Open Mouth Operations*

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Abstract

This paper explains how central bank statements, rather than open market operations, can be used to implement monetary policy. In the extreme, policy instruments can be held constant, and yet interest rates will evolve along the path desired by the central bank. We show how the recent implementation of monetary policy in New Zealand works in this way. Using announcement data from New Zealand, we find that open mouth operations lead to large changes in interest rates across all maturities, and these changes cannot be explained by open market operations. Implications are drawn for monetary policy in other jurisdictions.

Key words: Monetary policy; Open market operations; Announcements; Liquidity effect

JEL Classification: E42, E52, E58

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1 Introduction

Recent New Zealand monetary policy experience highlights an important channel by which a central bank can affect interest rates, which is via statements on its desired path for the short-term interest rate. New Zealand is striking because these statements — which we call open mouth operations — were exclusively used to implement monetary policy during the period we study (January 1989 to September 1997), while the conventional tool of open market operations was used solely to target a level of daily settlement cash balances that was very rarely changed.[1]

In this paper, we develop a model of monetary policy implementation in New Zealand which shows how the Reserve Bank of New Zealand (RBNZ) is able to control interest rates without changing conventional policy instruments. We also provide empirical evidence about the relative magnitude of interest rate adjustments arising from open mouth operations versus open market operations.

Although our interest in this topic was stimulated by the New Zealand experience, we believe that many central banks currently conduct monetary policy with open mouth operations and have done so in the past. Incorporating this informational channel into historical studies of monetary policy in other countries may therefore resolve a number of empirical puzzles, including why the liquidity effect is so hard to identify, despite the apparent ease with which monetary authorities can move overnight rates by any desired amount.

In our view the liquidity effect exists, but its use is not required to change market rates.[2] Open mouth operations can be used for this purpose. They work because implicit in a statement is a credible threat that, if market rates do not move to the announced level, the liquidity effect will be exploited to ensure rates do move. We argue that the central bank's threat to dry up, or flood, the market for bank reserves is sufficient to tie down the path of the overnight interest rate, as if it was using open market operations to achieve this path.

To illustrate how this works in practice, we provide a model of monetary policy implementation in New Zealand which shows exactly how the RBNZ is able to control interest rates without changing policy instruments. The key features are that the RBNZ uses open market operations solely to target a constant nominal stock of settlement cash balances, keeps deviations from this target within a constant level of forecast accuracy (in nominal terms), and pays interest on settlement cash and charges a discount rate, both of which move automatically (according to a simple formula) with market rates. This set-up, together with data on daily liquidity shocks caused by unanticipated flows between the government and private sector, allows us to measure the impact of statements on interest rates, controlling for the level of liquidity in the market.

[1]Ignoring three changes in the target, which lasted for one day only and were not used to alter monetary conditions, and a technical change which took place along with other changes on February 22nd, 1991, there were only three episodes when the cash target was changed during our period of study: an increase in the target on September 25th, 1991, a decrease on January 6th, 1993 which was fully reversed by February 3rd, 1993, and two decreases in August 1995.

[2]Thus we do not see any inconsistency between the finding of Hamilton (1997) of a significant liquidity effect from the unanticipated flow of funds between the US Treasury and the private sector, and that of Leeper and Gordon (1992) who find that the relationship between the monetary base and interest rates is imprecisely estimated and highly unstable over time.

Using announcements by the RBNZ, reported by Reuters and codified by us, we find that interest rates (including the overnight rate) jump immediately after announcements in the direction desired by the Bank, and that interest rate changes are not caused by changes in open market operations.

In many countries, open mouth operations take the form of signals, which involve a change in the structure of open market operations for a single day. For instance, Feinman (1993) shows that different types of open market operations were chosen by the Federal Reserve during the period 1984–1990 to keep agents informed of the underlying stance of monetary policy. In a recent Bank for International Settlements survey on monetary policy implementation, Borio (1997, Chapter 5) details the signalling strategies used in fourteen different countries. Such signals were also part of the RBNZ's communication strategy up until the early 1990s. Using data on RBNZ signals, we show that signals lead to sizeable changes in interest rates, and again we show this can not be because of their liquidity impact. Thus for one country we are able to answer the question posed by Borio (p. 43):

> "*Supplying, say, a somewhat larger amount [of reserves] than that targeted by banks is expected to put downward pressure on the overnight rate. It is still an open question, however, how much of the downward pressure occurs through a mechanical liquidity effect or, more fundamentally, through the signal conveyed regarding policy intentions.*"

The remainder of the paper proceeds as follows. Section 2 presents our theory of threat-based monetary policy, discusses the role of open mouth operations in this theory, and explains how money market equilibrium can be maintained under this policy. Section 3 explains how this theory has been put into practice in New Zealand. The data and codification of open mouth operations is described in Section 4. Section 5 provides an empirical investigation of open mouth operations. Finally, Section 6 concludes.

2 Theory

The starting point for our analysis is a traditional approach to monetary policy implementation, in which the central bank uses open market operations to influence nominal short-term interest rates over time, so as to best achieve its inflation and output objectives. This section shows how the central bank can achieve the same outcome without having to use open market operations to influence rates. This relies on the central bank having a credible threat (which ties down the level of interest rates).

Our theory will apply under a variety of macro models. A key requirement is that the central bank can achieve its inflation and output objectives by treating a nominal interest rate as its instrument. The particular macro model one considers puts specific restrictions on the nature of the interest rate rules which the central bank can choose. In particular, restrictions will typically be required so that nominal variables are uniquely determined. However, we simply take it as given that some appropriately restricted interest rate rule exists.[3]

[3]Sargent and Wallace (1975) first showed, in a simple rational expectations model, that interest rate rules could

2.1 Threat-Based Monetary Policy

To present the basic model of threat-based monetary policy, we treat time as discrete, with the unit of measurement equalling one day. We denote by $R_{t,t+m}$ the m-day, continuously compounded, nominal interest rate prevailing on day t, and assume that the term structure of interest rates can be described by the expectations hypothesis

$$R_{t,t+m} = \frac{1}{m}\sum_{k=0}^{m-1} E_t[R_{t+k,t+k+1}], \quad m \geq 1.$$

We suppose that, in order to meet its objectives, the central bank has a preferred level of the T-day rate. The preferred level is the one which the central bank thinks is most appropriate of all those it could achieve using open market operations; it must satisfy any restrictions that the economy puts on permissible interest rate rules. We let $\hat{R}_{t,t+T}$ denote the preferred level of the T-day rate on day t. In general, this is generated by some stochastic process which depends on the central bank's objectives, the monetary transmission mechanism, and the various shocks which impact on the economy.

We define a central bank as acting traditionally if it uses open market operations in order to set the overnight rate in such a way that market expectations will then set the T-day rate at the preferred level. That is, the central bank uses open market operations to set the overnight rate equal to some level $\hat{R}_{t,t+1}$ on day t, for all t, in such a way that

$$\frac{1}{T}\sum_{k=0}^{T-1} E_t[\hat{R}_{t+k,t+k+1}] = \hat{R}_{t,t+T}. \tag{1}$$

There are infinitely many possible paths for the overnight rate consistent with the evolution of the preferred level of the T-day rate if $T > 1$. However, if current expectations of future preferred levels of the T-day rate converge sufficiently quickly as the forecast horizon increases, just one of these paths for the overnight rate is expected to converge in the future. (We prove this in Appendix A.) This is the obvious process to adopt for the overnight rate, since all others lead to non-convergent behavior in the distant future. We call this the central bank's preferred level of the overnight rate, $\hat{R}_{t,t+1}$. The central bank could, if it wished, use open market operations each day in order to achieve this level of the overnight rate. This would ensure the market delivered the preferred level of the T-day rate.

The central bank can achieve exactly the same outcome without having to use open market operations to influence rates. It need only threaten to use open market operations if markets allow the overnight rate to deviate from the central bank's preferred level. Suppose that the market delivers the wrong overnight rate on day t. Then the central bank will use open market operations on day $t+1$ in order to achieve an overnight rate equal to $R^*_{t+1,t+2} = 2R_{t,t+2} - \hat{R}_{t,t+1}$. In these circumstances, an investor buying a two-day bond on day t knows that the overnight

lead to an indeterminate price level. McCallum (1981) proved this not to be the case, provided the interest rate rules depend on some nominal variable. However, Kerr and King (1996) have shown, in a variety of macro models where aggregate demand depends on expected future output, even this restriction is not sufficient to uniquely determine a price level. They find that if the monetary authority responds to deviations of the inflation rate from a target path, the monetary authority must make the nominal interest rate change by more than one-for-one with changes in the inflation rate if a unique rational expectations equilibrium is to exist.

holding return will equal $2R_{t,t+2} - R^*_{t+1,t+2} = \hat{R}_{t,t+1}$. On day t, nobody will be willing to lend overnight at a rate less than $\hat{R}_{t,t+1}$ (since they could earn a higher return by holding a two-day bond overnight), while nobody will be willing to borrow overnight at a rate higher than $\hat{R}_{t,t+1}$ (since it would be cheaper to short a two-day bond overnight). Therefore, the overnight rate must equal the central bank's preferred level if the overnight market is to clear.

Carrying out this threat may be costly to the central bank. If it is forced to act, the central bank must deliver an overnight rate which differs from its own preferred level by

$$R^*_{t+1,t+2} - \hat{R}_{t+1,t+2} = 2R_{t,t+2} - \left(\hat{R}_{t,t+1} + \hat{R}_{t+1,t+2}\right).$$

However, providing the long-run benefit of earning a reputation for carrying out its threats dominates the short-run cost to the central bank of deviating from preferred interest rate levels, the central bank's commitment will not be doubted. It will never be required to actually carry out its threat.

The central bank's threat determines the overnight rate, but how are interest rates of other maturities determined? Any yield curve delivered by the market must be consistent with the expectations hypothesis, otherwise markets for bonds of some maturities will not clear. The central bank's threat ties down the current overnight rate. Expectations of this threat applying in the future tie down the expected level of the overnight rate in the future. The expectations hypothesis then ensures the other rates are the same as they would be under traditional monetary policy implementation.

It remains to explain how money market equilibrium can be maintained, despite interest rate changes which are not caused by open market operations. Clearly, if interest rates increase and the stock of outstanding cash and reserves remains the same, then there is more money in circulation than the private sector wants to hold. As households, through banks, deposit this excess liquidity with the monetary authority (or borrow less from the monetary authority), the monetary base will automatically contract. The extent to which this automatic mechanism is allowed to work depends on the specific details of monetary policy implementation. In practice, there will be limits on the extent to which open mouth operations can move interest rates without adjusting policy instruments. These limits depend on the extent to which the central bank automatically accommodates changes in demand for money at market rates. In Section 3, we examine the case of an almost completely accommodating central bank, the RBNZ.

2.2 Open Mouth Operations

We have shown above that if the central bank makes a credible threat to launch future open market operations, markets will deliver the T-day interest rate equal to the central bank's preferred level. This assumes that the central bank's preferred rate is public knowledge. Without knowing the central bank's preferred rate, the private sector may deliver the wrong rate. This deviation, denoted ζ_t, is costly from the central bank's perspective. By making an announcement (an open mouth operation), the central bank can ensure the private sector delivers the correct rate. In choosing when to make such statements, the central bank trades off the flow costs of deviations away from its preferred level with the costs of making announcements. Since large deviations in the T-day rate away from the central bank's preferred rate will be disproportionately more costly than small deviations, we assume a quadratic flow cost function. When it makes an announcement, the central bank announces a view of its preferred interest rate which is different from the interest rate delivered by the private sector. It always faces the risk that its reputation will suffer if this view is subsequently found to be inferior. This risk exists even for announcements of small desired changes in interest rates, as the direction of change might turn out to be wrong. Being able to correctly pick the appropriate direction of change is at least as important for the central bank's reputation as picking the appropriate magnitude of change. For this reason, we assume the central bank incurs a small fixed cost each time it makes an announcement.

More formally suppose the central bank chooses the timing of its announcements, and the information released, in order to minimize its total cost

$$E_t\left[\sum_{s=0}^{\infty} e^{-\kappa s}\zeta_t^2 + \text{PV(announcement costs)}\right],$$

where κ is the rate at which future flow costs are discounted and PV represents the present value of announcement costs. Because of the lump-sum nature of announcement costs, the central bank will not bother correcting small deviations between the market T-day rate and its preferred level. Instead, the central bank will wait until the deviation reaches a critically large level before releasing its private view. Since the cost incurred does not depend on the actual information released, the central bank will maximize the benefit it receives from making the announcement by releasing all its private information, resetting the deviation to zero. This policy is an example of the (S, s) policies studied by Scarf (1960) in the context of the inventory problem.

As central bank announcements release new information, each announcement should lead to a discrete jump in the level of interest rates in the desired direction. Moreover, using only publicly available information, announcements should be unpredictable — if the private sector could anticipate the released information, that information would already be incorporated in market rates. We test these implications in Section 5.

3 Monetary Policy Implementation in New Zealand

In this section, we describe the implementation of monetary policy in New Zealand as it has been operating over our period of study.[4] In doing so, we detail how threat-based monetary policy with open mouth operations has been put into practice. We formally model the implementation of monetary policy, showing how money market equilibrium is maintained with policy instruments held constant. This is possible despite large changes in interest rates, output, and prices. The model highlights the only ways in which the RBNZ can influence the overnight rate, and thus provides the basis for our estimation methodology in Section 5.

[4]More extensive details of monetary policy implementation in New Zealand are contained in Huxford and Reddell (1996). An international perspective on New Zealand's monetary policy arrangements is given by McCallum (1995).

3.1 Putting Theory into Practice

The recent monetary policy implementation in New Zealand provides an ideal case study of threat-based monetary policy and the use of open mouth operations. The RBNZ's preferred rate is the three-month bank-bill rate, which is largely determined by the RBNZ's inflation target.[5] Every three months it announces the desired path of this rate, conditional on the information it has available at that time. These monetary policy statements represent one type of open mouth operation. Subsequent to the release of its quarterly statements, the preferred level of interest rates will move away from the previously announced rate as new information comes to hand. If markets interpret this new information in the same way as the RBNZ, then there will be no need for an open mouth operation. However, between these quarterly statements, market rates sometimes move out of line with those desired by the central bank due to differences between the private sector's view of inflationary pressures and that of the RBNZ. When this deviation is sufficiently large, additional announcements are made. A normal response is an official comment from a senior Bank official or the Governor, broadcast to the financial markets over the electronic wire services, or a formal news release by the Governor. Up until the early 1990s, the RBNZ used the structure of open market operations, as well as statements, to signal the strength of its views. Typically, this involved a decision not to resell discounted Reserve Bank bills to the market, a decision to reject some bids for treasury bills offered to the market, or to inject funds only by purchasing a security outright rather than through repurchase arrangements. However, the liquidity impact of such signals was negligible. In the words of the Reserve Bank (Huxford and Reddell, 1996), "Typically, it was not the direct financial impact of the decision concerned that mattered, but rather the implied signal of central bank disquiet." The use of such formal signalling was discontinued by 1995. We will study the impact of statements with and without the use of formal signalling.

Implicit in the above arrangements is the threat that if the markets do not deliver rates that the RBNZ has announced it wants, then the Bank's threat will be carried out and policy instruments will be used to force the change. Due to the high credibility of the RBNZ, this threat is seldom needed. The experience of New Zealand indicates only two times over the last nine years when the central bank's commitment was tested. In both cases, the market called into question the RBNZ's credibility and the RBNZ responded by changing its settlement cash target. For instance, after repeated warnings in the last two weeks of 1992 that the depreciation in the New Zealand dollar should be matched by firming interest rates, and with no such firming delivered by the market, the Reserve Bank cut the cash target from 20 million dollars to zero on January 7th, 1993. The deputy governor at the time, Peter Nicholl, said "This action should unequivocally illustrate our determination." Rates quickly responded[6] and the cash rate was returned to its original level by February 3rd, 1993.

[5] New Zealand's inflation targeting approach is described and explained in Archer (1997) and Walsh (1995).

[6] On the same day, the cash rate increased 500 basis points, the one-month rate increased 313 basis points, and the three-month rate increased 91 basis points.

3.2 A Model of the Market for Settlement Cash

The key features of the Reserve Bank's implementation procedures are that the RBNZ uses open market operations solely to target a constant nominal stock of settlement cash balances, keeps deviations from this target within a constant level of forecast accuracy (in nominal terms), and pays interest on settlement cash and charges a discount rate, both of which move automatically (according to a simple formula) with market rates. In this section, we show that these features ensure banks are willing to hold the constant stock of settlement cash regardless of the level of interest rates, output or prices, and that the money supply remains endogenous to movements in the nominal demand for money by households. Money market equilibrium is maintained at all times, despite interest rates being changed by statements rather than open market operations.

As with a number of countries, New Zealand has no reserve requirements. Without reserve requirements, the demand for reserves is essentially a demand for settlement cash balances (commercial bank deposits held with the RBNZ to be used for the settlement of payments). The RBNZ fixes a settlement cash target, which it attempts to meet by the end of each banking day using its daily open market operation. The role of this approach is to neutralize disturbances to liquidity caused by anticipated flows between the government and the private sector. Each day there is a net flow of funds between the government and private banks. This arises primarily from payments from the government to the private sector (government expenditure) and payments from the private sector to the government (tax revenue). These payments are made and received in settlement cash, through the banking system. We assume the net flow of funds can be described by the stochastic process

$$P_t Y_t (w_t \mu_t + (1 - w_t)\varepsilon_{t+1}),$$

where μ_t represents the predicted component of this flow and ε_{t+1} is the unpredicted component; that is, $E_t(\varepsilon_{t+1}) = 0$. We assume ε_{t+1} has a density function f and a cumulative distribution function F. The weight w_t on the predicted component depends on the forecasting effort of the central bank. Each morning, the RBNZ forecasts the net flow of funds between the government and the banking sector in the end of that day's settlement process. The magnitude of the net flow of funds is assumed to be proportional to nominal GDP ($P_t Y_t$). Each day there is also a flow of funds between households and the banking sector. Households are assumed to want to hold cash $M_t^d = P_t Y_t e^{-\theta R_t}$, where $R_t \equiv R_{t,t+1}$, so that the banking system gets an injection of cash from households (convertible to settlement cash) each day of

$$-\left(P_t Y_t e^{-\theta R_t} - P_{t-1} Y_{t-1} e^{-\theta R_{t-1}}\right).$$

If the banking system has settlement cash S_t at the beginning of day t, it will have S_{t+1} at the end of day t (before settlement), where

$$S_{t+1} = S_t + P_t Y_t (w_t \mu_t + (1 - w_t)\varepsilon_{t+1}) - \left(P_t Y_t e^{-\theta R_t} - P_{t-1} Y_{t-1} e^{-\theta R_{t-1}}\right) + v_t.$$

The term v_t represents the central bank's open market operation, which is carried out mid-morning and is designed so that the settlement cash held at the start of the next day is expected to be equal to the Reserve Bank's settlement cash target S_t^*. That is, v_t is chosen so that $E_t S_{t+1} = S_t^*$. This implies

$$S_{t+1} = S_t^* + P_t Y_t (1 - w_t)\varepsilon_{t+1}.$$

Notice the difference between the end-of-day settlement cash balances and the target level corresponds to the unpredicted component of the net flow of funds, $P_t Y_t(1 - w_t)\varepsilon_{t+1}$. For this reason we refer to this term as the Reserve Bank's settlement cash forecast error. A positive settlement cash forecast error corresponds to an injection of cash into the settlement process. A negative settlement cash forecast error corresponds to an equivalent withdrawal of cash. We will use this fact to explore the role of liquidity shocks on interest rates in Section 5.

We assume there are N identical banks. At the end of each day they must settle their accounts with the government with settlement cash; no overdraft facilities are allowed. Settlement cash earns a rate R_t^{SC}, which is below the market interest rate. If a bank falls short of settlement cash to settle its accounts it must discount Reserve Bank bills to attain additional settlement cash. However, doing so is expensive, as the discount rate R_t^D is above market rates. The settlement cash an individual bank will be holding at the end of the banking day (before settlement) will be

$$\frac{S_t^* + P_t Y_t (1 - w_t)\varepsilon_{t+1}}{N} + d_t, \tag{2}$$

where d_t is the amount the bank borrows in the inter-bank market to hold as additional settlement cash. If (2) is negative, the bank will have to discount Reserve Bank bills to settle its account; if (2) is positive, the bank will earn interest from the RBNZ on its holding of settlement cash. The expected dollar gain for an individual bank from borrowing d_t dollars in the inter-bank market at the daily rate of R_t is

$$E_t \pi_{t+1} = E_t V_{t+1}(d_t) - E_t V_{t+1}(0) - (1 + R_t) d_t, \tag{3}$$

where

$$\begin{aligned} E_t V_{t+1}(d_t) \;&=\; \int_{-\infty}^{\bar{\epsilon}} (1 + R_t^D) \left(\frac{S_t^* + P_t Y_t (1 - w_t)\varepsilon_{t+1}}{N} + d_t \right) f(\varepsilon_{t+1}) d\varepsilon_{t+1} \\ &\quad + \int_{\bar{\epsilon}}^{\infty} (1 + R_t^{SC}) \left(\frac{S_t^* + P_t Y_t (1 - w_t)\varepsilon_{t+1}}{N} + d_t \right) f(\varepsilon_{t+1}) d\varepsilon_{t+1} \end{aligned}$$

and $\bar{\epsilon} = (-N d_t - S_t^*)/(P_t Y_t (1 - w_t))$. The first integral term represents the cost to a bank when it has to discount Reserve Bank bills because it is holding insufficient settlement cash. The second integral term represents the return to a bank when it does not have to discount Reserve Bank bills, since it then receives interest on positive balances. Given the interest rates in the market, the bank is assumed to choose d_t to maximize (3). The first order condition is then

$$F\left(\frac{-N d_t^* - S_t^*}{P_t Y_t (1 - w_t)} \right) = \frac{R_t - R_t^{SC}}{R_t^D - R_t^{SC}}, \tag{4}$$

where d_t^* represents the solution. Recall that $R_t^{SC} < R_t < R_t^D$ and that F is a cumulative distribution function, so d_t^* is well-defined.

We first show how the monetary authority can obtain the interest rate it requires through what amounts to a standard use of open market operations. It simply adjusts S_t^* so that[7]

$$S_t^* = -P_t Y_t (1 - w_t) F^{-1} \left(\frac{R_t - R_t^{SC}}{R_t^D - R_t^{SC}} \right). \tag{5}$$

This ensures the equilibrium condition $d_t^* = 0$ is met; it is not possible for all banks to be net lenders or net borrowers in the inter-bank market.[8] The left hand side of (5) is interpretable as the stock of settlement cash, and the right hand side as nominal demand for settlement cash. With a constant level of forecasting effort ($w_t = w$), it is easy to show that the nominal demand for settlement cash is increasing in prices and nominal output, and decreasing in nominal interest rates. An increase in the settlement cash target, for a given level of prices and output, will lower the overnight interest rate. This represents a standard view of monetary policy implementation.

We now show that equilibrium can still be maintained even if the settlement cash target remains constant ($S_t^* = S^*$). This requires a mechanism to keep the demand for holding nominal settlement cash balances equal to the constant nominal settlement cash target. This mechanism consists of two components. The first is a rule for keeping deviations from the settlement cash target within a constant level of forecast accuracy (in nominal terms). This is done by choosing its forecasting effort w_t so that the distribution of its nominal forecast error $P_t Y_t (1 - w_t) \varepsilon_{t+1}$ remains constant; that is,

$$w_t = 1 - \frac{\phi}{P_t Y_t}, \tag{6}$$

for some constant ϕ. In practice, the rule the RBNZ follows is to try to achieve a forecast error of 20 million dollars or less, in four days out of five. Note that this rule is indeed expressed in nominal terms. The second component to the automatic mechanism is to pay interest on settlement cash and charge a discount rate which both move automatically with market rates. This is achieved by setting R_t^{SC} and R_t^D mechanically, using the rule

$$R_t^{SC} = \frac{23}{29} R_{t,t+1} + \frac{6}{29} R_{t,t+30} - \rho^{SC}, \tag{7}$$

$$R_t^D = \frac{30 - \tau}{29} R_{t,t+1} + \frac{\tau - 1}{29} R_{t,t+30} + \tau \rho^D + (\tau - 1) \rho^O, \tag{8}$$

where ρ^{SC} is the penalty margin on settlement cash,[9] ρ^D is the discount margin on discounting Reserve Bank bills, ρ^O is the additional cost of repurchasing the discounted Reserve Bank bills the following day,[10] and τ is the average maturity of the Reserve Bank bills discounted.[11]

[7] To ensure $R_t^{SC} < R_t < R_t^D$, it may also require the occasional adjustment in R_t^{SC} and R_t^D. This is again consistent with traditional monetary policy, where the return on settlement cash is zero and the discount rate is occasionally adjusted to bring it into line with movements in market rates.

[8] Given that the monetary authority automatically reacts to any change in demand for money from households by conducting open market operations to offset any flows between households and banks, this condition will also ensure the money market is in equilibrium at all times.

[9] The rate paid on a bank's settlement cash holdings is 300 basis points below the seven-day rate. The seven-day rate is calculated as a simple weighted average of the market one-day and thirty-day rates. The 300 basis point penalty margin on settlement cash was not used to alter interest rates. The only change in margins during our study period took place when the penalty margin on settlement cash was changed for technical reasons on December 18th, 1991. We explain such technical changes below.

[10] Whenever Reserve Bank bills are discounted, they are offered back to the market the following day.

[11] Reserve Bank bills (bills of 63 days maturity, issued by the RBNZ in twice-weekly tenders each of 70 million

Substituting (6), (7), and (8) into (4), we get

$$F\left(\frac{-(Nd_t^* + S^*)}{\phi}\right) = \frac{\frac{6}{29}(R_t - R_{t,t+30}) + \rho^{SC}}{\frac{7-\tau}{29}(R_t - R_{t,t+30}) + \tau\rho^D + (\tau - 1)\rho^O + \rho^{SC}}.$$

Provided the RBNZ keeps policy instruments constant at levels satisfying

$$F\left(\frac{-S^*}{\phi}\right) = \frac{\rho^{SC}}{\tau\rho^D + (\tau - 1)\rho^O + \rho^{SC}}, \tag{9}$$

the equilibrium $d_t^* = 0$ holds whenever $R_t = R_{t,t+30}$.[12] This suggests that, despite the level of interest rates varying substantially over time, a bank has no incentive to borrow in the inter-bank market to hold additional settlement cash or lend in the inter-bank market to reduce its holdings of settlement cash. In this sense, the condition (9) pins down the combinations of settlement cash target (S^*), the distribution of forecast errors (F), the value of τ and the discount and penalty margins, ρ^D and ρ^{SC}, which are consistent with money market equilbrium for any market interest rates. Provided the central bank sets these parameters correctly, it can hold them constant over time.

With a positive rate of inflation and output growth, (6) implies the monetary authority's forecasting effort must be continually improving. In the case of inflation, this lowers the real demand for settlement cash to match the decline in real settlement balances (S^*/P_t). In the case of output growth, this lowers the real demand for settlement cash to offset the increase in demand from higher output levels.[13] Because this improvement in forecasting may not be possible beyond some point, the Bank may be forced periodically to adjust some or all of its policy instruments in a one-off measure to lower the level of accuracy required in its forecasts, and thus allow the nominal distribution of forecast errors to remain constant. These one-off changes have the interpretation of technical adjustments in policy instruments. They imply no change in the stance of monetary policy. This is consistent with the commentary surrounding the two technical changes which occurred during our sample period.

With such a mechanism in place, together with a credible threat, it is possible for the central bank to oversee large changes in interest rates without resorting to formal policy changes. Figure 1 displays the nominal three-month interest rate in New Zealand (measured as the quarterly average) and the underlying inflation rate[14] (measured as an annual percentage change) from March 1989 to September 1997.

dollars) can be discounted back to the RBNZ for settlement cash if they have 28 or fewer days remaining to maturity. However, Reserve Bank bills are discounted at a rate above the market yield for equivalent maturity short-term securities (calculated as a weighted average of the one-day and thirty-day market rates). The difference between the discount rate and the market rate, called the discount margin and equal to 90 basis points, applies to the entire term to maturity of the bill discounted. Discounting is thus an expensive way for banks to raise settlement cash. The discount margin is seldom changed. Each of the four changes in the nearly nine year period we study corresponds to a simultaneous change in the target for settlement cash balances.

[12] In Appendix B we show that this last condition is not needed, provided there are some small transaction costs in lending or borrowing in the inter-bank market.

[13] Note that any change in the demand for money by households is automatically met with a change in the supply of money, through open market operations offsetting flows between households and banks.

[14] The measured underlying inflation rate is the measure of inflation that the RBNZ was targeting over this period. Unlike New Zealand's headline consumer price inflation rate, it excludes mortgage interest charges.

Figure 1 goes here

Despite the lack of formal policy changes, there was a period of mostly falling interest rates from early 1991 to early 1994, a subsequent period of interest rate firming till mid-1996, and a reversal with falling interest rates till the end of our sample in 1997.

According to this model of monetary policy implementation, the only ways the RBNZ can alter the level of liquidity in the market to affect interest rates are to change one of its policy instruments or make deliberate settlement cash forecast errors. Using data on the RBNZ's daily settlement cash forecast errors, and looking at cases where policy instruments were held constant, we are able to show that changes in interest rates result from open mouth operations, not from liquidity effects. We first detail the data used to do this.

4 Data

Our sample period is January 1st, 1989 through September 30th, 1997. We chose to start our sample in 1989 since this is the year the Reserve Bank Act was introduced, under which the Bank was mandated to target "price stability." All financial data was obtained from the RBNZ. For short maturities we used bank bill rates rather than T-bill rates, since we could not obtain daily data on T-bill rates until February 1997. There are three reasons why we think this is not a problem. Firstly, these are the rates the RBNZ refers to in its statements. Furthermore, the market for bank bills is much more liquid than the market for T-bills. Finally, bank bill rates command a premium of around 20 basis points over T-bill rates, and this low premium is quite stable over time, reflecting the consistently high credit rating of the banks that issue these bills.[15] Bank bills are discount instruments which pay no coupon. For the whole sample, we obtained the overnight cash rate ($R1D$), the one-month bank bill rate ($R1M$), the three-month bank bill rate ($R3M$), the five-year government bond yield ($R5Y$) and the trade-weighted index (TWI), which measures the foreign value of the New Zealand dollar based on a basket of New Zealand's five largest trading partners. We define the monetary conditions index to be $MCI = R3M + 50\ln(TWI)$, based on the RBNZ's rule that a two percent appreciation in TWI is equivalent to a 100 basis point increase in $R3M$. There were 2149 observations left on each variable after deleting missing observations for weekends and holidays. All rates are measured daily at 11am.[16] Daily settlement cash forecast errors of the RBNZ, denoted FE, were also obtained from the RBNZ for the same period.

To construct the dummy variable for open mouth operations, we obtained all articles from Reuters which contained the words "Reserve Bank" and either "Monetary" or "Brash."[17] We used several alternative search strings, including the names of other RBNZ officials, to cross-check these were appropriate search items. Using these we were only able to identify a few additional statements, which we in turn added. In addition, the articles were cross-checked with

[15] For instance, using our 1997 daily data, the average premium on $R1M$ is 21.75 basis points (standard deviation 1.82 basis points) and on $R3M$ is 21.80 basis points (standard deviation 2.28 basis points).

[16] We also obtained hourly data for $R1D$, $R1M$, $R3M$, $R5Y$, and TWI, from August 22nd, 1996 to September 30th, 1997.

[17] Donald Brash, governor of the RBNZ throughout the period, made a large number of the statements.

the chronology of events contained within the three major RBNZ publications — *Monetary Policy Statement*, *Economic Projections* and *Reserve Bank Bulletin*. No new articles were found from these sources. Using all the articles found we deleted articles which did not contain references to monetary conditions, where the comments made were judged to be neutral or ambiguous with regard to monetary conditions, or where formal policy instruments were changed (for example, changing the settlement cash target). The remaining articles were trimmed to highlight the relevant RBNZ statements. These observations are coded $STATEMENT = 1$, as opposed to all other observations which are coded $STATEMENT = 0$.[18]

Each statement is then coded according to the dummy variables $TIGHTEN$, $SIGNAL$ and $SURPRISE$. These are defined as zero except as follows:

- $TIGHTEN = 1$ if the statement suggests the RBNZ desires tighter monetary conditions. $TIGHTEN = -1$ if the statement suggests the RBNZ desires looser monetary conditions.
- $SIGNAL = 1$ if the statement is accompanied by a formal signal from the RBNZ (a change in the structure of that day's open market operation, as described in Section 3.1).
- $SURPRISE = 1$ if the statement is a surprise statement, as opposed to part of a formal release of information. Formal statements (*Monetary Policy Statements* and *Economic Projections*) are released at three-monthly intervals at dates which are known in advance and are coded as $SURPRISE = -1$. The remaining statements are from speeches, the dates of which are known in advance, and are coded $SURPRISE = 0$.

For most of our empirical work, we concentrate on the impact of surprise statements. We therefore define

$$A = \begin{cases} 1 & \text{if } STATEMENT = 1,\ TIGHTEN = 1, \text{ and } SURPRISE = 1, \\ -1 & \text{if } STATEMENT = 1,\ TIGHTEN = -1, \text{ and } SURPRISE = 1, \\ 0 & \text{otherwise.} \end{cases}$$

We use this dummy variable as our standard measure of open mouth operations, referring to $A = 1$ as a tightening announcement and $A = -1$ as a loosening announcement.

Statements were made on 106 days during our sample period. Of these, 66 statements indicated a need for tighter monetary conditions and 40 for looser conditions, 64 were genuine surprise statements ($SURPRISE = 1$), 18 were speeches ($SURPRISE = 0$) and the remaining 24 were part of regular information releases ($SURPRISE = -1$). In total, 15 announcements were accompanied by signals, with 13 of these being surprise announcements. The variable A took the value 1 on 37 days and -1 on 27 days.

5 Empirical Investigation of Open Mouth Operations

In this section, we explore whether open mouth operations are predictable, as well as their implications for interest rates and exchange rates.

[18] These articles, the authors' codification, and all financial data are available from the authors upon request.

5.1 Are Open Mouth Operations Predictable?

An implication of our theory is that an open mouth operation that occurs between three-monthly releases represents a surprise to the private sector. If the market already knows that the RBNZ wants a change in monetary conditions, the market will already have delivered it. We test this implication by seeing whether tightening and loosening announcements are predictable. To do this we employ an ordered probit model, using information on lagged announcements and financial variables to try to best predict announcements:

$$A_t = \begin{cases} -1 & \text{if } b(L)\Delta X_{t-1} + c(L)A_{t-1} + \xi_t < a_1, \\ 0 & \text{if } a_1 < b(L)\Delta X_{t-1} + c(L)A_{t-1} + \xi_t < a_2, \\ 1 & \text{if } a_2 < b(L)\Delta X_{t-1} + c(L)A_{t-1} + \xi_t, \end{cases}$$

where X_{t-1} represents a lagged interest rate, exchange rate or settlement cash forecast error, ξ_t is normally distributed and $b(L)$ and $c(L)$ are polynomials in the lag operator:

$$b(L) = \sum_{j=0}^{m} b_j L^j, \quad c(L) = \sum_{j=0}^{n} c_j L^j.$$

We estimate the model by maximum likelihood and conduct a Wald test that the coefficients on the lagged variables are jointly insignificant ($\mathrm{H}_0 : b_0 = 0, \ldots, b_m = 0, c_0 = 0, \ldots, c_n = 0$). We also calculate the change in estimated probability of an announcement following various events.

The number of lags m and n is chosen by optimizing over all possible lag lengths (with up to ten lags) using the Schwarz Bayesian Information Criterion. We consider seven different models, each corresponding to a different measure of X_{t-1}. In all seven cases, optimizing this criterion implies including no lags in the model. In itself, this is suggestive that lagged variables do not help predict announcements. To formally test this we consider the case that one lag of each variable is included in the model. Table 1 presents the results. Only in the models which include the exchange rate (the fifth and sixth rows of Table 1) is past information significant at the 5% level in predicting announcements.[19]

Table 1 goes here

From the estimated likelihood function, we calculate the change in probability of a tightening announcement following a tightening announcement the previous day, $\Pr[A_t = 1|A_{t-1} = 1] - \Pr[A_t = 1|A_{t-1} = 0]$, which we denote $\Delta \Pr|(A_{t-1} = 1)$. We also calculate the change in probability of a tightening announcement following a 25 basis point rise in an interest rate, exchange rate or the monetary conditions index the previous day, or a 25 million dollar RBNZ settlement cash forecast error the previous day. We denote this $\Delta \Pr|(\Delta X_{t-1} = 25)$. In calculating these probability changes we take the mean probability change over all observations. In each case, the impact on the probability of announcements today is negligible. A tightening announcement yesterday lowers the estimated probability of a tightening announcement today

[19] There is some evidence that over time markets learnt of this correlation between exchange rates and future announcements, thus eliminating it. We repeated the above test of predictability for the second half of the sample, and found p-values of 0.3844, 0.4492, 0.4303, 0.3081, 0.1717, 0.1889 and 0.2696 for the models with $R1D$, $R1M$, $R3M$, $R5Y$, TWI, MCI and FE respectively.

by slightly over half of one percent. Similarly, a 25 basis point rise in any of the financial rates lowers the estimated probability of a tightening announcement today by no more than half of one percent. Even though there is some evidence of statistical predictability of announcements when lagged exchange rates are included (at least in the earlier part of the sample), it is clear from these experiments that the magnitude of this effect is negligible.

5.2 The Impact of Open Mouth Operations

In what follows we study the dynamic response of interest rates, exchange rates and the daily settlement cash forecast error of the RBNZ, following open mouth operations. We use a structural VAR approach, taking announcements as exogenous shocks. Our structural model has the following form:

$$\begin{aligned} \Delta X_t &= \alpha + \alpha_X(L)\Delta X_{t-1} + \alpha_{FE}(L)FE_t + \alpha_A(L)A_t + \alpha_D\,\bar{D}_t + u_{1t} \\ FE_t &= \beta + \beta_X(L)\Delta X_{t-1} + \beta_{FE}(L)FE_{t-1} + \beta_A(L)A_t + \beta_D\,\bar{D}_t + u_{2t} \end{aligned} \tag{10}$$

where

$$\begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_{11} & 0 \\ 0 & \sigma_{22} \end{pmatrix}\right],$$

$$\alpha_y(L) = \sum_{j=0}^{p_y} \alpha_{y,j}L^j, \quad \beta_y(L) = \sum_{j=0}^{q_y} \beta_{y,j}L^j, \quad \text{for } y \in \{X, FE, A\},$$

L^j is the standard lag operator, X_t is an interest rate or exchange rate, FE_t is the RBNZ settlement cash forecast error, A_t is our measure of announcements and $\bar{D}_t$ is a vector of dummy variables for the days of the week as well as the day before and the day after each public holiday. Two types of identifying assumptions are made in (10).

Firstly, announcements do not depend on lagged or contemporaneous values of interest rates, exchange rates, or the RBNZ forecast error. This is consistent with our theory of open mouth operations. An alternative description would involve announcements depending on current or lagged monetary conditions. That is, when monetary conditions loosen the RBNZ releases a tightening statement. We have already shown in the previous section that announcements do not depend in an important way on lagged financial data. A sudden loosening of monetary conditions, however, might lead to a tightening statement within the same day. In this case we would expect a tightening announcement to be contemporaneously correlated with a fall in the interest rate. This is not what we find. Additional support for our identifying assumption arises from using hourly data. We have hourly data on interest rates and exchange rates from August 22nd, 1996 to September 30th, 1997. Figure 2 shows the monetary conditions index before and after each statement, for all nine statements in this period (there were five surprise announcements ($SURPRISE = 1$), as well as four statements made as part of the regular three-monthly releases of information ($SURPRISE = -1$)).

Figure 2 goes here

Up until the time of each statement, there is no obvious movement in monetary conditions. However, immediately following each statement, the monetary conditions index moves in the direction predicted by our theory.[20]

The second assumption is that the daily settlement cash forecast error does not depend on contemporaneous changes in interest rates or exchange rates, although it can depend on lagged interest rates or exchange rates. Forecasts are made using past information. The actual realization of the forecast error will depend on current net flows between the government and the private sector. It seems unlikely that the same day's interest rate or exchange rate could alter the size of these flows which are determined in advance. In any case, this assumption turns out not to matter in the sense that reversing this timing assumption does not materially alter the estimated announcement effects.

For each interest rate and exchange rate series ΔX_t, optimal lag lengths are chosen for $\alpha_X(L)$ and $\beta_X(L)$, together with the optimal lag lengths for $\alpha_{FE}(L)$, $\alpha_A(L)$, $\beta_{FE}(L)$ and $\beta_A(L)$, with a maximum of ten lags on each variable considered. The Schwarz Bayesian Information Criterion is used. We consider three different sample periods as well as two different definitions of announcements, as detailed below. Thus, for each equation we estimate six different regressions. For each of these, we consider one thousand different lag length permutations to choose the optimal lag lengths in the VAR. We find optimal lag structures are one lag of each variable for all equations estimated, except the equation for $\Delta R1D_t$ (which requires at most eight lags of $\Delta R1D_t$), the equation for $\Delta R1M_t$ (which requires at most ten lags of $\Delta R1M_t$), and the equation for $\Delta R3M_t$ (which requires at most three lags of $\Delta R3M_t$). The reduced form models are estimated using the SUR estimator, and a Choleski decomposition is used to recover the structural parameters. The dynamic impact of announcements and shocks to the forecast error is then calculated from the estimated structural model.

Figure 3 goes here

Figure 3 contains the impulse response functions of the one-day rate, the one-month rate, and the three-month rate to a surprise tightening announcement, using the whole sample period, with 95% approximate confidence intervals calculated using a Monte Carlo simulation with 1000 draws. A typical surprise tightening announcement leads to a 37 basis point jump in the one-day rate, an 18 basis point jump in the one-month rate, and a 14 basis point jump in the three-month rate, all after one day. Interest rates are measured at 11am, while announcements are made throughout the day, so the correct measure of the contemporaneous impact of announcements is the impact after one day. After three further days, the total impact is around 20 basis points on the one-day rate, 15 basis points on the one-month rate, and 13 basis points on the three-month rate. All three rates remain around these levels in subsequent days. The decline in these interest rates from day one to day four is the result of negative autocorrelation in the interest rate series, captured in the estimated model. For the five-year bond rate, the exchange rate and the monetary conditions index, because of the simpler lag structure (one lag of each variable), the impulse response is essentially flat after day one. Table 2 reports the results for all six rates, using two definitions of announcements (only surprise statements, as well as all types of

[20]The responses of individual interest rates and the TWI exchange rate exhibit similar behavior.

statements), for three different sample periods (whole sample, first half of sample, and second half of sample). The results show that announcement effects are broadly consistent over different sample periods, interest rate maturities and announcement types. For brevity, Table 2 reports only the impact on rates one day after the announcement.[21]

Table 2 goes here

How can we explain large jumps in interest rates and exchange rates immediately following an RBNZ announcement? A conventional explanation would be that tightening announcements contain new information implying higher current or future inflation, and thus a revision upwards by the market in nominal interest rates.[22] In this case, the New Zealand dollar should depreciate with the announcement. Another interpretation of announcements is that they signal a change in the preferences of the central bank, a tightening implying the central bank wants to get tough on inflation. In this case, long-term interest rates should fall as future inflation is now expected to be lower.

We find neither of these results. According to our theory of open mouth operations, announcements play quite a different role. The RBNZ's inflation target ties down fairly precisely the RBNZ's preferences over future inflation as well as long-term inflation outcomes. Instead, announcements reveal the RBNZ's interpretation of the monetary conditions that are needed to keep future inflation on target. In this case, tightening announcements raise both short-term and long-term interest rates and cause the exchange rate to appreciate. Consistent with this, we find interest rates of all maturities increase significantly following a tightening announcement, together with some appreciation of the exchange rate.[23] In the remainder of this section we rule out other explanations for our findings.

Another potential explanation for the announcement effects found above is that announcements occur simultaneously with changes in open market operations, and it is these open market operations which cause interest rates to change. It is true that, to the extent announcements change interest rates, these changes will affect the demand for money, and so lead to an endogenous change in open market operations as the RBNZ accommodates the new level of money demand. However, what we wish to show is that changes in open market operations are not responsible for the changes in interest rates we observe after announcements. Given that the RBNZ holds its policy instruments constant and that open market operations are conducted with the aim of leaving the system with the target level of aggregate settlement cash balances each day, the only way for the RBNZ to use open market operations to manipulate interest rates

[21] We also checked Table 2 for sensitivity to outliers. For each variable, we capped observations that were more than three standard deviations away from their mean. Overall, the magnitude of the announcement effects dropped slightly, although the statistical significance of the results was slightly enhanced.

[22] An immediate problem with this explanation is that all data pertinent to inflation is released to the public at the same time as it is released to the RBNZ.

[23] These announcement effects are consistent with those found by Engel and Frankel (1984) and others, who showed that under the period of money growth targeting in the United States, announcements of higher than expected money growth signalled future monetary tightening, thus raising real interest rates and appreciating the dollar. One difference between such announcement effects and the open mouth operations in New Zealand is that, with the latter, even overnight interest rates change with the announcement, despite the fact policy settings are (and will remain) unchanged.

is to make intentional "forecast errors." Each day the RBNZ makes forecasts of the net flow of funds between the government and the private sector and, based on these forecasts, conducts open market operations to offset the projected impact flows have on end of day settlement cash. By incurring a positive forecast error, the RBNZ can effectively inject cash into the settlement process without changing its settlement cash target. The last three rows of Table 2 report the impact of a tightening announcement on the forecast error for the same day as the announcement, for the cumulative forecast error after one further day and the cumulative forecast error after twenty days. On the day of the announcement, the forecast error varies between -7.77 million dollars and 4.89 million dollars, depending on the sample period and the definition of announcements used. A 95% confidence interval suggests that this forecast error is considerably less than 20 million dollars. In no cases are the results statistically significant at the 5% level. One day after the announcement, the cumulative forecast error varies between -2.92 million dollars and 0.38 million dollars and is not significant, while after 20 days the cumulative forecast error is essentially zero.

To confirm that open market operations cannot be responsible for the announcement effects found above, we examine the impact of a 20 million dollar forecast error on the cash rate.[24] We use our hourly data to construct the daily change in the cash rate, measured at 8am. We cannot use our daily data for this purpose, since the cash rate is measured at 11am, while open market operations occur some time between 9am and 11am (so between 11am and 11am the next day we will be measuring the impact of two, potentially offsetting, open market operations). Using the model defined by equation (10) above, we find that on the day of a 20 million dollar positive forecast error (from 8am on the day to 8am the next day), the cash rate falls by 0.31 basis points (standard error is 0.13), and that by the next day the cash rate is unaffected (cumulative change is -0.04 basis points with a standard error of 0.64).[25] These results are consistent with what we know about the RBNZ's operating procedures: any forecast error is reversed the subsequent day. This small daily liquidity effect implies that the channel from announcements to interest rates, through settlement cash forecast errors, can explain only a trivial part, if any, of the change in interest rates.

The final explanation we consider for our results is the use of formal signalling by the RBNZ. In the earlier part of the sample, the RBNZ occasionally used explicit signals when making announcements; that is, changes in the structure of open market operations for one day ($SIGNAL = 1$). We have three reasons for believing that the liquidity implications of these formal signals are not driving our results. Firstly, we re-estimated the model, dropping announcements which were accompanied by these signals. We find that the maximal announcement effect again occurs after one day. The cash rate rises by 17.96 basis points for surprise

[24] Hamilton (1997) models the Federal Reserve's forecasting errors caused by unanticipated flows between the U.S. Treasury and private sector banks, and uses estimated values for these forecast errors to estimate the liquidity effect in the U.S. Unlike Hamilton, we directly observe the equivalent forecasting errors for New Zealand.

[25] These results are based on using our specification in Table 2 for the cash rate regression with surprise announcements. The optimal lag length for the 8am interest rate series includes only one lag of the cash rate (not eight lags). Using only one lag for the cash rate gives results of -0.18 basis points on the day of the 20 million dollar forecast error (standard error is 0.12) and a cumulative change of 0.01 basis points one day after the 20 million dollar forecast error (standard error is 0.66).

announcements and 15.88 basis points for all announcements (the standard errors are 7.08 and 5.41 respectively). The smaller increase in short-term interest rates, compared to Table 2, can be explained by the role formal signalling played earlier in the sample as a mechanism for clarifying the direction of statements and signifying a larger required change in rates.[26] The important thing to note is that even dropping announcements with formal signals, announcements still have statistically and economically significant impacts on the cash rate (the results are similar for other rates). Secondly, results are presented for the second half of the sample, where there are no observations with $SIGNAL = 1$, in Table 2 above. This again shows the significance of our results does not depend on the inclusion of formal signals. Finally, the one day changes in open market operations are simply not large enough to explain the observed change in the cash rate based on a liquidity argument. According to our calculations, the average size of the change in open market operations, corresponding to these signals, was less than 21 million dollars. From our point estimate of the liquidity effect, this changes the cash rate by a trivial 0.33 basis points for one day.

6 Conclusion

This paper presented a model of monetary policy implementation in which investors, acting in self-interest, force interest rates to the levels desired by the monetary authority. If interest rates move out of line with those required by the monetary authority, a statement (an open mouth operation) is all that is needed to restore them. We detailed the implementation of monetary policy in New Zealand, arguing it works in this way. In the empirical section of the paper, we explored the impact of open mouth operations in New Zealand. We found that following RBNZ tightening announcements, interest rates of all maturities increase and the New Zealand dollar appreciates. We showed that these changes are not caused by simultaneous changes in open market operations. We argued that tightening announcements do not indicate a lowering in the RBNZ's inflation goal, or higher long-term inflationary outcomes. Instead, we argued that interest rates increase following tightening announcements predominantly because they signal that the RBNZ desires higher real interest rates compared to those delivered by the markets.

While we focused on New Zealand, because it provides an ideal case to test our theory, we believe the use of a threat to tie down rates, and open mouth operations to move rates, is of relevance in other jurisdications. This view appears to be shared by a recent Bank for International Settlements survey on monetary policy implementation in fourteen countries, excluding New Zealand (Borio, 1997, p. 89):

> "*But how can mere announcements have such a critical effect? That they clearly do is evident from the fact that in some cases policy signals are sent, and market rates change, without any liquidity operations ever taking place... [T]he answer perhaps lies in the fact that as monopolist supplier of settlement balances, the central bank could, if it so wanted, set the overnight rate. It could do so by injecting/withdrawing*

[26]In fact, re-estimating the model using only announcements when signals were used, we find that the cash rate rises by 103.66 basis points after a combinbed tightening signal and statement (standard error of 16.53).

the volume of settlement balances demanded by the market at the desired rate. And, through arbitrage, it could influence rates further along the money market yield curve for the period in which no further change was anticipated."

To the extent announcements in other countries play the same role that open mouth operations play in New Zealand, these announcements could help explain the difficulties in substantiating liquidity effects in empirical work, despite the apparent ease with which overnight rates, as well as other rates, move substantial amounts when changes are desired by monetary authorities. With this in mind, future research should examine the extent to which announcements and signals, rather than open market operations, initiate interest rate movements in countries other than New Zealand.[27] Regardless of the operating procedures of different central banks, we believe signalling monetary policy intentions lies at the heart of monetary policy implementation. In this regard, the experience of New Zealand may provide valuable lessons for central bankers in other countries.

A The Path for the Overnight Rate

Suppose the preferred level of the T-day rate satisfies

$$E_t[\hat{R}_{t+n,t+n+T}] = \bar{R}_t + O(n^{-k}), \tag{11}$$

for some $k > 1$ and some $\bar{R}_t$. Below we prove the existence of a unique process for the overnight rate such that (1) is satisfied and $\lim_{n\to\infty} E_t[\hat{R}_{t+n,t+n+1}]$ exists.

We first prove that if such a process for the overnight rate exists, it must be unique. If (1) is to hold, then

$$\hat{R}_{t,t+1} + T\sum_{i=0}^{N-1} E_t[\hat{R}_{t+1+iT,t+1+(i+1)T}] = T\sum_{i=0}^{N-1} E_t[\hat{R}_{t+iT,t+(i+1)T}] + E_t[\hat{R}_{t+NT,t+NT+1}]$$

must hold for all positive integers N. Therefore, the overnight rate must equal

$$\begin{aligned} \hat{R}_{t,t+1} &= E_t[\hat{R}_{t+NT,t+NT+1}] \\ &\quad + T\sum_{i=0}^{N-1}(E_t[\hat{R}_{t+iT,t+(i+1)T}] - \bar{R}_t) - T\sum_{i=0}^{N-1}(E_t[\hat{R}_{t+1+iT,t+1+(i+1)T}] - \bar{R}_t), \end{aligned}$$

again, for all positive integers N. Condition (11) implies that the two series above converge as $N \to \infty$. $E_t[\hat{R}_{t+n,t+n+1}]$ must converge to $\bar{R}_t$, since any other limit would be inconsistent with both (11) and (1) holding. Thus, if the required process for the overnight rate exists, it must equal

$$\hat{R}_{t,t+1} = \bar{R}_t + T\sum_{i=0}^{\infty}(E_t[\hat{R}_{t+iT,t+(i+1)T}] - \bar{R}_t) - T\sum_{i=0}^{\infty}(E_t[\hat{R}_{t+1+iT,t+1+(i+1)T}] - \bar{R}_t). \tag{12}$$

It is easily confirmed that this process satisfies (11) and converges.

[27] Three recent papers provide empirical evidence suggesting that the Fed does not control interest rates through a conventional liquidity effect: Demiralp and Jorda (1999) find that public announcements change interest rates rather than open market operations; Hanes (1999) finds that interest rates are controlled by guiding expectations of future overnight rates and following a consistent rule for open market operations; and Thornton (1999) finds that the Fed adjusts its funds rate target in response to changes in market rates.

B The Inter-Bank Market with Sloping Yield Curves

We wish to show that even when the yield curve from 1 to 30 days is not flat, a bank has no incentive to borrow in the inter-bank market to hold additional settlement cash, or lend in the inter-bank market to reduce its holdings of settlement cash; that is, they will choose $d_t = 0$. If this is not the case, there will be pressure from the settlement cash market for interest rates to adjust until banks choose $d_t = 0$, as it is not possible for all banks to be net lenders or net borrowers in the inter-bank market. We calibrate the model presented in the paper to the New Zealand situation in 1997 and show that, with a trivial amount of transaction costs, the optimal amount of borrowing is still zero, regardless of the level and slope of the yield curve. We take $N = 5$, $S^* = 5$ million dollars, $\rho^{SC} = 300$ basis points when annualized, $p^D = 90$ basis points when annualized, and $\rho^O = 50$ basis points when annualized. We assume a normal distribution for ε_{t+1} and choose its variance so that it fits the RBNZ's rule (to achieve a settlement cash forecast error of 20 million dollars or less, in four days out of five). We use (9) to determine τ; it equals 3.9 days. Using these numbers, we solve the first order condition (4) and substitute this into the expected profit function (3). Our results imply that for an annualized interest rate spread $(R_t - R_{t,t+30})$ of 100 basis points, which is larger than usual, an individual bank's optimal policy is to lend out 156 thousand dollars, giving the bank an expected gain of 33 cents. For a spread of -100 basis points, the optimal policy is to borrow 162 thousand dollars, giving the bank an expected gain of 34 cents. For a 300 basis point spread, which is much larger than usual, an individual bank's optimal policy is to lend out 455 thousand dollars, giving the bank an expected gain of \$2.89. For a spread of -300 basis points, the optimal policy is to borrow 516 thousand dollars in the inter-bank market, giving the bank an expected gain of \$3.22. These gains are trivial. Given realistic transaction costs, banks have no incentive to hold settlement cash levels different from the RBNZ target (that is, $d_t^* = 0$). This suggests that even very steeply-sloped yield curves, or dramatically changing interest rates, are consistent with equilibrium in the cash settlement market and the RBNZ keeping policy parameters constant.

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Table 1: Predictability of Announcements (A_t)

$(\Delta X_{t-1}, A_{t-1})$	p-value from test $b_0 = c_0 = 0$	$\Delta\,\mathrm{Pr}\,\vert(A_{t-1} = 1)$	$\Delta\,\mathrm{Pr}\,\vert(\Delta X_{t-1} = 25)$
$(\Delta R1D_{t-1}, A_{t-1})$	0.8107	−0.0057	0.0002
$(\Delta R1M_{t-1}, A_{t-1})$	0.8270	−0.0059	−0.0001
$(\Delta R3M_{t-1}, A_{t-1})$	0.8259	−0.0059	−0.0003
$(\Delta R5Y_{t-1}, A_{t-1})$	0.8266	−0.0059	−0.0003
$(\Delta TWI_{t-1}, A_{t-1})$	0.0420	−0.0061	−0.0047
$(\Delta MCI_{t-1}, A_{t-1})$	0.0452	−0.0066	−0.0050
(FE_{t-1}, A_{t-1})	0.7573	−0.0059	−0.0009

Table 2: Reaction of Financial Variables to Announcements

Sample period:	1/1/89–9/30/97		1/1/89–6/22/93		6/23/93–9/30/97	
Statements where:	Surprise	All	Surprise	All	Surprise	All
$\Delta R1D_t$	36.66	27.11	46.13	36.82	21.01	16.19
	(6.08)	(4.69)	(10.21)	(8.50)	(5.95)	(4.41)
$\Delta R1M_t$	17.97	14.80	18.17	15.88	16.79	13.80
	(2.80)	(2.11)	(4.18)	(3.12)	(3.68)	(2.70)
$\Delta R3M_t$	14.38	11.77	13.48	10.89	15.12	12.24
	(1.88)	(1.47)	(2.44)	(2.05)	(3.07)	(2.20)
$\Delta R5Y_t$	4.20	3.76	3.24	3.25	5.67	4.41
	(1.33)	(1.04)	(1.61)	(1.32)	(2.19)	(1.62)
ΔTWI_t	5.60	8.59	8.41	7.68	2.25	9.83
	(3.80)	(2.97)	(5.48)	(4.34)	(5.54)	(4.17)
ΔMCI_t	18.82	18.70	20.45	17.59	16.56	19.93
	(3.49)	(2.67)	(5.43)	(4.36)	(4.31)	(3.07)
FE_t	-0.46	-2.61	4.89	0.11	-7.77	-4.89
	(3.06)	(2.70)	(4.27)	(3.51)	(4.71)	(3.37)
FE_{t+1}	-0.55	-1.65	0.38	-2.29	-2.92	-0.81
	(3.08)	(2.54)	(4.30)	(3.54)	(4.60)	(3.37)
FE_{t+20}	2.2E-4	1.6E-4	-6.1E-4	-6.5E-4	-0.004	-0.003
	(2.3E-3)	(1.2E-3)	(3.7E-3)	(3.5E-3)	(0.007)	(0.005)

Note: Approximate standard errors are in parenthesis. Calculated using a Monte Carlo simulation with 1000 draws. The impact of announcements on forecast errors is found using the model estimated with $\Delta R1D_t$.

Figure 1: The three-month interest rate and inflation (January 1989 – December 1997)

Figure 2: The Monetary Conditions Index (MCI) before and after each announcement (normalized to zero just before each announcement and expressed in basis points)

T = tightening, L = loosening, S = surprise announcement, R = statement made at three-monthly release. The nine announcements represent all announcements made during 8/22/96–9/30/97.

Figure 3: Effects of a tightening announcement