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**Monetary policy and the volatility  
of real exchange rates in New Zealand**

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## **Monetary policy and the volatility of real exchange rates in New Zealand**

### **Abstract<sup>a</sup>**

The relationship between interest rates and exchange rates is puzzling and poorly understood. But under some standard assumptions, interest rates can be adjusted to smooth real exchange rate movements at the possible price of increased volatility in other variables. Estimates made under some generous suppositions about what monetary policy is able to accomplish suggest that decreasing real exchange rate volatility by about 25 per cent would require increasing output volatility by about 10-15 per cent, inflation volatility by about 0-15 per cent and interest rate volatility by about 15-40 per cent.

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### **1 Introduction**

The primary goal of monetary policy in New Zealand is price stability. But that is not the sole mandate of the Reserve Bank of New Zealand. Recent Policy Targets Agreements have also called on the Bank to “avoid unnecessary instability in output, interest rates and the exchange rate.”

Thus the Bank is directed to make output, interest rates and the exchange rate variables of interest beyond the usefulness of these variables for understanding and forecasting inflation, perhaps interpretable as a direction to trade off price stability with stability in these other variables. This paper considers the possibility of using interest rate policy to trade exchange rate stability against stability in other variables. It makes two points. Section 2 of the paper reminds the reader that the relationship between interest rate policy and exchange rates is quite uncertain. Specifically, I remind the reader of the empirical failure of “uncovered interest parity.” In light of such a failure, it will likely be difficult in practice to use interest rate adjustments to stabilise exchange rates with any precision.

The rest of the paper follows a considerable literature that ignores the reminder just noted. It embeds a standard interest parity relationship between interest rates and exchange rates in a linear macro model. It uses counterfactual calculations to supply rough quantitative estimates of that tradeoff, focusing on stability of real exchange rates on the one hand versus stability of output, inflation and interest rates on the other. The point estimates suggest that decreasing real exchange rate volatility by about 25 per cent would require increasing output and inflation volatility by roughly 10 per cent and interest rate volatility by roughly 20 per cent.

The estimates are derived from a simple linear model that is broadly consistent with both textbook and New Keynesian models. The mechanism the Bank is assumed to use to stabilise real exchange rates is to adjust interest rates in response to transitory movements in

exchange rates, with interest rate hikes (cuts) coming in response to transitory depreciations (appreciations) of the New Zealand dollar.

Three cautionary notes. First, these estimates are likely to be optimistic ones. This is not only because the model assumes that interest rate adjustments affect exchange rates in a reliable and well understood way. As well, and at a more prosaic level, the computations assume away a host of other practical problems: they assume that the Bank knows the steady state level of the real exchange rate, that the Bank can react to exchange rate movements as quickly as exchange rates react to interest rate movements, that excellent data on output and inflation are available contemporaneously, and so on. So in practice a 25 per cent reduction in real exchange rate volatility is likely to be associated with greater increases in volatility of other variables than stated above.

Second, this paper does not consider the desirability of explicitly targeting real exchange rate movements. As indicated above, I am motivated to estimate a tradeoff by statements in recent Policy Targets Agreements. The utility function to interpret the estimates is to be supplied by the reader. See among others Benigno and Benigno (2000), Clarida et al (2001), and Kollman (2002) for formal analyses of the welfare properties of monetary rules in open economies.

Third, the fact that the focus of this paper is on real exchange rate stabilisation should not be interpreted as an assertion that such stabilisation is the only or even most important way exchange rates might affect monetary policy. In a small open economy like New Zealand's, exchange rates, both real and nominal, are central to understanding and forecasting the evolution of inflation and output. I take this point as given, and consider the separate question of the cost of real exchange rate stabilisation.

Section 2 of the paper notes the uncertainty of the link between interest rates and exchange rates. Section 3 presents the model. Section 4 presents empirical results. Section 5 concludes. An Appendix includes some algebraic details.

## 2 Uncertain interest parity

For countries with roughly similar inflation rates, exchange rate changes are hard to predict. In my view, they are even harder to predict than are stock price changes, which are notoriously difficult to predict. Indeed, a vast literature studying exchange rate prediction has concluded that the best single predictor of the exchange rate next period—tomorrow, next week, next month, maybe even next year—is the exchange rate this period. One generally cannot do better than a “no change” forecast for exchange rates. The seminal reference is Meese and Rogoff (1983); a recent update is Cheung et al (2002).

Those unfamiliar with the exchange rate models may think this “random walk” result is precisely what is predicted by classic efficient markets theory as expounded by Samuelson (1965). But in fact this is not the case. Explaining why not will take us to the “uncovered interest parity” relationship that is the central link between interest rates and exchange rates in macroeconomic models such as the one developed and estimated in this paper.

Recall that the essence of Samuelson's (1965) model is not that asset prices changes are unpredictable but that asset *returns* are unpredictable. Samuelson explicitly noted that if an asset pays a dividend in a given time period, the asset's return (sum of dividend and price change) will be unpredictable only if there is, on average, an offsetting movement in the asset price. For equity returns, for example, this means that the day a stock goes ex-dividend, its price should fall, on average, by the amount of the dividend. And indeed this implication has been found to be more or less consistent with the behavior of US stock price data (an early reference is Elton and Gruber (1970)), at least once one takes into account complications induced by taxes and transactions costs.

The reader may wonder what a discussion about dividends has to do with exchange rates. It is of course true that holding foreign currency does not automatically entitle one to earn money labeled “dividends.” But from the point of view of Samuelson's (1965) efficient markets

theory, interest payments on nominally riskless government debt play precisely the role of dividends. To see why, let us define the following notation:

(2.1)

- $i_t$ : interest rate in New Zealand,
- $i_t^*$ : interest rate in foreign country,
- $s_t$ : log nominal exchange rate, measured as \$NZ/foreign currency,
- $E_t$ : mathematical expectations conditional on a period  $t$  information set.

I follow the convention that a higher value of  $s_t$  denotes a weaker (depreciated) currency.

In the notation of (2.1), uncovered interest parity may be written:

$$i_t = i_t^* + E_t s_{t+1} - s_t \quad (2.2)$$

The left hand side is the return from investing in domestic (New Zealand) bonds. The right hand side is the expected return from the following investment: convert from New Zealand dollars to foreign currency, buy the foreign bond that pays  $i_t^*$ , convert the proceeds back to New Zealand dollars. If investors are risk neutral, as assumed by Samuelson (1965), equality of expected returns should hold, and equation (2.2) follows. (For example, if the New Zealand interest rate  $i_t$  is (say) 4 per cent higher than the foreign interest rate  $i_t^*$ , then our hypothetical investor must expect that by investing abroad he will earn 4 per cent via depreciation of the New Zealand dollar [ $E_t s_{t+1} - s_t = .04$ ].) Alternatively, investors cannot expect to make money by borrowing at rate  $i_t$  and investing abroad. In (2.2), the expected asset price change is  $E_t s_{t+1} - s_t$ , while the net “dividend” is  $i_t^* - i_t$ . Samuelson’s (1965) model says that the total return  $i_t^* - i_t + E_t s_{t+1} - s_t$  is unpredictable.

Observe that uncovered interest parity (2.2) states that exchange rate changes are predictably related to interest rate differentials; according to uncovered interest parity, exchange rates do *not* follow a random walk. I began this section by noting that exchange rate changes are unpredictable, which means in particular that they are not well predicted by interest rate differentials. This is illustrated by figures 1(a)-1(c), which present scatterplots of begin of quarter 90 day interest rate differentials (horizontal axis) with subsequent quarterly percentage changes in nominal exchange rates (vertical axis), for the New Zealand dollar versus the currencies of Australia (figure 1a), Japan (1b) and the US (1c). The sample period is 1986:2-2003:1. The interest rate differentials are expressed at quarterly rates. Were uncovered interest parity to hold, the dots would be scattered around a forty five degree line. No such pattern is evident. Indeed, the point estimate of correlation between the two series is *negative* for the US and Japan, and the estimated positive correlation for Australia is insignificantly different from zero. A vast literature finds similar results. See Lewis (1995) for a general survey and Razzak and Margaritis (2002) for recent New Zealand evidence.

**Figure 1a**

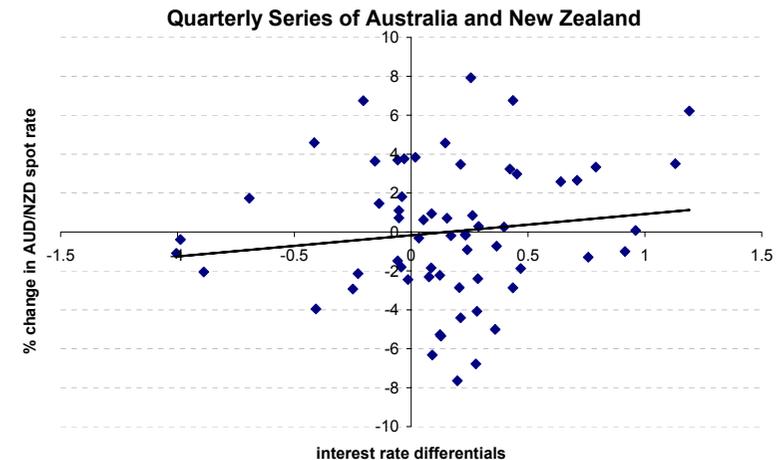


Figure 1b

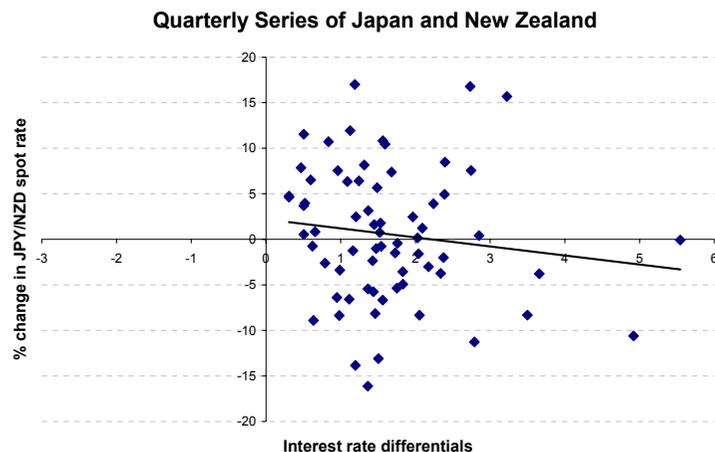
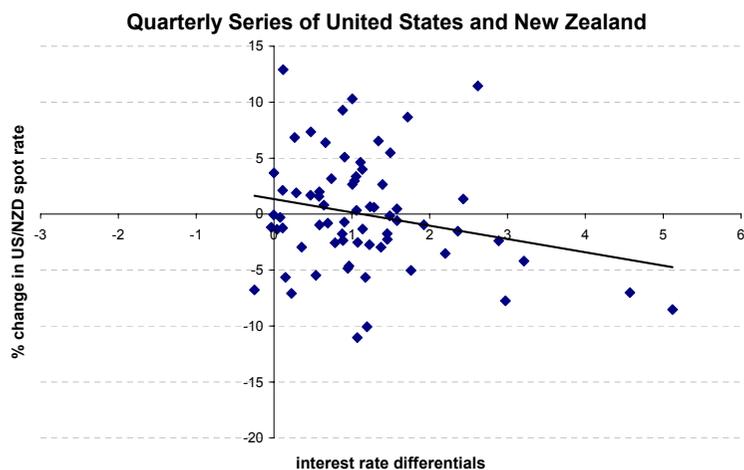


Figure 1c



So fitting the historical data requires the addition of variables to (2.2). In the empirical work presented below, I take the tack of appending a serially correlated shock, call it  $u_{rt}$ ; the “ $r$ ” stands for “risk premium.”

$$i_t - i_t^* = E_t s_{t+1} - s_t + u_{rt}. \quad (2.3)$$

In this empirical work, I use historical data and regression residuals to construct a series for  $u_{rt}$  (and other unobserved shocks, though such shocks are not important at the moment). When I trace out the effects of alternative interest rate policies, I assume that the time series for  $u_{rt}$  is invariant to such policies. That is, *ceteris paribus*, movements in  $i_t$  lead one-to-one to movements in expected exchange rate depreciation, where one of the *cetera* held fixed is  $u_{rt}$ . This may not be a good assumption, but it arguably is as good as any. A good assumption about how  $u_{rt}$  will change as monetary policy changes requires a good model for the shock  $u_{rt}$ . We do not have such a model. Possible explanations for  $u_{rt}$  include a risk premium generated as the usual covariance with the market portfolio (eg Backus et al (2001)) or misperceptions about determinants of exchange rates (eg Gourinchas and Tornell (2002)). Each explanation has substantial empirical or theoretical difficulties.

The lesson to be drawn is that the results about to be developed and presented need to be interpreted with an unusual amount of caution.

### 3 The model

#### A Specification

The model is broadly consistent with recent New Keynesian work on monetary policy in small open economies, such as Galí and Monacelli (2002). An IS curve, a Phillips curve, a monetary policy rule and an interest parity equation are specified for New Zealand. These are forward looking, with all dynamics and persistence due to serial correlation in exogenous shocks. As well, exogenous processes are posited for foreign (rest of world) output, inflation and interest rates.

For convenience, I refer to a foreign “country”, although the empirical work defines the foreign country as a trade weighted average of several foreign countries. Define the following notation in addition to that defined in (2.1):

(3.1)

$y_t$  = output gap in New Zealand,  $y_t^*$  = output gap in foreign country;  
 $p_t, p_t^*$ : log price levels (CPI);  
 $\pi_t, \pi_t^*$ : inflation  
 (first difference of log consumer price level);  
 $q_t = s_t - (p_t - p_t^*)$ : log real exchange rate;

I repeat that I follow the convention in which an increase in the exchange rate (real or nominal) corresponds to a depreciation rather than appreciation of the New Zealand dollar.

The IS and Phillips curve equations are:

$$y_t = \alpha_y y_t^* + \alpha_q q_t - \alpha_r (i_t - E_t \pi_{t+1}) + u_{yt} \quad (3.2)$$

$$\pi_t = \beta_\pi E_t \pi_{t+1} + \beta_y y_t + u_{\pi t} \quad (3.3)$$

In (3.2) and (3.3),  $u_{yt}$  and  $u_{\pi t}$  are exogenous shocks, which in the empirical work will be serially correlated. Here and throughout I suppress constant terms.

The IS curve (3.2) can be justified in either of two related ways. The first is as a textbook open economy aggregate demand curve. In this case,  $\alpha_y$  and  $\alpha_q$  are positive and reflect the responsiveness of net exports to movements in foreign output  $y_t^*$  and the real exchange rate  $q_t$ ;  $\alpha_r$  is negative. A second is from New Keynesian models with certain assumptions about, preferences, risk sharing and purchasing

power parity. For example, in Galí and Monacelli (2002), which assumes that uncovered interest parity and instantaneous purchasing power parity, (3.2) holds with  $\alpha_y^*$  and  $\alpha_q$  functions of preference parameters and  $\alpha_r = 0$ ; in the particularly simple case of logarithmic preferences,  $\alpha_y^* = 1$ ,  $\alpha_q > 0$  is increasing in the share of foreign produced goods in New Zealand consumption, and  $u_{yt}$  depends on the level of productivity in New Zealand relative to the foreign country.

Equation (3.3) again is consistent with both textbook and New Keynesian models. In textbooks,  $\beta_\pi = 1$ ; in the Calvo sticky price model,  $\beta_\pi$  is a little less than 1. In either,  $\beta_y$  is positive. In both textbook and New Keynesian models, the measure of inflation that appears in the Phillips curve is domestic rather than overall inflation  $\pi_t$ . The use of overall inflation is a shortcut.

I assume that monetary policy in New Zealand is adequately captured by a Taylor rule with a serially correlated shock  $u_{mt}$ :

$$i_t = \gamma_\pi \pi_t + \gamma_y y_t + \gamma_q q_t + u_{mt} \quad (3.4)$$

In (3.4),  $\gamma_\pi > 1$ ,  $\gamma_y \geq 0$  and  $\gamma_q \geq 0$ . The use of actual inflation is for consistency with work at the Reserve Bank (see Drew and Plantier (2000) and Plantier and Scrimgeour (2002)); from a technical point of view, I could proceed if expected inflation were in the monetary policy rule (3.4) as suggested by Huang et al (2001). A similar statement applies to the output gap.

The term in the real exchange rate  $\gamma_q$  is key to this study. To interpret this term, begin by noting that I sidestep altogether any questions about *levels* of variables, to focus on *variability*. Let me temporarily restore the levels, by rewriting (3.4) as follows:

$$(3.4)' \\ i_t - E_t \pi_{t+1} = \text{natural real interest rate} + (\gamma_\pi - 1)(E_t \pi_{t+1} - \text{inflation target}) \\ + \\ \gamma_y (\log \text{GDP} - \log \text{potential output}) + \gamma_q (q_t - \text{equilibrium value of } q_t) + \\ u_{mt}.$$

We see in (3.4)' that this reaction function, which was also used in Clarida et al (1998) and Engel and West (2002), allows the monetary authority to lean against the transitory movements in the real exchange rate. The larger is  $\gamma_q$ , then, the more does monetary policy attempt to lean against such transitory movements. (Whether it is reasonable to allow reaction to contemporaneous real exchange rates is discussed briefly below.) The empirical work proceeds essentially by tracing out how variations in  $\gamma_q$  affect volatility of output, inflation, interest rates and the real exchange rate.

In this empirical work, I abstract altogether from thorny questions about the determinants of the quantities present in (3.4)' but not (3.4) (ie the natural real interest rate, inflation target, potential output and equilibrium value of the real exchange rate). The empirical work relies on the Bank's staff to construct potential output and the equilibrium real exchange rate, and assumes the other quantities are constants, set equal to the mean value in the sample. It is technically feasible to use other deterministic models (trends, or step functions, for example) rather than constants, but I did not do so.

The next equation is interest parity (2.3), but written in real form, and with an exogenous risk premium shock  $u_{rt}$ :

$$i_t - i_t^* - (E_t \pi_{t+1} - E_t \pi_{t+1}^*) = E_t q_{t+1} - q_t + u_{rt}. \quad (3.5)$$

Equation (3.5) is obtained by subtracting  $E_t \pi_{t+1} - E_t \pi_{t+1}^* \equiv E_t p_{t+1} - p_t - (E_t p_{t+1}^* - p_t^*)$  from both sides of (2.3).

Note that the current values of  $i_t$  and  $q_t$  appear in the monetary rule (3.4) and in interest parity (3.5). The model will be solved under the assumption that the quarterly interest rate can be set to react to the contemporaneous real exchange rate, even while the exchange rate is reacting to interest rate movements. There are at least two reasons why one might find it objectionable to allow the current value of the exchange rate in the monetary policy rule. The first is one familiar from recent literature on Taylor rules, namely, that data on price levels, which are required to compute a real exchange rate, are not available contemporaneously.

The second, and probably more important for the present study, is that it is questionable that the monetary authority can react to the exchange rate (equation (3.4)) as rapidly as the exchange rate reacts to monetary policy (one interpretation of equation (3.5)). Specifically, with a monetary rule in the form (3.4), it is possible for the monetary authority to achieve very low variability in the real exchange rate by setting  $\gamma_q$  very high relative to  $\gamma_\pi$  and  $\gamma_y$ . Of course, the same applies to inflation when  $\gamma_\pi$  is set very high relative to  $\gamma_y$  and  $\gamma_q$ , or to output when  $\gamma_y$  is set very high relative to  $\gamma_\pi$  and  $\gamma_q$ . But the implication may be tolerable for variables like inflation and output, in that these variables move relatively sluggishly in the intervals between monetary policy decisions. But it is difficult to argue that exchange rates move sluggishly between interest rate decisions. This suggests a bound on the Bank's ability to lower variability in exchange rates, a bound that may not be well captured in a model that (as just stated) allows interest rates to react to exchange rates as rapidly as exchange rates react to interest rates. So for this reason as well the results presented here likely understate the cost of achieving a given reduction in exchange rate volatility.

To return to the model: equations (3.2) -(3.5) are four equations in seven variables: the four New Zealand variables  $y_t$ ,  $\pi_t$ ,  $i_t$  and  $q_t$  and the three foreign variables  $y_t^*$ ,  $\pi_t^*$ , and  $i_t^*$ . To close the model requires three more equations. I do not attempt to model the three foreign

variables, but instead assume simply that they follow exogenous processes:

$$y_t^* = u_{yt}^*, \quad (3.6)$$

$$\pi_t^* = u_{\pi t}^*, \quad (3.7)$$

$$i_t^* = u_{it}^*. \quad (3.8)$$

## B The monetary policy rule and volatility trade-offs

Is there indeed a cost to stabilizing the real exchange rate? Might it be that setting  $\gamma_q > 0$  leads to greater stability in not only the real exchange rate but also in output, inflation and interest rates? These questions are prompted by the observation that optimal control typically requires a response to all state variables. So even if the Reserve Bank were interested only in inflation stability, it could in principle achieve greater inflation stability with an interest rate rule that responds not only to output and inflation but also to the real exchange rate. If the inflation stabilizing choice involves a positive  $\gamma_q$ , as assumed above, then the additional term in  $q_t$  will be beneficial rather than costly in terms of inflation volatility.

The aim of this paper is to use the data to supply an answer to the questions at the beginning of the preceding paragraph. But in simplified versions of the model, it is possible to answer the question analytically. And even in simplified versions, the answer is: it depends. Whether a monetary rule expanded to include a term  $\gamma q_t$  lessens or exacerbates volatility in other variables depends on variances of shocks and parameter values. Rather than exhaustively catalog the dependence exhaustively, let me illustrate with two examples. I worked through both examples in a simplified setting in which all shocks are i.i.d. (not plausible empirically, but tractably analytically). The aim is to distinguish the implications for volatility of the real

exchange rate  $q$ , output  $y$ , inflation  $\pi$  and the interest rate  $i$  of  $\gamma_q > 0$  vs.  $\gamma_q = 0$ .

Consider first the response to a positive shock to the risk premium  $u_{rt}$ . For both  $\gamma_q = 0$  and for  $\gamma_q > 0$ , the impact effect of this shock is for  $q_t$ ,  $y_t$ ,  $\pi_t$  and  $i_t$  to rise. This is intuitive: an increase in exchange rate risk causes the currency to depreciate, which in turn is associated with a rise in output and inflation. For both  $\gamma_q = 0$  and  $\gamma_q > 0$ , the monetary rule (3.4) causes interest rates to rise in response. But for  $\gamma_q > 0$ , interest rates respond more strongly. The stronger interest response means that, in equilibrium, the responses of  $q_t$ ,  $y_t$  and  $\pi_t$  are less for  $\gamma_q > 0$  than for  $\gamma_q = 0$ . Thus the rule with  $\gamma_q > 0$  lessens volatility of  $y$  and  $\pi$  (and of course  $q$ ) but increases volatility of  $i$ .

As a second example, consider instead the effect of positive IS shock  $u_{yt}$ , interpreted in Galí and Monacelli (2002) as an increase in productivity in the home country (New Zealand, in the present application) relative to abroad. For both  $\gamma_q = 0$  and for  $\gamma_q > 0$ ,  $q_t$  falls (appreciation),  $y_t$ ,  $\pi_t$  and  $i_t$  rise. The effects on  $q_t$ ,  $y_t$  and  $\pi_t$  are intuitively expected; the rise in  $i_t$  is necessary to maintain interest parity. The equilibrium increase in  $i_t$  is less for  $\gamma_q > 0$  than for  $\gamma_q = 0$  (because  $q_t$  falls). So volatility of  $i_t$  is lower for  $\gamma_q > 0$ . Consequently, volatility of  $y_t$  and  $\pi_t$  increases.

These two examples illustrate that one cannot tell a priori whether the addition of the term  $\gamma q_t$  to the monetary policy rule will lessen or increase volatility of other variables. For the effect on volatility of output, inflation and interest rates is directly opposite for the two shocks:

Volatility more (+) or less (-) for  $\gamma_q > 0$  than for  $\gamma_q = 0$ ?

	$i$	$y$	$\pi$	$q$
Risk premium shock	+	-	-	-
IS shock	-	+	+	-

The volatility of  $q$  is unambiguously lessened by including  $\gamma q_t$  in the monetary rule. The previous analysis illustrates that whether inclusion of the term lessens or increases volatility of other variables depends on the variances of the shocks and on model parameters. Even in an i.i.d. world, one would have to turn to data to decide the sign of the change in volatility of output, inflation and interest rates. (N.B.: the point of this subsection is illustration, and *not* development of a complete set of comparative statics results that could be used to interpret the empirical results. In presentation of results, I will have occasion to refer to this subsection only to remind the reader that real exchange rate smoothing may result in either increases or decreases of volatility of other variables.)

### C Model solution and identification

Define the (7x1) vectors  $X_t$  and  $U_t$  as

$$X_t \equiv (y_t, \pi_t, i_t, q_t, y_t^*, \pi_t^*, i_t^*)', U_t \equiv (u_{yt}, u_{\pi t}, u_{it}, u_{qt}, u_{yt}^*, u_{\pi t}^*, u_{it}^*)'. \quad (3.9)$$

With suitable definitions of (7x7) matrices  $A_1$  and  $A_0$ , the system (3.2)-(3.8) may be written as

$$A_1 E_t X_{t+1} + A_0 X_t = U_t. \quad (3.10)$$

The form of the solution to (3.10) depends on the nature of the shock process  $U_t$ . It is easily seen from (3.10), for example, that if  $U_t$  is i.i.d., then one solution is  $X_t$  i.i.d., with  $X_t = A_0^{-1} U_t$  and  $E_t X_{t+1} = 0$ . Clearly if this model is to pick up serial correlation that is manifest in aggregate data, the shock  $U_t$  will have to be serially correlated. An assumption that is technically manageable, and leads to serial correlation in  $X_t$  that is roughly what we see in the data, is that  $U_t$  follows a vector autoregression of order 1:

$$U_t = \Phi U_{t-1} + W_t. \quad (3.11)$$

Here,  $\Phi$  is the (7x7) matrix of autoregressive coefficients and  $W_t$  is the serially uncorrelated (7x1) vector of innovations in  $U_t$ .

It may be shown that (3.10) and (3.11) imply that  $X_t$  also follows a vector AR(1), say

$$X_t = F X_{t-1} + V_t. \quad (3.12)$$

Here,  $F$  depends on both the parameters of the model embedded in  $A_0$  and  $A_1$  (that is, on  $\alpha_{y^*}, \alpha_q, \beta_\pi, \beta_y, \gamma_\pi, \gamma_y, \gamma_q$ ) and the serial correlation parameters  $\Phi$ ; the serially uncorrelated shock  $V_t$  is a linear transformation of the shock vector  $W_t$ , with the parameters of the transformation again dependent on both the model parameters and  $\Phi$ . See the Appendix.

Clearly one can estimate  $F$  and the variance-covariance matrix of  $V_t$  by least squares. The strategy I take to identify the model is to assume values for the model parameters  $\alpha_{y^*}, \alpha_q, \beta_\pi, \beta_y, \gamma_\pi, \gamma_y, \gamma_q$ , and let the data tell me what values of the serial correlation matrix  $\Phi$  and the variance-covariance matrix of  $W_t$  are consistent with the estimates of  $F$  and  $E V_t V_t'$ . The values I impose on the model parameters are ones that are presumed to apply during the period of estimation. For example, I set the monetary policy parameter  $\gamma_q$  to zero on the thought that exchange rate smoothing has not played a detectable role in New Zealand monetary policy during my sample. At any rate, given the assumed values, one can map the estimates of  $F$  and of the variance-covariance matrix of  $V_t$  into estimates of  $\Phi$  and of the variance-covariance matrix of  $W_t$ . I allow  $\Phi$  to be unrestricted—that is, I do not attempt restrictions conventional in calibration work, such as univariate AR(1) processes for all shocks. My aim is to well-capture the dynamic behavior of the data, recognizing since all the dynamics are in the shocks I provide an accounting but not an economic explanation of the persistence in the data.

I also do not attempt to test for or impose unit roots or cointegrating relations (though this setup in principle allows  $\Phi$  to have eigenvalues with unit modulus). Rather, I take it as a priori reasonable that the variables here are stationary, though mean reversion might be quite slow.

To trace out the effects of alternative policies to smooth exchange rates, I vary  $\gamma_q$  in (3.4), holding fixed other model parameters and the serial correlation matrix  $\Phi$ . This allows me to solve for how  $F$  and  $V_t$  would have varied, had the Reserve Bank of New Zealand followed a policy with alternative parameters. (Formulas are in the Appendix.) To summarize variation in  $F$  and  $V_t$ , I report implied standard deviations around steady state of New Zealand interest rates, output, inflation and the real exchange rate. My presumption is that if the variations in policy are suitably modest, serial correlation parameters and steady state values can reasonably be held fixed while policy parameters are varied. And similarly for the model parameters in the IS and Phillips curves. By construction, variations in  $\gamma_q$  will not affect standard deviations of foreign variables, since  $y_t^*$ ,  $\pi_t^*$  and  $i_t^*$  by assumption evolve exogenously (equations (3.6)-(3.8)).

## 4 Empirical results

### A Data

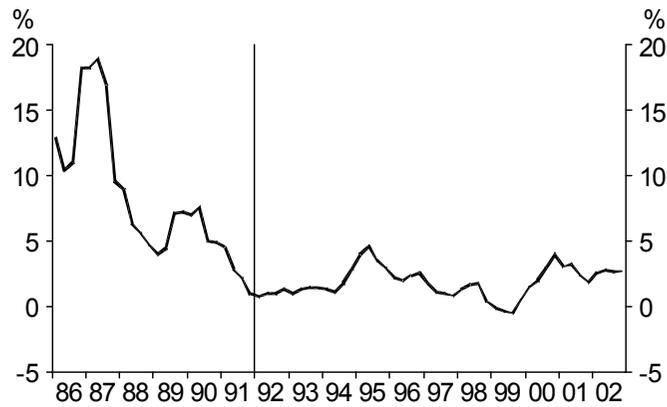
The data are quarterly, 1992:1-2002:3. Specific variables (names from the Bank's model or data series given in quotes when applicable) are:

- $y$  (NZ output gap: "gap"): the output gap
- $\pi$  (NZ inflation): headline CPI inflation
- $i$  (NZ interest rate: "r90d"): 90 day bank bill rate
- $q$  (real exchange rate: "z"): five country trade weighted index, constructed with GDP deflators
- $y^*$  (foreign output gap: "gaprow"): fourteen country trade weighted output gap
- $\pi^*$  (foreign inflation: "cpirow"): five country trade weighted CPI
- $i^*$  (foreign interest rate): five country trade weighted 90 day interest rates

In  $q$ ,  $\pi^*$  and  $i^*$ , the five countries are: Australia, United States, United Kingdom, Germany/Euro area and Japan. In  $y^*$ , the fourteen countries are: United States, Japan, Germany, France, United Kingdom, Italy, Canada, Australia, China, Hong Kong, Malaysia, Singapore, South Korea, and Taiwan.

Figure 2 plots the data from 1986-2002, with a vertical line denoting the start of the 1992 sample that I use. Note that the scale in the graphs is different; interest rates  $i$  and inflation  $\pi$  generally are higher in New Zealand than in the foreign country ( $i^*$  and  $\pi^*$ ). Note as well that the exchange rate series is plotted in levels, but appears in logs in the regressions.

Figure 2

NZ output gap -  $y$ NZ 90 day bank bill rate -  $i$ NZ inflation -  $\pi$ Foreign output gap -  $y^*$ 

Foreign inflation -  $\pi^*$ Foreign interest rate -  $i^*$ Real exchange rate -  $q$ 

The figure suggests that the data are generally slowly mean reverting. Indeed, one reason for beginning the sample in 1992 rather than 1986 was to avoid having to model the downward trend in New Zealand inflation  $\pi$  and interest rates  $i$ . But even in the post-1992 sample, the figures suggest that mean reversion has been more honored in the breach than in the observance for some variables, including in particular the foreign interest rate  $i^*$  and the New Zealand output gap  $y$ . The empirical work implicitly interprets the seeming trend in these variables as a reflection of a small sample, since this work assumes the data are stationary around a constant mean. Alternative treatments of trends would be desirable, but are not considered in this paper.

## B VAR Results

The estimates of the first order vector autoregression in  $(y_t, \pi_t, i_t, q_t, y_t^*, \pi_t^*, i_t^*)'$  is reported in Table 1. Predictably, lagged dependent variables typically earn coefficients that are numerically large and statistically significant, with the peculiar exceptions of inflation  $\pi_t$  and foreign inflation  $\pi_t^*$ . As one would expect, there is more evidence that foreign

variables Granger cause New Zealand variables than vice versa:  $\pi_t^*$  Granger causes  $\pi_t$  (t-value of  $0.37/0.11 \approx 3.4$ ) and  $i_t^*$  Granger causes  $i_t$  (t-value of  $0.32/0.12 \approx 2.7$ ). The New Zealand output gap  $y_t$  does Granger cause the foreign output gap (t-value of  $.09/.04 \approx 2.3$ ), perhaps a manifestation of what Bank economists have described to me as a tendency for the New Zealand output gap to have led the foreign output gap in recent years. The real exchange rate is statistically significant in the inflation and interest rate equations with numerically small coefficients of 0.05 and -0.02.

Most other coefficients are numerically small and statistically insignificant, suggesting a population value of zero or thereabouts; such zeroes would be rationalised in the model described in section 2 by a particular pattern of zeroes in the matrix  $\Phi$  (defined in 3.11).

(We do see some nonzero coefficients on variables other than own lags in the equations for the foreign variables  $y_t^*$ ,  $\pi_t^*$  and  $i_t^*$ . To clarify, such nonzero coefficients in the equations for foreign variables are rationalised by multivariate linkages between the various shocks. For example, let us use the estimates in Table 1 and the formulas in the Appendix to construct the equation for the exogenous process for foreign inflation  $\pi_t^*$  (defined in (3.7)). Then the result happens to be

$$u_{\pi}^* = 0.06u_{y,t-1} - 0.43u_{\pi,t-1} - 0.14u_{m,t-1} + 0.04u_{r,t-1} + 0.94u_{y,t-1}^* - 0.50u_{\pi,t-1}^* + 0.62u_{it}^* + w_{\pi}^*. \quad (4.1)$$

[Standard errors not available.] Unsurprisingly, the large coefficients on  $u_{y,t-1}^*$  and  $u_{it}^*$  are associated with large coefficients on  $y_{t-1}^*$  and  $i_{t-1}^*$  in the  $\pi_t^*$  equation reported in table 1.)

## C Effects of alternative monetary policy rules

Alternative values for the parameters  $\alpha_{y^*}$ ,  $\alpha_q$ ,  $\alpha_r$ ,  $\beta_{\pi}$ ,  $\beta_y$ ,  $\gamma_{\pi}$ ,  $\gamma_y$ , and  $\gamma_q$  are presented in table 1. My aim is to choose values more or less consistent with the structural models used at the RBNZ. My understanding is that one or more RBNZ models use a within-quarter elasticity of the New Zealand output gap with respect to world output of 1.5, with respect to the real exchange rate of about 0.15—hence the values for  $\alpha_{y^*}$  and  $\alpha_q$ . These models find it difficult to find a within-quarter effect of the interest rate, but there is some evidence that the elasticity may be as high as 0.5, so I set  $\alpha_r=0$  or  $\alpha_r=0.5$ . (Of course, even with  $\alpha_r=0$  monetary policy affects output: given time series for foreign variables  $y_t^*$ ,  $\pi_t^*$  and  $i_t^*$ , equations (3.2)-(3.5) determine the values of  $y_t$ ,  $\pi_t$ ,  $i_t$  and  $q_t$  simultaneously.) Setting  $\beta_{\pi}=0.99$  is consistent with quarterly calibration of the Calvo model, and, more generally, with a more or less long run vertical Phillips curve. The value  $\beta_y=0.1-0.2$  is consistent with my understanding of estimates of the short run slope of the Phillips curve in New Zealand. The monetary policy parameters ( $\gamma_{\pi}=1.5$ ,  $\gamma_y=0.5$  and  $\gamma_q=0$ ) seem, I am told, to do as good a job as any if New Zealand monetary policy is to be described via a Taylor rule (Drew and Plantier (2000) and Plantier and Scrimgeour (2002)).

Table 3 reports the results of varying the reaction coefficient on the real exchange rate in the monetary policy rule (3.4), repeated below for convenience:

$$i_t = \gamma_{\pi}\pi_t + \gamma_y y_t + \gamma_q q_t + u_{mt} \quad (3.4)$$

Panel B reports detailed results for parameter set A. As  $\gamma_q$  increases, the volatility of  $q$  of course falls. According to the estimates, if  $\gamma_q$  had been set to 0.07—a value consistent with some of the estimates for G7 countries in Clarida et al (1998)—the volatility of  $q$  would have fallen by 24 per cent, from 10.94 to 8.34. The price paid for a smoother exchange rate is an 11 per cent increase in output volatility (from 1.55 to 1.72), a 2 per cent increase in inflation volatility (from 1.13 to 1.16)

and a 18 per cent increase in interest rate volatility (from 1.58 to 1.98). (These are standard deviations centered around steady state values—around long run equilibrium real exchange rate, potential output, target inflation, and average interest rate.)

To facilitate interpretation, I present results for other specifications when  $\gamma_q$  has been set at a value that decreases volatility of  $q$  by about 25 per cent. Results for all three parameter sets are given in Table 3C; the results for parameter set A repeat what is in panel B. The results are broadly consistent across parameter sets.

The results may be contrasted with those of Brook and Stephens (2002) and Lam (2003). Brook and Stephens (2002) use the Reserve Bank's FPS model to consider the effect of adding to that model's reaction function a term that smooths real exchange rates. Brook and Stephens do not present standard deviations. But they interpret some impulse responses as suggesting that such smoothing would induce "significantly" greater volatility in inflation, while yielding less volatility in not only real exchange rates but perhaps interest rates as well.

Lam (2003) builds on Hunter (2001) in using a calibrated version of Svensson's (2000) open economy model. His estimates vary widely across specifications. In one set of results (top panel of Table 3 on p10 of Lam (2003)), reducing real exchange rate variability by 15 per cent causes the variability of other variables to skyrocket: the standard deviation of inflation more than triples, that of output increases by 50 per cent, that of the nominal interest rate doubles. (This panel only present results for a reductions in real exchange rate variability of 15 per cent or less.) In two other sets of results (middle and bottom panels of table 3 on p10 of Lam 2003), reducing real exchange rate variability by 25 per cent causes the standard deviations of inflation and output to increase by perhaps 5-20 per cent, while that of the interest rate falls by about 15-20 per cent. (Recall from the discussion in section 3 that even in this paper's model, an attempt to smooth exchange rates can lessen interest rate volatility as well, depending on the source of shocks.)

These results seem broadly consistent with those presented here, in the sense of suggesting a substantial volatility cost would be paid for smoothing real exchange rates. There is, however, an uncomfortably wide range of results (would interest rates be more or less variable if exchange rates were smoothed?). This underscores the imprecision of our understanding of the terms of the tradeoff between real exchange rate stability and stability of other variables.

## 5 Conclusions

The simple model used in this paper delivers rough estimates of the cost of using interest rate policy to smooth real exchange rate movements. The cost is measured in terms of increased volatility of inflation, output and interest rates. Specifically, it is estimated that a 25 per cent fall in the standard deviation of the real exchange rate can be accomplished at the price of increases in the standard deviations of output of about 10-15 per cent, of inflation volatility by about 0-15 per cent and of interest rate volatility by about 15-40 per cent.

The empirical work abstracts from well-known difficulties with uncovered interest parity, assuming that whatever shocks to interest parity occurred during the sample would have also occurred had the Bank been following an alternative interest rate policy. As well, the model is highly simplified and stylised, for example not distinguishing between domestic and overall inflation. Finally, the model makes assumptions that quite likely lead to an understatement of the cost to the RBNZ of exchange rate stabilisation. Specifically, the model assumes that the RBNZ knows the equilibrium value of the real exchange rate, and can react to exchange rate movements as quickly as the exchange rate reacts to interest rate movements. A priority for future research is relaxation of such assumptions. This would lead to higher costs associated with any given level of real exchange rate smoothing.

## Appendix

This appendix presents formulas linking the reduced form and structural equations. Those equations are repeated here for convenience:

(A.1)

Structural equations:  $A_1 E_t X_{t+1} + A_0 X_t = U_t, U_t = \Phi U_{t-1} + W_t, E W_t W_t' = \Omega_W,$

(A.2)

Reduced form equations:  $X_t = F X_{t-1} + V_t, E V_t V_t' = \Omega_V,$

To solve for reduced form parameter matrix  $F$  and shock  $V_t$  given the structural parameters  $A_1, A_0, \Phi$  and  $\Omega_W$ , guess a solution of the form

(A.3)

$X_t = D U_t,$

where  $D$  is a matrix to be determined. Upon using (A.3) and (A.3) led one period in (A.1), we obtain

(A.4)

$A_1 D \Phi + A_0 = I,$

which can be used to solve for  $D$ . Upon combining (A.2) and (A.3), we see that

(A.5)

$F = D \Phi D^{-1}, V_t = D W_t.$

To work from the reduced form to the structure: given  $A_1$  and  $A_0$ , whose values are imposed a priori, and least squares estimates  $\hat{F}$  and  $\hat{\Omega}_V$ , the solutions for  $\hat{\Phi}$  and  $\hat{\Omega}_W$  are:

(A.6)

$\hat{D} = (A_1 \hat{F} + A_0)^{-1}, \hat{\Phi} = \hat{D}^{-1} \hat{F} \hat{D}, \hat{\Omega}_W = \hat{D}^{-1} \hat{\Omega}_V \hat{D}^{-1}.$

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**Table 1: Estimates of vector autoregression**

Dependent variable	Regressors								Summary Statistics
	$y_{t-1}$	$\pi_{t-1}$	$i_{t-1}$	$q_{t-1}$	$y_{t-1}^*$	$\pi_{t-1}^*$	$i_{t-1}^*$	$R^{-2}$	s.e.
$y_t$	0.96 (0.09)	-0.19 (0.12)	-0.03 (0.11)	0.01 (0.01)	-0.24 (0.20)	0.01 (0.09)	-0.10 (0.13)	0.80	0.70
$\pi_t$	0.13 (0.12)	-0.21 (0.15)	0.12 (0.14)	0.05 (0.02)	0.25 (0.25)	0.37 (0.11)	-0.19 (0.16)	0.40	0.88
$i_t$	0.19 (0.09)	0.07 (0.11)	0.58 (0.10)	-0.02 (0.01)	0.28 (0.19)	0.05 (0.09)	0.32 (0.12)	0.82	0.67
$q_t$	-1.05 (0.33)	-0.05 (0.42)	-0.36 (0.39)	0.93 (0.05)	2.43 (0.72)	0.50 (0.33)	-0.13 (0.47)	0.95	2.53
$y_t^*$	0.09 (0.04)	0.04 (0.05)	-0.13 (0.05)	-0.01 (0.01)	0.78 (0.08)	-0.02 (0.04)	0.03 (0.05)	0.83	0.29
$\pi_t^*$	0.19 (0.14)	-0.33 (0.18)	-0.13 (0.17)	0.01 (0.02)	1.02 (0.30)	-0.31 (0.14)	0.54 (0.20)	0.35	1.07
$i_t^*$	0.01 (0.04)	0.16 (0.05)	-0.11 (0.05)	-0.01 (0.01)	0.00 (0.09)	0.05 (0.04)	0.96 (0.06)	0.91	0.32

Notes:

- 1 The data are quarterly, 1992:II-2002:III.
- 2 Variable definitions:  $y$ =output gap,  $i$ =interest rate,  $\pi$ =inflation,  $q$ =real exchange rate, “\*” denotes foreign variables.

**Table 2: Model parameters**

		$\alpha_{y^*}$	$\alpha_q$	$\alpha_r$	$\beta_\pi$	$\beta_y$	$\gamma_\pi$	$\gamma_y$	$\gamma_q$
A		1.5	0.15	0.0	.99	0.1	1.5	0.5	0.0
B		1.5	0.15	0.5	.99	0.1	1.5	0.5	0.0
C		1.5	0.15	0.0	.99	0.2	1.5	0.5	0.0

Notes:

1. For variables defined in notes to table 1, and with “ $u$ ” denoting a shock, the equations of the model are as follows. IS curve:  $y_t = \alpha_{y^*} y_t^* + \alpha_q q_t - \alpha_r (i_t - E_t \pi_{t+1}) + u_{yt}$ ; Phillips curve:  $\pi_t = \beta_\pi E_t \pi_{t+1} + \beta_y y_t + u_{\pi t}$ ; monetary policy:  $i_t = \gamma_\pi \pi_t + \gamma_y y_t + \gamma_q q_t + u_{mt}$ .

**Table 3:**  
**Standard deviations under alternative monetary policy parameters, 1992-2002**

**A Standard deviations under actual policy**

Standard deviation of			
$q$	$y$	$\pi$	$i$
10.94	1.55	1.13	1.58

**B Standard deviations under hypothetical alternative policies, parameter set A**

Standard deviation of					
Parameter					
Set	$\gamma_q$	$q$	$y$	$\pi$	$i$
A	0.00	10.94	1.55	1.13	1.58
	0.01	10.47	1.58	1.13	1.62
	0.05	8.95	1.68	1.14	1.78
	0.07	8.34	1.72	1.16	1.86
	0.10	7.56	1.78	1.19	1.98

**C Cost of lowering real exchange rate volatility by about 25 per cent, alternative parameter sets**

Percentage increase in standard deviation					
Parameter					
Set	$\gamma_q$	$q$	$y$	$\pi$	$i$
A	0.07	-24	11	218	
B	0.06	-26	14	3	16
C	0.08	-24	9	13	40

Notes:

- 1 Variable definitions are given in table 1.
- 2  $\gamma_q$  is the coefficient on the real exchange rate in the monetary rule (2.4),  $i_t = \gamma_\pi \pi_t + \gamma_y y_t + \gamma_q q_t + u_{mt}$ . The standard deviations in the  $\gamma_q=0$  line of panel B match those in panel A by construction, because it is assumed that during the estimation period, the rule was followed with  $\gamma_q=0$ .
- 3 The negative sign in the  $q$  column in panel 3C means that the volatility of  $q$  has fallen.