The Impact of Monetary Policy on the Exchange Rate: A Study Using Intraday Data*

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We investigate the impact of monetary policy on the exchange rate using an event study with intraday data for four countries. Carefully selecting the sample periods ensures that the policy change is exogenous to the exchange rate. An unanticipated tightening of 25 basis points leads to a rapid appreciation of around 0.35 percent. We also show that the impact depends on how the surprise affects expectations of future monetary policy. If expectations of future policy are revised by the full amount of the surprise, then the impact on the exchange rate is larger (0.4 percent) than if the surprise only brings forward an anticipated change in policy (0.2 percent).

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1. Introduction

Recent studies have had some success in identifying the response of the exchange rate to macroeconomic variables by using high-frequency data.[1] This paper makes two important contributions to

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[1]For example, see Andersen et al. (2003), Zettelmeyer (2004), Faust et al. (forthcoming), and the references therein.

the literature on the response of the exchange rate to monetary policy. First, we use intraday data, which allows us to more precisely control for endogeneity and external factors that may influence both exchange rates and interest rates (such as macroeconomic data releases). With intraday data we can also examine the temporal response of the exchange rate. Our second contribution is to consider how changes in the expected path of future monetary policy that result from a monetary surprise influence the response of the exchange rate. Some interest rate changes may surprise with respect to the timing of the change; for example, the rate rise expected next month might occur this month. Others may surprise with respect to the expected path of monetary policy; for example, a surprise rate rise might be taken to indicate that a tightening phase is going to reach a higher maximum than previously anticipated. Because these surprises will have different effects on the expected future path of monetary policy, they are unlikely to have equivalent effects on the exchange rate.

A greater understanding of the impact of interest rates on exchange rates is of interest for several reasons. The theory of uncovered interest parity (UIP), which connects expected changes in the exchange rate to interest differentials, is central to almost all international macroeconomic models. Yet empirically, UIP is a resounding failure (Engel 1996). In addition, the response of the exchange rate to monetary policy is also an important monetary transmission channel in small, open economies (see, for example, Grenville 1995 and Thiessen 1995).

Our study includes four countries (Australia, Canada, New Zealand, and the United Kingdom) that are relatively small, and so changes in their interest rates are unlikely to affect global interest rates. This is important for isolating the impact of the change in one country's interest rate on the exchange rate. If the country studied was large, such as the United States, then markets might build the likely impact of changes in domestic monetary policy on foreign interest rates into the exchange rate's response. This would contaminate the measured response of the exchange rate. Further, these four countries have highly liquid financial markets, freely floating exchange rates, and similar monetary policy regimes.

We use an event-study methodology as has become common in the literature on asset prices. An event study is particularly useful because it can abstract from the joint determination of interest rates and exchange rates. The event is a monetary policy decision (either a surprise change in the policy interest rate or no change when a policy announcement was anticipated). We can be confident that we have isolated events in which causality runs in only one direction, from interest rates to exchange rates, for two reasons. Firstly, we use a narrow event window, only examining a short period around the policy change. Secondly, for the countries we study, the institutional structure of monetary policy decision making means that the decision is made well before the event window we use.

Several papers have recently used high-frequency data to examine the response of asset prices to macroeconomic shocks, including interest rates. This paper most closely follows that of Zettelmeyer (2004), who examines the response of exchange rates to interest rates using daily data (but not intraday). Unlike Zettelmeyer, we restrict our sample to a period in which the central banks we study did not explicitly respond to the exchange rate. We also use a more-accurate measure of the monetary surprise (based on one-month rather than three-month interest rates) and a larger sample, in part because we include decisions in which monetary policy does not change—that is, "no-change" surprises. We can include these observations because, under the monetary policy regimes we examine, the timing of the announcement of these no-changes was predetermined. Faust et al. (forthcoming) use intraday data to examine the response of exchange rates to macroeconomic announcements, including interest rate changes. But they only study surprises in U.S. interest rates, and so the exchange rate responses are potentially clouded by anticipated changes in foreign interest rates. Andersen et al. (2003) also examine the intraday response of the exchange rate to macroeconomic announcements but do not consider interest rate shocks. Bernanke and Kuttner (2005), studying the response of equity markets to interest rates using daily data, consider how the impact differs depending on the changes to the profile of anticipated future monetary policy, as we do in this study. A related literature has attempted to consider the longer-run impact of interest rates on the exchange rate. In an early study using a vector autoregression (VAR), Eichenbaum and Evans (1995) suggest that there exists a delayed overshooting. But by identifying surprise interest rate shocks using daily data, Faust et al. (2003) find that this result is not robust to allowing the foreign interest rate to respond. Faust and Rogers (2003) also fail to find evidence of delayed overshooting in a less-restricted VAR.

The remainder of the paper is structured as follows. Section 2.1 briefly outlines the application of the event-study methodology to monetary policy decisions. In section 2.2 we review the monetary policy operations of the four countries in the study and discuss how they influence the set of events that we consider. The data are described in more detail in section 2.3. In section 3.1 we present the results of the instantaneous impact and the timing of the response of the exchange rate. In section 3.2 we demonstrate how the response of the exchange rate depends on the effect of the monetary surprise on expectations. We examine the robustness of the results in section 3.3. Section 4 concludes.

2. The Estimation Framework

2.1 Event-Study Methodology

We use an event-study approach, estimating the change in the exchange rate around the announcement of "monetary policy decisions." Decisions include both announced changes to monetary policy and announcements of decisions to not change policy ("no-change" decisions), so long as the market knew for certain that a policy announcement would take place.[2] Further discussion of the events used can be found in section 2.2. In many cases, monetary policy decisions are widely anticipated by the market, and so their impact should already be incorporated into interest rates and exchange rates. In order to identify the impact of a monetary policy decision, we isolate the surprise component of the change in monetary policy by using changes in market interest rates rather than the change in the policy interest rate.[3] This technique, developed in

[2]On the event days in which there is no change in policy, markets may have given some probability to there being a change in policy, and so there may well have still been a surprise that contained news.

[3]This does not mean that anticipated changes in monetary policy have no effect on the exchange rate, but that the effect has been incorporated into the exchange rate at the same time as markets came to the conclusion that there would be a change in monetary policy.

Kuttner (2001), is commonly used in the literature. Market interest rates incorporate a risk premium, but the change in the market interest rate is a good proxy for the policy surprise, as the risk premium is unlikely to move in the short time periods used in the event study (Piazzesi and Swanson 2004).

For each of the events, we measure the movement in the exchange rate around the event using intraday data. We use a short, seventy-minute event window. This reduces the amount of information received by the market in the event window, reducing the number of events that would have to be discarded due to the exchange rate and interest rate jointly responding to other news, such as a macroeconomic data release. Because the interest rate surprise will be a more-dominant piece of information in a short event window, it should also result in more-accurate estimates.

One potential source of concern is that exchange rate movements could influence monetary policy decisions. However, this is not likely in this study because in each central bank, the main deliberation on policy changes occurs the day before the announcement. Given that at a daily frequency the exchange rate is typically considered to be a random walk, the event window will not contain exchange rate movements that influenced the policy decision.[4] The daily market interest rates may be affected by other events or an endogenous response to exchange rate movements, but this is minimized by the fact that events occur on days for which monetary policy is likely to be the most important shock to interest rates. Unfortunately, intraday interest rate data are not available for our sample of countries and time.[5] The events that are excluded from our sample for reasons of contamination are outlined in section 2.2.

[4]There is some evidence of weak serial correlation in exchange rates, which is often found using nonlinear models; for example, see Gencay et al. (2002). However, such serial correlation is so weak as to not be relevant from a policy perspective.

[5]We investigated using intraday exchange rate forwards to derive a measure of the intraday interest rate shock based on covered interest rate parity. But quotes for exchange rate forwards are not updated frequently, and so the length of the period used to measure the shock varied from one event to another, potentially in a way that correlates with the nature of the shock. This measure of the shock was then found to result in larger standard errors, though the point estimates were roughly equivalent.

2.2 Monetary Policy Operations

The monetary policy operations of the four economies used in this study have changed considerably over the past decade (Brown 1997; Archer, Brookes, and Reddell 1999; Parent, Munro, and Parker 2003; Zettelmeyer 2004). This section briefly outlines the current monetary policy regimes, how they have changed, and how these changes may influence this study. Using this information, section 2.3 explains how the set of events used in the analysis were determined.

The four countries currently have very similar monetary policy operations. In particular, they all have

- fixed announcement dates for monetary policy decisions, albeit with the option to make changes at other times in response to extreme events;
- a short-term interest rate as the policy instrument;
- a preference for not surprising the market; and
- an inflation target.

While all four countries have been inflation targeters for the full sample considered in this paper, institutional aspects of monetary policy operations have changed since the early 1990s in important ways. Some of these changes have been gradual, while others have been more abrupt. In Australia, monetary policy operations have changed progressively since the early 1990s, to resemble the current operational framework by about 1998. Prior to 1998, though the dates of the Board meetings were known (usually the first Tuesday of every month, with no meeting in January), monetary policy decisions were typically not announced or implemented immediately after a meeting. From 1998 onward, all changes in monetary policy have been announced the day after a Board meeting. Only since September 2002 has there been a public announcement on the day after the Board meeting in the event that policy was not being changed. However, market commentary in the period 1998 to 2002 suggests that if policy was not changed the day after a Board meeting, then no change was anticipated until the subsequent meeting. So for Australia we have included no-change decisions from the beginning of 1998, as well as all changes in monetary policy from mid-1993. Table 1 provides a summary of the sample periods and number of events for each country.

Table 1. The Set of Events

	Australia	**Canada**	**New Zealand**	**United Kingdom**
Sample	July 30, 1993–June 2, 2004	October 28, 1996–June 8, 2004	March 17, 1999 June 10, 2004	July 10, 1997–June 10, 2004
Number of Events Used	79	33[b]	42	82
Number of Changes	24	23	20	27
Number of No-Changes	55	10	22	55
Regime Change	1998	December 2000	March 1999	June 1997
Old Regime	Policy changes included (9 events)	Policy changes included (4 events)	None included	None included
New Regime	Changes and no-changes included			
Meetings per Year	11	8	8	12
Announcement Time[a]	9:30 a.m. on the day after the Board meeting	9:00 a.m. on fixed announcement days	9:00 a.m. on fixed announcement days	12:30 p.m. on the second day of the Monetary Policy Committee meeting

[a]Some events do occur at different times.
[b]Changes after the September 11, 2001, terrorist attacks and in response to the Russian crisis are excluded. Also, eight events that coincide with changes in the federal funds rate are excluded.

In the other countries, changes in monetary policy operations have been more distinct and, in some cases, substantial. At the start of 1999, the Reserve Bank of New Zealand (RBNZ) moved from focusing on a monetary conditions index (a combination of the overnight interest rate and the exchange rate) as the main intermediate target of policy to using the overnight cash rate to implement monetary policy. Accordingly, we begin our New Zealand sample in 1999, as prior to this the motivation for interest rate changes was inextricably linked to exchange rate movements.

Like New Zealand, Canada has implemented a system of eight fixed announcement dates (starting December 2000). However, unlike New Zealand, there has been little change in the framework and focus of policy. We therefore include most changes to policy from 1996 onward, when our intraday exchange rate data for the Canadian dollar begin. Eight changes are excluded, when they are on the day of, or the day after, a change in the federal funds rate, reflecting the likelihood of contamination of the measure of the surprise in policy. Two further policy changes are excluded—the one following the August 1998 Russian crisis and the one after the September 11, 2001, terrorist attacks—again, for reasons of possible contamination.

In the United Kingdom, the operational responsibility for monetary policy passed from the government to the Bank of England in June 1997, ensuring an independent monetary policymaker. From this date on, policy announcements of either a change or no change occurred according to a preannounced schedule. We exclude monetary policy decisions made prior to June 1997, owing to the large shift in the monetary policy regime and uncertainty about the exact time at which changes were announced prior to 1997.

For each event, we searched Bloomberg and other sources to ensure that there was no contaminating information in the event window. Because we use a narrow event window, we did not find cause to exclude any events other than those outlined for Canada.[6] We also record the exact time of the event in order to make the events completely comparable.

[6]A few events are excluded due to missing intraday exchange rate data.

Given the similarities of the current monetary policy regimes in the four countries, we also present results using a pooled sample. In order to keep the pooled sample as homogenous as possible, only those events that are part of the current regimes, in which monetary policy is implemented according to fixed announcement dates, are included. This is the full sample for New Zealand and the United Kingdom and the sample from 1998 for Australia and the end of 2000 for Canada.

2.3 The Data

The two data series used in the event study are interest rates and exchange rates. We use bank bill interest rates (one-month and three-month rates) and futures contracts on the three-month bank bill interest rate. Most of the literature for the United States has calculated monetary policy surprises using federal funds futures contracts (see, for example, Kuttner 2001, Faust et al. 2003, and Bernanke and Kuttner 2005). However, futures contracts over the policy instrument interest rates are not available for the countries we use over our sample period, and so we use bank bill interest rates to calculate monetary policy surprises. One advantage of bank bill rates is that, unlike futures, the horizon of the instrument does not vary from one event to another, thereby simplifying the calculation of the surprise. Piazzesi and Swanson (2004) find that eurodollar interest rate futures provide good measures of interest rate surprises for the United States and are only marginally outperformed by federal funds futures. The interest rate surprise is calculated as the change in the one-month or three-month bank bill interest rate from the close of the day prior to the monetary surprise to the close of the day of the monetary surprise. Note that the surprise can be nonzero even when the policy interest rate was not changed, if the market placed at least some probability on there being a change. The surprises are measured in percentage points (100 basis points). The interest rates we use, and their sources, are described in the appendix.

The bilateral exchange rates are the U.S. dollar price of the domestic currency, from the Reuters electronic trading system, at ten-minute intervals. At each ten-minute interval, the

Table 2. The Data

	Australia	Canada	New Zealand	United Kingdom
Number of Events Used	79	33	42	82
Average $\|\Delta i\|$	0.13	0.21	0.15	0.09
Average $\|\Delta i^s\|$	0.07	0.06	0.05	0.07
Ratio of Event to Nonevent Day Exchange Rate Volatility[a]	1.34	1.17	1.33	1.13
Average $\|\Delta e_{10m}\|$	0.049	0.041	0.059	0.052

Notes: $|\Delta i|$ is the absolute change in the official interest rate in percentage points. $|\Delta i^s|$ is the absolute change in the one-month interest rate in percentage points.
[a]The volatility is calculated as the average absolute change in the exchange rate over ten-minute intervals. Averages are taken over a window starting two hours before the event and ending six hours after. The sample of nonevent days is constructed by taking the day exactly one week prior to each event.
$|\Delta e_{10m}|$ is the absolute percent change over ten-minute intervals on event days.

exchange rate observation is the average of the closest active bid and ask quotes. Goodhart and Payne (1996) and Danielsson and Payne (2002) have found that at ten-minute intervals, quote data are good proxies for actual transaction prices in exchange rate markets.

Table 2 gives a brief summary of the data. The average absolute change in the policy rate, $|\Delta i|$, is based on change and no-change event days in the sample. The average absolute change is typically about twice as large as the average absolute surprise, $|\Delta i^s|$. Exchange rate volatility—measured as the average absolute change in the exchange rate over ten-minute intervals—is higher on event days than on nonevent days (from two hours before to six hours after the event), providing some initial evidence that monetary policy has an effect on the exchange rate.

3. Results

3.1 The Impact of Monetary Policy Shocks

To quantify the impact of monetary policy on the exchange rate, we regress the change in the exchange rate over the event window on the monetary policy surprise, as represented by equation (1),

$$\Delta e_{[t-10m,t+60m]} = \alpha + \beta \Delta i_t^s + \varepsilon_t, \quad (1)$$

where $\Delta e_{[t-10m,t+60m]}$ is the percentage change in the U.S. dollar bilateral exchange rate from ten minutes before the event to sixty minutes after, and Δi_t^s is the surprise move in policy measured by the daily change in market interest rates.[7] We use the exchange rate from ten minutes before the policy change, rather than at the time of the policy change, in case there are mismatches in the timing of our exchange rate data and policy implementation. We present results using surprises derived from both one-month and three-month interest rates.

These regressions suggest that a 100-basis-point surprise tightening of monetary policy is estimated to lead to an appreciation of the exchange rate in the range of 1–2 percent in the hour following the event (table 3). When we use the sample pooled across countries, the estimate is in the middle of this range, just under 1.5 percent.[8] In recent years, the countries used in this study have moved their policy rates in 25-basis-point increments.[9] A 25-basis-point surprise would lead to an appreciation of 0.25–0.50 percent. The surprise in monetary policy explains only about 10–20 percent of the movement in the exchange rate over the seventy-minute interval. The low

[7]Note that the daily interest rate change, which we use because intraday interest rate data are not available, is potentially a noisy indicator of the true interest rate surprise and so could lessen the explanatory power of our regressions. Equation (1) includes both change and no-change events in order to have a sufficiently large sample. In section 3.3, we examine whether change and no-change surprises have different impacts.

[8]The data do not reject the restriction that the coefficient on interest rates is constant across countries.

[9]For all countries, there are some larger policy moves earlier in the sample. However, because it is only the surprise component—not the change in the policy rate—that enters the regression, these changes are not necessarily larger values in the regression.

Table 3. Impact of a 100-Basis-Point Monetary Policy Surprise

Country	One Month	Three Month	$\overline{R}^2$	Observa-tions
Australia	0.96 (0.00)		0.16	79
		1.88 (0.00)	0.32	79
Canada	1.56 (0.00)		0.22	33
		1.67 (0.00)	0.23	33
New Zealand	1.83 (0.02)		0.11	42
		1.97 (0.01)	0.15	42
United Kingdom	1.04 (0.00)		0.11	82
		1.58 (0.00)	0.17	82
Pooled Sample	1.45 (0.00)		0.13	222
		1.77 (0.00)	0.17	222

Notes: The dependent variable is the change in the exchange rate (relative to the U.S. dollar) from ten minutes before the event to sixty minutes after. P-values are in parentheses.

proportion of exchange rate movements explained by the interest rate surprise, even in such a short window with an important piece of information, is in line with other work on the exchange rate—for example, Andersen et al. (2003) and Faust et al. (forthcoming).

For all countries and the pooled sample, the coefficient on the interest rate surprise is larger when the surprise is measured using a three-month interest rate than in the equivalent regression using a one-month interest rate. Presumably this is because the three-month rate includes the impact of the decision on expectations of future monetary policy, at least over the next three months, an important issue that we explore in section 3.2. The point estimates for the three-month surprises for Australia and Canada are similar to those in Zettelmeyer (2004) using daily data. However, his result for New Zealand is larger, 2.7 percent, possibly because his sample, being mostly before 1999 when a monetary conditions index was being used, does not contain purely exogenous monetary shocks. The point estimates are also similar in magnitude to the 1.2 for the deutschemark/euro exchange rate response to changes in U.S. interest rates contained in Faust et al. (forthcoming). However, their estimate for the pound's response to U.S. interest rates of 0.66 is smaller, suggesting that their result may contain some bias in estimating the impact of a change in a large country's interest rate on the bilateral exchange rate with a smaller country.

The timing of the impact of a monetary policy surprise on the exchange rate can be determined by estimating equation (2) for k ranging from two hours before the event to six hours after (at ten-minute intervals).

$$\Delta e_{[t,t+k]} = \alpha + \beta \Delta i_t^s + \varepsilon_t \tag{2}$$

The results are shown in figures 1–4, where the surprise is measured using the one-month interest rate. In all four countries, there is a sharp spike in the impact in the ten minutes following the event, demonstrating that monetary policy announcements have a rapid impact on the exchange rate. The relative stability of the coefficients over the six hours after the event indicate that the surprise has little additional influence after its immediate impact. The standard errors, the dashed lines in the graphs, widen further from the event as the policy change becomes a smaller proportion of the information incorporated into the exchange rate. As a result, the statistical significance using daily data will be substantially weaker.

For Australia and Canada, there is significant movement in the exchange rate prior to the event in the same direction as the response following the event. Given that this is gradual for Canada, it is suggestive of late changes in market expectations of the policy announcement, perhaps as participants' expectations coalesce around a particular policy announcement. Such changes in market expectations would presumably also be reflected in intraday

Figure 1. Australian Dollar: Response to a 100-Basis-Point Interest Rate Surprise

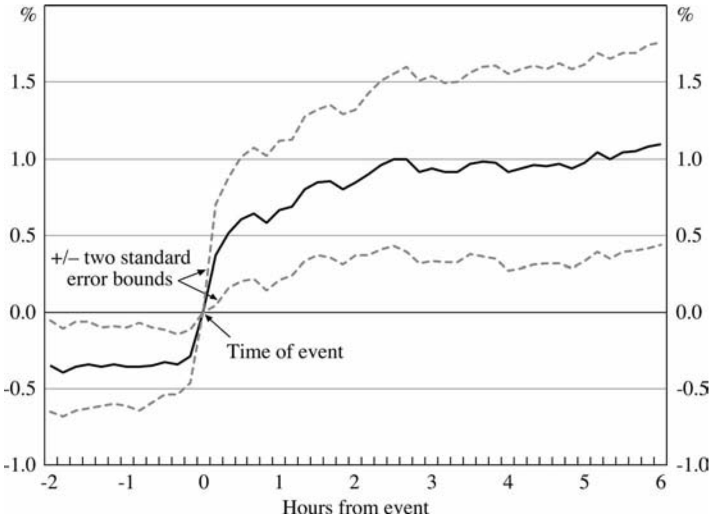


Figure 2. Canadian Dollar: Response to a 100-Basis-Point Interest Rate Surprise

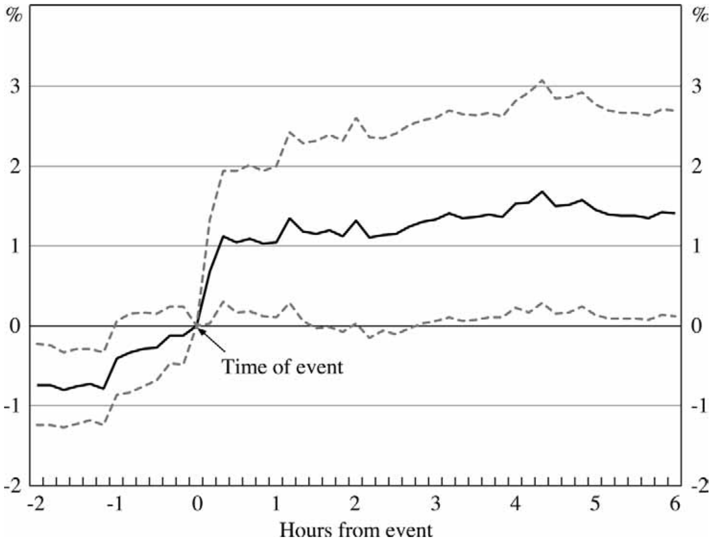
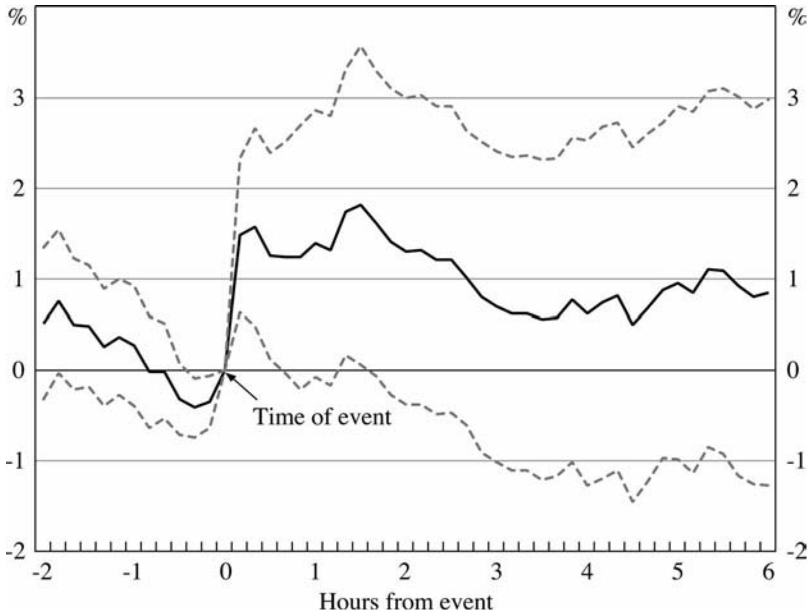


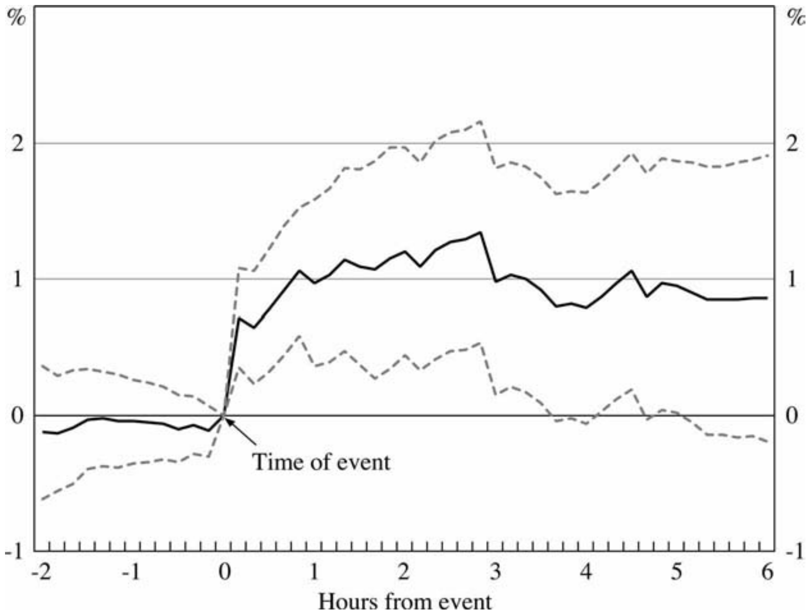
Figure 3. New Zealand Dollar: Response to a 100-Basis-Point Interest Rate Surprise



interest rate data were they available. For Australia, the sharp jump that occurs ten minutes before the event most likely reflects slight differences between the timing of the announcement and the exchange rate data. The significance of this change immediately prior to the event is not unduly influenced by any particular observations, and so the result does not appear to be the result of leaked information.[10] It is because of this possible timing mismeasurement that we base our main results on the exchange rate starting ten minutes before the event.

[10]This result is not sensitive to the exclusion of the only two events for Australia in which there is any suggestion of some participants seemingly having early access to the policy outcome: one in which the monetary policy decision was mistakenly released to some market participants six minutes early (February 2, 2000) and the other in which Bloomberg mistakenly released a report about one minute early, even though it did not yet know the outcome (July 3, 2002). Note that these do not affect our main results, because we use the exchange rate from ten minutes before the policy change.

Figure 4. British Pound: Response to a 100-Basis-Point Interest Rate Surprise

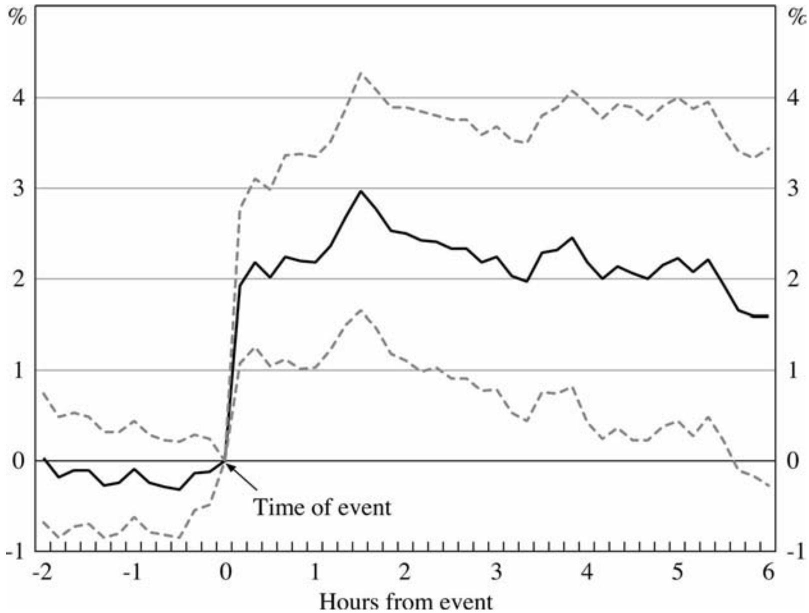


Given the importance for New Zealand of financial linkages with Australia, and New Zealand's smaller relative size, it is also interesting to examine the impact of monetary policy surprises in New Zealand on the New Zealand dollar/Australian dollar bilateral exchange rate. Figure 5 demonstrates that the response is more precisely estimated, and larger, than the response of the New Zealand dollar/U.S. dollar exchange rate shown in figure 3.

3.2 The Importance of Expectations

The impact of a policy decision on expectations of future policy may be important in determining the exchange rate's response. This is apparent from the different results obtained when measuring the monetary policy surprise using one-month and three-month interest rates. A monetary policy decision might simply surprise the market in its timing (a "timing" surprise), or it might be a surprise that shifts policy expectations at all horizons (a "level" surprise).

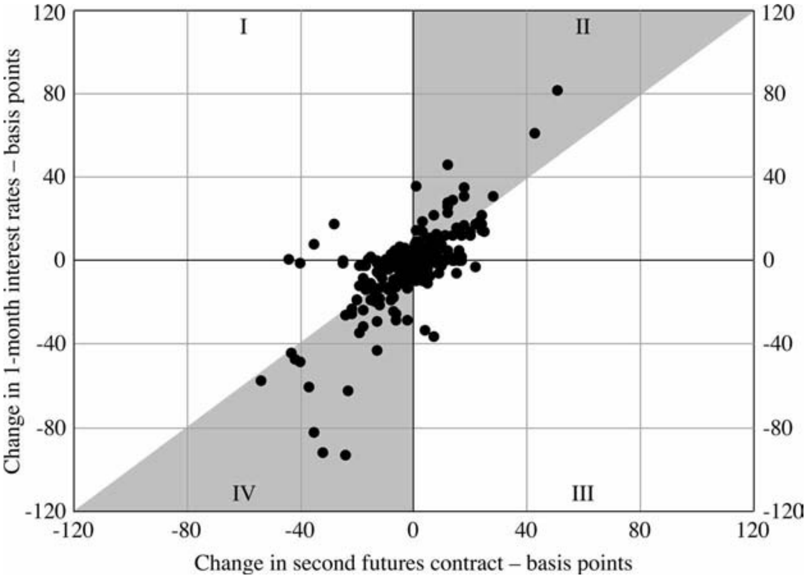
Figure 5. New Zealand Dollar/Australian Dollar Bilateral Rate: Response to a 100-Basis-Point Interest Rate Surprise



A change in current monetary policy could even shift expectations of future policy by more than the impact on one-month interest rates if market participants believe that it indicates that future changes in the same direction are likely.

To test whether expectations are important, we examine changes in three-month interest rate futures (details of these contracts are in the appendix). These are not perfect measures of policy expectations, but changes in these interest rates have been shown to be a reasonable guide to changes in policy expectations (Piazzesi and Swanson 2004). Typically, about eight futures contracts trade at any one time, giving a horizon of about two years in total. What is termed the "first" interest rate futures contract expires sometime in the next three months and is settled on the three-month interest rate prevailing on that expiration date. The "second" futures contract is settled on the three-month interest rate prevailing three months after the expiration of the first contract, and so on. Because the futures

Figure 6. Change in Spot Interest Rate versus Change in Futures Rate



contracts expire at fixed points in time three months apart, but monetary policy events can happen at any time in a three-month period, the horizon until the contract expiration can differ from one event to another. While not ideal, this is unavoidable given that one-month futures contracts are not available for these countries over the relevant sample and the time between the fixed announcement dates can vary in Canada and New Zealand. We consider the sensitivity to this measurement issue in section 3.3.

Figure 6 shows a scatter plot of the change in the one-month interest rate against the change in the second futures contract, on days with a monetary policy event, for all four countries. We use the second futures contract, as it has the advantage that it does not expire until after at least two complete monetary policy decision cycles.

Given that monetary policy changes are not quickly reversed, surprises that lead to a positive (negative) change in the one-month interest rate are unlikely to also lead to a negative (positive) change in the futures rate. This suggests that there should be very few points in quadrants I and III. It would seem likely that most surprises would be somewhere between a level and timing surprise. Changes in the futures rate should then be of the same sign as, but smaller in magnitude than, the change in the one-month rate. In this case, most observations would lie in the shaded area in figure 6. The data broadly fit this pattern, especially for large monetary surprises, although there are still quite a number of points outside the shaded area. If all surprises had the same effect on expectations of future policy, then they would lie on a straight line. The scatter plot shows that this is clearly not the case, and regressions for each country indicate that the change in the one-month interest rate explains only about half of the change in the second futures rate. It thus appears that there is sufficient heterogeneity to test whether the effect that a monetary policy decision has on expectations of future policy is important in determining the decision's impact on the exchange rate.

We incorporate information on the change in the futures contract in equation (3):

$$\Delta e_{[t-10m,t+60m]} = \alpha + \beta \Delta i_t^s + \gamma \Delta i_t^{s,f} + \varepsilon_t. \qquad (3)$$

A "timing" surprise—a surprise that does not change expectations of the level of future policy—is captured by β, since there is no change in the futures interest rate (that is, $\Delta i_t^{s,f} = 0$). A "level" surprise—a surprise that changes expectations of future interest rates by as much as the surprise in current policy, i.e., $\Delta i_t^s = \Delta i_t^{s,f}$—is measured by $\beta + \gamma$. The results are presented in table 4.

These results confirm that a surprise in the level of policy leads to a greater change in the exchange rate than does a surprise in the timing of policy. Estimates of the impact of a 100-basis-point surprise in timing, β, for the individual countries are imprecisely estimated but range from being negative to around 1 percent. However, in the larger pooled sample, the estimate is very precisely estimated to be 0.87. A 100-basis-point surprise increase in the level of the (current and future) policy instrument is estimated to lead to a 1.3–2.2 percent appreciation in the exchange rate, as seen by the estimates of $\beta + \gamma$. The pooled sample produces an estimate in the middle of this range, 1.68. These estimates of the impact of a level surprise are highly significant for all of the countries and the pooled sample. This indicates that a 25-basis-point timing (level)

Table 4. Timing and Level Surprises

	Timing Surprise β	γ	**Level Surprise** $\beta + \gamma$[a]	$\overline{R}^2$	**Observations**
Australia	0.46	0.80	1.26	0.21	79
	(0.14)	(0.02)	(0.00)		
Canada	0.84	0.85	1.69	0.23	33
	(0.26)	(0.20)	(0.00)		
New Zealand	1.06	0.74	1.80	0.11	42
	(0.35)	(0.35)	(0.02)		
United Kingdom	−0.21	2.44	2.22	0.29	82
	(0.59)	(0.00)	(0.00)		
Pooled Sample	0.87	0.81	1.68	0.17	222
	(0.00)	(0.00)	(0.00)		

Note: P-values are in parentheses.
[a]The p-value for $\beta + \gamma$ is calculated using a Wald test.

surprise would appreciate the exchange rate by around 0.2 percent (0.4 percent). Clearly, a level surprise has a much larger impact on the exchange rate than a timing surprise.

A key economic theory governing exchange rates is the prediction of UIP that if domestic interest rates are higher than foreign rates, the exchange rate should depreciate gradually in order to equalize returns. Macroeconomic models that incorporate UIP and rational expectations, such as Dornbusch (1976), typically predict a sharp appreciation in response to a surprise monetary tightening in order for the exchange rate to subsequently depreciate in line with UIP. While UIP fails empirically, our results show the exchange rate immediately appreciates in response to a monetary tightening, which accords with the prediction of these exchange rate models. Our work cannot say anything about whether the exchange rate subsequently depreciates as predicted by UIP, but it is interesting to compare the magnitude of our results to the initial jump that would be consistent with UIP.

To calculate the jump in the exchange rate in response to a surprise tightening in monetary policy that is consistent with UIP, we need to know both how long the change in monetary policy will be sustained and the level that the exchange rate is expected to return to after the change in the interest differential is eliminated. Using our estimates that separate the timing from the level effects, we can attempt to control for the first of these issues. But without knowing what caused the monetary surprise, and what impact that news had on the equilibrium value of the exchange rate, we cannot determine the level to which the exchange rate is expected to return. For the purpose of this calculation, we assume that the expected long-run value of the exchange rate did not change with the monetary surprise. If the monetary decision is a pure timing surprise, the interest rate given by the futures contract that expires in three to six months does not change. Assuming that the surprise lasts four and one-half months (that is, the midpoint of three and six months), in order for UIP to subsequently hold, a 100-basis-point surprise increase would require an immediate appreciation of less than 0.50 percent (0.375 percent).[11] In contrast, we estimate the response to a 100-basis-point timing surprise to be more than twice as large, 0.87 percent. So while UIP is found to fail empirically, our results suggest that the initial response of the exchange rate to a monetary policy surprise is in the direction predicted by macroeconomic models in which UIP holds, but it is seemingly larger than this theory would suggest. Of course, this interpretation is subject to the important caveat that we do not know how the long-run equilibrium level of the exchange rate has changed.

3.3 Robustness

To test the robustness of our findings, we include a range of other variables in the regressions. For brevity, we only report results using the pooled sample. The equivalent regressions for the individual countries produce similar results, though understandably with larger standard errors. Table 5 reports specifications using surprises based on one-month bank bill interest rates, while table 6 repeats the regressions using surprises based on three-month bank bill rates.

[11] This is the amount that the exchange rate would need to depreciate over the subsequent four and one-half months in order to equalize returns. This calculation assumes that the foreign interest rate remains constant.

Table 5. Pooled Results: One-Month Surprise

	Surprise Change β	Futures Contract 2nd γ	Futures Contract 3rd γ	Expected Change	Maturity[a]	Change Dummy × Surprise Change	Change Dummy × 2nd Future	$\overline{R}^2$
I	1.45							0.13
	(0.00)							
II	0.87	0.81						0.17
	(0.00)	(0.00)						
III	0.95		0.74					0.17
	(0.00)		(0.00)					
IV	0.89	0.83		−0.21				0.18
	(0.00)	(0.00)		(0.00)				
V	0.94	0.76		−0.21	0.00			0.17
	(0.00)	(0.01)		(0.09)	(0.61)			
VI	0.61	0.72		−0.25	0.00	0.58		0.17
	(0.16)	(0.01)		(0.06)	(0.61)	(0.26)		
VII	0.74	0.47		−0.24	−0.01	0.15	0.63	0.18
	(0.10)	(0.19)		(0.06)	(0.46)	(0.82)	(0.26)	

Notes: The dependent variable is the change in the exchange rate (relative to the U.S. dollar) from ten minutes before the event to sixty minutes after. P-values are in parentheses. There are 222 observations in all regressions.
[a]The maturity variable is: (the change in the futures contract) × (the difference between the days to maturity and the average days to maturity).

The coefficients on monetary policy surprises are found to be robust and maintain their statistical significance across a range of specifications. Specifications I and II repeat the pooled results from tables 3 and 4. The estimates using the three-month interest rate surprise are slightly larger, reflecting their less-precise separation of timing and level surprises. Using the third rather than the second futures contract, specification III, does not change the results appreciably.

One surprising result is that the coefficient on the expected change (the change in monetary policy less the unexpected change) is always about −0.2 percent and marginally significant (specifications IV–VII). This runs counter to our priors that only unexpected changes in monetary policy should affect the exchange rate. This result owes a lot to one particular event in New Zealand on May 17, 2000. The tightening in monetary policy on this day was almost completely anticipated. But the particularly hawkish monetary policy statement released with the decision seemingly led to concerns

Table 6. Pooled Results: Three-Month Surprise

	Surprise Change	Futures Contract		Expected Change	Maturity[a]	Change Dummy ×		$\overline{R}^2$
	β	2nd (γ)	3rd (γ)			Surprise Change	2nd Future	
I	1.77 (0.00)							0.17
II	1.27 (0.00)	0.52 (0.08)						0.18
III	1.32 (0.00)		0.48 (0.07)					0.18
IV	1.32 (0.00)	0.51 (0.08)		−0.21 (0.08)				0.19
V	1.42 (0.00)	0.41 (0.22)		−0.20 (0.10)	−0.01 (0.49)			0.18
VI	0.94 (0.08)	0.39 (0.24)		−0.23 (0.06)	−0.01 (0.48)	0.72 (0.20)		0.19
VII	1.01 (0.08)	0.30 (0.45)		−0.23 (0.06)	−0.01 (0.45)	0.49 (0.54)	0.25 (0.71)	0.18

Notes: The dependent variable is the change in the exchange rate (relative to the U.S. dollar) from ten minutes before the event to sixty minutes after. P-values are in parentheses. There are 222 observations in all regressions.
[a]The maturity variable is: (the change in the futures contract) × (the difference between the days to maturity and the average days to maturity).

about the impact of the indicated course of policy on the growth of the economy and a sharp *depreciation* of the exchange rate. Excluding this observation, the expected change in policy does not have a statistically significant impact on the exchange rate.

A variable that controls for the changing number of days until maturity of futures contracts, used in specifications V–VII, is always economically and statistically insignificant. This suggests that our conclusions about the timing and level surprises are not unduly influenced by the fact that the horizon of interest rate futures is not constant across events.

The coefficient on a dummy for whether the decision was a change in monetary policy, multiplied by the monetary policy surprise, is always positive though not significant (specifications VI and VII). This suggests that there may be a slightly greater effect on the exchange rate when the surprise monetary decision is a change in the policy interest rate. Alternatively, this could simply reflect the fact that the proportion of the interest rate change that is caused by monetary policy is likely to be higher when the surprise is larger, which typically occurs when monetary policy is changing.

4. Conclusions

In this paper, we use an event study to isolate the impact of changes in monetary policy on the exchange rate. Two important aspects of our study enable us to abstract from endogeneity and the influence of other exogenous news. First, we use a sample period for four countries (Australia, Canada, New Zealand, and the United Kingdom) in which monetary policy does not focus on the exchange rate and the decision is predetermined when it is implemented. Second, we use intraday data with a narrow event window. The results indicate that the exchange rate appreciates on average by around 1.5 percent in response to an unanticipated 100-basis-point increase in the policy interest rate. The estimates for individual countries range from 1.0 percent to 1.8 percent. For a 25-basis-point surprise, this equates to an average appreciation of 0.35 percent (0.25–0.50 percent for individual countries). These results are slightly smaller than those in Zettelmeyer (2004) but, for the most part, are marginally larger than those in Faust et al. (forthcoming).

The impact of monetary policy changes on the exchange rate is found to occur virtually instantaneously. If we use an event window that ends well after the monetary policy decision, the estimates do not change, indicating that the news is rapidly incorporated into exchange rates, although the standard errors widen. Despite using a narrow event window in which no other identifiable events occurred, the monetary shock explains only 10–20 percent of the variation in the exchange rate in that short window. In general, the results suggest that monetary policy can account for only a small part of the observed volatility in the exchange rate. The small proportion explained by such high-profile news indicates that there is still much to learn in explaining exchange rate movements.

In the second part of the paper, we present new evidence that not all monetary surprises will have the same effect on the exchange rate. Those that cause a revision to expectations of future policy are found to have a much larger impact than surprises in the timing of a change in monetary policy. A 100-basis-point (25-basis-point) increase in current and future policy interest rates is found to appreciate the exchange rate by around 1.7 percent (0.4 percent). Estimates for individual countries range from 1.3 percent to 2.2 percent. In contrast, a monetary surprise that only brings forward an anticipated change in policy is found to appreciate the exchange rate by just 0.9 percent (0.2 percent).

Appendix

Table 7. Data Description and Sources

	Australia	Canada	New Zealand	United Kingdom
Interest Rates				
One-Month Interest Rate	Thirty-day bank bills (RBA)	One-month bankers acceptances (BoC)	One-month wholesale bill (RBNZ)	One-month LIBOR (Datastream: LDNIB1M)
Three-Month Interest Rate	Ninety-day bank bills (RBA)	Three-month bankers acceptances (BoC)	Three-month wholesale bill (RBNZ)	Three-month LIBOR (Datastream: LDNIB3M)
Futures Contracts	Ninety-day bank bills (Bloomberg: IR1 commodity)	Three-month bankers acceptances (Bloomberg: BA1 commodity)	Three-month bank bills (Bloomberg: ZB1 commodity)	Three-month LIBOR (Bloomberg: L1 commodity)
Futures Exchange	Sydney Futures Exchange	Montreal Exchange	Sydney Futures Exchange	London International Financial Futures Exchange
Settlement Months	March, June, September, and December for all countries			
Expiration Day	Second Friday	Third Tuesday	Thursday after first Wednesday after 9th of month	Third Thursday
Exchange Rates	RBA/Reuters, ten-minute intervals, midpoint of two closest quotes			

Note: RBA is the Reserve Bank of Australia, BoC is the Bank of Canada, and RBNZ is the Reserve Bank of New Zealand.

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