

# **Exchange rate depreciation and exports: The case of Singapore revisited**

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November 2004

This paper revisits the weak relationship between exchange rate depreciation and exports for Singapore, using a bivariate GARCH-M model that simultaneously estimates time-varying risk. The evidence shows that depreciation does not significantly improve exports, but that exchange rate risk significantly impedes exports. In sum, Singaporean policy makers can better promote export growth by stabilizing the exchange rate rather than generating its depreciation.

Keywords: depreciation, exchange rate risk, exports, bivariate GARCH-M model

JEL classification: F14, F31

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### **I. Introduction**

A traditional view expects that exchange rate depreciation improves exports. For example, Junz and Rhomberg (1973) and Wilson and Takacs (1979), employing data from a fixed exchange rate period, and Bahmani-Oskooee and Kara (2003), using data from a flexible exchange rate period, provide evidence that depreciation improves exports for developed countries. In an interesting paper, Abeysinghe and Yeok (1998) find that exchange rate appreciation does not adversely affect exports for Singapore because exports possess high import content. This paper argues that exchange rate risk provides another channel the exchange rate to affect exports in Singapore. That is, exchange rate risk adversely affects exports, although exchange rate depreciation does not affect exports.

The probable effects of exchange rate risk received considerable attention, since the collapse of fixed exchange rates in the early 1970s. Little consensus regarding its effect on exports, however, exists. Ethier (1973) argues that exchange risk could lower exports due to profit risk. De Grauwe (1988) suggests that exporters might increase volume to offset potential 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 real exports to the US. Chowdhury (1993), Arize (1995, 1997), Weliwita et al. (1999), Arize et al. (2000), Arize et al. (2003) and Fang and Thompson (2004) find negative effects of exchange risk on US, G7, LDC, and NIC exports. Contrary evidence exists, however. Asseery and Peel (1991) find positive relationships for multilateral exports, except for the UK. Kroner and Lastrapes (1993) uncover positive effects of conditional variance on exports of France, Germany, and Japan, but negative effects for the UK and US. McKenzie and Brooks (1997) discover positive risk relationship for

Germany and the US. And Klaassen (2004) finds no effect on monthly bilateral US exports to the other G7 countries.

The effects of the exchange rate or exchange rate risk on exports individually may produce biased inference, if both affect exports and one is omitted. No research combines the two effects of exchange rate changes together to analyze the relationship between exchange rates and exports in the previous literature.

Generalized autoregressive conditional heteroscedasticity (GARCH) models specify the relationships between means and variances as in Engle et al. (1987) and Bollerslev et al. (1992). We apply the bivariate GARCH-M modeling approach to Singapore to provide evidence for the effects exchange rate depreciation and its time varying variance on exports. Our methodology differs from the study of Abeysinghe and Yeok (1998). They use OLS estimation with no risk variable to explain the effect of exchange rate depreciation on exports. This specification may overestimate the effect of depreciation if exports and exchange rate risk are negatively related as shown in Arized et al. (2003). This paper estimates simultaneously the effects of exchange rate depreciation and its risk and evaluates their joint effect on exports.

The rest of this paper is organized as follows. Section 2 describes the preliminary statistics for exports and the exchange rates, focusing on properties of time varying variances of the two variables. Section 3 briefly presents the main elements of the bivariate GARCH-M model, reports the estimates of the model, and quantitatively analyzes the effects of exchange rate risk on exports. Section 4 concludes.

## **II. Data and time-varying variances**

To assess the net effect of exchange rate depreciation and its risk on exports, we employ a nonstructural partial reduced-form approach of Rose (1990) and Klaassen (2004), where the real exports ( $x$ ) depend directly on real foreign income ( $y$ ), the real exchange rate ( $q$ ), and real

exchange rate risk ( $h_q$ ). Real foreign income positively affects the demand for exports. An increase in the real exchange rate, a depreciation, implies cheaper exports abroad and improves real exports. The effect of real exchange rate risk proves theoretically ambiguous.

To provide evidence, we use bilateral exports between Singapore and the U.S. on a monthly basis over the sample period from January 1979 to October 2002. Seasonally adjusted real export revenue equals nominal export revenue in domestic currency deflated by the consumer price index (CPI). We convert the bilateral nominal exchange rate, defined as the domestic currency price of the U.S. dollar, into a real exchange rate by multiplying the nominal rate by the ratio of the U.S. CPI to the domestic CPI. Foreign income equals the industrial production index of the US, with base year 1995. All data come from the International Financial Statistics and Direction of Trade of the IMF.

Two reasons suggest the adoption of the bilateral approach. First, the ratio of bilateral exports between Singapore and the US to Singapore's total exports is 15.3% over the sample period. The US accounts for a substantial proportion of exports from Singapore. Second, using bilateral exports avoids the asymmetric response of trade flows to exchange rate depreciation and its risk across countries. We, then, can focus on the simple relationship between exchange rate changes and exports. In addition, Klaassen (2004) finds that the exchange risk in developed countries does not exhibit enough variability to uncover its effect on exports, and suggests studying the risk effect, using data on developing countries, for which volatile exchange rate risk may exist.

Statistical analysis of variables identifies appropriate GARCH models for further analyses. In our sample, Singapore experienced exchange rate depreciation and export growth. The average rate of export growth equals 0.530% while the average depreciation rate equals

0.093%. Both the mean and the standard deviation of export growth greatly exceed those of the rate of depreciation. Skewness statistics for the growth rate of real exports ( $\Delta l x_t$ ) and the growth rate of the real exchange rate ( $\Delta l q_t$ ) cannot reject symmetry, but Kurtosis statistics significantly exceed 3 at the 5-percent level, implying leptokurtic series with fat tails. The Jarque-Bera test rejects normality. Non-normality and the fat-tailed nature suggest estimating GARCH models under the Student-t distribution.

After selecting lag length by the AIC criterion, the Augmented Dickey-Fuller (ADF) test shows that  $\Delta l x_t$  and  $\Delta l q_t$  prove individually stationary [i.e.,  $I(0)$ ] series at the 5-percent level. Valid inference in GARCH models requires stationarity in variables. The Ljung-Box Q-statistic tests for autocorrelation. The number of lags ( $k$ ) affects the power of the test. Tsay (2002) suggests choosing  $k = \ln(T)$ . The number of observations,  $T$ , in our sample equals 285, accordingly, we set  $k = 5.65$ . We test for autocorrelations up to 6 lags. Ljung-Box Q-statistics indicate autocorrelations in  $\Delta l x_t$ , but no autocorrelation in  $\Delta l q_t$ . Ljung-Box Q-statistics for squared  $\Delta l x_t$  and squared  $\Delta l q_t$  suggest the possible presence of time-varying variance for the two series. To adequately capture the dynamic structure of the data, we employ an ARMA process for both the mean and variance equations of the two variables.

We estimate univariate GARCH(1,1) models first to identify properties of the changing variances for  $\Delta l x_t$  and  $\Delta l q_t$ . The Ljung-Box  $Q(k)$  statistics for the standardized residuals of  $\Delta l x_t$  show no autocorrelations up to 6 lags, suggesting that the AR(2) process achieves white noise. Since the exchange rate does not possess autocorrelation, we specify the mean equation of  $\Delta l q_t$  as a constant. No evidence of autocorrelation emerges, given the low Ljung-Box  $Q(k)$  statistics for the standardized residuals of  $\Delta l q_t$ . The estimates in the two variance equations are significantly positive. Moreover,  $\alpha_1 + \alpha_2 = 0.933 < 1$  and  $\beta_1 + \beta_2 = 0.807 < 1$  show that each

time-varying variance process is stable for  $\Delta l x_t$  and  $\Delta l q_t$ . The higher coefficient of volatility persistence of  $\Delta l x_t$  relative to that of  $\Delta l q_t$  is consistent with the higher standard deviation of  $\Delta l x_t$ . The low Ljung-Box Q-statistics for the squared standardized residuals up to 6 lags show no remaining heteroscedasticity. The estimated coefficients of the degree of freedom  $\nu$  are significant at the 5-percent level, implying the appropriateness of employing the GARCH(1,1) for both  $\Delta l x_t$  and  $\Delta l q_t$  under the t-distribution.

The two variables,  $\Delta l x_t$  and  $\Delta l q_t$ , possess time-varying variances, suggesting the use of the bivariate GARCH model to examine the relationship between exports and exchange rate changes.

### III. The empirical bivariate GARCH-M model and estimation

The following eclectic GARCH-M model provides the framework for assessing the net effect of exchange rate depreciation and its risk on exports.

$$\Delta l x_t = a_0 + \sum_{i=1}^2 a_i \cdot \Delta l x_{t-i} + b \cdot \Delta l y_{t-1} + c \cdot \Delta l q_{t-1} + d \cdot h_{q,t-1} + \varepsilon_{x,t} \quad (1)$$

$$\Delta l q_t = e_0 + \varepsilon_{q,t} \quad (2)$$

$$\varepsilon_t = (\varepsilon_{x,t}, \varepsilon_{q,t})' \quad \varepsilon_t | \Psi_{t-1} \sim Student-t(\nu) \quad (3)$$

$$H_t = \begin{pmatrix} h_{x,t} & h_{xq,t} \\ h_{xq,t} & h_{q,t} \end{pmatrix} \quad (4)$$

$$h_{x,t} = \alpha_0 + \alpha_1 \cdot \varepsilon_{x,t-1}^2 + \alpha_2 \cdot h_{x,t-1} \quad (5)$$

$$h_{q,t} = \beta_0 + \beta_1 \cdot \varepsilon_{q,t-1}^2 + \beta_2 \cdot h_{q,t-1} \quad (6)$$

$$h_{xq,t} = \rho_{xq} \cdot \sqrt{h_{x,t} \cdot h_{q,t}} \quad (7)$$

where  $\Delta l x_t \equiv 100 \times (\ln x_t - \ln x_{t-1})$ ,  $\Delta l q_t \equiv 100 \times (\ln q_t - \ln q_{t-1})$ ,  $\Delta l y_t \equiv 100 \times (\ln y_t - \ln y_{t-1})$ ;  $\varepsilon_t$ ,

conditional on the information set  $\Psi_{t-1}$  available at time  $t-1$ , follows a bivariate Student-t distribution with degrees of freedom,  $\nu$ .  $h_{x,t}$  and  $h_{q,t}$  equal conditional variances while  $h_{xq,t}$  equals the covariance. Now,  $\rho_{xq}$  equals the correlation coefficient of  $\Delta l x_t$  and  $\Delta l q_t$ . The presence of  $h_{q,t}$  in equation (1) means that equations (1) to (7) constitute a bivariate GARCH(1,1)-M model. The conditions that  $\alpha_i > 0$ , and  $\beta_i > 0$  ensure positive conditional variance. The conditions that  $\alpha_1 + \alpha_2 < 1$  and  $\beta_1 + \beta_2 < 1$  imply stable variances. The constant correlation specification (Bollerslev 1990) is modeled through (7). This specification reduces the number of parameters and increases the degrees of freedom of model estimation. All parameters in equations (1) to (7) are estimated by maximizing the following log-likelihood function of bivariate Student-t distribution:

$$\ln L_t = \ln \Gamma\left(\frac{\nu+2}{2}\right) - \ln(\nu-2) - \ln \Gamma\left(\frac{\nu}{2}\right) - 0.5 \ln |H_t| - \left(\frac{\nu+2}{2}\right) \cdot \ln \left(1 + \frac{\varepsilon_t' H_t^{-1} \varepsilon_t}{\nu-2}\right) \quad (8)$$

where  $\Gamma(\bullet)$  equals the Gamma function.

The model explains changes in exports. The reduced-form equation includes the depreciation rate and its risk as well as the rate of change of foreign income as explanatory variables. The statistical significance and sign of the estimated  $c$  and  $d$  coefficients in equation (1) provide a simple and straightforward test of the relationship between real export growth and exchange rate depreciation and its volatility. If the estimate of  $c$  exceeds zero, then exchange rate depreciation improves exports. Exchange rate volatility affects exports through exporters' responses to perceived risk. When exchange rate uncertainty leads to profit risk, then, *ceteris paribus*, the demand for exports falls (i.e.  $d < 0$ ). The net effect on exports includes the exchange rate depreciation and its volatility.

The estimation results are as follows:<sup>1</sup>

$$\Delta l x_t = 1.485 - 0.621 \Delta l x_{t-1} - 0.266 \Delta l x_{t-2} + 0.880 \Delta l y_{t-1} + 0.229 \Delta l q_{t-1} - 0.254 h_{q,t-1}$$

(0.431)\*      (0.051)\*      (0.050)\*      (0.711)      (0.277)      (0.150)\*

$$\Delta l q_t = 0.032$$

(0.082)

$$h_{x,t} = 2.692 + 0.104 \varepsilon_{x,t-1}^2 + 0.864 h_{R,t-1}$$

(0.666)\*      (0.014)\*      (0.011)\*

$$h_{q,t} = 0.362 + 0.154 \varepsilon_{q,t-1}^2 + 0.700 h_{q,t-1}$$

(0.054)\*      (0.028)\*      (0.026)\*

$$h_{xq,t} = 0.104 \cdot \sqrt{h_{x,t} \cdot h_{q,t}}$$

(0.072)

$$\nu = 7.955$$

(2.261)\*

$$Q_2(3)=4.173 \quad Q_2(6)=11.153 \quad Q_2^2(3)=8.995 \quad Q_2^2(6)=22.145$$

Estimated coefficients in the two variance equations are positive and significant. Volatility persistence equals 0.968 for  $\Delta l x_t$  and 0.854 for  $\Delta l q_t$ . The two variance processes converge. The estimated correlation coefficient between  $\Delta l x_t$  and  $\Delta l q_t$  equal 0.104 that nearly equals the coefficient of 0.102 calculated from the two series. The degree of freedom of the t-distribution, estimated jointly with other parameters, is significant. That is, the hypothesis of using a standardized student-t distribution is not rejected at the 5-percent level. The bivariate Ljung-Box  $Q_2(k)$  statistics (Hosking, 1980) for the standardized and squared standardized residuals of  $\Delta l x_t$  and  $\Delta l q_t$  do not detect any remaining autocorrelation or conditional heteroscedasticity at the 5-percent level. The bivariate GARCH-M model in equations (1) to (7)

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<sup>1</sup>  $Q_2(k)$  and  $Q_2^2(k)$  are the bivariate Ljung-Box statistics (Hosking, 1980) for standardized and squared standardized residuals for autocorrelations up to k lags;  $\nu$  is degree of freedom. \* denotes significance at the 5% level.

is adequate for further inferences.

The marginal effect of real US income (industrial production) on exports exhibits the expected positive sign, which is not significant at the 5% level. Thus, bilateral exports from Singapore to the US do not respond to US economic activity.

Exchange rate depreciation exhibits the expected positive effect, which is also not significant. Exchange rate risk possesses a significantly negative effect on exports, however. Regarding the magnitude of the effect, the mean value of conditional variance  $h_{q,t}$  in the bivariate GARCH-M model is 2.55. The *ceteris paribus* average monthly effect of the risk on export revenue (mean value of  $h_{q,t} \times d$ ) equals -0.65 percent. The standard deviation of  $h_{q,t}$  of 1.75 implies that the range of potential monthly influences on export revenue calculated by (mean of  $h_{q,t} \pm$  standard deviation) $\times d$  covers the range [-0.20%, 1.09%], a rather substantial effect, since the mean growth rate of real exports equals just over 0.5 percent, as noted above.

The mean value (=0.093) and the estimated coefficient (=0.229) of the depreciation rate implies the average monthly impact of 0.02 percent. When the net effect of the exchange rate movement is gauged by the sum of the two average effects, the significant risk effect dominates, leading to a negative net effect.

#### **IV. Conclusion**

Previous research that investigated the responsiveness of exports to exchange rate depreciation generally concluded that exports react increasingly to exchange rate depreciation. This paper has revisited the weak relationship between exchange rate depreciation and exports in Singapore by using monthly data over the period of 1979-2002. Unlike Abeysinghe and Yeok's (1998) OLS estimates based on annual data of 1975-1992, we account for the time varying variance of the data, employ bivariate GARCH-M modeling technique to estimate the effects of exchange rate

depreciation and its risk on exports.

In sum, the effect of exchange rate depreciation on exports is positive but insignificant, supporting the findings of Abeysinghe and Yeok's (1998). Second, time-varying real exchange rate risk exhibits a significant negative effect on exports of substantial magnitude. Third, the exchange risk effect dominates the depreciation effect, leading to a negative net effect of exchange rate changes on export revenue.

The policy implications suggest that Singaporean authorities can elicit stronger export growth by ensuring a more stable exchange rate rather than by engineering its depreciation.

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