Exchange rate puzzle: the case of New Zealand

Baiding Hu[1], Yingjie Lin, Paul Dalziel

Abstract

This paper examines the impact of monetary policy shocks on the exchange rate in the New Zealand context using an event-study approach. New Zealand is a small open economy with a significant tradable sector. Consequently, fluctuations in the exchange rate, calculated as foreign currency against one New Zealand dollar, can have large macroeconomic impacts. However, how monetary policy affects exchange rates is unclear. Grilli and Roubini (1995) find that while positive innovations in U.S. interest rates lead to an impact appreciation of the U.S. dollar, positive innovations in the interest rates of the other G-7 countries are associated with an impact depreciation of their currency. The authors coin this finding an "exchange rate puzzle" (ERP). In the New Zealand context, Wilkinson *et al.* (2001) find the ERP existing using data 1985 to 1998, while Zettelmeyer (2004) does not using a more up-to-date data set ending in August 1999. This paper adopts a combination of event-study approach and an asset pricing model of the exchange rate (Engel and West, 2010) to examine the impact of monetary policy shocks on the change of the exchange rate. The exchange rate is defined as the value of the US dollar (USD) in terms of the NZD (a rise in the exchange rate is a depreciation of the NZD). We find that the ERP existed and the global financial crisis had a mediating effect on the ERP, showing the exchange rate responded asymmetrically to monetary policy shocks.

Key words: Monetary Policy Shocks, ERP, OCR, Event Study, GFC.
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[1] Correspondence: Baiding.Hu@lincoln.ac.nz.

1. Introduction

This paper examines the impact of monetary policy shocks on the exchange rate in the New Zealand context using a combination of the event-study approach and an asset pricing model. New Zealand is a small open economy with a significant tradable sector. Consequently, fluctuations in the exchange rate, calculated as foreign currency against one New Zealand dollar, can have large macroeconomic impacts. The Governor of the Reserve Bank of New Zealand, for example, told the New Zealand Manufacturers and Exporters Association in February 2013 that "the exchange rate is significantly over-valued relative to what would be sustainable long term in the absence of sizeable increases in the terms of trade and productivity" (Wheeler, 2013, p. 5). Against that background, it is often suggested that the Reserve Bank should ease monetary policy in an attempt to lower the exchange rate. In January to March 2013, for example, three political parties represented in the New Zealand Parliament (the Labour Party, Greens, New Zealand First and Mana) held public hearings as part of their parliamentary inquiry into the condition of New Zealand's manufacturing sector; the subsequent report's first recommendation was that the government should adopt macroeconomic settings that are supportive of manufacturing and exporting, including a fairer and less volatile exchange rate through reforms to monetary policy (Manufacturing Inquiry, 2013).

Before such a recommendation could be implemented, however, it is important to acknowledge that the economics literature warns that the relationship between changes in monetary policy and changes in the exchange rate are not always straight forward. Grilli and Roubini (1995) find that while positive innovations in U.S. interest rates lead to an impact appreciation of the U.S. dollar, positive innovations in the interest rates of the other G-7 countries are associated with an impact depreciation of their currency. The authors coin this finding an "exchange rate puzzle" (ERP). They offer two explanations for such a puzzle; one is that the U.S. is the "leader" country in the setting of monetary policy for the G-7 area, while the other countries are "followers". The other explanation suggests endogenous policy reaction to underlying inflationary shocks that are a cause of exchange rate depreciation. Wilkinson *et al.* (2001), using data on the New Zealand (NZ) exchange rates from 1985 to 1998, found that a contraction in monetary policy may lead to a depreciation of the New Zealand Dollar (NZD) rather than an appreciation, hence the ERP existed. Zettelmeyer (2004), using a more up-to-date data set ending in August 1999, found that the NZ-US exchange rate reacted to short-term interest rate changes trigged by monetary policy shocks in the direction showing the absence of the ERP. The contrast of the findings from the two studies may be attributable to the difference in their approaches; the former uses a Vector Autoregressive (VAR) model while the latter an event study analysis, which necessarily implies different reconstructions of monetary policy shocks.

To avoid the criticisms on VAR which will be elaborated in the next section, this paper adopts a combination of event-study approach and an asset pricing model of the exchange rate (Engel and West, 2010) to examine the impact of monetary policy shocks on the change of the exchange rate. The exchange rate is defined as the value of the US dollar (USD) in terms of the NZD (a rise in the exchange rate is a depreciation of the NZD). Since March 1999 the Reserve Bank of New Zealand (RBNZ) has adopted Official Cash Rate (OCR) as the monetary policy instrument. Therefore, the present research uses changes in market OCR expectations as the measure of monetary policy shock. With the asset pricing model, we are able to extend Zettelmeyer's work to account for the effects on the exchange rate of US asset returns, risk-free returns and currency risk premium. Vithessonthi (2014) finds that the Thai baht and the Japanese yen exchange rate return reacted asymmetrically to monetary policy surprises during the recent Global Financial Crisis (GFC) period in relation to the non-financial crisis period. Our sample is collected for period October 2013 – January 2014, which enables us to test if there is any GFC effect on the USD-NZD exchange rate behaviour.

The plan of the paper is as follows. Section 2 presents a literature review on the relationship between monetary policy shocks and exchange rate movements, paying particular attention to research examining the ERP. Section 3 elaborates the modelling framework and estimation procedures. Section 4 describes the data and models used in this study and presents the empirical results, some concluding remarks contained in Section 5.

2. A brief literature review

2.1. Monetary policy shocks and exchange rate

Dornbusch's (1976) well known exchange rate overshooting hypothesis states that an interest rate increase leads to an immediate appreciation in the nominal exchange rate, in line with uncovered interest parity. The so-called ERP occurs when the overshooting hypothesis is inconsistent with data, or when a contractionary monetary policy shock is followed by a depreciation of the domestic currency. Sims (1992) noted that *increases* in the money supply were associated with *appreciation* of the exchange rate in France and in Germany (but not in Japan, the United Kingdom or the United States). Grilli and Roubini (1995) find that while positive innovations in U.S. interest rates lead to an impact appreciation of the U.S. dollar, positive innovations in the interest rates of the other G-7 countries are associated with an impact depreciation of their currency. They offer two explanations for such a puzzle; one is that the U.S. is the "leader" country in the setting of monetary policy for the G-7 area, while the other countries are "followers". The other explanation suggests endogenous policy reaction to underlying inflationary shocks that are a cause of exchange rate depreciation. Eichenbaum and Evans (1995), Cushman and Zha (1997), Bonser-Neal, Roley, and Gordon (1998), and Kim and Roubini (2000), to name just a few more, have examined the relationship between monetary policy shocks and exchange rates movements in different countries, with conflicting results. The purpose of this paper is to test whether there is any evidence for the ERP in the New Zealand context.

2.2 Measures of monetary policy shocks: VAR vs Event Study

There are two approaches to measuring monetary policy shocks. One is VAR method, which includes the Structural Vector Autoregression (SVAR) model and the Vector Error Correction Model (VECM). The VAR approach is commonly used to examine the long run dynamic effects of monetary policy changes on the exchange rate. The second approach is the event-study method, which is typically used to examine the short run effects or the same day effects of monetary policy changes on the exchange rate. The fundamental difference between the two approaches is in the way that monetary policy shocks are measured. In the VAR model, the monetary policy shock is measured by the disturbance term to the short term interest rate. Under the SVAR model, the monetary policy shock is measured by the structural disturbance to the short term interest rate. With the event study approach, the monetary policy shock is measured as the change in a short term interest rate within an event window.

In the literature various different measures of monetary policy shocks are used, for example, changes in base money (M1) in Cushman and Zha (1997) and Wilkinson *et al* (2001), changes in non-borrowed reserves in Koray and McMillin (1999), Kim (2001), and Faust and Rogers (2003). The most popular measure of monetary policy shocks seems, however, changes in the relative short term interest rate which is very strongly influenced by the central bank's base interest razettte (the OCR in New Zealand).

According to Bernanke and Blinder (1992), for example, changes in short term interest rates are dominated by monetary policy shocks, but are not as sensitive to other influences. Therefore, short term interest rates are more informative in indicating monetary policy shocks compared to other indicators. The market interest rate is the monetary authority's interest rate plus a risk premium.

Criticisms of VAR

The VAR approach in general measures monetary policy shock based on regression residuals pertaining to the monetary variable equation, subject to imposition of identifying restrictions. Dungey and Fry (2009) demonstrated a combination of three identifying techniques to measure, amongst other things, monetary policy shock in the New Zealand economy. The monetary policy shock is measured as a function of the residual of the short-term interest rate equation in their VAR system. They found that a positive monetary policy shock led the New Zealand dollar appreciated for the first two years, thus no evidence for ERP.

The VAR approach may be the most suitable tool for modelling interactions between monetary and fiscal policies. In circumstances where such policy interactions can be ignored in quantifying monetary policy shock, the Rudebusch (1998)'s criticisms on the VAR approach warrant alternative approaches to measuring monetary policy shocks.

According to Rudebusch, VAR models do not make sense for measuring monetary policy shocks, in the context of the USA, for two reasons that are closely related to important characteristics of the VAR model. One is related to the monetary policy equation or monetary reaction equation in the VAR system, which models the endogenous part of the monetary policy. Rudebusch found that the equation was unable to estimate the reaction of Federal Reserve correctly due to four major shortcomings inherent in the standard VAR approach. First, while economic structure and monetary policy reactions have been changing over time, the VAR kept using a simple constant linear structure for estimating the monetary policy reactions and shocks. Secondly, the information set or the right-hand-side variables in the monetary VAR were not broad enough. However, inclusion of extra variables in the VAR would worsen the possible multicollinearity problem. Thirdly, the monetary VARs used final and revised data to model policy reactions while in the real world policy makers had to react to initial releases of data. Fourthly, the significance of lagged variables in the VARs suggested that the Federal Reserve would react to old information systematically, which is unlikely in reality. Brunner (2000) also casted doubt on this particular point, but from an opposite angle, that all economic data from the previous periods are assumed to be available for all researchers at the beginning of the examining period.

As an alternative, Rudebusch suggested utilising rates from the federal funds futures contracts. This avoided the problem that the interest rate residuals from the VAR were uncorrelated with financial market shocks. In financial markets, shocks in future market may differ from the VAR interest rate residuals. This conjecture was supported by the lack of fit of the shocks estimated from the VAR to the ones based on the federal funds futures contracts. What is more disappointing is that even the VARs that Rudebusch examined could not agree with each other on the size of the monetary policy shocks.

Even though the VAR model is commonly used to examine the relationship between monetary policy and the exchange rate, many researchers have expressed dissatisfaction with this model. Engel and Frankel (1984), Hardouvelis (1984), Hakkio and Pearce (1985), and Ito and Roley (1987) noted that in comparison with the VAR approach, an event study has better outcomes on isolating the economic news' effects from the effects of monetary policy shocks on the exchange rate.

The event-study approach

The event study approach analyses immediate market reactions to the announcement of monetary policy by the central monetary authority. Hardouvelis (1988), for example, used an event study to analyse the impact of monetary policy shocks on the exchange rate in the U.S., with the sample period October 1979 to August 1984. The result showed no ERP. Similarly, Lewis (1995) examined the effect of monetary policy shocks on U.S. foreign exchange rates, with base money, non-borrowed reserves, and the Federal Funds rate as the measures of monetary policy shocks. The sample period was from 1985 to 1990 and again no ERP was found. A later study by Bonser-Neal et al. (1998), using the event study approach, also supports the two studies mentioned above.

In the context of New Zealand, Wilkinson *et al.* (2001) argued there was some evidence of the ERP in New Zealand. Their research used monthly data for the period March 1985 to March 1998 for both New Zealand and Australia, including short-term interest rates, foreign-domestic interest rate differentials, and base money to measure monetary policy shocks in three different VAR models for the sake of comparison. The results showed that an increase in the New Zealand base money would lead to an initial appreciation of the NZ Dollar against the Japanese Yen, British Pound, and US Dollar in all three models. In addition, an increase of the short-term interest rate depreciated the NZ Dollar against the Australian Dollar by a small amount, but appreciated the NZ Dollar against the other three currencies in this case. However, there is no ERP when the monetary policy shocks were measured by the interest rate differentials for all four currencies. Overall, the research concluded that the New Zealand exchange rate was mainly explained by its past values. Although monetary policy shocks did have impacts on the exchange rates, their contributions were weaker than the effects of CPI and production. In addition, the results also reported little evidence on the overshooting hypothesis in New Zealand. For Australia, the results were more consistent with the Dornbusch's overshooting hypothesis and previous studies.

Zettelmeyer (2004) used the event study approach to estimating the impacts of monetary policy shocks on exchange rates in Australia, Canada, and New Zealand. An instrumental variable was introduced to solve the endogeneity problem between the exchange rate and the interest rate. In addition, each news on the announcement day was classified from 1 to 3. Class "1" indicated no significant influence on the announcement. Class "2" represented that the news could have some influence on the monetary policy but such evidence was not traceable from any document. Class "3" meant the impact of the public news was significant and the relative data needed to be removed. By eliminating the endogeneity problems, the results were consistent with the standard economic theory. As monetary policy shock was identified by changes in the 90-day interest rate, the results indicated that the exchange rate increased by two to three percent when the 90-day interest rate rose by one percentage point.

Kearns and Manners (2006) also examined the impact of monetary policy on the exchange rate using an event study approach with intraday data in Australia, New Zealand, Canada, and United Kingdom. Since the monetary policy change had been determined before the announcement was made to the public, the influence from other news on the announcement day could be ignored; hence the endogeneity problem discussed in Zettelmeyer (2004) could be ignored. To reduce the effects of public news on the exchange rate, they applied a 70-minutes event window on the dependent variable. The results indicated a positive relationship between interest rates and exchange rates in all four countries. Tightening monetary policy leads to the exchange rate to appreciate, which is consistent with the Dornbusch's overshooting hypothesis. Moreover, an unexpected rise in the interest rate by 100-basis-points led the exchange rate to increase by approximately 1.5 per cent.

Karim *et al*. (2007) examined the effects of monetary policy shocks on the exchange rate within a SVAR model in the New Zealand context and also found no evidence for ERP. In addition, the results showed that the monetary policy shocks had a smaller effect on the exchange rate than the changes in other economic activities. In fact, the monetary policy shock only resulted in a one percent variation in the NZD/UDS exchange rate, and less than one percent variation in the NZD/GBP rate.

3. Modelling framework

3.1 The exchange rate model

In this paper, we attempt to explain the impact of monetary policy shock on the exchange rate of NZ/US currency using the asset pricing model due to Engel and West (2010). Following the authors, we use lower case letters to denote logarithms to specify the unconditional mean of the real exchange rate as,

$$q_t = -R_t - \Lambda_t + \bar{q} \tag{1}$$

The R_t is the relative return defined as $\sum_{j=0}^{\infty} E_t\left(r_{t+j}^{NZ} - r_{t+j}^{US}\right)$, and the Λ_t is the risk premium for holding the US dollar and is defined as $\sum_{j=0}^{\infty} E_t\, \lambda_{t+j}$. The r_t^K is the real interest rate for country K, $K \in \{NZ, US\}$, which equals the nominal interest rate divided by the expected inflation rate, namely, $r_t^K \equiv i_t^K - E_t\pi_{t+1}^K$. The λ_t, defined as $r_t^{US} - r_t^{NZ}$ + $E_t q_{t+1} - q_t$, is the excess return on US interest-bearing assets computed as the real interest rate differential between the US and NZ taking into account the expected real exchange rate change over the next period. The $\bar{q}$ is the long-run equilibrium exchange rate. Munro (2014) found that large changes in Λ_t occurred during financial turmoil periods, such as, the Asia Financial Crisis, the 911 terrorist attack, and the GFC.

Considering that the relative returns may also be subject to shocks to the risk premium, Munro (2014) suggests to model the real exchange rate and the relative return simultaneously, namely,

$$q_t = -\alpha R_t - E_t\Lambda_t + \bar{q} \tag{2}$$

$$R_t = R_t^f - \gamma E_t\Lambda_t \tag{3}$$

where α is an unknown constant to accommodate the possible scenarios that the relative return is not fully priced into the level of the real exchange rate ($|\alpha| < 1$); and similarly, a nonzero γ allows for asymmetrical effects of the risk premium on the relative return and the real exchange rate. The risk-free component of the relative return, R_t^f, is equal to the relative expected value of the inverse of the sum of all future consumption discount factors (page 5, Munro 2014).

Engel and West (2005) find that relative economic fundamentals, such as, inflation differentials, interest rate differentials, follow a random walk process. Therefore, R_t and Λ_t in equations (2) and (3) can be viewed as being made up of past shocks, which implies that the percentage change in the level of the exchange rate is driven by shocks to relative returns of the NZ and US currencies, and shocks to the risk premium of holding the US currency. Since the interest is in modelling changes in the exchange rate, equations (2) and (3) are written in first difference forms,

$$\Delta q_t = -\alpha \Delta R_t - \eta_t^{\Lambda} \tag{4}$$

$$\Delta R_t = \eta_t^{R^f} - \gamma \eta_t^{\Lambda} \tag{5}$$

where $\eta_t^{R^f}$ and η_t^{Λ} are the shocks to the relative risk-free return and the risk premium, respectively. Because the relative risk-free return is assumed to follow a random walk process, $\eta_t^{R^f}$ can be estimated by ΔR_t^f, and as a result, η_t^{Λ} can be estimated upon obtaining an estimate of γ from equation (5)[2].

The first difference forms of the model as given by equations (4) and (5) fit well the event study approach that the present research adopts whereby an event is an OCR announcement by the RBNZ; and the first differences of the variables straddle the event window. The event window for the present study is the 24-hour period to 11:00 am on the OCR announcement day, thus $\Delta X_t = X_t - X_{t-1}$, $X \in \{i^{f\_NZ}, i^{f\_US}, \eta^{R^{f\_NZ}}, \eta^{R^{f\_US}}, \eta^{\Lambda\_NZ}, \eta^{\Lambda\_US}\}$; *t* and *t-1* are 11:00am on the announcement day and the same time the previous day. The timeframe of the event window corresponds to the 24-hour period to 5pm in the previous day in the US (or 6pm or 7pm, depending on whether day-light saving is on in either country, more detailed information is in Appendix).

The $\eta_t^{R^f}$ encapsulates three categories of random factors that affect monetary policy, namely, first, those that make monetary policy deviate from the set path; second,

[2] Munro (2014) estimated the model coefficients using a Bayesian methodology.

unexpected change in monetary policy; and third, expectations about future monetary policy that are not reflected in the short-term interest rate. Over the sample period 23 October 2003 – 30 January 2014, there are three US Federal Open Market Committee meetings (FOMC) (The details are in the Appendix) that overlap the 24-hour window. To rule out possible simultaneous effects of both US and NZ policy announcements for the three dates (events), these three particular observations will be excluded in the regression analysis below. Thus, we can expect that for the remaining events, the η_t^{Rf} should only contain shocks originated from NZ monetary policy surprises.

Equations (4) and (5) provide a framework for simultaneously modelling return and exchange rate, and show that the dynamic processes of the two variables are purely driven by shocks to relative risk-free return and currency premium. The α in (4) measures the impact of a shock to risk-free return on the change in the exchange rate provided the correlation between η_t^{Rf} and η_t^{Λ} is zero. Munro (2014) finds that such a correlation was insignificantly different from zero for eight currency pairs including the NZ-US pair for period December 1989-July 2013. However, such an estimate of α will capture the compound effects of the three forces as mentioned above which is not exactly what is needed for the purpose of the present study which aims for evaluating the contribution of a monetary policy shock to exchange rate changes.

3.2 Measure of monetary policy shock

Since this study uses the event-study approach, identification of monetary policy shocks does not involve sifting through regression residuals like the VAR approach but focuses on the exogeneity and unexpectedness of each policy action under study. Zettelmeyer (2004) used changes in short-term interest rates to measure monetary policy shock after controlling for potential endogeneity of monetary policy actions (OCR announcements) and other shocks that might have also affected the interest rates. Specifically, Zettelmeyer (2004) argues that three month interest rates are used as a policy measure because they are sufficiently short to reflect the policy targets that the authorities set for the immediate future, but at the same time sufficiently long to react only to the extent that changes in the policy rate were unanticipated.

Zettelmeyer's approach is to instrument the 90-day interest rate to obtain the monetary policy shock to the exchange market. The instrumental variable is the direction of underlying central bank policy, which takes values, -1, 0 and 1 as formed in Bonato et al (1999), for a regression similar to equation (8). Since this particular instrumental variable primarily shows the *intention* of the policy announcement, and such an intention is subject to interpretation by the market, Zettelmeyer noted that the actual impact of the announcement may have been different.

The asset pricing model for the exchange rate given in Engel and West (2010) and further elaborated in Munro (2014) implies that use of short-term interest rates as a measure of risk free return ruled out the possibility that the risk adjustment component in interest rate may cancel that of the exchange rate and, as a result, ignored the risk premium components of the interest rate.

Unlike Zettelmeyer, the instrument used in the present paper is a market based measure of OCR surprises and therefore should be more capable of capturing market reactions than the direction variable. More specifically, the study uses the difference between the actual OCR level and the market OCR expectation for the OCR announcement day (Monetary Policy Statements and OCR Reviews).

In New Zealand, OIS securities are an "over-the-counter" derivative on the OCR, where an agreement is made to exchange the compounded return of the realised OCR on a notional initial principle over a future period against the return based on a specified OIS rate. The $\overline{OCR}$ are formed one day before the OCR announcement day. Since the $\overline{OCR}$ data are not subject to the endogeneity (reverse causality) problem as discussed in Zettelmeyer (2004), changes in the short-term interest rate that are only attributable to changes in $\overline{OCR}$ are deemed the size of the impact of monetary policy shock perceived by the market. As the instrument for the short-term interest rate, changes in $\overline{OCR}$ not only capture the directions of the shock but also the magnitude of it and hence is more informative than the underlying direction variable in Zettelmeyer (2004).

Apart from using as the instrumental variable a market based measure of policy, the present paper also differs from Zettelmeyer's in terms of the channel through which monetary shocks are transmitted to the market. In Zettelmeyer, the 90-day interest rate is used as the channel to transmit policy shocks, while the present paper uses shocks to the unobservable risk free return. As Munro (2014) demonstrated, in the exchange market, only risk-free returns matter and interest rates account for a minor share of exchange rate variances. Thus, we chose to use risk-free return shocks to be instrumented and to explain the exchange rate movements.

Since a monetary policy shock directly affects risk-free return, evaluation of the effect of OCR surprises on exchange rate calls for a correlation analysis relating the aforementioned surprises to the resulting changes in the exchange rate, with the risk-free return as the transmitting media. Given that ΔR_t is the relative real asset return of NZ to US, equation (5) implies that the η_t^{Rf} component of the relative return in general should be made up of the shock to NZ risk free return, $\eta_t^{Rf\_NZ}$, and that to US risk free return, $\eta_t^{Rf\_US}$. Because, during either of the window periods, only in New Zealand is there a policy change or policy expectation; and Δi_t^{US} can be considered equal to 0 since the federal funds rate stayed unchanged, $\eta_t^{Rf\_US}$ can be ignored from η_t^{Rf}. Therefore, the task becomes to extract the component of $\eta_t^{Rf\_NZ}$ that is attributable to monetary policy shock originated from New Zealand. Since Δq_t is the change in exchange rate over the window period, the aggregate shock realised over the same window period, $\eta_t^{Rf\_NZ}$, contains an element, $\dot{\eta}_t^{Rf\_NZ}$, which is generated by the monetary policy shock originated in New Zealand; the $\dot{\eta}_t^{Rf\_NZ}$ is deemed zero if the level of the announced OCR is in accordance with market expectations over the window period. Before discussing the extraction of $\dot{\eta}_t^{Rf\_NZ}$ from $\eta_t^{Rf\_NZ}$, it is necessary to estimate the latter first.

Given the statistical evidence reported in Engel and West (2005) and the argument presented in Munro (2014), the level of New Zealand risk free return can be written as a random walk process and the level of New Zealand real asset return can be written as the level of risk free return plus a currency risk premium, namely,

$$R_t^{f\_NZ} = R_{t-1}^{f\_NZ} + \eta_t^{Rf\text{-}NZ} \tag{6}$$

$$R_t^{NZ} = R_t^{f\_NZ} + \mathrm{v}_t^{NZ} \tag{7}$$

Equations (6) and (7) comprise a state space model with the level of risk free return, $R_t^{f\_NZ}$, as the state variable and real asset return, R_t^{NZ}, as the observed variable. The disturbance term, v_t^{NZ}, as suggested by equation (2), is predominantly currency risk premium. The empirical evidence presented in Munro (2014, Table 4) shows that the correlation between $\eta_t^{Rf\_NZ}$ and $\eta_t^{\Lambda\_\mathrm{NZ}}$ is not significantly different from zero. Because Λ_t^{NZ} follows a near random walk process (Engel and West, 2005), Λ_t^{NZ} can be viewed as being made up by the present and all the past $\eta^{\Lambda\_\mathrm{NZ}}$, and the near zero correlation between $\eta_t^{Rf\_NZ}$ and $\eta_t^{\Lambda\_\mathrm{NZ}}$ should imply a near zero correlation between $\eta_t^{Rf\_NZ}$ and Λ_t^{NZ}. Therefore, the $\eta_t^{Rf\_NZ}$ can then be backed out by applying Kalman filter to the system.

To extract $\dot{\eta}_t^{Rf\_NZ}$ econometrically amounts to projecting $\eta_t^{Rf\_NZ}$ into the space spanned by the differences between actual OCRs and market OCR expectations; which are used as the measure of monetary policy shock. Denote the Kalman filter estimate of $\eta_t^{Rf\_NZ}$ by $\hat{\eta}_t^{Rf\_NZ}$, market OCR expectations by $\overline{OCR}$, and market surprises by $\Delta\overline{OCR}(= \overline{OCR} - OCR)$, then the fitted value from the regression in equation (8) is taken to be the estimate of $\dot{\eta}_t^{Rf\_NZ}$, the impact on the risk free return of the monetary policy shock.

$$\hat{\eta}_t^{Rf\_NZ} = \alpha + \beta\Delta\overline{OCR}_t + \epsilon_t \tag{8}$$

Thus, we instrument shocks to risk free return by OCR surprises since OCR surprises are absorbed by the exchange market via the channel of expected relative return which, in turn, is determined by risk free return. In essence, the least squares estimation of equation (8) addresses the possibility that the risk free return may be affected by factors that also affect the changes in the OCR.

4. Data and empirical results

4.1 Data

RBNZ collects exchange rate data on a daily basis at 11:00am and 5:10pm. Thus, there are two sizes for our event window that straddles the OCR announcement. One is a 24-hour window, that is, the 24-hour period to 11:00am on the OCR announcement day. The 24-hour window based on the 5:10pm data is disregarded simply because the amount of time elapsed from the announcement to the end of the window is too large for any change in the interest rates to only subject to the announcement. The other one is the 18-hour window, namely, from 5:10pm on the day before the announcement through 11am on the announcement day. Figures 1 shows the changes in the exchange rates for both the 24-hour and 18-hour windows. The window size did not seem to matter since the two series almost traces over each other.

(insert Figure 1)

The entire sample period starts from 23 October 2003 to 30 January 2014, for which the OCR expectation data are available. But the 5:10pm data only begin in September 2006, which means a loss of about a quarter of the total observations if the 18-hour window sample is used instead of the 24-hour one. Nevertheless, the shortened window width should increase the likelihood that the differences in the exchange rate between 11:00am on the OCR announcement days and 5:10pm the day before were only driven by events occurring shortly after the announcement time. Therefore, the smaller sample will be utilised to provide a "second opinion" for estimates based on the full sample. The sample period also includes the global financial crisis, which allows statistical testing of the significance of the GFC in altering the effects of monetary policy shocks on the exchange rate. Since March 1999, the OCR has been the instrument for the RBNZ to implement its monetary policy. In general, the RBNZ reviews the OCR eight times in each year, and makes adjustments deemed necessary. The dates for possible changes are announced in advance, so that the financial markets can anticipate the direction and level of any change with whatever public knowledge is available at the time. This includes the possibility of an announcement that there will be no change. The market OCR expectations, $\overline{OCR}$, are constructed using overnight indexed swap rates (OIS) due to Krippner (2009); the actual OCR changes and OCR shocks, both in percentage points, are presented in Figure 2.

(insert Figure 2)

For the real relative return between NZ and US, two measures are constructed. One is based on the 10-year zero coupon swaps rate (Bloomberg codes: I04910y Index and I05210Y Index, respectively, for NZ and US data); the other is based on the 10-year plain vanilla swaps rate (Bloomberg codes: NDSW10 Curncy and USSW10 Curncy, respectively, for NZ and US data). Due to lack of daily inflation data in either country, the relative return is deflated using quarterly CPIs because the highest frequency of NZ CPI is quarterly (Bloomberg codes: NZCPCCPI Index and CPURNSA Index, respectively, for NZ and US, rebased on the June quarter 2006). Figure 3 shows the changes in the NZ-US relative real returns based on the 10-year zero coupon swap rate and the 10-year plain vanilla swap rate, on the OCR announcement dates.

The expected relative real return between NZ and US had to be constructed. Following Munro (2014), relative nominal returns over the next 10 years are summed and deflated by the expected future relative inflation rate. Two measures of relative nominal returns are considered, namely, the 10-year zero coupon swaps rate and the 10-year plain vanilla swap rate. The expected future relative inflation rate is calculated as a forward sum of forecast values based on an AR(1) process. In Munro (2014), the coefficient was estimated to be 0.88 for the NZ-US exchange rate for period December 1994 – July 2013. Considering that our sample largely overlaps with Munro's, we also use 0.88 for constructing this particular variable; however, two variations are included as well, which are 0.91 and 0.85 to check sensitivity of estimation results to the value of the coefficient. The plots of both types of swap rates constructed using 0.88 are presented in Figure 3.

(insert Figure 3)

Table 1 provides a comparison of the present study with two recent studies using the event-study approach to examining the relation between monetary policy shocks and the NZ exchange rate. The comparison reveals that the present study not only uses a larger sample, but employs an asset pricing model to address differentials in returns between the two countries and currency risks. The instrumental variable in Zettelmeyer's study is a discrete variable with three values, namely, -1, 0, and 1; such trichotomy certainly limits the correlation between the instrumental variable and the interest rate which is a continuous variable. The instrument in the present study is a continuous variable and has a high correlation with the continuous real relative return variable. The expansion of the sample also allows for testing of the statistical significance of GFC in altering the relations between monetary policy shocks and the exchange rate.

(insert Table 1)

4.2 Empirical results

To arrive an econometric model suitable for the present study, a general functional form for combining equations (4) and (5) may be written as $\Delta q_t = f(\eta_t^{Rf\_NZ}, \eta_t^{Rf\_US}, \eta_t^{\Lambda})$. Ignoring the shocks to US risk free returns (the reasons were discussed above), substituting $\dot{\eta}_t^{Rf\_NZ}$ by its estimate, $\hat{\dot{\eta}}_t^{Rf\_NZ}$, from equation (8) and assuming a linear functional form gives the two-variable model

$$\Delta q_t = \alpha + \beta_\eta \hat{\dot{\eta}}_t^{Rf\_NZ} + \xi_t \quad (9)$$

where the error term ξ consists of the currency premium, η_t^{Λ}, and non-monetary policy shocks $(\eta_t^{Rf\_NZ} - \dot{\eta}_t^{Rf\_NZ})$. Equation (9) is similar to Zettelmeyer's model that the expected change in the exchange rate within the window is only attributable to shocks generated by unexpected monetary policy changes. The shocks that enters the model are the shocks to the risk free return specified in equation (6), which, in turn, is a reflection of monetary policy shock generated by the OCR announcement.

Zettelmeyer (2004) found that adding controls to the two-variable model did not change the modelling outcomes. Since our sample period covers the GFC which Zettelmeyer's did not, our second model specification includes a control variable to account for possible GFC impact on the relationship between the exchange rate and shocks to NZ's risk free return. This model is given as equation (10) below.

$$\Delta q_t = \alpha + \alpha_{GFC} D_{GFC} + \beta_\eta \hat{\dot{\eta}}_t^{Rf\_NZ} + \beta_{GFC} \hat{\dot{\eta}}_t^{Rf\_NZ} D_{GFC} + \xi_t \quad (10)$$

The model given in equation (10) allows hypothesis-testing about whether there is asymmetrical response of the exchange rate to monetary policy shocks between the GFC and non-GFC periods. There are two sets of estimates for both equations (9) and (10), corresponding to the two types of swap rates used to measure the relative return in equation (7).

(insert Table 2)

The estimation results of equations (8), (9) and (10) are presented in Table 2 for both the window sizes and the two. Panel A of the table shows that OCR shocks are highly significant in explaining the shocks to the risk free returns that are part of the relative real returns. Therefore, there is the strong evidence that the shocks to the risk free returns can be attributed to the OCR shocks. This supports instrumenting the shocks to risk free return by the OCR shocks to address measurement error due to non-policy economic shocks that happened to coincide with a policy announcement.

Panel B presents the estimates of the magnitude and direction of changes in the exchange rate as a result of OCR shocks which are channelled through the risk free component of the expected relative real returns. The small R^2 values are consistent with both Zettelmeyer (2004) and Kearns and Manners (2006). Clearly, controlling for the GFC effects has improved the model specification in terms of significance of model coefficients and R^2. For both the window sizes， the significances of the coefficients are determined using the corrected standard error estimates according to the Newey-West heteroscedasticity and autocorrelation consistent estimator to address possible serial correlations in the regression residuals.

Interpretations of the responses in terms of OCR shocks need refer to the first stage regression results in panel A of Table 2 which indicates that if the OCR shock increases by a 100 basis points, the shock to the risk free return will increase by 0.4859 percentage points for zero coupon based relative real return, and 0.7382 percentage points for the vanilla based relative real return. The estimated responses of the exchange rate to monetary policy shocks are found to be 6.5 and 4.3 percentage points, respectively, for the zero coupon based and vanilla based relative real returns, for the 24-hour window period; these responses increased to 8.5 and 5.7 percentage points for the 18-hour window. Thus, a positive OCR shock of a 100 basis points would cause the exchange rate to depreciate by about 3.2 percentage points for both the measures of relative real returns for the 24-hour window, and about 4 percentage points for the 18-hour window. Hence, there is evidence for ERP. However, during the GFC period, a positive OCR shock of a 100 basis points would appreciate the NZ currency by 0.4 to 0.9 percentage points depending on the measure of the relative real return and window size; the ERP was absent.

The response of the exchange rate to the monetary shock behaved differently during the GFC and non-GFC periods. In particular, for a contractionary monetary policy shock the exchange rate depreciated before and after the GFC period and appreciated slightly during the GFC period; and there is a stark difference in magnitude of the response of the exchange rate to monetary shock between the two periods. Such a contrast pattern is also found in Vithessonthi (2014) in the case of Thailand for the Thai baht and the Japanese Yen exchange rate. An explanation offered in Vithessonthi (2014) regarding the difference in magnitude is that during the GFC period capital flight from the US resulted in large capital inflows to safer countries which may moderate the response of the spot exchange rate to monetary policy surprises.

5. Conclusions

In recent years, a high exchange rate has created difficulties for New Zealand’s export sectors. Some commentators have put pressure on the Reserve Bank of New Zealand to lower the highly appreciated New Zealand dollar by relaxing monetary policy. Although there have been previous studies examining the relationship between monetary policy shocks and exchange rate movements, there has not been enough research focusing on how monetary policy shocks influence the exchange rate since the RBNZ adopted the Official Cash Rate as its monetary policy instrument in March 1999. The research reported in this paper was carried out to examine the relationship between monetary policy shocks and New Zealand exchange rate movements since that date, taking into account possible influence from the global financial crisis.

Coupling an event study approach with an asset pricing model, this research employed data for the period October 2003-January 2014 and found evidence for the ERP in New Zealand for the pre- and post-GFC periods. The GFC has significantly altered how the exchange rate responded to monetary policy shocks in that the ERP was absent for the period. This finding shows that exchange rate return reacts asymmetrically to monetary policy surprises during the GFC period. Additionally, the effect of a monetary policy surprise on the exchange rate change was stronger during the financial crisis period. It is, however, necessary to point out that the low R^2s in the regressions showed a limited role that monetary policy shock had in determining exchange rate movements. This result is consistent with some previous studies. Eichenbaum and Evans (1995), for example, noted that monetary policy was important to maintain a stable economic development, but the movements of exchange rate are not exclusively determined by the monetary policy shocks. In addition, Dalziel (2002) and Karim, Lee and Gan (2007) also argued that monetary policy shocks only explain relatively small changes of exchange rate movements.

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Appendix

24-hour period in the US corresponding to the 24 hours to 11am in Auckland

	US Daylight saving	US Non-Daylight saving
NZ Daylight saving	6pm-6pm (previous day)	5pm-5pm (previous day)
NZ Non-Daylight saving	7pm-7pm (previous day)	None existent

18-hour period in the US corresponding to the 18 hours to 11am in Auckland

	US Daylight saving	US Non-Daylight saving
NZ Daylight saving	12am-6pm (previous day)	11pm-5pm (previous day)
NZ Non-Daylight saving	1am-7pm (previous day)	None existent

Dates when $\eta_t^{Rf\_US}$ may not be ignorable and hence are excluded in the estimation

NZ OCR Announcement Dates	USA FOMC Meeting Dates
31/01/2013	29-30/01/2013
31/10/2013	29-30/10/2013
30/01/2014	28-29/01/2014

Estimation results of equations (9) and (10): ρ_π =0.91 and ρ_π =0.85

ρ_π =0.91

Section A

	Eq. (8)	
	10YZC	10YVS
γ_1	0.0027	0.01600
γ_2	0.6929**	0.93987***

Section B

	24-hour				18-hour			
	Eq. (9)		Eq. (10)		Eq. (9)		Eq. (10)	
	10YZC	10YVS	10YZC	10YVS	10YZC	10YVS	10YZC	10YVS
$\boldsymbol{\alpha}$	0.0006	0.0006	-0.0030	-0.0033	-0.0015	-0.0015	-0.0059	-0.0065
$\boldsymbol{\beta_\eta}$	-0.0043	-0.0031	0.0455**	0.0336**	-0.0058	-0.0043	0.0600**	0.0441**
$\boldsymbol{\alpha_{GFC}}$			0.0050	0.0055			0.0067	0.0073
$\boldsymbol{\beta_{GFC}}$			-0.0517**	-0.0381**			-0.0644**	-0.0475**
$\boldsymbol{N}$	82	82	82	82	59	59	59	59
$\boldsymbol{R^2}$	0.006	0.006	0.06	0.07	0.008	0.008	0.05	0.05

***: significant at 1%; **: significant at 5%; *: significant at 10%

$\rho_\pi = 0.85$		
Section A		
Eq. (8)		
	10YZC	10YVS
γ_1	0.0130	0.0263
γ_2	0.3625**	0.6095***

Section B

	24-hour				18-hour			
	Eq. (9)		Eq. (10)		Eq. (9)		Eq. (10)	
	10YZC	10YVS	10YZC	10YVS	10YZC	10YVS	10YZC	10YVS
$\boldsymbol{\alpha}$	0.0008	0.0007	-0.0040	-0.0042	-0.0014	-0.0014	-0.0066	-0.0076
$\boldsymbol{\beta_\eta}$	-0.0081	-0.0048	0.0870**	0.0518**	-0.0111	-0.0066	0.0853**	0.0680**
$\boldsymbol{\alpha_{GFC}}$			0.0062	0.0064			0.0073	0.0084
$\boldsymbol{\beta_{GFC}}$			-0.0987**	-0.0587**			-0.0918**	-0.0732**
$\boldsymbol{N}$	82	82	82	82	59	59	59	59
$\boldsymbol{R^2}$	0.006	0.006	0.06	0.07	0.008	0.008	0.05	0.05

***: significant at 1%; **: significant at 5%; *: significant at 10%

Table 1: A comparison of the present study to other event studies

	Zettelmeyer (2004)	Kearns and Manners (2006)	This Research
Model/Estimation Method	Two-stage least squares	Ordinary least squares	Asset pricing model/Kalman filter and least squares
Event window	24 hours	70 minutes for exchange rate, 24 hours for interest rate.	24 and 18 hours
Instrument Variable	Future direction of monetary policy condition.	N/A	Market based OCR shocks
Variables	90-day interest rate Directions of monetary policy Nominal exchange rate	30-day interest rate 90-day interest rate Nominal exchange rate	Real domestic and foreign relative returns Nominal exchange rate GFC indicator
Sample period	08/01/1990 ~ 01/19/2000	17/03/1999 ~ 10/06/2004	23/10/2003 ~ 30/01/2014
Observations	35	42	83

Table 2: Estimation Results (10YZC: 10 year zero coupon swap rate; 10YVS: 10 year vanilla swap rate)

Section A		
	Eq. (8)	
	10YZC	10YVS
γ_1	0.0092	0.0224
γ_2	0.4859**	0.7328***

Section B

	24-hour				18-hour			
	Eq. (9)		Eq. (10)		Eq. (9)		Eq. (10)	
	10YZC	10YVS	10YZC	10YVS	10YZC	10YVS	10YZC	10YVS
$\boldsymbol{\alpha}$	0.0006	0.0007	-0.0035	-0.0038	-0.0014	-0.0014	-0.0066	-0.0071
$\boldsymbol{\beta_\eta}$	-0.0061	-0.0040	0.0649**	0.0431**	-0.0055	-0.0083	0.0853**	0.0566**
$\boldsymbol{\alpha_{GFC}}$			0.0055	0.0060			0.0073	0.0079
$\boldsymbol{\beta_{GFC}}$			-0.0737**	-0.0489**			-0.0918**	-0.0609**
$\boldsymbol{N}$	82	82	82	82	59	59	59	59
$\boldsymbol{R^2}$	0.006	0.006	0.06	0.07	0.008	0.008	0.05	0.05

Figure 1

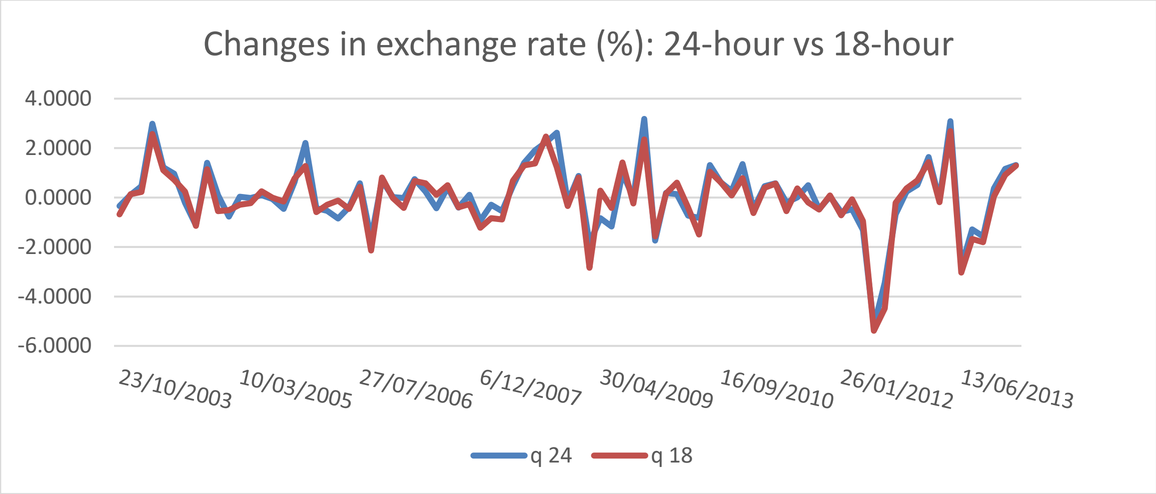

Figure 2

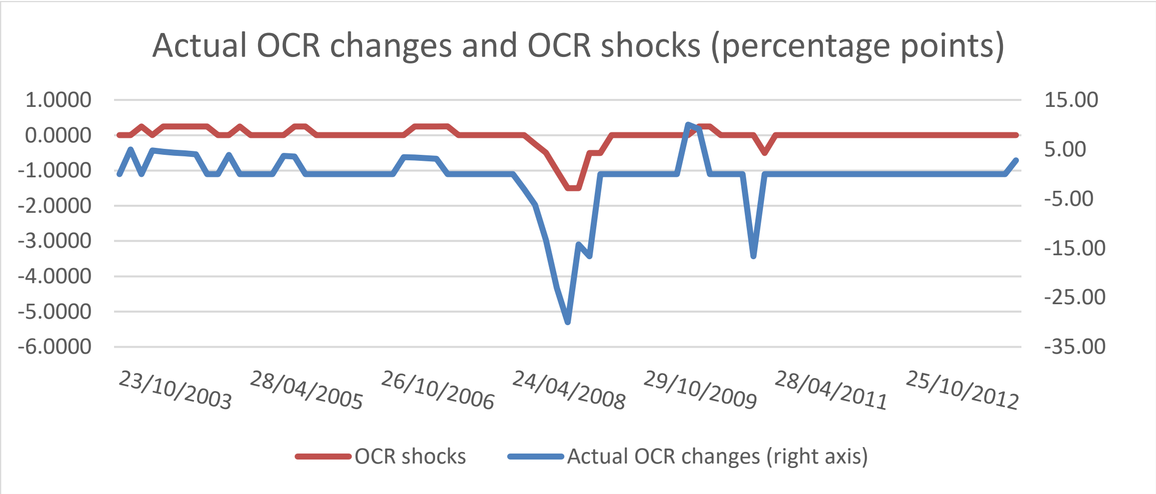

Figure 3