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# Managing in the Middle: Characterizing Singapore's Exchange Rate Policy*

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It is by now common knowledge that there can be a significant divergence in the de facto versus *de jure* exchange rate regimes operated by economies. Although much of the recent published literature in Asia has focused on the crisis-hit economies, Korea and Thailand in particular, scant attention has been paid to Singapore, which officially targets its nominal effective exchange rate (around a band). The present paper examines the degree of exchange rate intervention for Singapore using various methods of assessing de facto exchange rate regimes. In the main, we show that although the Singapore dollar is primarily influenced by the US dollar, in keeping with its *de jure* classification of a basket pegged regime, other major currencies, such as the yen and the euro, also impact the Singapore dollar. There is also evidence to indicate that Singapore uses the nominal effective exchange rate strategically as a policy instrument to satisfy domestic inflation objectives.

*Keywords*: band-basket-crawl arrangement, managed float, monetary policy rules, reserves, Singapore.

*JEL classification codes*: F31, F33.

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## I. Introduction

It is by now common knowledge that there can be a significant divergence in the de facto versus *de jure* exchange rate regimes operated by economies. This has led to the rapid growth of two strands of literature. One strand attempts to characterize de facto exchange rate regimes. However, there remains much debate about the most appropriate set of regime categories to use.[1] The second strand of the literature focuses more narrowly on the degree of de facto exchange

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[1] For instance, Bubula and Otker-Robe (2002, 2003), Calvo and Reinhart (2002), Levy-Yeyati and Sturzenegger (2002), Reinhart and Rogoff (2004) and Shambough (2004). Willett et al. (2005) offer a comprehensive overview and nuanced discussion of the literature on exchange rate classification.

rate flexibility of the exchange rate. The basic set of questions this literature, which has largely focused on Asia, has attempted to answer is whether exchange rates in Asia have become more flexible post-Asian crisis, and if they do appear to be managed, what are they being managed against (i.e. the US dollar (USD), yen, euro or basket of currencies). This second strand of the literature has thus far concentrated on the inflation targeters in Asia; namely, Korea, the Philippines, Thailand and Indonesia, where there remain nagging suspicions about whether Asian currencies have reverted to soft dollar pegging (see Cavoli and Rajan (2005) and references cited within).

The present paper extends the second strand of the literature to consider the case of Singapore. Officially, the Monetary Authority of Singapore (MAS) has been targeting its nominal effective exchange rate (NEER) (around a band) since 1981. We are interested in exploring a number of questions pertaining to the Singapore dollar (SGD), including: (i) is Singapore a true basket pegger, and if so, against which currencies; (ii) has there been a change in the degree of flexibility over time; and (iii) can Singapore's exchange rate policy be characterized as mechanical (i.e. the exchange rate is maintained within a predetermined parity), or strategically focused on other objectives (i.e. inflation and growth)? The manner in which Singapore operates its exchange rate regime is of pertinence at a time when other countries in the region, including China and Malaysia, are gradually introducing greater exchange rate flexibility by adopting currency basket regimes (see Hilsenrath and Kissel, 2005).

A wide array of methods has been used in the published literature to compute de facto exchange rate regimes. No single method captures all the applicable characteristics of any actual regime and sometimes different methods lead to conflicting conclusions. In view of this, it is essential that studies of this type use a range of measures such that as many of the salient characteristics of each regime are captured, as well as to ensure the robustness of the results. The remainder of the present paper examines several methods that are commonly used to measure the degree of de facto exchange rate flexibility for Singapore.

The remainder of the paper is organized as follows. Section II examines the degree of influence that a vector of major currencies has on the home currency. We do this by using Frankel and Wei (1994) regressions for SGD.[2] This method essentially involves conducting an OLS test of the local currency on other currencies that are considered to influence the former. We augment the basic Frankel–Wei method using time-varying parameter estimation techniques. Section III investigates the degree of exchange rate flexibility with particular emphasis on the nexus between exchange rates and foreign reserves. We construct various exchange rate flexibility indices as well as examine generalized autoregressive conditional heteroscedasticity (GARCH) techniques, such as those found in Dominguez (1998) and Guimãeres and Karagdag (2004).

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[2] Such regressions have recently been used in several subsequent studies, such as McKinnon (2001) and Cavoli and Rajan (2005).

Section IV estimates a simple monetary policy rule (MPR) for Singapore where the nominal exchange rate is the instrument of policy that reacts to information about inflation and growth. Section V concludes with a summary and discussion of some policy implications.

Unless otherwise stated, the empirical analysis in the paper is based on monthly observations for the period January 1985 to December 2004.[3] Data is from the *IMF International Financial Statistics*. Exchange rates are taken from line *RF* (*RH* for the pound sterling) and the cross rates for the local currency against the yen, pound, euro and Swiss franc are calculated from the quoted bilateral exchange rates. Foreign reserves for Singapore are calculated as net foreign assets (line 11–16c) scaled by lagged money base (line 14).

## II. Regression Based Approach to Exchange Rate Movements

This section examines the degree of influence between the target currencies (SGD) and a vector of major currencies that includes the USD, the yen, the UK pound and the euro by applying the well–known Frankel–Wei regressions (see Frankel and Wei, 1994). The term 'degree of influence' is used for these tests as an alternative interpretation to the coefficients being seen as 'weights' in the currency basket. The basket weights story can only be valid under this method if the right-hand side variables are uncorrelated. Unfortunately, this cannot be assured using the Frankel–Wei methodology.[4]

We estimate Equation (1) below:

$$\Delta e_t = \alpha_0 + \alpha_1 \Delta US_t + \alpha_2 \Delta JP_t + \alpha_3 \Delta UK_t + \alpha_4 \Delta EU_t + \mu_t, \tag{1}$$

where $e$ refers to the SGD. All currencies are expressed in logs and the numeraire currency used is the Swiss franc.[5]

The higher the values of $\alpha$ corresponding to each major currency the larger is the degree of influence of that currency on the local currency. As such, a high degree of influence provides some information about the possible degree of fixity of the local currency (SGD) to the major currency. However, a large coefficient value does not automatically imply a pegged exchange rate; it might merely reflect naturally occurring market-driven correlations between two

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[3] Two qualifications should be noted. First, data using euros are for the period January 1999 to December 2004. Second, for comparison we include an Appendix computing the Frankel–Wei regression in Section II using daily data.

[4] This point is often missed by many others who use this methodology. Also see footnote 5.

[5] In constructing the Frankel–Wei equation, we acknowledge that changes in the cross rates might influence the currency pair we wish to examine. By estimating the equation in first differences and adding a constant we are assuming that the effect of the cross rates are fixed over the estimation period. We thank an anonymous referee of this journal for pointing this out. The model is estimated in first differences as cointegration testing reveal insufficient evidence on any cointegrating relationships among the variables in Equation (1). Results of the cointegration tests are available from the authors on request.

**Table 1 Frankel–Wei OLS estimates**

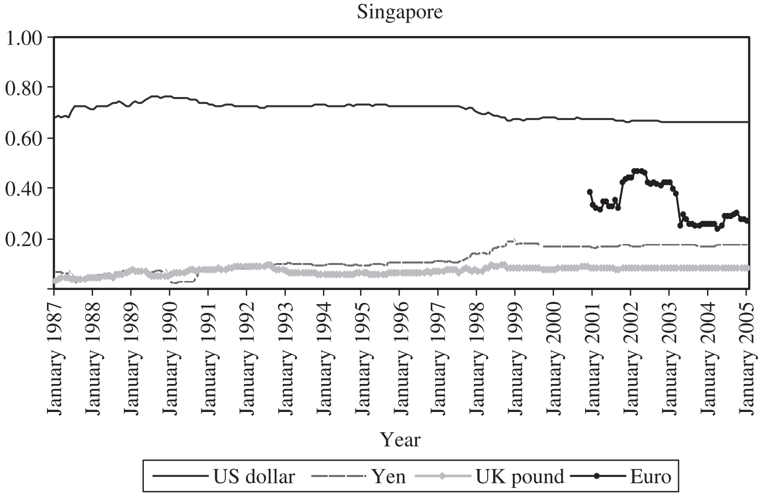
| *Dependant variable* | *Singapore dollar* | *Singapore dollar* | *Singapore dollar* |
|---|---|---|---|
| Constant | –0.00 | 0.00 | 0.00 |
| | (–0.17) | (0.24) | (0.25) |
| US dollar | 0.66 | 0.62 | 0.61 |
| | (24.65)*** | (12.84)*** | (12.51)*** |
| Yen | 0.18 | 0.20 | 0.19 |
| | (5.46)*** | (4.16)*** | (4.17)*** |
| UK pound | 0.08 | — | 0.02 |
| | (2.63)** | | (0.31) |
| Euro | — | 0.28 | 0.27 |
| | | (2.55)** | (2.42)** |
| Adjusted $R^2$ | 0.83 | 0.86 | 0.85 |
| Durbin Watson | 1.45 | 1.94 | 1.94 |
| Wald test[a] | 5.44 | 0.63 | 0.65 |
| | (0.02) | (0.43) | (0.42) |
| Observation | 241 | 72 | 72 |

Notes: Figures in brackets are *t*-statistics. All currencies are expressed per Swiss franc and are in log differences. ** and *** represent significance at the 10% and 5% level, respectively. [a]Wald test (*F*-test) for coefficient restriction where null hypothesis is that all currencies on the right-hand side = 1.

currencies. In this context, the standard deviation of the coefficient value might provide additional useful information in the sense that a small standard deviation is more likely to imply an attempt to systematically maintain the correlation between two currencies by way of intervention (Baig, 2001).

We use a time series of monthly observations from January 1985 to December 2004 for most of the regressions except in the case of the euro where the sample is January 1999 to December 2004. This sub-period allows us to examine the particular significance of the euro as a major currency since it actually came into existence. The standard time-invariant OLS estimates are summarized in Table 1. As is apparent, the coefficient values for the USD, yen and pound are all significant for the full sample. Interestingly, when the sub-sample that includes the euro is re-estimated (columns 2 and 3), the coefficient for the pound becomes less significant; the euro appears to have replaced the pound in influencing the SGD. In the sub-sample including the euro, the US dollar and the yen are still both significant; the euro does not have as significant an impact on the overall regression results in this case. The importance of the yen on the SGD is understandable in view of the strong economic linkages between the two countries, particularly with regard to trade and investment. Table 1 also formally tests the null hypothesis of whether all the currencies on the right-hand side of Equation (1) (the $\alpha$ coefficients) sum to 1. This is done using the Wald test. The results indicate that the null is rejected for column 1 but not

**Figure 1 Recursive OLS estimates of Frankel–Wei regression**



rejected for columns 2 and 3. The latter results suggest that there is evidence that the currencies tested might form the currencies in the basket.[6]

We expand the Frankel–Wei analysis by re-estimating Equation (1) using recursive OLS estimates. Recursive OLS simply involves the equation being estimated repeatedly using subsets of the sample data that are increased by one observation at each iteration.[7] Such recursive estimates allow us to track the evolution of the $\alpha$ coefficients over time. This allows us to ascertain whether one of the major currencies is becoming more influential compared to another. As with the standard errors in the time-invariant regressions, the *variation* of the degree of influence is important in extracting information about the possibility of exchange rate movements being policy driven. For example, the coefficient value for a particular currency on the local currency is high but relatively stable. This is possibly suggestive of sustained intervention by the central bank to manage the value of that particular currency pair. If the estimated value is high but variable, the correlation might possibly be market driven rather than conscious central bank intervention.

Results of the recursive regressions are presented in Figure 1. The figure contains the dynamic properties of the coefficients for the USD, the yen, the pound and the euro. The influence of the euro occurs in the latter part of the

[6] As prompted by a referee of this journal, we have run the Frankel–Wei tests using daily data. Although the point estimates were not the same as for monthly data, the estimates were not substantially different. We then ran recursive least squares estimates and found that the dynamic patterns of each currency are very similar to the monthly estimates. These results are available in Appendix 1.

[7] We estimated the initial regression using the same number of observations as there are coefficients to be estimated in the $\alpha$ vector (therefore, the first 18 months of values are volatile and ignored given the low degrees of freedom). We obtained largely similar results using a Kalman Filter test. Results are broadly unchanged and, therefore, are not reported here.

sample. The USD emerges as the single most significant currency influencing the SGD. The degree of influence of the USD has remained stable at approximately 0.6–0.7. The stability of the USD's influence on the SGD over such a long period of time seems suggestive of actual central bank intervention (rather than the market moving the two currencies together). The degree of influence of the yen and the pound is also quite stable, an indication that the SGD is managed against those currencies as well. This offers support to the notion that Singapore does indeed operate a basket peg arrangement (more on this later). Also noticeable is the influence of the euro as part of the basket. An interesting feature of the SGD's estimate is the slight reduction in the influence of the USD in 1998. This corresponds to an offsetting increase in the influence of the yen. This might suggest an adjustment of weights in Singapore's currency basket post-crisis. This could also be consistent with the hypothesis that post-crisis some of Singapore's trading partners, such as Korea, moved away from strong USD pegging and have been influenced relatively more by the yen (e.g. see Cavoli and Rajan, 2005; Oh, 2004; Taguchi, 2004), thus implying a consequent shift in Singapore's basket weights.

## III. Measuring the Extent of Exchange Rate Flexibility

### *III.1 Exchange market pressure based indices*

The second measure of exchange rate behavior adopted in this paper is the exchange rate flexibility index. There are several different types of indices based on the idea of exchange market pressure (EMP) (e.g. see the seminal contribution from Girton and Roper (1977) and a recent one in Guimãeres and Karacadag (2004)). The theoretical foundation for EMP stems from a basic monetary model incorporating the demand for money, its supply and relative purchasing power parity (PPP) (Tanner, 2001; Pentecost et al., 2001). Consider the usual stylized depiction of the asset side of the central bank balance sheet. Expressed as log differences, the stock of money is given as follows:[8]

$$\Delta m = \Delta d + \Delta f, \tag{2}$$

where $\Delta m = \Delta M/M$, $\Delta d = \Delta D/M$ and $\Delta f = \Delta F/M$ and $M$, $D$ *and* $F$ are, respectively, the stocks of overall base money, domestic and foreign assets.[9] The demand for money can be given by the conventional expression:

$$\Delta m - \Delta p = -\alpha\Delta i + \beta\Delta y. \tag{3}$$

The (log difference of the) exchange rate is determined by the relative PPP condition:

$$\Delta e = \Delta p - \Delta p^*, \tag{4}$$

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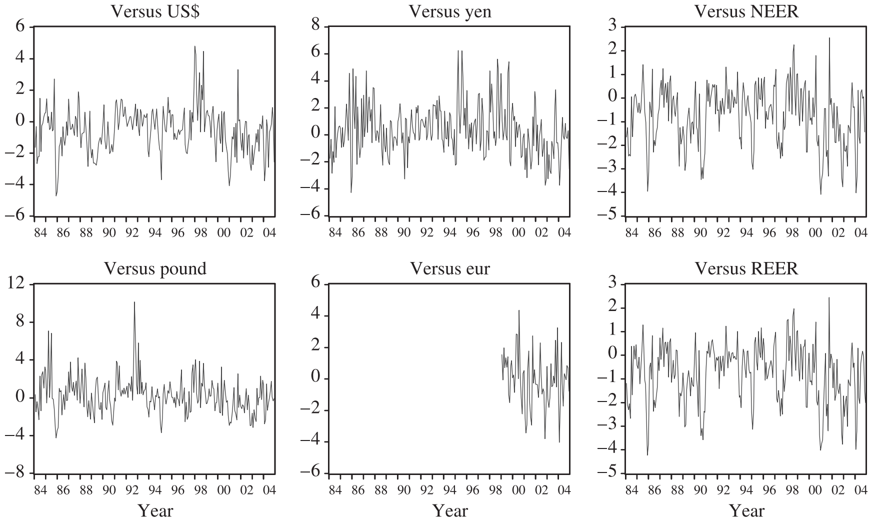
[8] All lowercase variables except for $i$, $d$ and $f$ are in logs.

[9] We assume the money multiplier equals 1.

**Figure 2 Index 1 for Singapore**



where $\Delta p$ and $\Delta p^*$ is domestic and foreign inflation, respectively. Equating Equations (2) and (3), substituting Equation (4) and rearranging, we obtain:

$$\text{Index 1} = \Delta e - \Delta f = \Delta d - \Delta p^* - \beta \Delta y + \alpha \Delta i. \qquad (5)$$

Equation (5) is the basic equation for EMP. The degree of flexibility of an exchange rate regime (or the degree of exchange market pressure) can be ascertained by the left-hand side of Equation (5): the relationship between the exchange rate and foreign reserves, ($\Delta e - \Delta f$). A low index value in this instance might imply less exchange rate flexibility or a higher level of intervention.[10] Other things being equal, higher reserve volatility will reduce the index value, possibly suggesting that reserves are being used as a monetary policy tool to limit exchange rate flexibility. A caveat is in order. Ideally, one would need to cleanse the reserve data to focus only on reserves change resulting from policy intervention rather than valuation changes (resulting from currency fluctuations). However, this is not possible as the MAS, like many other central banks, do not provide data on the currency composition of reserves.

Figure 2 presents values of Index 1 for Singapore using a number of currency pairs, the real effective exchange rate (REER) and the NEER.[11] The index is

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[10] Sometimes interest rates are also included in the denominator of Equation (6). We acknowledge that an interest rate defence could be used to maintain an exchange rate parity or to try and defend a certain reserve level. However, following Baig (2001), Glick and Wihlborg (1997), Bayoumi and Eichengreen (1998) and many others, we exclude interest rate volatility, partly because it is not always clear whether interest rate variations capture policy changes or general market conditions.

[11] Using a number of currencies (the same ones as in the Frankel–Wei tests in the previous section) allows us to gain information about how each currency might be managed relative to the others.

**Table 2 Index 1: Descriptive statistics and unit root tests, Singapore**

| *Series* | *Versus US$* | *Versus yen* | *Versus eur* | *Versus pound* | *Versus REER* | *Versus NEER* |
|---|---|---|---|---|---|---|
| Mean | –0.53 | 0.36 | –0.07 | 0.24 | –0.76 | –0.79 |
| Median | –0.49 | 0.18 | –0.06 | 0.05 | –0.58 | –0.60 |
| Maximum | 4.80 | 6.27 | 4.37 | 10.16 | 2.56 | 2.45 |
| Minimum | –4.72 | –4.27 | –4.03 | –4.24 | –4.08 | –4.23 |
| Standard deviation | 1.43 | 1.90 | 1.67 | 1.50 | 1.25 | 1.26 |
| Skewness | 0.25 | 0.48 | 0.02 | 1.00 | –0.36 | –0.45 |
| Kurtosis | 4.43 | 3.50 | 3.20 | 5.97 | 2.84 | 2.87 |
| Observation | 251 | 251 | 71 | 251 | 250 | 251 |
| ADF | –8.80 | –11.81 | –6.68 | –10.60 | –8.69 | –8.54 |
| KPSS | 0.17 | 0.32 | 0.26 | 0.07 | 0.17 | 0.18 |

Notes: For the ADF tests, the critical values (10%, 5% and 1% significance levels, respectively) are as follows: –2.57, –2.87 and –3.46 for SG/US, SG/yen, REER and NEER, –1.61, –1.95 and –2.60 for SG/eur, –3.14, –3.43 and –4.00 for SG/pound. For the KPSS test, the critical values (10%, 5% and 1% significance levels, respectively) are as follows: 0.12, 0.15 and 0.22 for SG/pound and 0.35, 0.46 and 0.74 for the other currencies. ADF, Augmented Dickey–Fuller; KPSS, Kwiatkowski–Phillips–Schmidt–Shin; NEER, nominal effective exchange rate; REER, real effective exchange rate.

constructed by taking the absolute values of the log difference of each exchange rate series and the absolute value of the percentage difference between the level of reserves (net foreign assets) and their Hodrick–Prescott (HP) filtered trend and scaled by lagged money base.[12] De-trending the reserves data is designed to control for the central banks' stockpiling of reserves for pre-cautionary motives.[13] Specifically, we know that Singapore, like most of its Asian counterparts, has been accumulating reserves since 1998, a reflection of the fact that the currencies have been undervalued relative to market rates (Ouyang and Rajan, 2007). However, we are interested here in the management of volatility as opposed to the management of the value of the exchange rate. The result is an index that is more easily interpretable than if absolute values are taken. The lower the index value the higher the possible degree of fixity or intervention to regulate exchange rate movements.

Table 2 presents some descriptive statistics and stationarity test results for Index 1 for Singapore. The objective here is essentially to obtain information about the characteristics of the data. Against the other currency pairs, the USD exchange rate index was lowest, again helping to confirm the results from the previous section regarding the likelihood that Singapore is pegged to a basket

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[12] This method of measuring reserve changes in quite common in the EMP literature (e.g. see Bayoumi and Eichengreen, 1998; Tanner, 2001; Pentecost et al., 2001; Baig, 2001).

[13] See Willett et al. (2005) for a discussion of problems with trends in reserves data and ways of dealing with it.

of currencies rather than to a single currency. We can use Index 1 to ascertain whether the index has changed over time. This might offer evidence of a change in regime or a change in the index value of one currency at the expense of another. As such, we conduct unit root tests to determine if there has been a mean-reversion in the data. Table 2 presents two such tests for each country and currency. It is well known that the Augmented Dickey–Fuller (ADF) test has low power in predicting the difference between unit root and near unit root processes. As such, the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test for stationarity is included for robustness. There is strong evidence of mean reversion in each currency pair, while the evidence for REER and NEER is mixed, with the KPSS tests showing a rejection of stationarity and the ADF tests show a rejection of a unit root. Overall, there is little evidence of a transition in regime under both sets of tests.

Using Index 1 as a baseline measure we can construct another measure of exchange rate flexibility. Consider the following:

$$\text{Index } 2 = \Delta e/(\Delta e + \Delta f), \tag{6}$$

where $\Delta e(\Delta f)$ are as calculated in the previous section except that we take the 12-monthly mean of $\Delta e$ and $\Delta f$ to form non-overlapping annual mean absolute deviations of each series. The index is deliberately constructed in this manner such that it returns a value between zero and one.[14] This offers a more intuitive interpretation than Index 1 in that it provides a scaling device for the relative exchange rate volatility; the closer Index 2 is to 1 ($\Delta f \rightarrow 0$), the more flexible the exchange rate regime and the closer to 0 ($\Delta e \rightarrow 0$), the more fixed the regime.

As is apparent in Figure 3, the SGD's index is lower in the cases of the REER and NEER (which closely track each other), largely because of a decline in the SGD's index vis-à-vis the yen. This further supports the notion that Singapore has adopted a basket type arrangement with the USD still having the largest weight, but with the weight of the yen having increased over time. It also appears that the degree of flexibility has steadily decreased over the sample, especially since the Asian crisis.

### *3.2 Generalized autoregressive conditional heteroscedasticity-based model of exchange rate flexibility*

The final method of examining exchange rate flexibility is to estimate a simple GARCH model, which has become increasingly commonplace in the literature because it allows for the more explicit modeling of conditional exchange rate

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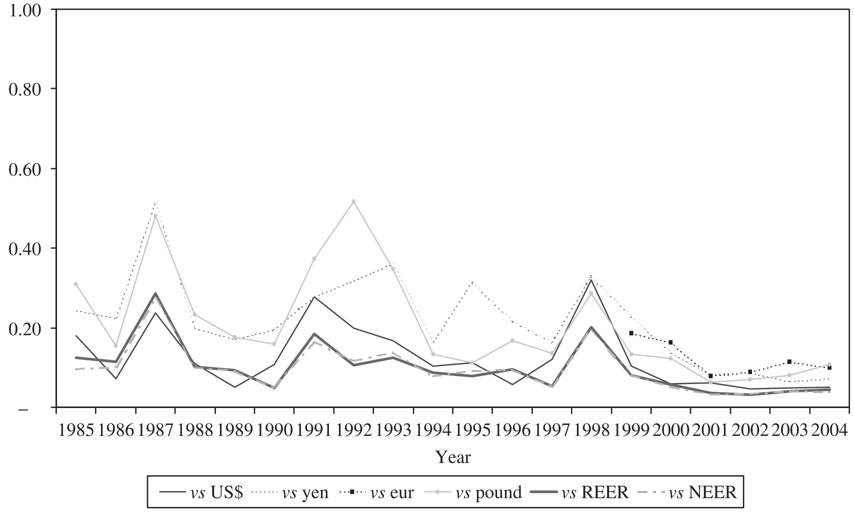
[14] Note that $1 - \Delta e/(\Delta e + \Delta f) = \Delta f/(\Delta e + \Delta f)$, which is defined as a measure of exchange rate intervention. An index such as Index 2 can also be constructed using standard deviations (e.g. $\delta_{\Delta e}/\delta_{\Delta e} + \delta_{\Delta f}$). Baig (2001) and Calvo and Reinhart (2002) use variances. The index values using standard deviations are broadly similar to those for Index 2 and are not reported here. They are available on request.

**Figure 3 Index 2: Exchange rate flexibility index for Singapore**



volatility. As we are essentially interested in the relationship between exchange rates and reserves, we estimate the following model:

$$\Delta e_t = b_0 + b_1(L)\Delta e_{t-1} + b_2\Delta f_t + b_3 X_t + \mu_t \qquad (7)$$

$$\mu_t \sim \mathrm{N}(0, h_t) \qquad (8)$$

$$h_t = \beta_0 + \beta_1(L)\,\mu_t^2 + \beta_2(L)h_{t-1} + \beta_3|\Delta f_t| + \beta_4|X_t| + \varepsilon_t, \qquad (9)$$

where all variables are as defined previously except $X_t$, a vector of other variables deemed to influence the (log difference of the) exchange rate and $|\cdot|$ is the absolute value operator. The elements of $X_t$ used in the present study are those from the model described by Equations (2–5) and their inclusion in the model are determined, along with lag length for $\Delta e$ and the autoregressive conditional heteroscedasticity (ARCH) and GARCH terms, by the Schwartz Criteria. Other ARCH based estimation methods (such as exponential GARCH) are also assessed by the Schwartz Criteria.

Essentially, the GARCH model allows us to observe the *conditional* volatility of the exchange rate, $h_t$, once the influence of the effect of possible intervention and other influences are controlled for. In effect, it offers information about the underlying flexibility of a currency as well as explaining the factors underlying the movements (in first difference and volatility) of a currency. As with Dominguez (1998) and Guimãeres and Karagdag (2004), the effect of possible intervention is allowed both in the mean equation in Equation (7) ($\Delta f_t$) and in the variance equation in Equation (9) $|\Delta f_t|$.

Some results from the GARCH framework are presented in Table 3 and Figure 4. Table 3 presents the estimates to the model. It is interesting to note

**Table 3 GARCH estimates**

| *Dependent variable* | *Singapore dollar per* | | | |
|---|---|---|---|---|
| | *USD* | *Yen* | *UK* | *Euro* |
| Mean equation | | | | |
| Constant | –0.13 | 0.16 | –0.00 | 0.15 |
| | (–2.11)** | (1.59) | | (0.78) |
| Lagged $\Delta e$ | 0.28 | 0.30 | 0.22 | 0.34 |
| | (4.31)*** | (6.04)*** | (2.89)*** | (3.42)*** |
| $\Delta f$ | 0.06 | 0.21 | 0.12 | –0.04 |
| | (1.61)* | (4.13)*** | (2.09)** | (–0.47) |
| $\Delta i$ | 0.66 | –0.45 | | |
| | (3.89)*** | (–1.94)* | | |
| Variance equation | | | | |
| Constant | –0.12 | –0.03 | 0.87 | 0.63 |
| | (–2.22)** | (–0.19) | (1.99)** | (2.06)** |
| ARCH (1) | 0.03 | –0.09 | 0.19 | –0.11 |
| | (0.75) | (–4.04)*** | (1.72)* | (–1.52) |
| GARCH (1) | 0.74 | 1.02 | 0.67 | 1.08 |
| | (8.16)*** | (36.18)*** | (4.93)*** | (15.07)*** |
| ARCH (2) | | | | |
| GARCH (2) | | | | |
| $\lvert\Delta f\rvert$ | 0.12 | 0.05 | –0.11 | –0.26 |
| | (3.05)*** | (0.75) | (–0.84) | (–2.73)*** |
| $\lvert\Delta i\rvert$ | 0.60 | 0.95 | | |
| | (2.27)** | (4.13)*** | | |

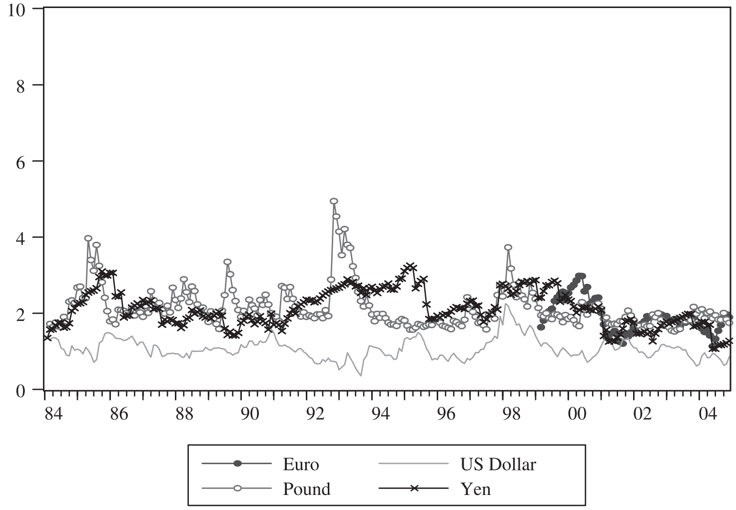
Notes: The table presents estimates from the GARCH model given by Equations (7–9). Variable in parentheses are z-statistics. Lag length and variables presented above were selected based on SBC criteria. The exception is $\Delta f$ as we wish to assess the relationship between it and $\Delta e$. *, ** and *** represent 10%, 5% and 1% significance levels, respectively. GARCH, generalized autoregressive conditional heteroscedasticity.

that $\Delta f$ is statistically significant in most cases for both equations, possibly implying that intervention is used to manage both the level and volatility of the exchange rate. Figure 4 presents the conditional standard deviations, $\sqrt{h_t}$, of the SGD against the USD, yen, pound and euro. The flexibility of the SGD against the USD is lower than for other currencies. This is consistent with the results for the indices above. Additionally, there appears to be less of a gap between the flexibility of the SGD versus the USD and for other currencies. In the context of a possible basket peg, it is clear that the USD occupies the greatest weight, as confirmed by the Frankel–Wei tests in Section II.

## IV. Estimating Monetary Policy Rules for Singapore

The previous two sections indicate that Singapore appears to have been operating a genuine (i.e. de facto) basket pegged arrangement. In particular, as noted,

**Figure 4 Conditional standard deviations from the generalized autoregressive conditional heteroscedasticity model (Equations (7–9)): Singapore**



the MAS has managed the Singapore dollar as a flexible band-basket-crawl (BBC). The parity (basket) is determined on the basis of an undisclosed basket of currencies (major trading partners). The MAS allows the SGD to vary within an undisclosed 'band' around the central parity as a means of ensuring greater exchange rate flexibility (Khor et al., 2004; Rajan, 2002).[15] The objective of ensuring that the REER is broadly aligned with overall macroeconomic fundamentals has also been the driving force behind BBC regimes, thus the reason for a 'crawl' to account for inflation differentials.[16]

It is not often recognized that there are two ways of operating a BBC arrangement. One way is to operate a largely mechanical regime, whereby the central bank tries to keep the effective rate more or less within a band (Williamson, 1998). Another way of operating a basket peg would be for the central bank to pursue a policy that has a more activist or strategic orientation. In other words, the BBC arrangement is viewed as a means to an end; the monetary authority maintains an implicit or explicit monetary policy rule (MPR), whereby it varies

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[15] The MAS reviews both the band and parity from time-to-time and makes alterations according to changing market circumstances if necessary.

[16] The SGD was on a gradual upward crawl (appreciation) until 1997–1998. This upward crawl was a deliberate policy by the MAS to keep inflation under check. This so-called strong Singapore dollar policy was also a tool used to promote structural adjustment (to higher value-added, less price-sensitive activities). However, this policy was on an extended hiatus after the East Asian crisis until April 2004 in view of the sharp slowdown in the country's average economic growth post-crisis and the deflationary global environment.

the effective exchange rate on the basis of its inflation and output gaps (also see Parrado, 2004; McCallum, 2005). This has a parallel with the conventional inflation targeting literature where various types of interest rate rules have been estimated with the objective of assessing the inflation-targeting regime (e.g. see Clarida et al., 1998, Leitemo and Soderström, 2001; Ades et al., 2002; Mohanty and Klau, 2004).

To assess the possibility of whether Singapore has an activist exchange rate centered monetary policy, we estimate a simple reaction function or MPR (Equation 10) for Singapore where the NEER is used as the policy instrument.[17]

$$\Delta e_t = \gamma_0 + \gamma_1\pi_t + \gamma_2 y_t + \gamma_3 \Delta e_{t-1} + \varepsilon_t, \tag{10}$$

where $\pi_t$ is the annual rate of inflation minus a target and $y_t$ represents the output gap (i.e. the deviation of output from its HP trend). Equation (10) is our baseline specification for which we estimate two measures of $\Delta e_t$: (i) the (log) difference of the NEER, $\Delta ER_t$; and (ii) the deviation of the exchange rate from its HP trend, $ERgap_t$. The baseline specification uses the current value of inflation as a regressor.[18] The sample used is January 1985 to April 2004, using quarterly observations.

Table 4 presents the OLS and two-stage least squares (TSLS) results from Equation (10).[19] Care must be exercised when interpreting the MPR. This is because the parameters to the MPR, the γs in Equation (10), comprise policy parameters (those in an appropriately specified loss function) and the parameters given in the macro model (see Appendix II for some technical details). What we are looking for is the possibility that the MAS uses the exchange rate as a policy instrument in an attempt to arrive at some basic stylized facts about

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[17] The theoretical motivation for Equation (10) is based on Ball (1999). See Appendix II.

[18] The rule is estimated in the form presented in Equation (10) and not as in Clarida et al. (1998) or Parrado (2004) and others because we feel it more accurately reflects the actual derivation of a MPR under optimal policy (see Appendix 2 for some technical details). In these derivations, the MPR reacts to the state variables of an appropriately specified macro model. The absence of so-called forward-looking variables in our estimation equation does not imply that policy is not forward-looking: the forward-looking behavior would be captured in a central bank loss function that would be minimized to derive optimal policy. Rather, the rule simply describes how the instrument of policy reacts to variables whose value is known at time $t$ such that the loss function is minimized. However, for completeness, we estimate some MPR with leading values for inflation below: the results are contained in Table 5).

[19] It is usual in the empirical literature of MPR to use an estimator that imposes exogeneity (such as the generalized method of moments (GMM). The interest rate rules of Clarida et al. (1998), Ades et al. (2002) and Mohanty and Klau (2004) are estimated using GMM, as are the exchange rate rules estimated by Parrado (2004). We have accounted for possible endogeneity using TSLS due to concerns over the small sample properties of GMM. The instruments used were contemporaneous and lagged (one period) values of the other regressors, lagged (one period) inflation and contemporaneous, and lagged (one period) values of the difference in the money base. Cointegration analysis involving NEER, CPI and output levels, and subsequent robustness testing reveal insufficient evidence of cointegrating relationships that would form part of the NEER equation, Equation (10). These tests are available upon request from the authors.

**Table 4 Monetary policy rule for Singapore: Baseline model**

| *Dependent variable* | *OLS* | | *Two stage least squares* | |
|---|---|---|---|---|
| | $\Delta ER_t$ | *Ergap* | $\Delta ER_t$ | *ERgap* |
| Constant | –0.74<br>(–2.59)*** | –0.43<br>(–1.74)* | –0.74<br>(–2.87)*** | –0.62<br>(–2.60)*** |
| $INFL_t$ | 0.62<br>(4.21)*** | 0.28<br>(2.35)** | 0.62<br>(4.16)*** | 0.39<br>(3.33)*** |
| $OUTP\_GAP_t$ | 0.03<br>(1.12) | 0.02<br>(0.62) | 0.03<br>(1.09) | –0.06<br>(–1.32) |
| $\Delta ER_{t-1}$ | 0.06<br>(0.43) | — | 0.06<br>(0.40) | — |
| $ERgap_{t-1}$ | — | 0.84<br>(13.93)*** | — | 0.76<br>(12.36)*** |
| Adjusted $R^2$ | 0.29 | 0.75 | 0.29 | 0.72 |
| Durbin–Watson | 2.00 | 1.88 | 1.99 | 1.72 |
| Observation | 80 | 80 | 79 | 79 |

Notes: ER is the nominal effective exchange rate (NEER). ER gap refers to the deviation of the NEER from its HP trend. Figures in parentheses are *t*-statistics. *, ** and *** represent 10%, 5% and 1% significance levels, respectively.

exchange rate behavior. Those coefficients that are statistically significant and the correct sign offers evidence that the exchange rate reacts to information about other macro variables in a way that *might* represent a monetary policy choice.[20]

Returning to Table 5, the MPR for Singapore suggests very little importance of the output gap in determining either measure of Singapore's NEER. There is some possibility that the exchange rate reacts to inflation in all cases tested. The sign is correct for each of the regressions. A positive coefficient value suggests that if inflation rises then the NEER will have to appreciate to dampen possible excess demand conditions. If we substitute $\Delta ER_t$ for $ERgap_t$ as the dependent variable, the estimated coefficient for inflation is generally smaller in magnitude (0.28 OLS, 0.39 TSLS) than they are for $\Delta ER_t$ (0.62, 0.62), and interestingly, the coefficient value for the lagged exchange rate variable is higher in magnitude (and statistically significant). This is indicative of the possibility of greater instrument smoothing in the model using the $ERgap_t$.

In addition to the OLS/TSLS tests for Equation (10), we used recursive OLS techniques to evaluate the stability of the inflation coefficient over time and to ascertain the dynamic characteristics of both the inflation and output coefficient. The results are presented in Figures 5 and 6. Figure 5 presents the results for the model, where $\Delta ER_t$ is the dependent variable and Figure 6 presents the results

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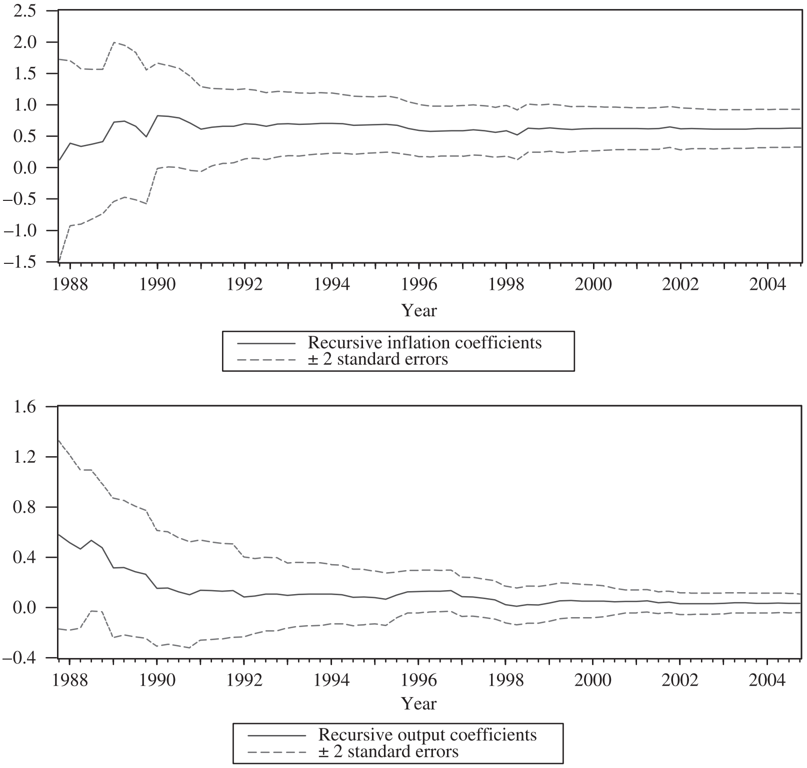
[20] Note that it is not entirely correct to refer to the coefficients of the rule as being directly attributable to the sole reactions of the central banks as is sometimes done in the literature.

**Table 5 Monetary policy rule for Singapore: Leading values for inflation**

| *Dependent variable* | $\Delta ER_t$ | $\Delta ER_t$ | $\Delta ER_t$ | $\Delta ER_t$ | $ERgap_t$ | $ERgap_t$ | $ERgap_t$ | $ERgap_t$ |
|---|---|---|---|---|---|---|---|---|
| Constant | –0.98 | –1.38 | –1.20 | –1.12 | –0.72 | –0.93 | –1.12 | –1.21 |
| | (–2.97)*** | (–2.73)*** | (–2.12)** | (–1.85)* | (–2.63)** | (–2.60)** | (–2.58)** | (–2.35)** |
| $INFL_{t+1}$ | 0.78 | — | — | — | 0.44 | — | — | — |
| | (3.72)*** | | | | (3.16)*** | | | |
| $INFL_{t+2}$ | — | 1.08 | — | — | — | 0.58 | — | — |
| | | (3.13)*** | | | | (3.00)*** | | |
| $INFL_{t+3}$ | — | — | 0.93 | — | — | 0.70 | — | — |
| | | | (2.38)** | | | (2.87)*** | | |
| $INFL_{t+4}$ | — | — | — | 0.86** | — | — | — | 0.76 |
| | | | | (2.07) | | | | (2.50)** |
| $OUTP\_gap_t$ | 0.01 | –0.02 | 0.01 | 0.05 | –0.08 | –0.12 | –0.13 | –0.08 |
| | (0.21) | (–0.33) | (0.31) | (1.21) | (–1.53) | (–1.83)* | (–1.63) | (–0.98) |
| $\Delta ER_{t-1}$ | 0.03 | –0.08 | 0.03 | 0.12 | — | — | — | — |
| | (0.21) | (–0.48) | (0.19) | (0.84) | | | | |
| $ERgap_{t-1}$ | — | — | — | — | 0.79 | 0.81 | 0.88 | 0.96 |
| | | | | | (13.27)*** | (12.77)*** | (12.89)*** | (11.46)*** |
| Adjusted $R^2$ | 0.29 | 0.16 | 0.22 | 0.16 | 0.71 | 0.64 | 0.59 | 0.54 |
| | 1.94 | 1.69 | 1.69 | 1.85 | 1.70 | 1.54 | 1.33 | 1.32 |
| Observation | 78 | 77 | 76 | 75 | 78 | 77 | 76 | 75 |

Note: The above results are obtained using two stage least squares. ER is the nominal effective exchange rate (NEER). *ERgap* refers to the deviation of the NEER from its HP trend. Figures in parentheses are *t*-statistics. (*)(**)(***) represent 10%, 5% and 1% significance levels, respectively.

**Figure 5 Recursive OLS estimates of baseline monetary policy rule (dependent variable, $\Delta e$)**



for $ERgap_t$.[21] Interestingly, the coefficient value for output was materially higher at the beginning of the sample before stabilizing in around January 1990. It is difficult to state categorically that this represents an erosion of the output objective by the central bank, but it does represent something of a disconnection between output and both measures of the NEER estimated. The coefficient for inflation seems to be quite stable over the sample period. This suggests that the MAS might have been an ‘inflation nutter’ in the sense that the MPR has focused almost exclusively on inflation. It has been able to do so as the government has actively used supply side policies (tax and wage cuts) to close any output gaps (we return to this point in the final section).

In keeping with the literature on MPR, we estimate Equation (10) using leading values for inflation as regressors. We are interested in investigating whether the instrument reacts to what might be considered future values of

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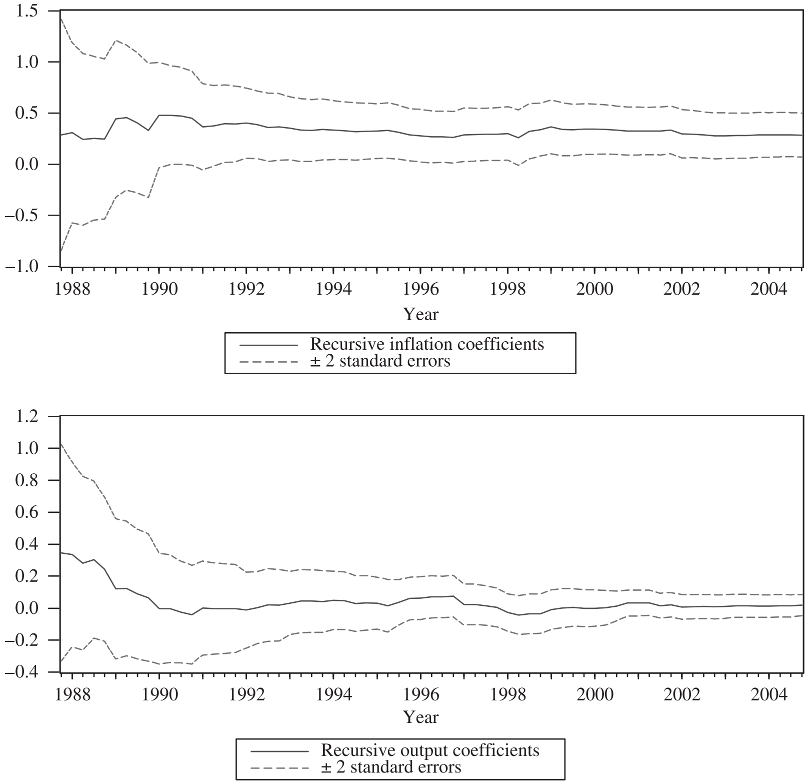
[21] The recursive OLS estimates are taken from the baseline model. As with the recursive OLS results for the Frankel–Wei regressions, the first few observations are removed as they do not exhibit sufficient degrees of freedom to be meaningful.

**Figure 6 Recursive OLS estimates of baseline monetary policy rule (dependent variable, *ERgap*)**



inflation. To control for the possible endogeneity of inflation, we use TSLS; the results are also presented in Table 5 where estimates are given for values of $\pi_{t+k}$ where $k = 1$ to 4 (quarters).[22,23] Reassuringly, the results are not dissimilar to those presented in Table 4 for the baseline model. For the model using $\Delta ER$, the coefficient values for inflation are significant and seem quite robust to the value of $k$. As with the baseline estimates, the coefficient values are smaller for the model where *ERgap* is used and appear to increase as $k$ increases.

## V. Concluding Remarks

Despite the fact that different types of exchange rate flexibility measures are designed to capture different characteristics of exchange rate behavior, our

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[22] The instruments used here are the same as those used for the baseline model in Table 4.

[23] The MPR would actually be as follows: $\Delta e_t = \gamma_0 + \gamma_1 E_t\pi_{t+k} + \gamma_2 y_t + \gamma_3 \Delta e_{t-1} + \xi_t$, where $E_t\pi_{t+k} = \pi_{t+k} + \omega_{t+k}$. As such, $\xi_t = \varepsilon_t + \gamma_1\omega_{t+k}$.

empirical analysis suggests that there is a great deal of convergence with regard to understanding the de facto exchange rate regime in SGD. The magnitude and stability of the time-varying coefficients of the recursive OLS results indicate a willingness to manage SGD dollar against a basket of major currencies, particularly post 1998.[24] The flexibility indices are supportive of this hypothesis. In other words, Singapore seems to be pursuing a 'genuine' currency basket arrangement, as suggested by the official policy pronouncements.

In view of this, we have attempted to determine whether a simple effective exchange rate based monetary policy rule can be estimated for Singapore. As with Parrado (2004), we find evidence that Singapore's monetary policy has had a strategic orientation in the sense that the nominal effective exchange rate has been adjusted to stabilize inflation and output. In other words, although the long-term aim is to ensure that the Singapore effective exchange rate is consistent with underlying fundamentals, in the short term the MAS has used the exchange rate as a counter-cyclical tool. Although not explicitly captured in our empirical analysis, as noted previously, there is an asymmetry in the way the MAS uses the exchange rate as a countercyclical tool. In particular, while they have generally been willing to appreciate the NEER to counter overheating pressures, they are much more circumspect about using it to stimulate the economy during downturns because of concerns about inflation. This asymmetry is captured in the empirical analysis by Willett et al. (2005), who find that 'Singapore showed a fear of depreciation' (p. 34).[25]

Although the MAS has been consciously using the exchange rate as a countercyclical tool, the real effective value of the SGD appears to have been broadly aligned with alternative estimates of the long-run equilibrium rate based on underlying macroeconomic fundamentals (see Khor et al., 2004; MacDonald, 2004; Rajan and Siregar, 2002). However, one cannot be sure whether this is a result of a conscious exchange rate policy of the MAS to return the NEER to its 'neutral' level over the duration of the business cycle,[26] or a consequence of the fairly high domestic wage and price flexibility in Singapore which leads to a reversion of the REER to its longer run equilibrium value. This is clearly an area that needs to be explored in more detail.

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[24] Note that Reinhart and Rogoff (2004) characterize Singapore as a de facto moving band around the USD between June 1973 and November 1998 and a managed floater between December 1998 and December 2001.

[25] During downturns, the Singapore policy-makers make extensive use of incomes policies (i.e. reducing wages and other costs) to depreciate the REER (Rajan, 2004).

[26] For instance, the MAS explicitly states that 'the exchange rate policy band is periodically reviewed to ensure that it remains consistent with the underlying fundamentals of the economy' (Khor et al., 2004, p. 3).

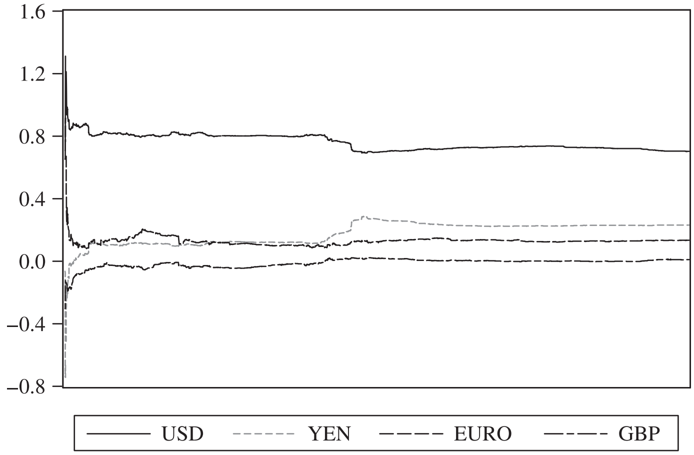
## Appendix I

**Table 1A Robustness exercise: Frankel–Wei OLS tests using daily data**

*Dependent variable: D(LOG(SING))*
*Method: Least squares*
*Included observations: 2975 after adjustments*

| *Variable* | *Coefficient* | *Standard error* | t-*statistic* | *Probability* |
|---|---|---|---|---|
| C | 2.08E-05 | 6.25E-05 | 0.333220 | 0.7390 |
| D(LOG(US)) | 0.703387 | 0.013569 | 51.83861 | 0.0000 |
| D(LOG(JPY)) | 0.231709 | 0.009533 | 24.30666 | 0.0000 |
| D(LOG(EUR)) | 0.134360 | 0.024544 | 5.474237 | 0.0000 |
| D(LOG(UK)) | 0.010080 | 0.016125 | 0.625119 | 0.5319 |
| $R^2$ | 0.767186 | | | |
| Durbin–Watson statistic | 2.230914 | | | |

**Figure 1A Robustness exercise: Frankel–Wei recursive least squares tests using daily data**



Note: Sample of data is from 1 January 1993 to 31 December 2006.

## Appendix II

The following section derives an optimal exchange rate rule in matrix form. It is this rule that forms the basis to Equation (10) and is estimated in Section IV. An appropriate model with which to base the rule is the following one similar to Ball (1999):

$$y_{t+1} = \beta_1 y_t - \beta_2 r_t - \beta_3 e_t + \varepsilon_{t+1} \tag{A1}$$

$$\pi_{t+1} = \pi_t + \alpha_1 y_t - \alpha_3 e_t + \alpha_4 e_{t-1} + \eta_{t+1} \tag{A2}$$

$$e_t = \theta r_t, \tag{A3}$$

where all variables are expressed as deviations from some steady-state value. Substitute Equation (A3) for $r_t$ into Equation (A1):

$$y_{t+1} = \beta_1 y_t - (\beta_2/\theta + \delta)e_t + \varepsilon_{t+1}, \tag{A4}$$

which, along with Equation (A2) is expressed as:

$$x_{t+1} = Ax_t + Be_t + \Sigma_t, \tag{A5}$$

where $x_t = [y_t \ \pi_t \ e_{t-1}]$. This problem is the stochastic linear optimal regulator problem (see Ljungvist and Sargent, 2000). We can find an optimal rule for the control variable in the system, our policy instrument, $e_t$, by optimizing the following central bank loss function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \{\lambda_\pi \pi_t^2 + \lambda_y y_t^2\},$$

which can be generalized to

$$E_0 \sum_{t=0}^{\infty} \beta^t \{X_t' R X_t + e_t' Q e_t\}, \tag{A6}$$

where diagonals of $R$ are $[\lambda_y \ \lambda_\pi \ 0]$ and $Q = 0$. The loss function is minimized subject to Equation (A5) by using the Bellman equation. To allow for the evolution of the state, we guess that the value function is quadratic and has the form, $X'PX + d$ and, therefore, the Bellman equation becomes:

$$\begin{aligned} X'PX &= \max_e \{x_t' R x_t + e_t' Q e_t + \delta E[x_{t+1}' P x_{t+1} + d]\} \\ &= \max_e \{x_t' R x_t + e_t' Q e_t + \delta E[(Ax_t + Be_t + \Sigma_{t+1})' P (Ax_t + Be_t + \Sigma_t)] + \delta d\}, \end{aligned} \tag{A7}$$

where $d = \delta(1 - \delta)^{-1}$ $tr\ P\Sigma$. The first order condition to this problem is $\delta(Q + \delta B'PB)e_t = -B'PAx_t$, which, when expressed for the policy instrument, $e$, becomes:

$$e_t = -\delta(Q + \delta B'PB)^{-1} B'PAx_t \tag{A8}$$

and

$$P = R + \delta A'PA - \delta^2 A'PB(Q + \delta B'PB)^{-1}B'PA, \tag{A9}$$

where P is usually solved by iteration. Equation (A8) can be expressed as $e_t = Fx_t$. It is clear that $F$ is the vector of optimal coefficients to the policy rule. In scalar form, the rule is represented by:

$$e_t = f_1 y_t + f_2 \pi_t + f_4 e_{t-1} \tag{A8a}$$

and this is used as the basis for the estimated rule for Singapore in Equation (10).

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