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Investigating The Relationship Between Exchange Rate Volatility And Macroeconomic Volatility In Singapore

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INVESTIGATING THE RELATIONSHIP BETWEEN EXCHANGE RATE VOLATILITY AND MACROECONOMIC VOLATILITY IN SINGAPORE*

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ABSTRACT

This paper examines the characteristics of the Singapore dollar nominal effective exchange rate (SGD NEER) since 1980s and investigates whether the short-term movements in the currency has affected the behaviour of key real macroeconomic variables in the economy. Our analysis of time series properties of the SGD NEER, which utilises a GARCH framework, picked up an increase in the volatility of the domestic currency particularly after the Asian Crisis. The paper then examines the relationship between exchange rate volatility and the volatility of real macroeconomic variables. We adopted a flexible-price monetary model following Flood and Rose (1995) to assess the impact of the increase in exchange rate volatility on real macroeconomic variables in Singapore. Our analysis found little evidence of a relationship between exchange rate volatility and that of a number of key macroeconomic variables. In addition, the paper also specifically assesses the effects of exchange rate volatility on bilateral trade flows in Singapore using a standard 'gravity' model as well as a multivariate error correction model and found the impact to be relatively small. The results of the analysis provide some support to the argument that volatility in the foreign exchange market may not be transferred to other parts of the economy.

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1. INTRODUCTION

1. After industrialised countries abandoned the fixed exchange rates of the Bretton Woods system in the 1970s, many observers did not anticipate the high volatility of exchange rates that followed. Numerous empirical studies have documented the large, persistent and volatile deviations of nominal exchange rates from the 'benchmark' purchasing power parity relationship in the post-Bretton Woods era, and the large swings in real exchange rates of key industrialised countries. The consequences of exchange rate volatility on trade and real economic activity has naturally become the subject of intense study in the literature.

2. In this paper, we examine the volatility of the Singapore dollar nominal effective exchange rate (SGD NEER) since 1980s and assess its impact on the behaviour of key macroeconomic variables in the Singapore economy, over the period 1980 to 2002. Our analysis points to an increase in the volatility of the Singapore dollar after the Asian Crisis. However, further econometric analysis suggests that this volatility has not affected the stability of Singapore's key macroeconomic variables (including trade flows).

3. The plan of the paper is as follows. Section 2 begins by highlighting the effects of exchange rate volatility on the real economy as well as the results from recent empirical studies in this area. These studies have generally been unable to establish a robust statistically significant link between exchange rate volatility and trade. Next in Section 3, we examine evidence of any significant changes in the volatility of the SGD NEER since the Asian crisis. We then investigate the relationship between volatility in SGD NEER and key macroeconomic variables. First, we use standard scatter plots to detect trade-offs between exchange rate volatility and volatility of key macroeconomic variables for eight regional countries including Singapore. Second, we adopt an empirical framework to assess the effect of SGD NEER volatility on trade flows. Third, we proceed to formalise the link between the volatility of macroeconomic variables and the exchange rate across different volatility regimes using the flexible price monetary model of the foreign exchange market for Singapore.

2. HOW DOES EXCHANGE RATE VOLATILITY AFFECT THE ECONOMY?

4. Exchange rate volatility is a cause for concern if it disrupts economic activity. In the international system, the price of a country's currency plays a major role in determining the cost of its imports and exports, which in turn, affects its economic welfare. Since, some East Asian countries compete directly with each other for export markets and rely on imported materials or components to fuel their manufacturing sectors, currency fluctuations may have a significant impact on commercial trade flows.

5. McKinnon and Ohno (1997) argue that excessive exchange rate volatility and persistent misalignments can depress trade flows, distort investment decisions, and misallocate the outsourcing locations chosen by multinational firms. For instance, exchange rate volatility can reduce the volume of international trade by creating uncertainty about the profits made from international transactions and also restrict the international flow of capital by reducing both direct investment in foreign operating facilities and financial portfolio investment. Increased exchange rate volatility may also lead to higher prices for internationally traded goods by causing traders to add a risk premium to cover unanticipated exchange rate fluctuations.

6. However, most of the empirical work in this area is generally unable to establish a statistically significant link between exchange rate volatility and trade. Moreover, in instances where a negative relationship is found, the impact appears to be small. [See for example, the surveys in IMF (1984) and Belanger and Gutierrez (1990)]. More recent work has confirmed minimal impact of exchange rate volatility. For example, Flood and Rose (1995), Obstfeld and Rogoff (2000) and Duarte and Stockman (2001), find that movements in exchange rates tend to be 'disconnected' from the behaviour of real economic variables. Some of these studies develop formal intertemporal models that imply high exchange rate volatility can be caused by local currency pricing, heterogeneity in the way that products are sold (and prices set) in international markets, and the presence of 'noise traders' in foreign exchange markets. However, they also show that it is possible for high exchange rate volatility to have little if any impact on macroeconomic variables.

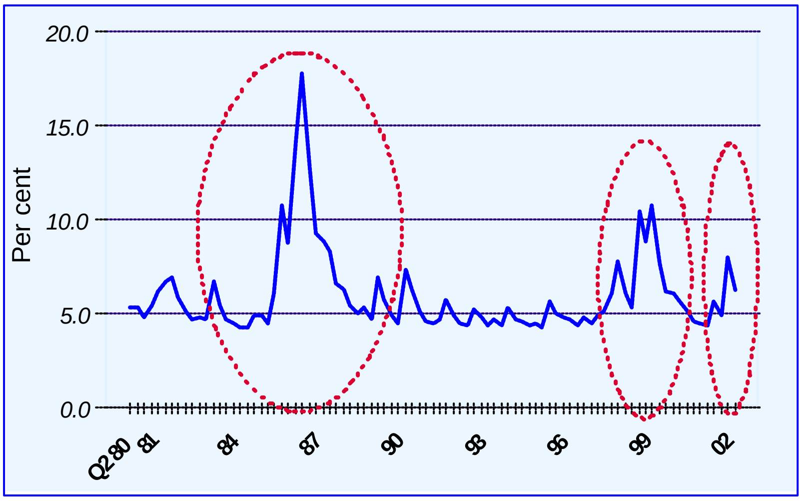
3. EXCHANGE RATE VOLATILITY IN SINGAPORE

7. We begin by examining if there has been any change in the nature of the volatility of the Singapore dollar nominal effective exchange rate (SGD NEER) since the Asian crisis.

3.1. TIME-VARYING CONDITIONAL STANDARD DEVIATION USING GARCH (1,1) MODEL

8. A GARCH (1,1) model was used to estimate the conditional variance or time-varying volatility of the log differences of SGD NEER[1]. GARCH (1,1) is the tool of choice because it uses both the first and second moments of the series to measure conditional volatility[2]. The conditional standard deviations of the series are used to distinguish between periods of low and high volatility regimes. Chart 1 plots the estimates of the conditional standard deviations of the SGD NEER over time on an annualised basis, and suggests that there have been three distinct periods of heightened volatility corresponding to the 1985 recession, 1998 financial crisis and 2001 recession.

Chart 1: SGD NEER Conditional standard deviation*, 1980-2002



*Annualised basis

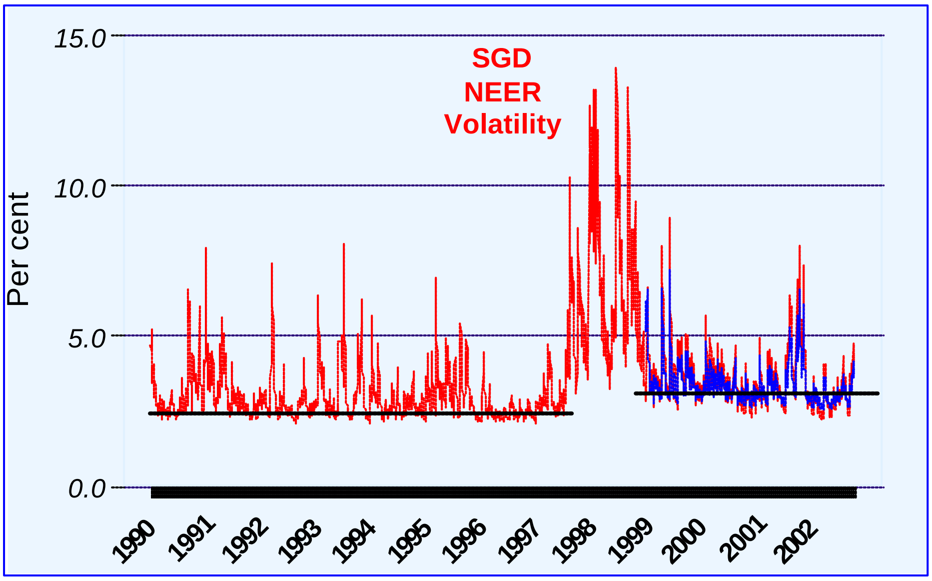
[1] The SGD NEER series provided by JPMorgan Chase Bank.

[2] In the GARCH model, the conditional standard deviations are a function of past values of log differences of SGD NEER.

9. Our estimates show that the time-varying annual standard deviation or volatility of the SGD NEER in the first half of this year was around 7.1%, against the average of 5.1% in 2000 and 2001. (This compares with the 20-year historical average of around 5.2%. This mean estimate excludes periods of heightened volatility such as those seen during the Asian crisis.)

10. In addition, we estimated the daily volatility of the log differences in SGD NEER between 2 Jan 1990 and 11 Oct 2002, while controlling for movements in currencies of other countries in our currency basket. Chart 2 shows this daily conditional SGD NEER volatility on an annualised basis. The red line is the conditional volatility of the SGD NEER without controlling for movements in the NEER basket of currencies, while the blue line represents the conditional volatility of SGD NEER after controlling for the movements of major currencies such as the USD/Euro, USD/Yen and USD/Rupiah. The time series illustrates the familiar cluster pattern around periods of volatility followed by periods of relative tranquillity, for example during and after the Asian Crisis 1997-1998. In addition, we find that despite controlling for cross-movements in the major currencies, volatility levels remain quite similar.

Chart 2: Volatility of SGD NEER*, 1990 – 2002



*Note: Volatility is on annualised basis. Blue line represents SGD NEER volatility conditional on movements in other currencies in the basket.

11. Note that volatility levels appear to have increased in recent years compared to the pre-crisis period. More recently, however, the calculated volatility has declined after the increased volatility following the Sep 11

terrorist attacks in 2001, and appears to have settled around the average mean recorded over the post-crisis period. The chart reveals that the volatility of the SGD NEER since 1999 has settled around a new and higher mean, about 1.4 times higher than that over the period 1 Jan 1990 to 31 Jun 1997[3]. Thus, there appears to be an upward shift in the mean volatility level of the SGD NEER.

12. Although the mean volatility of the SGD NEER could return to its previous (lower) level as economic conditions stabilise[4], the fact that the volatility was higher for a fairly extended period during the post-Asian crisis period lends some weight to the structural shift interpretation. In addition, financial markets have since become more complex and volatile with the introduction of new financial products into the local and global markets since 1998. Furthermore, post crisis exchange rate regimes have naturally shown greater exchange rate flexibility given that the currencies have been allowed to fluctuate more freely and over a wider interval. Hernandez and Montiel (2002), for example, examined the extent of exchange rate variability for the Asian crisis countries pre- and post-crisis and found evidence that there has indeed been an increase in volatility after the crisis.

[3] The Z-statistic for differences in mean between the two periods is 21.16 and is above the 5% significance level of 1.96. We therefore conclude that the difference is statistically significant and could not have arisen by chance.

[4] Extension of results to the latest sample period covering 2002 data, show that the volatility of the SGD NEER has declined in 2002. For instance, the calculated volatility over the period Jan 2002 to Feb 2003 has appeared to settle around an average mean which is about a fifth less than that recorded in 2001, due to a general decline in the volatility of movements in the major currencies in 2002.

4. EXAMINING THE LINK BETWEEN VOLATILITY OF EXCHANGE RATE AND MACROECONOMIC FUNDAMENTALS

13. In this section, we examine the relationship between exchange rate volatility and the volatility of key macroeconomic variables, by first exploring the simple volatility trade-offs observed among countries in the region. Next, we examine the effect of SGD NEER volatility on trade flows. We then adopt a flexible-price monetary model (as applied by Flood and Rose (1995)) in a more rigorous assessment of the impact of the increase in exchange rate volatility on real macroeconomic variables in Singapore.

4.1 VOLATILITY TRADE-OFFS

14. First, we use standard scatter plots to detect trade-offs between exchange rate volatility and macroeconomic volatility in eight regional countries, (Singapore, Hong Kong, South Korea, Taiwan, Malaysia, Indonesia, Thailand and Philippines). The volatility trade-offs are illustrated using scatter plots of the standard deviations (of the first difference of the natural logarithm) of the nominal effective exchange rate (NEER) against domestic output, interest rates and money[5]. We would expect a negative correlation (a trade-off) between the volatility of the NEER and key macroeconomic variables in a situation where a reduction of volatility in the foreign exchange market is associated with an increase in volatility in other variables elsewhere in the economic system.

15. The scatter plots are shown in Chart 3, which graph exchange rate volatility against volatility of domestic output, 3-month interbank rate, export volume, import volume and M1. In these graphs, observations are marked based on their country and sample periods.

[5] For each of the eight countries, we obtained the monthly JP Morgan Chase measure of their nominal effective rate indices from 1980Q1 through 2002Q2. After dividing our sample into five four-year samples corresponding to periods of low and high exchange rate volatility ({1} 1981Q1-1984Q4, {2} 1985Q1-1988Q4, {3} 1989Q1-1992Q4, {4} 1993Q1-1996Q4, {5} 1997Q1-2002Q1), we computed the sample standard deviation of the first differences of the natural logarithm of the effective exchange rate for each of the five periods and eight countries. Similar calculations were made for domestic output, interest rates and money. We are then left with a panel of 40 observations (eight countries by five sample periods) of volatility.

Charts 3 (a) – (e): Scatter Plots – Volatility Trade-offs between NEER and Key Macroeconomic Variables

Chart 3(a): NEER vs M1

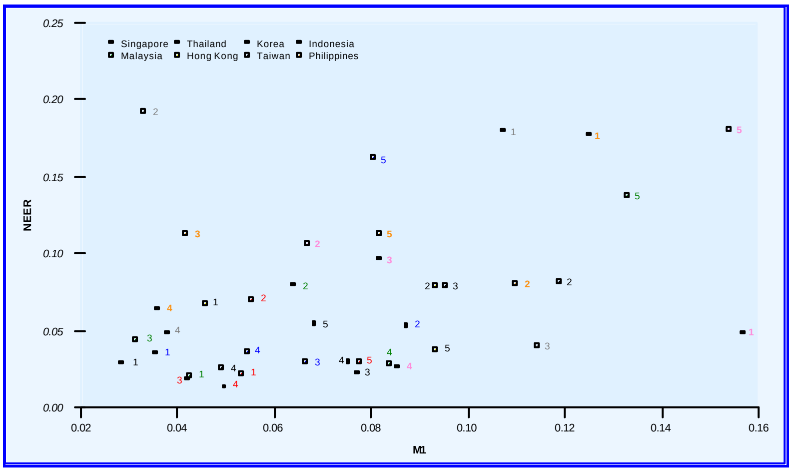


Chart 3(b): NEER vs 3-mth interest rate

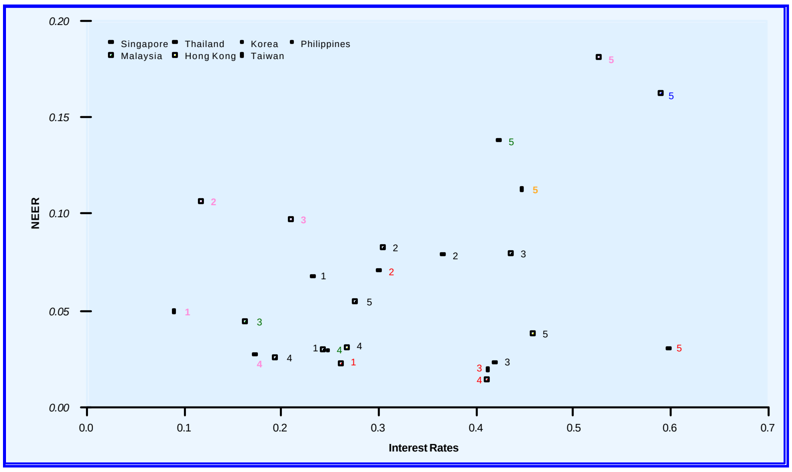
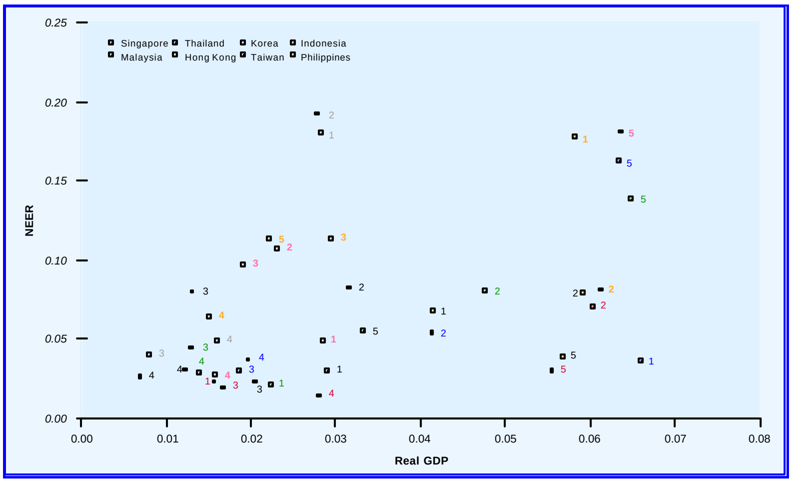


Chart 3(c): NEER vs Output



Sample periods:

(1) 1981Q1 – 1984Q4

(2) 1985Q1 – 1988Q4

(3) 1989Q1 – 1992Q4

(4) 1993Q1 – 1996Q4

(5) 1997Q1 – 2002Q1

Chart 3(d): NEER vs Import Volume

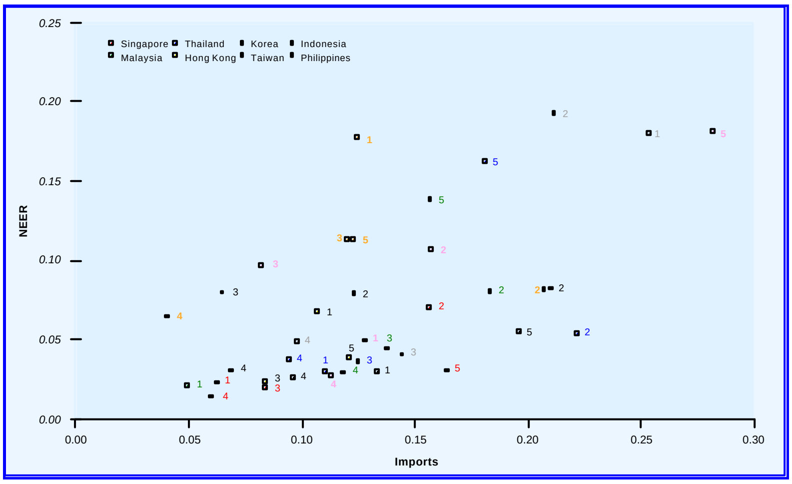
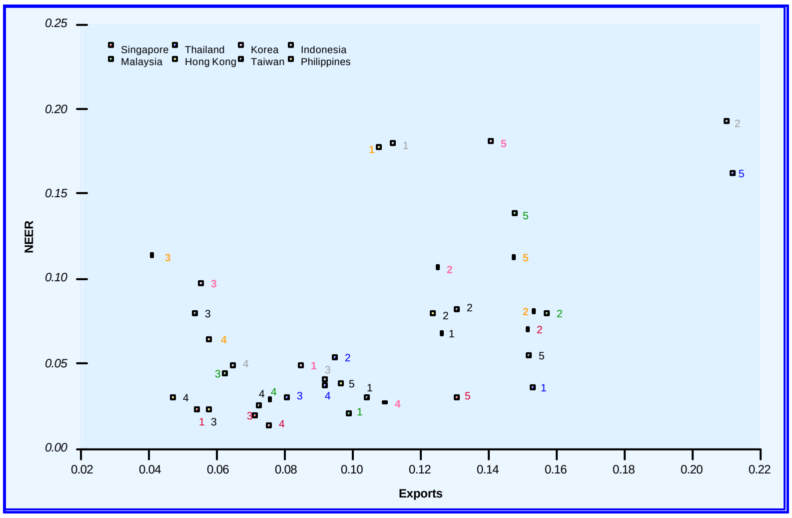


Chart 3(e): NEER vs Export Volume



16. The scatter plots are not indicative of any negative correlation between exchange rate volatility and the volatility of standard macroeconomic variables such as output, money supply, export and import volumes and interest rates. This also applies in Singapore's case (see red observation points). Nonetheless, some weak evidence of a trade-off between exchange rate volatility and interest rate volatility is apparent in the charts, reflecting an increase in interest rate volatility for any reduction in exchange rate volatility. [Chart 3(b)] However, if the outliers (sample period two and five) containing the 1985 recession and 1997 crisis periods are removed, even this weak relationship disappears.

17. In addition, there is some weak evidence of a positive relationship between Singapore's exchange rate volatility and M1, output, import and

export volatility. [Charts 3(c) – (e)] Again, this finding is weakened substantially if sample period (2) capturing the 1985 recession period is excluded. In sum, the evidence from these simple plots suggests correlation between exchange rate volatility and that of macroeconomic variables is weak[6].

4.2 EFFECTS OF SGD NEER VOLATILITY ON TRADE FLOWS

18. The next step in our analysis is to examine the relationship between volatility in the foreign exchange market and that in the real economy. Given the importance of the tradable goods sector in the economy, the most immediate focus would be on the impact on trade flows. In this section, therefore, we set up an empirical framework to assess volatility in the SGD NEER and trade flows. This will then set the stage for the more formalised framework to explore the relationship between exchange rate and macroeconomic volatility.

4.2.1 Gravity Model of Bilateral Trade

19. We make use of a single equation 'gravity' model as well as a multivariate error correction model. The standard gravity model of bilateral trade is used to assess the effects of exchange rate volatility on Singapore's international bilateral trade flows. The gravity model is a conventional empirical model used to estimate the effects of various factors on bilateral international trade. Past studies suggest that the estimated effects of distance and output (the traditional gravity effects) are economically and statistically significant and reasonably consistent across studies.

20. Similarly, in our estimation equation, bilateral trade was expressed as a function of the distance between the countries and their joint income. In addition, to assess the exchange rate volatility effect, the basic gravity equation is then augmented with the volatility of the bilateral nominal exchange rate between Singapore and other countries. A number of extra conditioning variables, such as joint income per capita, were also included.

[6] The lack of a negative correlation in the scatter plots has also been supported by various tests, which generally confirm the lack of a statistically significant correlation between the variables.

21. The specification of the single equation Singapore gravity model used is:

$$\ln(X_{Spore,j}) = \beta_0 + \beta_1 \ln D_{Spore,j} + \beta_2 \ln(Y_{Spore} Y_j)_t + \beta_3 \ln(Y_{Spore} Y_j / Pop_{Spore} Pop_j)_t + \delta V(e_{Spore,i}) + \varepsilon_{Spore,t}$$

where j denotes countries, t denotes time and the variables are defined as

$X_{Spore,j}$	Value of bilateral trade between Singapore and country j
Y	Real GDP
Pop	Population
$D_{spore,j}$	The distance between Singapore and country j
$V(e_{Spore,i})$	The volatility of the bilateral (between Singapore and country j) nominal exchange rate in the period before t (Standard deviation of the first difference of the monthly natural logarithm of the IFS bilateral nominal exchange rate in the five years preceding period t)

22. The parameter of interest is δ. It measures the response of bilateral trade to bilateral exchange rate volatility. The parameters β_1, β_2 and β_3 are bilateral trade responses to distance, output and output per capita.

23. The gravity model was estimated using ordinary least squares and standard errors were computed which are robust to clustering by country-pairs. Table 1 shows the results of the pooled OLS estimates of the Singapore gravity equation (with year controls) [7].

Table 1: Results of Pooled Estimates

Dependent Variable: log (Value of bilateral trade between Singapore and country j) [ln($X_{Spore,j}$)]				
Independent Variable	**Coeff.**	**Std.Err.**	**t-stat.**	**p-value**
Distance, β_1	-2.100	0.14	-14.77	0.0000
Output, β_2	0.700	0.05	14.58	0.0000
Output per capita, β_3	0.420	0.08	5.16	0.0000
Exchange Rate Volatility, δ	-0.055	0.02	-2.90	0.0040
Specification/Fit of Model				
Number of observations	458			
R-squared	0.6210			
Std. Error of Equation	1.7553			
Sample period	Panel data spanning five different years (1970, 1975, 1980, 1985 and 1990)			

[7] In addition, Prof. Andrew Rose also estimated the 'gravity' model using updated data until 2000 over 186 countries and found no significant difference in results.

24. The results provide economically reasonable and statistically significant coefficients. For instance, both higher GDP and higher GDP per capita (for the country pairing) increase trade while greater distance between two countries lowers trade. These traditional gravity effects are not only large but economically sensible in size, highly statistically significant, and generally in line with estimates from the literature.

25. The estimate of the coefficient on exchange rate volatility, δ, is –0.055%. This suggests that a 1% increase in the Singapore dollar exchange rate volatility will decrease bilateral trade flows between Singapore and trading partners by 0.055%, holding all else constant. Hence, the impact of exchange rate volatility on Singapore's bilateral trade with the other 117 countries in the sample is quite small, although still statistically significant. This is in line with the results of an earlier study by Rose (2000), which found an even smaller exchange rate impact on bilateral trade of –0.017%, using a larger dataset comprising 186 countries' international trade data[8].

4.2.2 Multivariate Error Correction Model

26. Next, we used a multivariate error correction model to investigate the effect of exchange rate volatility on real export volume (instead of bilateral trade flows), using quarterly data from Q2 1982 to Q1 2002. The error correction model has several advantages. First it allows for a lagged relationship that may exist between volume of exports and its various determinants that may not be captured by standard trade models. Second, it captures the long run relationship between exports and explanatory variables and considers the short-run dynamics by which exports converge to the equilibrium long-run values.

[8] The data set for Singapore is extracted from a larger data set of 186 countries with 33,903 bilateral trade observations spanning five different years (1970, 1975, 1980, 1985 and 1990) used in Rose (2000). The trade data are taken from the World Trade Database, the population and real GDP per capita data are from Penn World Table 5.6 and World Development Indicator (1998 WDI).

27. The simple standard specification used to estimate the long-run relationship between real exports, the level of real activity, competitiveness and exchange rate volatility is given as [Gotur (1985), Aseery and Peel (1991)]:

$$\ln X_t = \delta_0 + \delta_1 \ln Y_t + \delta_2 \ln P_t + \delta_3 V_t$$

- X Singapore's real export volume index
- Y Composite foreign GDP of Singapore's ten most important trading partners - measure of real foreign activity
- P Ratio of Spore's dollar denominated export unit value to the aggregate export unit value for its ten major trading partners - to measure price competitiveness
- V GARCH conditional standard deviation*100 – exchange rate volatility

28. The short-run dynamics are estimated by specifying the changes in ln X as a function of lagged residuals from the cointegrating regression and changes in ln Y, ln P and V.

29. Table 2 shows that the coefficient of the first differences of V [ΔIn(V(-1))], which provides an approximation of the estimated short run impact response of Singapore's real export volume to a change in the exchange rate volatility in the previous quarter is negative, small though not statistically significant[9]. Nonetheless, the short-run dynamics suggest that a 1% rise in volatility will decrease Singapore's real export volume by about 0.012% in response to the previous quarter's change in exchange rate volatility, holding all else constant. This result lends support to that of the gravity model, in which the short-run impact response of real exports to exchange rate volatility is relatively small.

[9] We had also estimated with various lag structures and found similar results.

Table 2: Estimation and Test Results of the VECM equation for Changes in log (Real export volume index) [Dln X]

Dependent Variable: Changes in log (Real export volume index) [Dln X_t]			
Independent Variable	**Coeff.**	**Std.Err.**	**t-stat.**
Error correction term	-0.0975	0.0296	3.2917
Δ(ln X(-1))	-0.1772	0.1529	1.1586
Δ(ln Y(-1))	-1.6027	0.8966	1.7876
Δ(ln(P(-1))	-0.0720	0.6767	0.1065
Δ(ln V(-1))	-0.0117	0.0180	0.6444
Specification/Fit of Model			
Sample period	Q1 1980 and Q2 2002		
Number of observations	84		
R-squared	0.2700		
Std Error of Equation	0.0351		

30. Our main findings show that the economic impact of exchange rate volatility on Singapore's trade flows is fairly small. It appears that exporters, importers, and investors' ability to predict exchange rate movements and their use of recent financial innovations have allowed them to efficiently manage the volatility in international currency markets.

4.3 USING THE FLEXIBLE-PRICE MONETARY MODEL OF THE FOREIGN EXCHANGE MARKET

31. We now attempt a more formal modelling of the link between the volatility of macroeconomic variables and the exchange rate across different regimes, i.e. between periods of high and low exchange rate volatility, and appreciation/depreciation regimes. To do this, we adopt a similar methodology to that used by Flood and Rose (1995, 1999). Unlike these studies where the link between exchange rate and macroeconomic fundamentals was examined for the period before and after the Bretton Woods regime, the regime changes in Singapore after 1980 are not as clear-cut. Nevertheless, using a GARCH (1,1) model and the two-stage Markov-Switching model, we are able to identify different periods of exchange rate volatility and appreciation/depreciation regimes. Thus, we examine the change in volatility in exchange rates and macroeconomic variables over these periods.[10]

[10] The Markov-Switching model was also used to help identify regime changes. We find that over the last two decades, the SGD NEER has been in an appreciating regime for most of the sample period, except for three relatively brief periods when it was in a depreciating regime. In particular, we note that depreciation cycles relative to trend in Singapore occurred during the 1985 recession, the 1998 crisis and the 2001 downturn, which also coincide with the periods of higher SGD NEER volatility, identified earlier using the GARCH (1,1) model.

32. We construct two measures, namely virtual and traditional fundamentals, to assess changes in exchange rate and macroeconomic volatility. The virtual fundamental (VF) measures the unexplained movements in the nominal exchange rate after allowing for exchange rate expectations resulting from the domestic and foreign interest rate differential (assuming UIP holds). In contrast, the traditional fundamental (TF) provides us with a composite measure of macroeconomic fundamentals, within the framework of a flexible-price monetary model. Therefore, VF volatility proxies for exchange rate uncertainty, while TF volatility measures fluctuations in real macroeconomic variables[11].

4.3.1 Flood and Rose (1995) Methodology

33. Following Flood and Rose (1995,1999), we use a standard flexible-price monetary model of the foreign exchange market. This consists of asset market equilibrium and purchasing power parity (PPP) conditions, expressed in logarithms:

$$m_t - p_t = \beta y_t - \alpha i_t + \varepsilon_t \quad (1)$$

$$p_t = e_t + p^*_t + ?_t \quad (2)$$

where: m_t denotes the natural logarithm of the stock of money at time t, p denotes the price level, y denotes real output, e is the domestic price of foreign exchange, i denotes nominal interest rate (in levels), an asterisk represents a foreign variable, ε_t and $?_t$ are white noise error terms, and α and β are structural parameters.

34. Assuming there is an identical foreign analogue to (1) and subtracting it from (1) and substituting into (2) leads to:

$$e_t = (m-m^*)_t - \beta(y-y^*)_t + \alpha(i-i^*)_t - (\varepsilon - \varepsilon^*)_t - ?_t \quad (3)$$

[11] We can also add the assumption of uncovered interest parity (UIP) – $(i-i^*)_t = E_t(de_t)/dt$, where $E_t(de_t)/dt$ is the expected rate of change of the exchange rate. Virtual fundamentals are then expressed as a measure of f_t, the unexplained component of the exchange rate movement after taking into consideration UIP movements, VF as: $e_t - \alpha(i-i^*) = e_t - \alpha E_t(de_t)/dt = f_t$.

which expresses the exchange rate as a function of macroeconomic fundamentals, namely differentials of money, output, interest rates and shocks.

35. This equation implies a volatility trade-off. If the exchange rate is fixed, then (ε or ?) shocks make the money, output or interest rates variables more volatile. If the exchange rate is floating freely, then the same shocks create exchange rate volatility. In Singapore, the shocks would be similar to the flexible exchange rate case, since the exchange rate is allowed to fluctuate within a specified band in a managed float system. This also means that based on the model, exchange rate volatility in the left-hand side of equation (3) should mirror fundamental macroeconomic volatility of the right hand side. Following that, we calculate a measure of "fundamentals" in the flexible-price model called the virtual and traditional fundamentals, which represent different terms in the right-hand side of equation (3).

36. The virtual fundamental (VF) which is tightly related to the exchange rate, is measured by

$$VF_t = e_t - \alpha(i-i^*)_t \quad (4)$$

The construction of virtual fundamentals would require a value for α of the interest semi-elasticity of money demand.

37. Similarly, the traditional fundamental (TF) can be defined as

$$TF_t = (m-m^*)_t - \beta(y-y^*)_t \quad (5)$$

A β value corresponding to the income elasticity of money demand is required to measure traditional fundamentals.

38. In similar fashion to Flood and Rose (1995), instead of directly estimating α and β to calculate the virtual and traditional fundamentals, we use the average interest and income elasticity from past studies of 0.5 and 1.0 respectively. In our estimation of the VF and TF series in Equations (4) and (5), we have used the SGD NEER (instead of a bilateral exchange rate) and weighted indices of the foreign variables.

4.4 EMPIRICAL RESULTS

39. Having computed the VF and TF series for Singapore since 1980, we now examine their volatilities between periods of high and low exchange rate volatility, which were estimated earlier using the GARCH and M-S models. This allows us to assess if VF and TF volatility have changed significantly over time. If they have changed over similar periods, it is suggestive that changes in Singapore's exchange rate volatility are accompanied by changes in the volatility of macroeconomic variables.

40. First, we calculate the quarter-on-quarter changes in VF and TF. Second, sample standard deviations (which is a proxy of volatility) of these quarterly changes are computed for sample periods coinciding with high and low exchange rate volatility estimated using the GARCH and M-S models. Third, for each of the VF and TF, we calculated volatility ratios by dividing the current sample period standard deviation by the previous period's standard deviation. For example, in Table 3 the virtual fundamental volatility ratio comparing the two periods in the 1980s was computed by dividing the standard deviation in sample period Q3 1985 to Q2 1988, by the standard deviation in sample period Q2 1980 to Q2 1985. The ratios of the sample standard deviations of the VF and TF were calculated under the assumption that the changes in the TF and VF are normally distributed.[12] As such, we can then apply the F-test on the volatility ratios to examine if there is a significant change in the volatility (variance) between the two sample periods in question to test the null hypothesis of no change or equal volatility.

41. Table 3 shows the ratio of the sample standard deviation (of the quarter-on-quarter changes of VF and TF) in a particular period to the standard deviation in the previous period. Highlighted statistics denote combinations where the alternate hypothesis of a substantial change in volatility between subsequent periods cannot be rejected at various significance levels. In general, the null hypothesis of no change in volatility is rejected more frequently for the VF series compared with the TF series.

[12] Under this assumption, the ratio of the regime specific sample variances, e.g. ($\Delta TF_{high}/\Delta TF_{low}$), suitably scaled by a factor to correct for degrees of freedom, is distributed as F under the null hypothesis of equal variances across regimes.

Table 3: Volatility Ratios of the Quarterly Changes in VF and TF between different sample periods

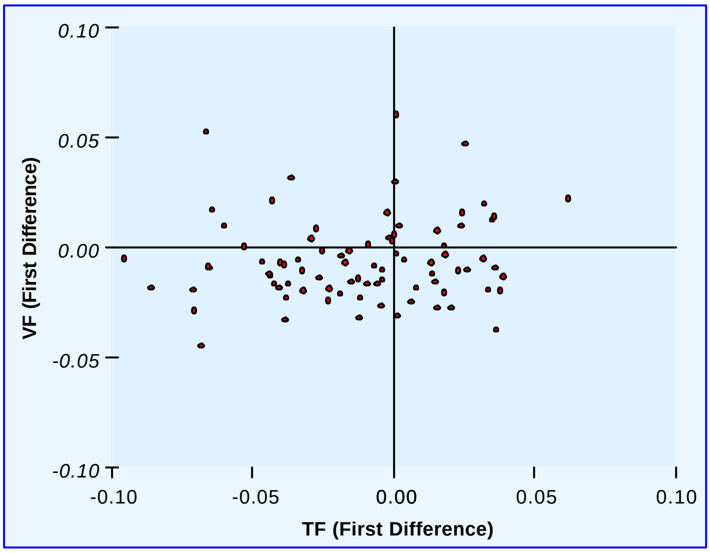
Test Period (Volatility Ratio = Standard deviation in period 1/ Standard deviation in period 2)	**VF Volatility Ratio**	**TF Volatility Ratio**
Sample periods determined using GARCH model		
(85Q3-88Q2/80Q2-85Q2)	2.17**	0.96
(88Q3-97Q4/85Q3-88Q2)	0.53**	0.63*
(98Q1-99Q2/88Q3-97Q4)	2.26**	1.63
(99Q3-01Q2/98Q1-99Q2)	0.29**	0.56
(01Q3-02Q2/99Q3-01Q2)	2.17*	2.72*
Sample periods determined using M-S Model		
(85Q2-88Q2/80Q2-85Q1)	2.55**	0.99
(88Q3-98Q1/85Q2-88Q2)	0.55**	0.62*
(98Q2-99Q3/88Q3-98Q1)	2.25**	1.52
(99Q4-01Q3/98Q2-99Q3)	0.34**	0.59

* One asterisk indicates that the null hypothesis of equal volatility is rejected at 5% significance level.

**Two asterisks indicate that the null hypothesis of equal volatility is rejected at 1% significance level.

42. Table 3 shows that in general the volatility of virtual fundamentals has seen significant changes during the 1980 - 2002 period. Our point of interest is whether the TF series mimics the increase in volatility experienced by the VF series. A preliminary scatter plot between the first-differences of VF and TF, provided in Chart 4 does not provide any visual evidence of a clear relationship.

Chart 4: Scatter Plot – Correlation between VF and TF first differences



43. Similarly, our results in Table 3 confirm that the TF series does not exhibit the significant changes in volatility experienced by the VF series. The results from applying sample periods identified by both the GARCH and M-S models, show that apart from a decrease in volatility after the 1985 recession, there is no conclusive evidence of substantial changes in the volatility of the TF series over the other sample periods. In particular, we note that despite significant movements in exchange rate volatility, particularly during the Asian Crisis, there is no strong evidence of a statistically significant increase in the volatility of traditional fundamentals when comparing the 88Q3-97Q4 vs 98Q1-99Q2 crisis period. Similarly, comparing 98Q1-99Q2 with the post-crisis period of 99Q3-01Q2, the data does not show a statistically significant fall in volatility of TF, even as the volatility of VF moderated.

44. In summary, our results imply that changes in Singapore's exchange rate volatility are not necessarily accompanied by changes in the volatility of macroeconomic variables.

5. SUM UP

45. Past studies have shown that exchange rate volatility can be high and yet not matter for real economic variables. In this respect, we are influenced by the seminal findings of Baxter and Stockman (1990) and Flood and Rose (1995). They show that high exchange rate volatility in floating exchange rate regimes is not obviously tied to or reflected empirically in high volatility of other macroeconomic variables.

46. Our study has found little evidence of any strong correlation between exchange rate volatility and the volatility displayed by a number of key macroeconomic variables. In the spirit of Flood and Rose (1995), we have established that traditional fundamentals remained quite stable in spite of increases in exchange rate volatility. While we have found some impact of exchange rate volatility on bilateral trade flows in Singapore, this appears to be relatively small.

47. A somewhat different interpretation of the empirical findings from these studies emerges from a consideration of the following extract from Frankel and Mussa (1980),

> "... while as a technical matter, government policy can reduce exchange rate fluctuations, even to the extent of pegging an exchange rate, it may not be assumed that such policies will automatically eliminate the disturbances that are presently reflected in the turbulence of exchange rates. Such policies may only transfer the effect of disturbances from the foreign exchange market to somewhere else in the economic system. There is no presumption that transferring disturbances will reduce their overall impact and lower their social cost. Indeed, since the foreign exchange market is a market in which risk can easily be bought and sold, it may be sensible to concentrate dsturbances in this market, rather than transfer them to other markets, such as labor markets, where they cannot be dealt with in as efficient a manner."

48. Thus, it may be that the development of deep and efficient financial markets, which allows for a freely flexible exchange rate, could be an important component of the infrastructure of a country in minimising fluctuations of underlying domestic economic activity. In Singapore's context, the econometric evidence in this paper is also not inconsistent with the

hypothesis that the flexibility accorded by the presence of bands in the managed exchange rate float system, may have helped to prevent a spillover of volatility into the real economy. In particular, the bands provide the flexibility for the exchange rate system to accommodate short-term fluctuations in the foreign exchange markets. In periods of heightened volatility, there may also be occasion to widen the band as was done in October 2001, for example after the terrorist attacks in the US. Subsequently, the bands were narrowed again when market and economic conditions stabilised. Such flexibility accorded by the system has allowed us to accommodate changes in the equilibrium value of the Singapore dollar and thus prevent the currency from being misaligned. At the same time, we have avoided the rigidity of a fixed exchange rate system, which may imply greater adjustments, and hence volatility in the real economy in response to shocks in international markets.

REFERENCES

Akhtar, M. A., and R Spence Hilton, May 1984, "Exchange Rate Uncertainty and International Trade: Some Conceptual Issues and New estimates for Germany and the United States", Research Paper No. 8403, Federal Reserve Bank of New York.

Asseery, A., and David A. Peel, 1991, "The Effects of Exchange Rate Volatility on Exports", Economics Letters, Vol. 37, pp. 173-177.

Baxter, Marianne and Alan Stockman, 1989, "Business Cycles and the exchange rate system", Journal of Monetary Economics, Vol. 23, pp. 377-400.

Belanger, Denis and Sylvia Gutierrez, 1990, "Impact of the variability in the exchange rate on international trade: A critical survey of the literature", L'Actualite Economique, 66 (Mar): pp. 65-83.

Chowdury, Abdur R, 1993, "Does Exchange Rate Volatility Depress Trade Flows? - Evidence from Error Correction Models", The Review of Economics and Statistics, Vol. 74 (4), pp. 700-706.

Devereux, Michael B., and Charles Engel, 2002, "Exchange Rate Pass-Through, Exchange Rate Volatility, and Exchange Rate Disconnect", NBER Working paper 8858, pp. 1- 41.

Flood, Robert and Andrew K. Rose, 1995, "Fixed exchange rates: a virtual quest for fundamentals", Journal of Monetary Economics, Vol. 36, pp. 3-37.

Flood, Robert and Andrew K. Rose, 1999, "Understanding Exchange Rate Volatility without the Contrivance of Macroeconomics", Economic Journal, Vol. 109 (459), pp. 660-672.

Frenkel, Jacob A., and Michael L. Mussa, 1980, "The Efficiency of Foreign Exchange Markets and Measures of Turbulence", American Economic Association Papers and Proceedings, Vol.70-2, pp. 374-381.

Friedman, J. H., 1984, SMART User's Guide, Laboratory for Computational Statistics, Stanford University Technical Report No. 1.

Friedman, J. H., 1984, "A variable span scatter-plot smoother", Laboratory for Computational Statistics, Stanford University Technical Report No. 5.

Gotur, Padma, 1985, "Effects of Exchange Rate Volatility on trade: Some Further Evidence", IMF Staff Papers, Vol. 32, pp. 475-512.

Hernandez, Leonardo and Peter Montiel, 2001, "Post-Crisis Exchange Rate Policy in Five Asian Countries: Filling in the "Hollow-Middle"?", William's College Center for Development Economics Working Paper, pp. 1-34.

International Monetary Fund, 1984, "Exchange Rate Variability and World Trade", IMF Occasional Paper No. 28.

Maskus, Keith E., 1986, "Exchange Rate Risk and U.S. Trade: A Sectoral Analysis", in Financial Market Volatility and the Economy (1990), Federal Reserve Bank of Kansas City.

McKinnon. R., and Kenichi Ohno, 1997, Dollar and Yen, MIT Press.

Obstfeld, Maurice and Kenneth Rogoff, 2000, "The six major puzzles in international macroeconomics: Is there a common cause?", NBER Macroeconomics Annual 2000, pp. 330-390.

Rose, Andrew, 2000, "One Money, One Market: Estimating the Effect of Common Currencies on Trade", Economic Policy, Vol. 15(30), pp. 7- 46.

Sriram, Subramaniam S., 2001, "A Survey of Recent Empirical Money Demand Studies", IMF Staff Papers, Vol. 47(3), pp. 334-365.