimates of the ARMA components and dummy variables in mean equations (1') and (2) are significant and the parameters in the two variance equations are positive. Every country

exhibits time-varying variances for exports and exchange rates, suggesting the bivariate GARCH model. The significance of λ_1 and λ_2 in equation (5) confirms the use of dummy variables to alleviate the effect of structural breaks. Volatility persistence for $\Delta l x_t$ varies from 0.177 in Taiwan to 0.981 in Indonesia, and for $\Delta l q_t$ from 0.186 in Taiwan to 0.885 in Thailand. The two variance processes converge. Joint estimates of the degrees of freedom of the t-distribution are significant, the hypothesis of the multivariate Student-t distribution is not rejected.

Both θ_1 and θ_2 in the GARCH(1,1) process of Q_t are significantly positive and $\theta_1 + \theta_2 < 1$. The sum of $\theta_1 + \theta_2$ lie between 0.662 in the Philippines and 0.962 in Malaysia. Table 4 reports statistics of conditional correlation coefficients between $\Delta l x_t$ and $\Delta l q_t$, using the bivariate GARCH(1,1)-M-DCC model of equations (1') to (9). The average of the coefficients ranges from 0.011 in Malaysia to 0.201 in Japan. The mean or the median is close to the unconditional coefficient in Table 2. Values of the maximum, the minimum, and the standard deviation show that the coefficient is not constant. Figure 3 plots the fitted conditional correlation coefficient between $\Delta l x_t$ and $\Delta l q_t$. The plot illustrates that the correlation coefficient fluctuates over time, similar to that of Figure 1. This characteristic along with the non-zero estimates for θ_1 and θ_2 suggests the use of the time-varying correlation coefficient model for each country.

Bivariate Ljung-Box $Q_2(k)$ statistics (Hosking, 1980) for standardized residuals and squared standardized residuals of $\Delta l x_t$ and $\Delta l q_t$ do not detect remaining autocorrelation or conditional heteroskedasticity at the 5% level. The bivariate GARCH-M DCC model in equations (1') to (9) adequately represent each country.

The marginal effect of US manufacturing income on exports proves significantly positive for all countries. Seven of the eight Asian countries experience contemporaneous effects, three experience one-month-lagged, and two experience two-month-lagged effects. The cumulative effect ranges from 1.745 for Malaysia, 2.371 for Japan, to 3.282 for Thailand. Different countries respond differently to the US economy. Generally, quick adjustments and large estimates reflect the small open economy property of these economies.

Depreciation exhibits the expected positive effect on exports for the eight countries studied, but insignificant in Malaysia and Singapore.¹ The cumulative depreciation effect ranges from 0.226 for Singapore, 2.182 for the Philippines, to 2.477 for Korea. Every country exhibits lower individual or cumulative depreciation effect than the US income effect, except Korea.

Exchange rate risk possesses significant effects on exports for all countries, negative or positive in periods of depreciation or appreciation. Table 5 reports results of the sum tests for the asymmetric effect of the exchange rate risk. The likelihood ratio (LR) statistic with a χ^2 distribution and one degree of freedom tests the significance of the sum $\sum d_{1i}$, $\sum (d_{1i} + d_{2i})$, or $\sum d_{2i}$, whether the total influence of exchange rate risk on exports is zero in depreciations, appreciations, or the differences between the two sums.

IV. Asymmetric Effects of Exchange Rate Risk

The sum of the coefficients of exchange rate risk in depreciation is significant for all countries except Singapore and Thailand. Five countries exhibit significant negative effects; one exhibits a significant positive effect. The magnitude of the sum ranges from 0.614 in Malaysia to -3.479 in Taiwan. The coefficient sum in appreciation is significant for Japan, Korea, Philippines, Singapore, and Thailand. Three countries exhibit a significantly negative sum; two exhibit a

¹ Fang and Miller (2004) report similar findings for Singapore, using a bilateral GARCH-M model with constant variance. Abeyasinghe and Yeok (1998), using OLS, find that appreciation does not diminish Singapore's exports due to their high import content. Lower import prices reduce the cost of export production.

significantly positive sum. The magnitude ranges from 0.494 for the Philippines to -3.671 for Singapore. Generally, the exchange rate risk affects exports for all countries. The effect proves negative for depreciations or appreciations in four countries -- Indonesia, Japan, Singapore, and Taiwan. It exhibits a mixed negative or positive effect for depreciations or appreciations for the other four countries -- Korea, Malaysia, the Philippines and Thailand.

An asymmetric effect of exchange rate risk on exports exists, if either $\sum d_{1i}$ or $\sum(d_{1i} + d_{2i})$ (or both) significantly differs from zero and $\sum d_{2i}$ also differs significantly from zero. Since the exchange rate risk exhibits significant effects on exports either in depreciation or appreciation (or both), the difference between the two coefficient sums, $\sum d_{2i}$, determines the test. $\sum d_{2i}$ significantly differs from zero for Japan, Korea, Malaysia, the Philippines, and Singapore. Thus, exchange rate risk asymmetrically affects exports in the five countries. The difference between the two coefficient sums insignificantly differs from zero in Indonesia, Taiwan, and Thailand, implying that the adjustment in the export revenue symmetric responds to exchange rate risk.²

Exchange rate depreciation (appreciation) exhibits the expected positive (negative) effect on exports (i.e., c_i coefficients) in each country, except for Malaysia and Singapore. The effect of exchange rate risk can complement or offset such exchange rate effects, depending on the country, whether the exchange rate depreciates (appreciates), and whether the exchange rate risk increases (decreases). Assuming that larger exchange rate adjustments associate with higher exchange rate risk, we can draw the following inferences from our estimates. If these Asian countries try to stimulate their exports by depreciating their currencies, those attempts to stimulate exports receive reinforcement in Malaysia, but offsetting effects in Indonesia, Japan,

² We adopt a strong test of symmetry. A weaker test requires only that the effect of exchange rate risk during either an appreciation or a depreciation significantly differs from zero while those effects do not significantly differ from each other. On that ground, Indonesia, Taiwan, and Thailand all qualify for asymmetric effects.

Korea, the Philippines, and Taiwan.

Previous empirical results on the effects of exchange rate risk without distinguishing asymmetric responses provide mixed results. As a comparison, we also estimate the symmetric-effect GARCH model in equations (1) to (9). Table 6 reports estimates. Diagnostic tests support the statistical appropriateness of the dynamic conditional correlation bivariate GARCH-M model. First, the positive effects of US manufacturing income of the two models produce a reasonable match. Second, significant positive depreciation effects exist for all eight countries in the symmetric effect model. Although they exhibit similar patterns in the two models, the effect proves insignificant in the asymmetric model for Malaysia and Singapore. That is, the symmetric model provides more evidence of the positive depreciation effect than does the asymmetric model. Third, testing for the significance of the cumulative exchange rate risk effect, the symmetric model concludes significant negative risk effects for three countries -- Indonesia, Japan and Taiwan – and no effects for the other five countries. These findings agree with the majority of prior studies, which conclude with either a negative exchange rate risk effect or no effect. In contrast, the asymmetric model identifies significant negative exchange rate risk effects for all countries, except Malaysia, for appreciations, depreciations, or both. Malaysia along with Korea and the Philippines exhibit significant positive effects for appreciations or depreciations. The asymmetric model that allows different responses during depreciations and appreciations provides more evidence of the effect of exchange risk on exports.

More recently, Klaassen (2004) finds no exchange rate risk effect on monthly bilateral US exports to other G7 countries, arguing that the exchange rate risk does not exhibit sufficient variability to uncover its effect on exports, and suggests studying the effect, using data on developing countries, for which much more volatile exchange rate risk may exist. The present paper uses data on monthly bilateral exports from eight Asian countries to the US -- seven

developing and one developed. Applying the newly developed dynamic conditional correlation bivariate GARCH(1,1)-M model and allowing asymmetric responses, we find significant exchange rate risk effects for all countries studied.

V. Summary and Discussion

This paper applies dynamic conditional correlation bivariate GARCH-M model to examine the asymmetric effects of exchange rate risk on exports using monthly bilateral exports from eight Asian countries to the US over the period 1979-2003. The empirical results summarize as follows. For all the eight countries, foreign income affects exports positively and significantly with contemporaneous, one-month-lagged or two-month-lagged effects. Exchange rate depreciation exhibits the normal positive effect, but insignificant in two countries. Real exchange rate risk produces significant effect on exports for all countries, negative or positive. For Japan, Korea, Malaysia, the Philippines, and Singapore, the effects of exchange rate risk are asymmetric. The pattern of asymmetry for Japan, Singapore, and Thailand respond negatively to exchange rate risk during depreciations. Korea and the Philippines respond positively to exchange rate risk in appreciation and negatively in depreciation. Malaysia exhibits only a positive exchange rate risk effect during depreciations.

In sum, the conventional assumption of a symmetric effect of exchange rate risk at the aggregate level appears invalid. Given our asymmetric effects, then unfavorable effects of exchange rate risk on exports proves significant in five countries – Indonesia, Japan, Korea, the Philippines, and Taiwan – during depreciations, but in only three countries – Japan, Singapore, and Thailand – during appreciations. Favorable effects of exchange rate risk exist during appreciations and unfavorable effect during depreciations for Korea and the Philippines. The role of the exchange rate in determining export revenue may prove less predictable, given asymmetric effects. Consider the effect of depreciations in Korea and the Philippines. In Figure 2, their

currencies depreciated substantially against the dollar in recent years, especially after the Asian crisis of 1997. Although both countries possess strong positive depreciation effects (the highest estimates among the eight countries in Table 3), the asymmetric effect generates a negative exchange rate risk effect, leading to an uncertain net effect of the depreciation on exports. This last statement assumes that the recent depreciation associates with higher exchange rate risk, which appears to be the case from Figure 2. The negative exchange rate risk effect could offset or even dominate the positive depreciation effect. For Malaysia, the asymmetric exchange rate risk effect reinforces the positive effect of depreciation.

Table 1. US share of total exports

Country	Ratio
INDONESIA	16.0%
JAPAN	30.5%
KOREA	26.5%
MALAYSIA	17.6%
PHILIPPINES	34.1%
SINGAPORE	18.7%
TAIWAN	32.8%
THAILAND	18.7%

The data are obtained from Direction of Trade of the IMF, exports to the US/total exports.

Table 2. Preliminary statistics for exports and the exchange rate

	INDONESIA		JAPAN		KOREA		MALAYSIA	
	Δx_t	Δl_t	Δx_t	Δl_t	Δx_t	Δl_t	Δx_t	Δl_t
Sample size	291	291	291	291	291	291	291	291
Mean	0.486	0.336	0.218	0.020	0.542	0.123	0.617	0.254
SD	23.561	6.257	5.263	2.792	10.886	2.785	9.815	2.085
Maximum	112.428	56.678	15.506	6.801	41.158	34.325	36.894	14.890
Minimum	-120.641	-26.884	-18.577	-10.068	-42.280	-8.509	-32.974	-15.417
Skewness	-0.166 (0.144)	3.026 (0.144)	-0.035 (0.144)	-0.609 (0.144)	-0.186 (0.144)	6.678 (0.144)	0.049 (0.144)	0.348 (0.144)
Kurtosis	8.475 (0.287)	32.407 (0.287)	3.787 (0.287)	3.757 (0.287)	5.013 (0.287)	82.118 (0.287)	4.118 (0.287)	26.085 (0.287)
J-B N	364.801*	10929.82*	7.573*	24.945*	50.807*	78061.06*	15.278*	6467.65*
$Q(3)$	70.030*	11.934*	52.199*	27.323*	70.169*	59.985*	68.233*	13.182*
$Q(6)$	77.207*	29.785*	66.728*	28.284*	90.065*	64.426*	70.957*	14.315*
$Q^2(3)$	62.163*	55.883*	14.311*	8.800*	44.415*	13.136*	19.944*	139.630*
$Q^2(6)$	62.257*	87.651*	16.013*	17.596*	47.158*	13.622*	26.883*	188.000*
ADF(m)	-21.005*(1)	-14.494*(0)	-9.673*(2)	-12.641*(0)	-19.635*(1)	-12.047*(1)	-18.864*(1)	-13.875*(0)
ρ_{sq}	0.213		0.206		0.215		0.081	

	PHILIPPINES		SINGAPORE		TAIWAN		THAILAND	
	Δx_t	Δl_t	Δx_t	Δl_t	Δx_t	Δl_t	Δx_t	Δl_t
Sample size	291	291	291	291	291	291	291	291
Mean	0.622	0.186	0.487	0.095	0.283	0.053	1.031	0.196
SD	9.528	2.702	12.145	1.411	8.956	1.560	11.542	2.609
Maximum	35.601	21.006	55.490	6.380	37.592	9.020	49.175	16.295
Minimum	-38.113	-8.687	-54.574	-4.995	-25.208	-6.546	-43.237	-15.911
Skewness	-0.050 (0.144)	2.577 (0.144)	-0.218 (0.144)	0.069 (0.144)	0.407 (0.144)	0.109 (0.144)	-0.144 (0.144)	1.872 (0.144)
Kurtosis	5.418 (0.287)	20.495 (0.287)	6.618 (0.287)	4.950 (0.287)	4.645 (0.287)	7.954 (0.287)	6.404 (0.287)	24.106 (0.287)
J-B N	71.019*	4033.18*	160.985*	46.330*	40.824*	298.168*	141.504*	5570.93*
$Q(3)$	64.406*	8.400*	100.780*	17.620*	89.918*	14.133*	38.784*	23.865*
$Q(6)$	66.996*	9.516	101.580*	20.500*	90.098*	22.365*	58.018*	28.645*
$Q^2(3)$	31.870*	6.203	59.289*	48.710*	36.352*	3.324	53.417*	129.850*
$Q^2(6)$	35.351*	8.823	59.721*	86.074*	39.742*	6.538	109.77*	187.150*
ADF(m)	-18.787*(1)	-14.335*(0)	-19.291*(1)	-13.543*(0)	-20.683*(1)	-13.980*(0)	-14.982*(1)	-12.766*(0)
ρ_{sq}	0.259		0.046		0.018		0.110	

SD represents standard deviation; J-B N denotes Jacque-Bera normality test; $Q(k)$ and $Q^2(k)$ are Ljung-Box statistics for the level and squared terms for autocorrelations up to k lags; ADF(m) is the augmented Dickey-Fuller unit root test with lags m selected by the SIC criterion; * and ** denote significance at the 5% and 10% level, respectively.

Table 3. Estimates for dynamic conditional correlation bivariate GARCH-M model (1')-(9)

	INDONESIA		JAPAN		KOREA		MALAYSIA		PHILIPPINES		SINGAPORE		TAIWAN		THAILAND	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
a_0	1.832*	0.413	4.901*	0.123	1.007**	0.557	0.439	0.403	0.401	0.286	4.555*	0.277	4.622*	0.358	1.182*	0.316
a_1	-0.649*	0.048	-0.574*	0.044	-0.600*	0.050	-0.628*	0.048	-0.629*	0.046	-0.697*	0.049	-0.712*	0.047	-0.654*	0.051
a_2	-0.354*	0.046	-0.269*	0.038	-0.302*	0.046	-0.254*	0.050	-0.241*	0.044	-0.251*	0.048	-0.292*	0.044	-0.329*	0.045
b_0	2.988*	0.674	1.387*	0.303	1.749*	0.742			1.621*	0.484	2.651*	0.596	1.295*	0.579	2.075*	0.739
b_1							1.745*	0.600	1.401*	0.429			1.554*	0.562		
b_2			0.984*	0.282											1.207*	0.572
c_0	0.362*	0.053			0.708*	0.128			1.229*	0.181	0.226	0.215			0.554*	0.086
c_1			0.304*	0.063	1.032*	0.115			0.738*	0.115			0.820*	0.228	0.540*	0.072
c_2	0.210*	0.074	0.286*	0.077	0.737*	0.090	0.288	0.205	0.215**	0.123					0.286*	0.087
d_{10}					-1.461*	0.145	1.240*	0.184	-0.446**	0.240						
d_{11}			-1.410*	0.036	-1.723*	0.262			0.706*	0.156			-3.479*	0.233	0.199*	0.030
d_{12}	-0.376*	0.072			2.392*	0.216	-0.626*	0.184	-0.996*	0.243	-2.339*	0.153				
d_{20}	0.579*	0.096	-0.627*	0.075					0.632*	0.250					0.372*	0.118
d_{21}	-0.400*	0.109	-0.334*	0.080			-0.783*	0.239	0.598*	0.202	-1.332*	0.075	0.758*	0.350	-0.813*	0.050
d_{22}					1.011*	0.187									-0.422*	0.092
s_0	0.069	0.057	0.187	0.185	0.033	0.070	0.113**	0.063	0.005	0.095	0.043	0.071	0.087	0.091	-0.042	0.059
s_1	0.207*	0.065	0.308*	0.060	0.351*	0.052	0.177*	0.067	0.357*	0.059	0.235*	0.054	0.212*	0.061	0.211*	0.061
γ_1	30.261*	1.508													6.072*	0.643
γ_2	16.552*	0.495													15.066*	0.329
α_0	1.642*	0.609	13.189*	1.496	36.998*	4.438	5.713*	1.277	8.213*	3.289	7.257*	1.082	42.448*	5.102	1.464*	0.504
α_1	0.079*	0.012	0.204*	0.094	0.404*	0.077	0.143*	0.028	0.249*	0.086	0.271*	0.013	0.177*	0.090	0.085*	0.008
α_2	0.901*	0.010			0.303*	0.023	0.793*	0.021	0.721*	0.073	0.675*	0.028			0.887*	0.007
β_0	0.251*	0.043	6.112*	0.317	0.108*	0.020	0.796*	0.097	0.695*	0.178	0.268*	0.008	1.834*	0.182	0.078*	0.011
β_1	0.451*	0.074	0.191*	0.043	0.094*	0.017	0.333*	0.088	0.338*	0.104	0.086*	0.009	0.186*	0.060	0.087*	0.003
β_2	0.309*	0.047			0.781*	0.021			0.425*	0.070	0.766*	0.016			0.798*	0.013
λ_1	12.008*	4.216			0.713*	0.255	42.343*	20.030	9.095**	4.961					12.431*	4.790
λ_2									16.388**	9.253						
ν	5.951*	1.074	6.835*	1.729	4.051*	0.409	5.170*	0.831	3.018*	0.202	7.315*	1.814	4.822*	0.704	6.433*	1.047
θ_1	0.135*	0.061	0.024*	0.004	0.111*	0.051	0.032*	0.001	0.200*	0.058	0.056**	0.029	0.073*	0.026	0.029*	0.014
θ_2	0.717*	0.131	0.670*	0.024	0.712*	0.008	0.930*	0.001	0.462*	0.116	0.695*	0.171	0.755*	0.198	0.891*	0.022
$\rho_{sq,t}$	0.110		0.201		0.112		0.011		0.169		0.044		0.014		0.064	
$Q_2(6)$	35.167		19.255		30.017		28.935		32.510		11.301		28.691		31.584	
$Q_2^2(6)$	12.090		20.064		16.656		9.593		29.215		21.853		22.378		25.184	
$LR(k)$	3.360(6)		4.510(7)		2.916(4)		10.166(8)		1.726(2)		2.002(8)		4.714(9)		5.926(3)	

$Q_2(6)$ and $Q_2^2(6)$ are the bivariate Ljung-Box statistics (Hosking,1980) of the standardized and squared standardized residuals for autocorrelations up to 6 lags. $LR(k)$ is the likelihood ratio statistic following a χ^2 distribution with the degree of freedom k (in the parentheses) that tests that the restricted simple model has the same explanatory power as the unrestricted general model when we eliminate the k insignificant estimates. * and ** denote significance at 5% and 10% level, respectively.

Table 4. Statistics for dynamic conditional correlations

	INDONESIA	JAPAN	KOREA	MALAYSIA	PHILIPPINES	SINGAPORE	TAIWAN	THAILAND
Mean	0.110	0.201	0.112	0.011	0.169	0.044	0.014	0.064
Median	0.106	0.202	0.134	0.021	0.183	0.053	-0.001	0.063
Maximum	0.609	0.305	0.396	0.155	0.494	0.246	0.420	0.220
Minimum	-0.413	0.094	-0.453	-0.155	-0.392	-0.185	-0.270	-0.104
Std. Dev.	0.197	0.029	0.127	0.065	0.118	0.066	0.116	0.052

Table 5. Tests of asymmetric effect of exchange rate risk

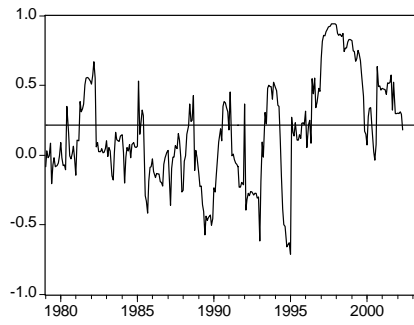
	$\sum d_{1i}$	$\sum (d_{1i} + d_{2i})$	$\sum d_{2i}$
INDONESIA	-0.376 *	-0.198	0.178
<i>LR statistic</i>	5.434 (0.020)	1.687 (0.194)	0.600 (0.439)
JAPAN	-1.411 **	-2.371 *	-0.960 *
<i>LR statistic</i>	3.444 (0.063)	7.385 (0.007)	9.327 (0.002)
KOREA	-0.793 **	0.218 *	1.011 **
<i>LR statistic</i>	3.693 (0.055)	15.107 (0.000)	3.509 (0.061)
MALAYSIA	0.614 *	-0.169	-0.783 *
<i>LR statistic</i>	3.951 (0.047)	0.243 (0.622)	4.274 (0.039)
PHILIPPINES	-0.735 **	0.494 **	1.229 *
<i>LR statistic</i>	3.249 (0.071)	3.154 (0.076)	5.432 (0.020)
SINGAPORE	-2.339	-3.671 *	-1.332 *
<i>LR statistic</i>	2.087 (0.149)	4.635 (0.031)	4.277 (0.039)
TAIWAN	-3.479 **	-2.722	0.757
<i>LR statistic</i>	3.323 (0.068)	1.968 (0.161)	1.070 (0.301)
THAILAND	0.199	-0.663 *	-0.862
<i>LR statistic</i>	0.256 (0.613)	4.657 (0.031)	1.840 (0.175)

LR statistic is the likelihood ratio statistic following a χ^2 distribution with one degree of freedom that tests $\sum d_{1i} = 0$, $\sum (d_{1i} + d_{2i}) = 0$ and $\sum d_{2i} = 0$. *P-values* are in parentheses. * and ** denote significance at 5% and 10% level, respectively.

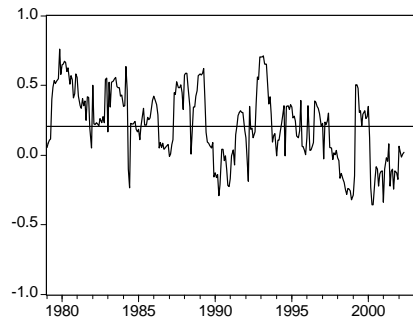
Table 6. Estimates for dynamic conditional correlation bivariate GARCH-M model (1)-(9)

	INDONESIA		JAPAN		KOREA		MALAYSIA		PHILIPPINES		SINGAPORE		TAIWAN		THAILAND	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
a_0	1.691 *	0.415	3.937 *	0.240	0.761 **	0.427	0.442	0.408	0.128	0.305	3.366 *	0.099	10.165 *	0.241	1.314 *	0.370
a_1	-0.643 *	0.048	-0.570 *	0.044	-0.577 *	0.049	-0.625 *	0.047	-0.617 *	0.042	-0.684 *	0.049	-0.736 *	0.070	-0.645 *	0.047
a_2	-0.353 *	0.047	-0.272 *	0.041	-0.277 *	0.042	-0.250 *	0.050	-0.230 *	0.043	-0.257 *	0.035	-0.324 *	0.047	-0.321 *	0.045
b_0	2.865 *	0.667	1.212 *	0.347	1.521 *	0.651			1.176 *	0.471	2.618 *	0.566	1.539 *	0.554	2.446 *	0.570
b_1							1.828 *	0.604	1.550 *	0.415			1.579 *	0.524		
b_2			1.066 *	0.336												
c_0			0.298 *	0.082	0.562 *	0.118			0.936 *	0.106					0.474 *	0.131
c_1	0.280 *	0.069	0.453 *	0.079	0.924 *	0.195	0.380 *	0.188	0.395 *	0.133	0.419 **	0.215	0.590 *	0.256	0.780 *	0.166
c_2	0.148 **	0.076	0.325 *	0.078											0.485 *	0.130
d_0	0.421 *	0.083			-0.088	0.229	1.189 *	0.188	0.664 *	0.122	1.579 *	0.071				
d_1	-0.653 *	0.086	-1.476 *	0.080					0.741 *	0.123			-1.959 *	0.097	-0.253 *	0.122
d_2							-0.962 *	0.199	-1.308 *	0.124	-3.804 *	0.084	-4.973 *	0.103		
s_0	0.072	0.056	0.174	0.189	0.033	0.069	0.117 **	0.063	0.004	0.094	0.037	0.088	0.106	0.093	-0.042	0.059
s_1	0.202 *	0.068	0.310 *	0.058	0.351 *	0.055	0.183 *	0.068	0.356 *	0.057	0.236 *	0.053	0.218 *	0.060	0.212 *	0.062
γ_1	30.258 *	1.483													6.065 *	1.206
γ_2	16.037 *	0.598													15.069 *	1.198
α_0	1.839 *	0.701	13.528 *	1.892	40.966 *	6.764	5.722 *	1.275	8.397 *	1.820	4.106 *	0.053	44.521 *	5.117	1.559 *	0.479
α_1	0.096 *	0.015	0.182 **	0.097	0.363 *	0.118	0.139 *	0.027	0.240 *	0.053	0.173 *	0.006	0.092	0.069	0.082 *	0.012
α_2	0.887 *	0.011			0.282 *	0.075	0.797 *	0.020	0.725 *	0.028	0.793 *	0.005			0.890 *	0.010
β_0	0.251 *	0.044	6.164 *	0.479	0.118 *	0.023	0.796 *	0.099	0.713 *	0.146	0.309 *	0.023	1.823 *	0.083	0.083 *	0.016
β_1	0.489 *	0.087	0.172 *	0.055	0.101 *	0.027	0.357 *	0.099	0.333 *	0.067	0.099 *	0.023	0.164 *	0.031	0.100 *	0.021
β_2	0.299 *	0.048			0.761 *	0.024			0.401 *	0.059	0.732 *	0.016			0.787 *	0.017
λ_1	10.869 *	4.018			0.799 *	0.307	34.865 *	15.375	16.632 *	5.160					10.868 *	3.659
λ_2									18.962	11.580						
ν	5.691 *	0.934	7.131 *	1.858	4.143 *	0.461	5.069 *	0.795	3.023 *	0.170	7.174 *	0.579	5.164 *	0.946	6.105 *	1.257
θ_1	0.160 **	0.082	0.057 **	0.032	0.099 *	0.030	0.011	0.018	0.204 **	0.110	0.061 **	0.034	0.049 *	0.023	0.040 *	0.006
θ_2	0.592 *	0.198	0.730 *	0.073	0.828 *	0.005	0.984 *	0.037	0.441 *	0.120	0.649 *	0.155	0.859 *	0.115	0.952 *	0.013
$Q_2(6)$	32.658		20.294		30.200		28.275		36.108		8.848		28.183		36.001	
$Q_2^2(6)$	13.299		20.950		14.066		10.643		15.949		20.672		16.552		23.231	
$\sum d_i$	-0.232 *		-1.476 **		-0.088		0.227		0.097		-2.226		-6.932 *		-0.253	
χ^2	(4.624)		(3.273)		(0.082)		(0.642)		(0.263)		(1.968)		(6.889)		(2.478)	
$LR(k)$	4.788 (4)		3.414 (5)		5.621 (5)		7.844 (5)		1.962 (2)		3.606 (5)		2.874 (4)		5.858 (4)	

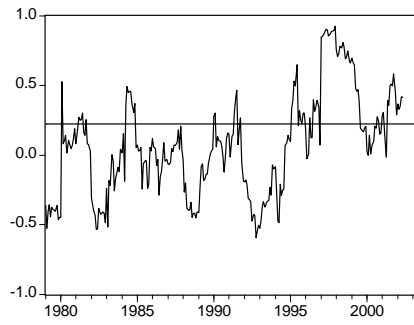
See Table 3. $LR \chi^2$ statistics are in parentheses testing for the significance of $\sum d_i$. * and ** denote significance at 5% and 10% level, respectively.



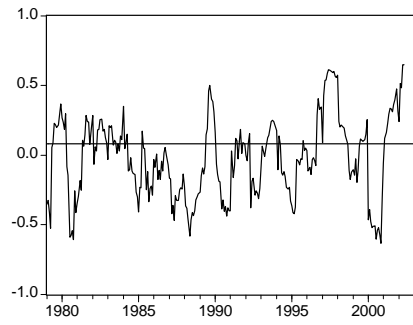
Indonesia



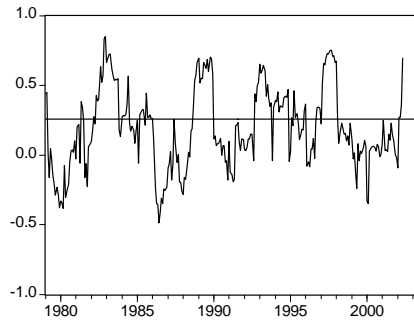
Japan



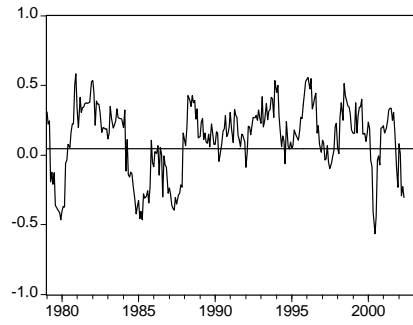
Korea



Malaysia



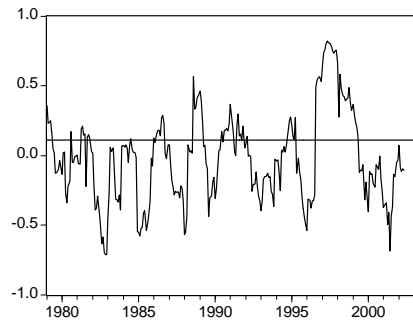
Philippines



Singapore



Taiwan



Thailand

Figure 1. 12-period rolling correlations

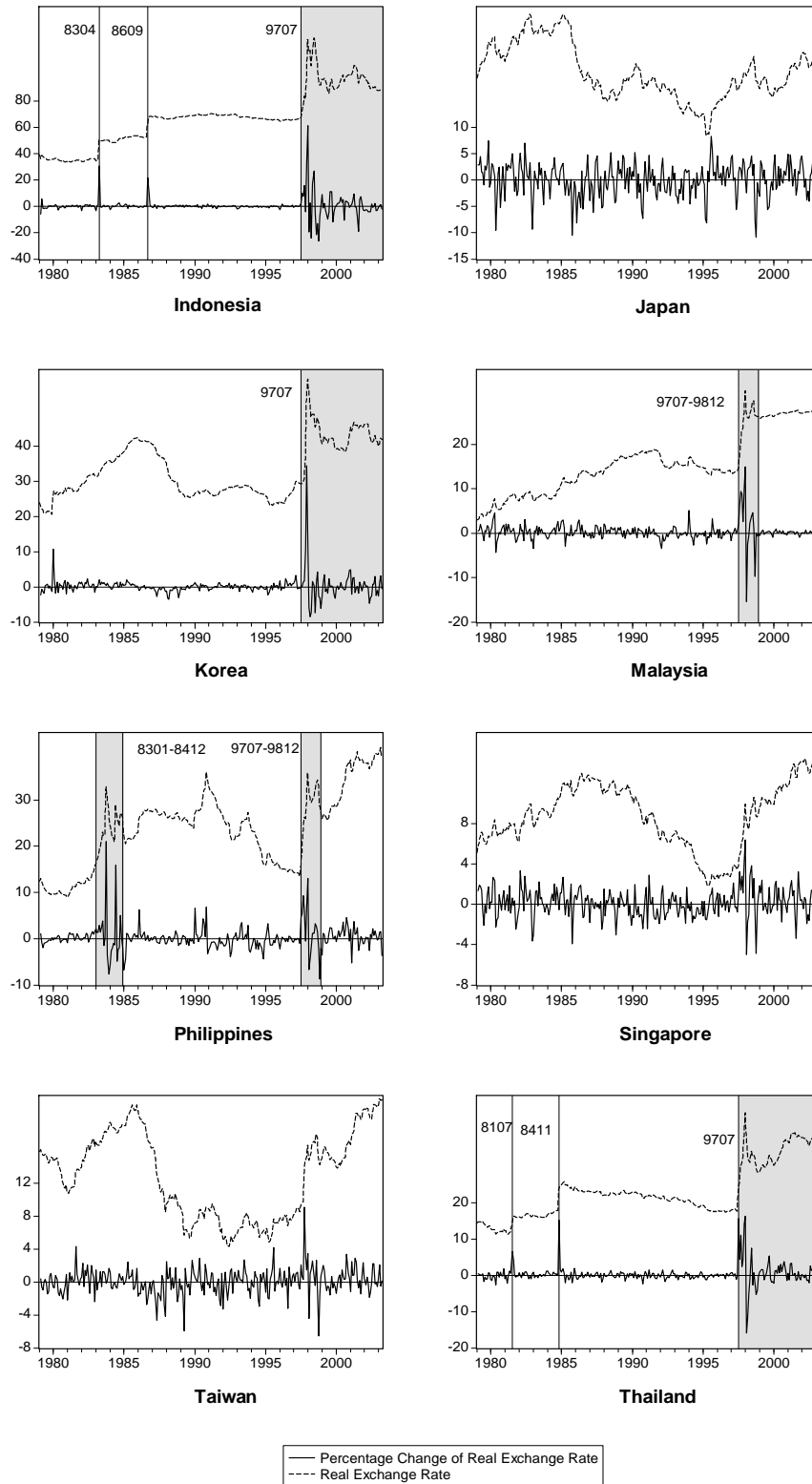
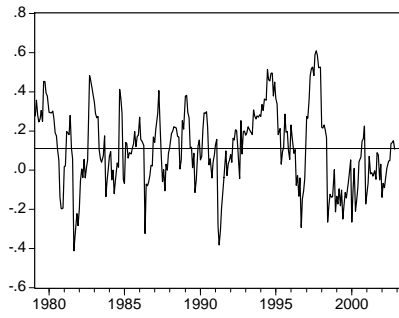
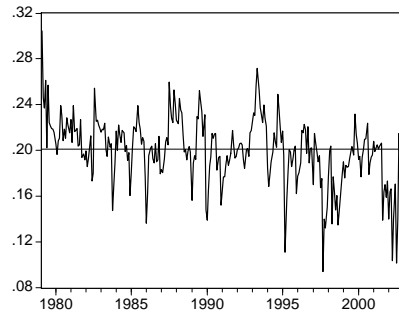


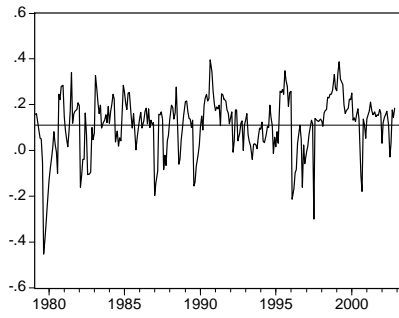
Figure 2. Structural changes for exchange rates



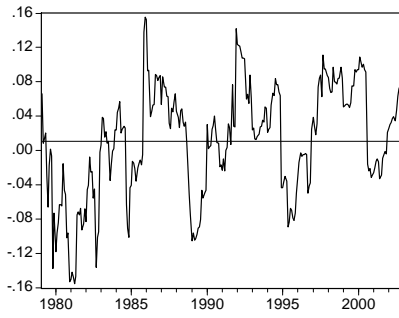
Indonesia



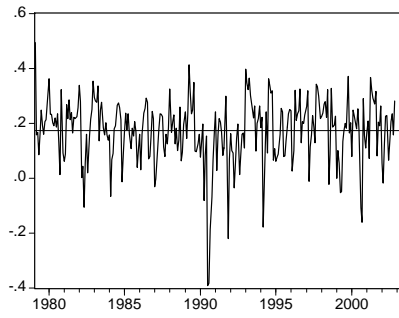
Japan



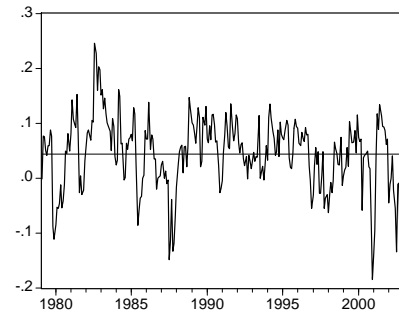
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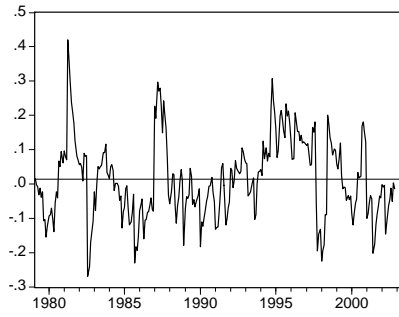
Malaysia



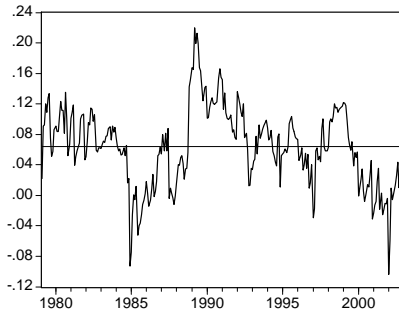
Philippines



Singapore



Taiwan



Thailand

Figure 3. Dynamic conditional correlations

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