Should the Reserve Bank worry about the exchange rate?

Nguyen, Luan

17 October 2016

Should the Reserve Bank worry about the exchange rate?

Luan Nguyen

17 October 2016

Abstract

This research paper is focused on estimating a set of parameters for a simple monetary policy model of New Zealand and calibrate these parameters to compute viability kernels. We found output gap to be persistent across our sample period. There is weak evidence of a downward sloping IS curve and an upward sloping Phillips curve. The estimation results for the real exchange rate parameter in the IS equation and the uncovered interest rate parity do not confirm the theoretical predictions. By calibrating the estimated parameters to our viability analysis, we recommend that the Reserve Bank should not worry about the exchange rate, the OCR be lowered further and increasing the scope of fiscal policy in sharing the burden with monetary policy.[1]

[1] I thank my supervisor, Jacek Krawczyk for his great support throughout the year with my thesis. I also thank Yuong Ha and other staff members at the Reserve Bank who have provided inputs and data for this research paper. Finally, a big thank to Maximilien Driscoll O'Keefe for helping me on using VIKAASA for viability theory

Contents

1 Introduction

The landscape in which New Zealand monetary policy is operating in has changed dramatically over the years. Rising house prices especially in the greater Auckland region, depressed dairy prices, high net immigration, and near-zero policy interest rates worldwide present several challenges for New Zealand monetary policy. At the same time, New Zealand has become a much more opened economy with extensive international trades with many trading partners. Because of our rapidly growing international trade, the Reserve Bank authorities and local newspapers have become more concerned with the negative impacts of the “overvaluation” of the New Zealand dollar on exports and output growth.

The aim of this paper is to attempt to assess the validity of this concern about the value of the New Zealand dollar and propose policy recommendations by (1) estimating a simple monetary policy model on New Zealand data and (2) using viability theory for the analysis of an economic state-constrained control problem.

A number of studies have attempted to estimate a set of relations for an economy using simple monetary policy models and some have shown that the results are largely consistent with macroeconomic theory. Among others, Rudebusch and Svensson, 1999 estimated an IS equation and a Phillips curve with multiple lags for the U.S. economy and assuming that the U.S. is a closed economy, have found evidence of a downward sloping IS curve and an upward sloping Phillips curve with moderately statistically significant estimates. Krawczyk and Sethi (2007) follows the same approach from Rudebusch and Svensson (1999) assuming for simplicity of the estimation procedure that New Zealand is a closed economy with backward looking expectations, found similar evidence to RS but their estimates were not statistically significant. Krawczyk and Sethi (2007) then calibrated their parameters for viability analysis of monetary policy in a closed economy.

In this paper, we follow closely the modelling approach outlined in Krawczyk and Kim (2014). In their paper, Krawczyk and Kim (2014) derived a continuous-time theoretical model for an open economy and calibrated it using the UK data for viability analysis. Additionally, they also proposed a modification to the uncovered interest rate parity equation by adding a control variable for the short-term nominal interest rate. In this paper, as in Krawczyk and Kim (2014), the New Zealand economy is modelled by a system of 3 equations: an IS equation (Equation 1), a Phillips curve (Equation 2), and a condition for the uncovered interest rate parity (UIP) (Equation 3).[2]

$$\frac{dy}{dt} = \alpha y - \beta_2(i - \pi) + \phi q \tag{1}$$

$$\frac{d\pi}{dt} = 2\beta_3 y \tag{2}$$

$$\frac{dq}{dt} = (i - \pi) + \delta u \tag{3}$$

$$\frac{di}{dt} = u \in U = [\underline{u}, \bar{u}], \tag{4}$$

where y is the output gap, i is a short-term nominal interest rate, π is the inflation rate,and q is the real exchange rate. From this system of equations, we expect to find causal effects from the explanatory variables on the dependent variables. The Phillips curve relates output gap to the inflation rate while the IS equation relates the real interest rate and real exchange rate to changes in the output gap[3]. The uncovered interest rate parity condition relates the real exchange rate to the real interest rate and to the nominal interest rate modification as in Krawczyk and Kim (2014). To better reflect the interest rate smoothing behaviour of central banks, Equation 4 constrains interest rate movements to be within a bound $[\underline{u}, \bar{u}]$.

This paper should be useful for policy makers and New Zealand economists, who are inter-

[2]Note that we have a total of 4 equations in our base model. We refer this to a system of 3 equations because we will estimate the discrete-time version of Equations 1-3 in Section 5 and calibrate Equation 4

[3]The negative sign on β_2 illustrates the negative relationship. When we estimate β_2 in Section 5, we will effectively test whether β_2 is actually negative or not

ested in macroeconomics and monetary policy. Our paper is unique in that we both estimated parameters for New Zealand using a simple open economy monetary policy model and calibrated these parameters into our viability analysis. The parameters that we have estimated in this paper can be calibrated into future studies. We contribute to the existing literature by incorporating the real exchange rate into the system of equations that has been estimated by Krawczyk and Sethi (2007). By doing so, we can investigate the extent towards which the New Zealand economy should be modelled as an open economy instead of a closed economy. It is also interesting to see whether there has been any significant changes in how economic agents in the New Zealand context react to monetary policy and other economic variables throughout the sample period. Through calibration of the estimated parameters and conducting viability analysis, we will be able to propose recommendations to agencies such as the Reserve Bank and thus help them to formulate better policies for the benefit of the New Zealand economy.

This paper has been written as part of the SEF Honours Programme at Victoria University of Wellington. The purpose of this research paper is to introduce economics and finance students to conduct a sizable research project under the supervision of a lecturer which can be a first step towards more in-depth academic research and further post-graduate study. The aim of this particular research is for me to estimate a set of parameters that reflects monetary policy in New Zealand and combine these estimates with viability theory in order to formulate policy recommendations. From this research paper, I have learned how to use MATLAB with VIKAASA, Excel, and Latex. I have gained more insights and different perspectives on monetary policy in New Zealand through the lens of a state-space model and viability theory. These technical skills, as well as the many other things that I have learned throughout this year will be very valuable for my future career. It has been a very memorable experience.

The remainder of this paper progresses as follow. Section 2 of this paper discusses the data that we use and provides a thorough look at developments in the exchange rate and exports.

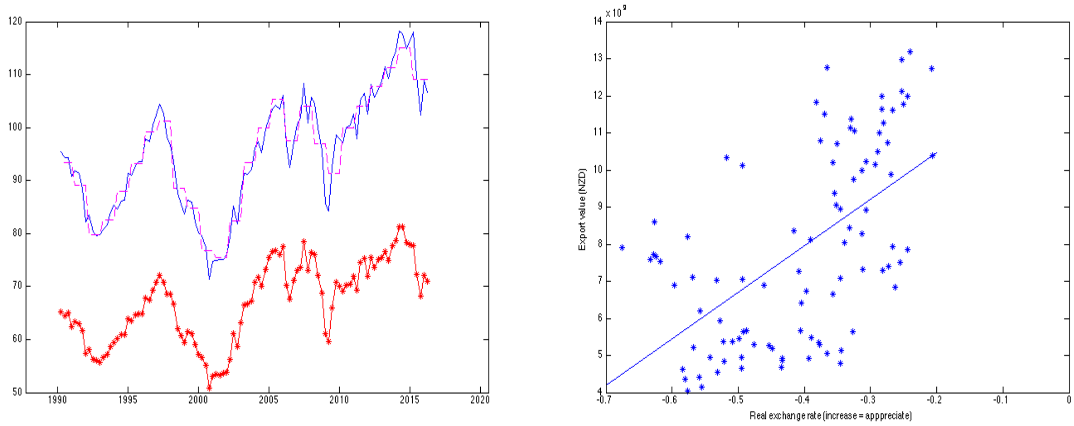
Section 3 explains monetary policy in New Zealand. Section 4 explains our simple model. Section 5 discusses the estimation results. Section 6 provides a robustness check for our model. Section 7 includes a brief introduction to viability theory and a viability analysis. Section 8 proposes recommendations to the Reserve Bank and other interested government agencies. Section 9 concludes this paper.

2 Data and the New Zealand economy

This paper focuses on four key macroeconomic variables: nominal interest rate, inflation, output gap, and real exchange rate. This section will discuss these variables with an emphasis on the real exchange rate and exports which are of particular interest in this study.

From 1991 to 2015, the New Zealand dollar has appreciated in real terms (as shown in Figure 1a). The phrase "the exchange rate is overvalued" and the notion that this may negatively affect New Zealand's export competitiveness have been recently and very frequently mentioned by the Reserve Bank officials and local newspapers. The current strength of the New Zealand dollar can be explained by factors such as the country's current high terms of trade and relatively strong economic performance (McDermott, 2013). As commented in a Reserve Bank press release, an option for the Reserve Bank is to change the focus of monetary policy to target the exchange rate (McDermott, 2013).

Figure 1b shows the correlation between real exchange rate at time $t-1$ and the export value at time t in New Zealand dollar term for the period 1991-2015. The scattered plot and the OLS regression line shows positive correlation between export value and the real value of the NZ dollar. Interestingly, this finding shows that a real depreciation is correlated with lower export value even though in theory New Zealand products should become more appealing to foreign consumers as its currency depreciates. It can be argued that New Zealand major trading



(a) Real Trade-Weighted Index from RBNZ (red), BIS (blue), World Bank (purple)

(b) Correlation between Export Value and Real Exchange Rate

Figure 1: Real Exchange Rate and New Zealand Exports

partners such as Australia and China have relatively inelastic demand for New Zealand goods. Chinese population growth and particularly rapid growth in the middle-income class may have caused demand for New Zealand food products to grow which then puts upward pressure on the New Zealand dollar. The development in foreign exchange hedging instruments could have also mitigated the real increase in cost for foreign customers buying New Zealand products. Brookes, Hargreaves, Lucas, and White (2000) shows that short-term exposures to currency fluctuations can be hedged with negligible costs. Goldberg and Tille (2008) found that exporters with large percentage of homogenous export goods such as commodity products are likely to invoice their trades in low transaction cost vehicle currencies which allows exporters to maintain price parity with their competitors. Fabling and Sanderson (2015) found that even though the U.S. accounts for only 12.1% of trade value, the US dollar accounts for a staggering 56.7% of trade value. On the other hand, on a trade-weighted basis, the NZ dollar accounts for only 20% of trade (Fabling & Sanderson, 2015). This reflects the relatively heavy use of the US dollar as a vehicle currency in trade for New Zealand exporters which may lower the impact that the expensive NZ dollar has on foreign consumers. Furthermore, the result shown in Figure 1b that we have obtained using macro-level data is consistent with past empirical works which failed to find a negative relationship between exchange rate variability and country-level aggregate exports (Mabin, 2011).

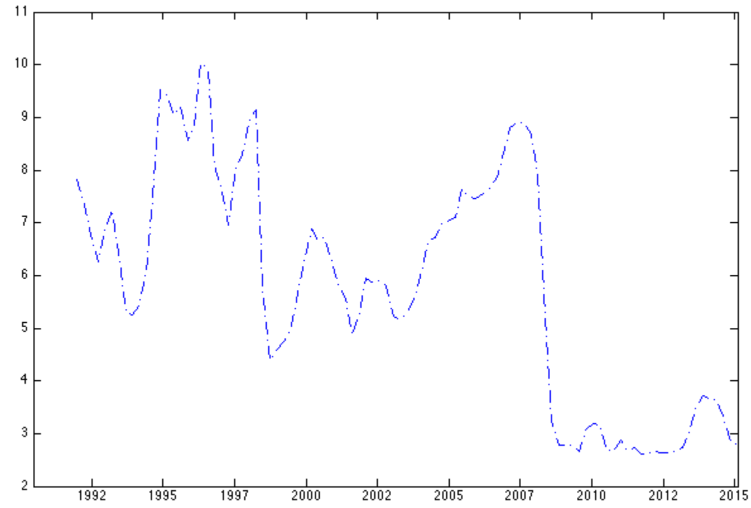
To construct our measure of real exchange rate for estimation consistent with the estimation procedure in Krawczyk and Kim (2014), we used a log-adjusted real trade weighted index (real TWI) obtained from the Reserve Bank. For comparison, we have also looked at real exchange rate data from the World Bank and the Bank of International Settlement (BIS) to compare with the data from the Reserve Bank (see Figure 1a). The Reserve Bank of New Zealand's TWI (trade-weighted index) weights the selected currencies partly by their trade shares and partly by their GDP, the latter designed to pick up some trade in services and intangibles (Hargreaves & White, 1999). In spite of differences in construction of the respective indices, we found the trends across the 3 data sets to be relatively similar over the sample period.

Our measure of real exchange rate q increases when the NZD depreciates in real terms. By definition, a nominal effective exchange rate or a nominal TWI is an index of weighted average of bilateral exchange rates between the domestic economy and its main trading partners (Steenkamp, 2014). An improvement in this measure is the real effective exchange rate or the real TWI which is the nominal TWI adjusted by some measure of relative prices or costs (Klau & Fung, 2006). It is a measure of international competitiveness, as components of monetary/financial conditions indices, as a gauge of the transmission of external shocks, as an intermediate target for monetary policy or as an operational target (Klau & Fung, 2006). Our academic interpretation of q is different from the definition adopted by the Reserve Bank whereby with the latter an increase in real TWI corresponds to a real appreciation of the domestic currency against a basket of currencies. Our measure of real exchange rate also distinguishes between whether the currency is overvalued, correctly valued or undervalued. A value for q of 0 indicates that the real exchange rate is correctly priced. A negative value for q indicates that the New Zealand dollar is overvalued. A positive value for q indicates that the New Zealand dollar is undervalued.

We use the 90-day bill rate to proxy for the short-term nominal interest rate as it follows closely the official cash rate (OCR). The OCR is the interest rate that the Reserve Bank is able to use to impact the direction of the New Zealand economy. From Figure 2, the 90-day bill rate dropped from around 9% down to around 2.5% in 2008-2009 and stayed at that level for a few years. Compared to other developed economies, the policy short-term interest rate in New Zealand was relatively higher prior to the global financial crisis which gave more room for monetary policy to act in the event of a downturn. As at the beginning of October 2016, the OCR and the 90-day bill rate sit at around 2%. It is noted that the variables that we use in our regression model are in deviation from equilibrium values. For our model the equilibrium level of short-term interest rate is 4%. Therefore, the current value of interest rate in deviation from equilibrium is -2% (2% minus 4%). The 4% neutral rate is consistent with the estimated range for the New Zealand nominal neutral 90-day interest rate computed by the Reserve Bank which sits between 3.8% and 4.9% with a target estimate of 4.5% (Richardson & Williams, 2015). In theory, this is the level of the nominal 90-day bill rate that implies the current monetary policy setting to be neither expansionary or contractionary (Richardson & Williams, 2015). With the current OCR and 90-day bill rate around 2%, this implies that current monetary policy is expansionary even though there is a possibility that the neutral interest rate has declined over the past few years.

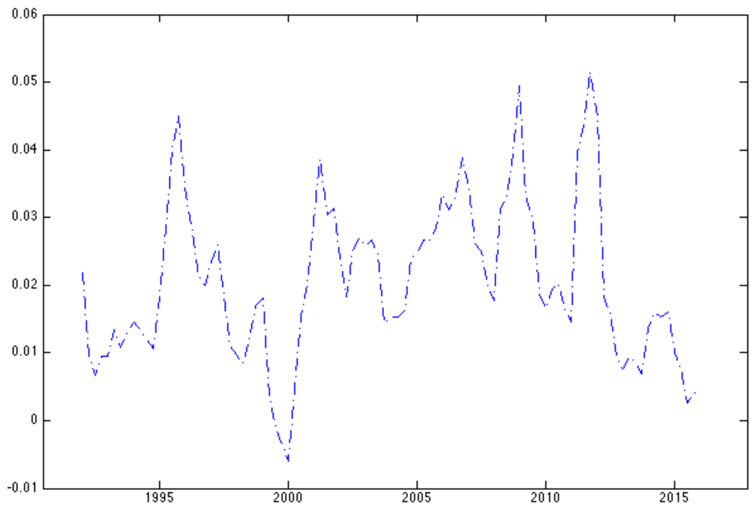
For inflation rate, we use annualised quarterly CPI in deviation from the long-term target 2% as set out in the Policy Targets Agreement. This measure of inflation includes both non-tradable and tradable inflation, and therefore it reflects the inflation rate of an open-economy which is affected by both domestic and foreign sources. Figure 4 shows that inflation rate has decreased significantly from its peak at 5% in 2011 down to close to 0% in late 2015. As at Oc-

Figure 2: 90-day Bill Rate



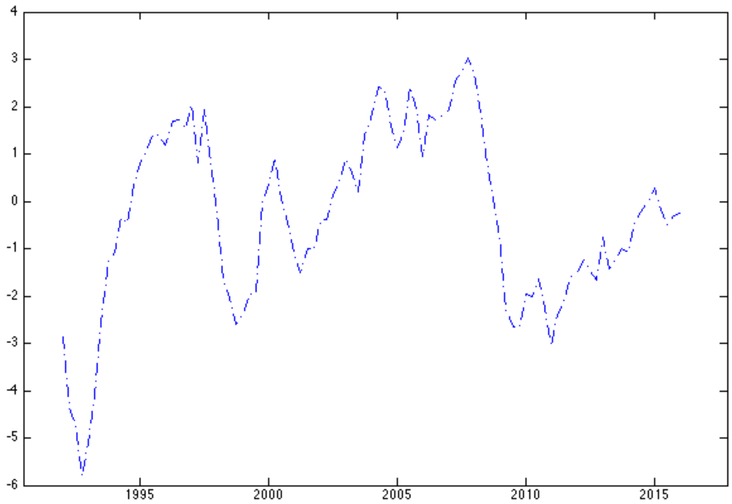
tober 2016, headline inflation is at 0.4% which implies that inflation in deviation is currently at −1.6%. This demonstrates the deflationary environment the New Zealand is in at the moment.

Figure 3: Annualised Quarterly Inflation Rate



The final variable that we discuss about in this section is output gap. Output gap gives an estimate of deviations of realised output from natural output level in an environment where the natural level of output is consistently changing. As this level is consistently changing, the natural level of output gap needs to be estimated using some econometrics approach. We

Figure 4: MV Output Gap



obtained such estimate from the RBNZ which is the multivariate-filtered (MV) output gap. The MV filter uses information contained in broad macroeconomic relationships to better isolate the components of real output attributable to aggregate supply and demand disturbances (Conway & Hunt, 1997). The MV output gap augments the Hodrick-Prescott (HP) filter by adding in an inflation gap, an employment gap, and a capacity utilisation gap (Conway & Hunt, 1997). Figure 4 shows that the measure of output gap has steadily increased since 2010 as the New Zealand economy recovers from the aftermath of the global financial crisis and is currently operating close to its full employment level.

3 Overview of Monetary Policy in New Zealand

The simple monetary policy model that we estimate and analyse using viability theory in this paper captures aspects of the operations and objectives of the Reserve Bank of New Zealand. In the current Policy Targets Agreement, it is stated that price stability plays an important part in supporting the Government's economic objective of delivering permanently higher incomes and living standards for New Zealanders (RBNZ, 2016). Under section 9 of the

Reserve Bank of New Zealand Act (1989), it is required that the Minister of Finance and the Governor of the Reserve Bank have an agreement setting out specific targets for achieving and maintaining price stability (RBNZ, 2016). Specifically, the operational target of the Reserve Bank bank is to keep annual CPI between 1-3 percent, on average, over the medium term, with a 2 percent long-term target midpoint (RBNZ, 2016). Apart from maintaining price stability, the Act also mentions that the RBNZ should have regard to the efficiency and soundness of the financial system as considerations in the conduct of monetary policy (RBNZ, 2016). The PTA states that in achieving price stability, the Reserve Bank must seek to avoid unnecessary instability in output, interest rates and the exchange rate (RBNZ, 2016). In this paper, we will employ a simple model that can capture these objectives of the Reserve Bank. In short, our model encapsulates the behaviour of a central bank that uses a nominal short-term interest rate as an instrument to control inflation and, to a lesser extent, the output gap and, to an even lesser extent, the real exchange rate (Krawczyk & Sethi, 2007).

4 A simple model of the NZ economy

We now give a brief description of the model that we estimate in this paper. We will focus on explaining the open-economy model even though we will use the closed economy model as a starting point in section 5. For those who are interested, Krawczyk and Kim (2014) gives a more detailed description of the open-economy model and also viability theory.

As discussed briefly in the introduction, the New Zealand economy and monetary policy in New Zealand can be modeled by a system of 3 equations. In this paper, we are interested in calibrating parameters for the continuous-time model in the form derived by Krawczyk and Kim (2014) as inputs for our viability analysis. In order to estimate this set of parameters, we discretize the continuous-time model (Equation 1-4) and use the discrete-time system of equations (Equation 5-7) for OLS estimation.

$$y_t = \beta_1 y_{t-1} + \beta_2 (i_{t-1} - \pi_{t-1}) + \phi q_{t-1} + \eta_{y,t} \tag{5}$$

$$\pi_t - \pi_{t-1} = \beta_3 y_{t-1} + \eta_{\pi,t} \tag{6}$$

$$q_t - q_{t-1} - (i_{t-1} - \pi_{t-1}) = \delta(i_{t-1} - i_{t-2}) + \eta_{q,t} \tag{7}$$

Equation 5 is a discrete-time simplified version of the IS and aggregate demand equations. It coincides with the equilibrium in the goods market, whereby the amount of goods being supplied by producers equal the amount of goods demanded by consumers. This equation also corresponds to the amount of money people save equal to the amount of money that people invest. An increase in the real interest rate leads to higher cost of borrowing and higher cost of capital, which then leads to lower investments and lower output. We expect β_2 to be negative as it captures the negative causal relationship between real interest rate (nominal interest rate less inflation rate) and output gap. Current output gap also depends on the output gap in the previous quarter. We expect β_1 to be positive and less than 1 such that the actual level of output will converge back to its natural level in the medium run as the theory generally predicts.

In an open economy, output gap can also be affected through an additional channel which is the real exchange rate, q. The inclusion of the real exchange rate into the IS equation should be very important for an economy like New Zealand. New Zealand is a small and open economy that can be adversely affected by the exchange rate and the relative price between New Zealand and its major trading partners. An increase in the real exchange rate makes New Zealand goods relatively more expensive for its trading partners. This is expected to lower exports (assuming elastic demand for New Zealand exports), increase New Zealand imports of foreign goods (assuming elastic demand for imports) and ultimately leads to a decrease in output gap. The theory thus predicts that ϕ be positive. However, as we have discussed in Section 2, we do not expect to find the right and significant relationship between the real exchange rate and output gap.

Equation 6 captures the augmented Phillips curve in which the changes in inflation rate is driven by the size of the output gap. Our approach to estimate the PC equation assumes that economic agents are backward looking by thinking about future inflation rate through past behavior of inflation. Several empirical works suggest that the expected inflation term is empirically unimportant once lagged inflation is included in the inflation adjustment equation Krawczyk and Sethi, 2007. Recent works by the Reserve Bank of New Zealand shows that inflation expectation is becoming more backward-looking rather than forward-looking partially as a result of the low-interest rate environment Karagedikli, Ryan, Steenkamp, and Vehbi, 2013. Therefore, our model ignores the expected inflation term and this retains the causality property of our model.

Equation 7 represents the uncovered interest rate parity condition or UIP. In the long run, changes in the real exchange rate is reflected by changes in the real interest rate. Following the approach of Krawczyk and Kim (2014), we include a policy instrument with coefficient δ to capture the effect of the changes in nominal interest rate on changes in the real exchange rate. This model assumes that the Reserve Bank can effect the real exchange rate by changing the OCR or short-term nominal interest rate. We expect that δ be negative for our model to be consistent with the theory on uncovered interest rate parity.

There are a number of important features from our model that needs to be emphasised. Our model explicitly assumes that time t output gap is expected to be effected by changes in real interest rate, real exchange rate and the level of output gap at time $t-1$. From this assumption, our model attempts to find causal relationships between the explanatory variables and the dependent variables. Simply put, we assume that past events cause future events to happen. This assumption is also consistent with a long-standing view that many macroeconomic variables do not respond instantaneously to monetary policy shocks. The use of actual inflation also reflects our aim to construct a causal model and our model has the Markov property. In terms of our estimation procedure, our OLS regressions follow the same structure as Equations 5-7, all of which do not have intercept terms. The theoretical reason for this model specification is that given no fundamental macroeconomic change from the previous periods, we should expect no change in output in the current period. The same argument can also be applied to the Phillips curve and the uncovered interest rate parity regressions.

5 Estimation Results

This section presents the estimation results for (1) the case of New Zealand assuming it is a closed economy and (2) the case of New Zealand being an open economy. We compute parameters for the 3 samples to investigate the overall trend over the past 26 years and changes in these parameters over time. We look at the full sample ($1991-2015$), $1991-2005$, and $2006-2015$ to directly compare our results with Krawczyk and Sethi (2007) in order to investigate macroeconomic trends across the two sub-periods. To make our results more robust to longer amount of time for monetary policy to have an impact on the economy, we have also looked at a model specification with two lags ($t-2$) instead of one lag ($t-1$) for two of our equations.

5.1 New Zealand assumed a Closed Economy

We start by looking at New Zealand as a closed economy. Note that this is an unrealistic assumption and we will relax it in section 5.2. Under the assumption of a closed economy, New Zealand is assumed to evolve according to the Phillips curve and the IS curve without the effect from the real exchange rate. For the closed economy model, we follow the approach used in Krawczyk and Sethi (2007) by estimating the following two equations:

Table 1: **OLS Regressions for Closed Economy model**

	1991Q4-2015Q4	1991Q4-2005Q4	2006Q1-2015Q4
β_1	0.92848	0.91173	0.99493
	(25.875)	*(18.34)*	*(11.457)*
β_1	-0.010046	-0.012699	-0.057714
	(-0.42563)	*(-0.41513)*	*(-0.86265)*
β_3	0.022482	0.018867	0.036732
	(0.61878)	*(0.48801)*	*(0.52804)*
R^2 (IS Curve)	0.8757	0.8636	0.8949
R^2 (Phillips Curve)	0.004	-0.0013	0.0013

t-statistics are shown in brackets

$$y_t = \beta_1 y_{t-1} + \beta_2(i_{t-1} - \pi_{t-1}) + \eta_{y,t} \quad (8)$$

$$\pi_t - \pi_{t-1} = \beta_3 y_{t-1} + \eta_{\pi,t} \quad (9)$$

where y_t is the output gap at time t, i_{t-1} is the real interest rate in the previous quarter, π_{t-1} is the inflation rate in the previous quarter, and η_t are serially uncorrelated residuals. In a closed economy, the real exchange rate has no effect on the output gap and the uncovered interest rate parity equation is ommitted because there is no relationship between real exchange rate and nominal interest rate.

Table 1 shows OLS estimates for the IS and PC equations when we assume New Zealand is a closed economy. The coefficients β_1 are close to 1 and statistically significant which implies that output gap is very persistent across our sample period. Output gap is relatively stable as a β_1 less than 1 indicates that the output gap is converging towards its natural level. However, from untabulated results, for the most recent 30 quarters, there are periods when β_1 are greater than 1 which may suggest that output gap is becoming unstable over time as β_1 increases. This instability may cause a downward spiral as a negative output gap in this period will cause the output gap in the next period to be more negative and leading the economy further into recession.

The coefficients β_2 are negative for the three samples which is consistent with the downward sloping IS curve that has been generally supported by macroeconomic theory. A downward sloping IS curve posits that an increase in the real interest rate will lead to an increase in the real cost of borrowing and investment and this will then lower the output gap. However, these coefficients are small and statistically insignificant which signifies that the IS curve is relatively flat and output gap is not very responsive to changes in the real interest rate. The R^2 of the IS regression are high which means that the explanatory variables explain the variation in output gap quite well. This high explanatory power is however mostly driven by the persistence in output gap.

For the Phillips curve, the results are consistent with an upward sloping Phillips curve but the estimates for β_3 are small and statistically insignificant. The R^2 is very small and even negative for the period 1991Q4-2005Q4 which suggests that the estimated parameter from our regression does not explain variations in the change in inflation rate well.

5.2 Open Economy

In reality, New Zealand is an open economy with extensive trading with countries such as Australia and China and therefore is to some extent impacted by changes in the real value of the New Zealand currency. We now relax the assumption of New Zealand being a closed economy and include the real exchange rate and the modified uncovered interest rate parity in our system of equations. In this sub-section, we follow closely the open economy model derived by Kim and Krawczyk (2013) by estimating the following three equations:

$$y_t = \beta_1 y_{t-1} + \beta_2(i_{t-1} - \pi_{t-1}) + \phi q_{t-1} + \eta_{y,t} \tag{10}$$

$$\pi_t - \pi_{t-1} = \beta_3 y_{t-1} + \eta_{\pi,t} \tag{11}$$

$$q_t - q_{t-1} - (i_{t-1} - \pi_{t-1}) = \delta(i_{t-1} - i_{t-2}) + \eta_{q,t} \tag{12}$$

The output gap in the IS equation now also depends on the previous-quarter real exchange rate q_{t-1}. According to our model specification, a real appreciation of the New Zealand dollar corresponds to a decrease in the variable q, which we then expect to have a negative causal effect on the output gap in the next quarter. In Equation 12, the modified uncovered interest rate parity condition relates the change in the real exchange rate to the real interest rate and a change in nominal interest rate from the previous quarter.

Table 2 shows OLS estimates for the three equations when we assume that New Zealand is an open economy. Similar to our finding from the closed economy model, output gap is persistent and stable in the open economy model. The negative coefficients β_2 for the open economy model have larger magnitudes and statistical significance than for the closed economy model. The coefficients ϕ on real exchange rate are positive for all except the period 2006-2015. This finding suggests that a real appreciation of the New Zealand dollar may lead to a higher level of output for the period 2006-2015. Our estimate for ϕ for 2006-2015 is thus inconsistent with macroeconomic theory because a real depreciation of the New Zealand dollar should lead to a higher output gap. By adding in another explanatory variable, the R^2 of the IS equation are largely unchanged from the closed economy model. The coefficient estimate β_3 in the Phillips curve regression is positive and statistically insignificant for the three samples and therefore there is no significant improvement from using the open-economy model relative to the closed economy model estimates.

Table 2: OLS Regressions for Opened Economy model (with 3-month lag)

	1991Q4-2015Q4	1991Q4-2005Q4	2006Q1-2015Q4
β_1	0.93833	0.9347	0.93555
	(22.786)	*(18.274)*	*(9.0544)*
β_2	-0.022286	-0.088692	-0.016467
	(-0.6501)	*(-1.5616)*	*(-0.21283)*
ϕ	0.0011955	0.0062779	-0.0034191
	(0.49414)	*(1.5793)*	*(-1.0567)*
β_3	0.022482	0.018867	0.036732
	(0.61878)	*(0.48801)*	*(0.52804)*
δ	-0.23369	-0.4651	0.32073
	(-0.35909)	*(-0.60438)*	*(0.26216)*
R^2 (IS Curve)	0.8761	0.8698	0.8979
R^2 (Phillips Curve)	0.004	-0.0013	0.0013
R^2 (UIP)	-0.2388	-1.2904	0.0004

t-statistics are shown in brackets

5.3 Open Economy with 6-month lag

Our model assumes that changes in the explanatory variables in the last quarter take effect on the dependent variables in the following quarter. In this subsection, we compute estimates for the open economy model by assuming that it takes up to 6 months (two quarters) for monetary policy to take full effect. We note that the effect of changes in the nominal interest rate on changes in the real exchange rate do not require a period as long as 6 months. We therefore modify Equations 10-11, while keep Equation 12 unchanged, to:

$$y_t = \beta_1 y_{t-2} + \beta_2(i_{t-2} - \pi_{t-2}) + \phi q_{t-2} + \eta_{y,t} \tag{13}$$

$$\pi_t - \pi_{t-1} = \beta_3 y_{t-2} + \eta_{\pi,t} \tag{14}$$

$$q_t - q_{t-1} - (i_{t-1} - \pi_{t-1}) = \delta(i_{t-1} - i_{t-2}) + \eta_{q,t} \tag{15}$$

Table 3 displays OLS regression estimates for the open economy model with 2-quarter lag to capture the fact that change or shock today is assumed to take effect within the next 6 months rather than 3 months. The coefficients on lagged output gap β_1 for the full sample and the period 1991-2005 decreased significantly to 0.84 and 0.827 respectively which is then more consistent with data from the UK as in Batini and Haldane (1999). However, by increasing the lag to two quarters, for the sample period 2006-2015, the coefficient β_1 slightly increased to 0.94632 which shows some futher evidence that the output gap in New Zealand has become more persistent over time. It can be observed that the coefficients β_1 have become steeper relative to the model with 1-quarter lag. This suggests that by looking at a 6-month interval rather than 3-month interval, output gap is then more sensitive to changes in the real interest rate. However, the effect of real interest rate on the output gap remains very small and insignificant.

The Phillips curve remains upward sloping when we adopt the 6-month lag specification. For 2006-2015, β_3 increased from 0.024658 to 0.036732 by changing from 3-month to 6-month lag. This increase is consistent with a recent research by Karagedikli, Ryan, Steenkamp, and

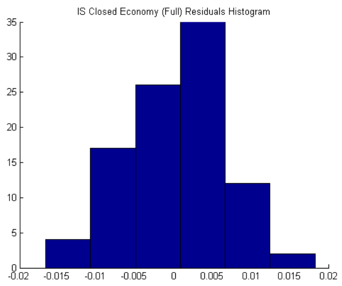
Table 3: OLS Regressions for Opened Economy model (with 6-month lag)

	1991Q4-2015Q4	1991Q4-2005Q4	2006Q1-2015Q4
β_1	0.84135	0.82735	0.94632
	(13.659)	*(11.098)*	*(6.2703)*
β_2	-0.05099	-0.17571	-0.11667
	(-0.99268)	*(-2.1465)*	*(-1.0126)*
ϕ	0.0031401	0.012975	-0.0046143
	(0.86271)	*(2.2636)*	*(-0.96074)*
β_3	0.022482	0.018867	0.036732
	(0.61878)	*(0.48801)*	*(0.52804)*
δ	-0.23369	-0.46518	0.32073
	(-0.35909)	*(-0.60438)*	*(0.26216)*
R^2 (IS Curve)	0.8761	0.7113	0.7697
R^2 (Phillips Curve)	0.004	-0.0013	0.0013
R^2 (UIP)	-0.2388	-1.2904	0.0004

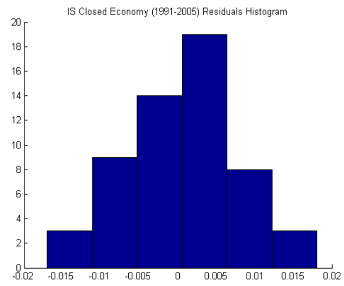
t-statistics are shown in brackets

Vehbi (2013) which concludes that from several empirical specifications of the Phillips curve, inflation expectations in New Zealand have become more backward-looking over time. As noted in that paper, inflation has remained persistently low even as the economy grew faster than its potential and previously slack resources were increasingly being used (Karagedikli, Ryan, Steenkamp, & Vehbi, 2013). In recent years, a number of countries have experienced extended periods of time when inflation outcomes were not consistent with the conventional Phillips curve forecasts (Karagedikli, Ryan, Steenkamp, & Vehbi, 2013).

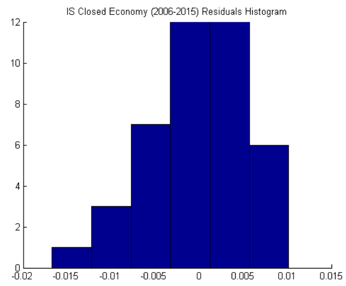
From our estimation results, we have shown so far that the real exchange rate of the New Zealand currency is not a significant or obvious driver of the output gap of New Zealand. The overall results for the parameters ϕ and δ supports the empirical difficulties in modelling the real exchange rate and the uncovered interest rate parity (Ha, 2016). There are multiple reasons to explain why changes in the real exchange rate cannot be fully captured by changes in the nominal interest rate in our model. In fact, the nominal interest rate is not by itself an exogenous shock. The nominal interest rate would be the key channel through which all other shocks would be expressed through (Ha, 2016). For example, a higher terms of trade would result in stronger growth and inflation, in turn higher nominal interest rate, which in turn lead to a higher TWI (Ha, 2016). Output gap was found to be relatively unresponsive to changes in the real exchange rate. The primary reason is that the real TWI responds endogenously to other shocks, rather than the change in the real TWI being a shock itself (Ha, 2016). In fact, variables that contribute to the output gap such as agricultural production are more influenced by climate change than the measure of real TWI (Ha, 2016).



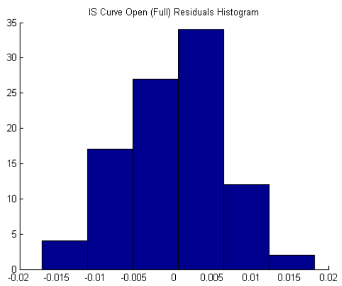
(a) IS closed full



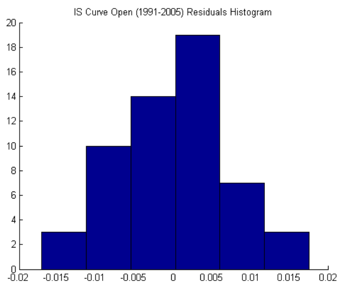
(b) IS closed 91-05



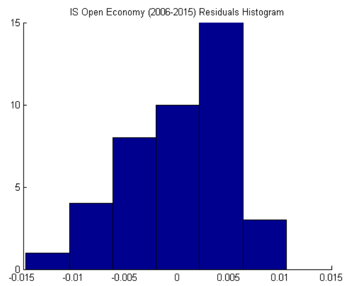
(c) IS closed 06-15



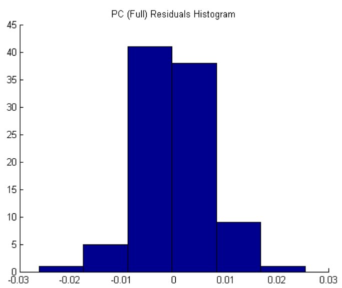
(d) IS open full



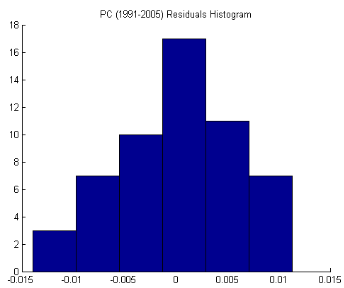
(e) IS open 91-05



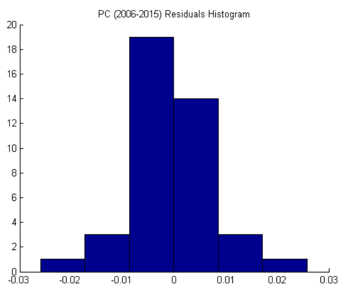
(f) IS open 06-15



(g) PC full



(h) PC 91-05



(i) PC 06-15

Figure 5: Residual Histograms

We find that output gap is persistent throughout our sample period to the extent that the current output gap is largely determined by the output gap in the previous one to two quarters. On the other hand, β_2 and β_3 have the right signs but with low statistical significance. There is some evidence of a downward sloping IS curve but our results are not statistically significant. The coefficient estimates for the Phillips curve are positive but statistically insignificant.

To further investigate the validity of our results on the parameters with correct signs but low statistical significance, we plot residual histograms in Figure 5 for our regressions. The residuals for the open-economy and closed-economy IS regressions are approximately normally distributed with mean zero which supports our inference on β_1 and β_2 despite the statistical insignificance of coefficients β_2. Similarly, the residuals for our Phillips curve are normally distributed with mean zero which supports our inference on β_3 being positive and on an upward sloping Phillips curve.

6 Robustness check

6.1 Stationarity

A concern for our study is that the trends for our macroeconomic variables are non-stationary. A stationary time-series is one whose statistical properties such as mean, variance, and autocorrelation are all constant over time (Manuca & Savit, 1996). Non-stationarity is a concern because if the series is consistently increasing over time, the sample mean and variance will grow with the size of the sample, and they will always underestimate the mean and variance in future periods. In the presence of non-stationarity, it is the case that the behaviour of our regressions will change over time and there is a different data generating process to each of our sub-periods. This simply means that the true coefficient estimates may vary over our sample period. In untabulated Augmented Dickey-Fuller test, we found evidence that output gap and inflation are stationary. On the other hand, the 90-day bill rate and the real exchange rate are non-stationary. This suggests that the 26-year macroeconomic relationships that we attempted to estimate have varied over the sample period.

6.2 Negative R^2

It is noted that a number of our regressions have significantly negative values for R^2. This is a natural outcome from our restriction on the intercept terms and underlying population features. Eisenhauer (2003) discusses that regression through the origin by dropping the constant term can diminish the model's fit to the data. If estimated R^2 are strongly negative or decrease by a significant amount when predictor variables are added, then the specification of the fixed part of the model must be doubted (Snijders & Bosker, 1994). To test whether relaxing this restriction on the intercepts will improve the model's fit to the data, we run regressions with intercepts for the full sample. In results not shown, the R^2 values are now all positive but remains very small. Except for the UIP, the intercepts are all statistically insignificantly different from zero. These robustness checks provide more support for our original model specification as relaxing the restriction do not materially improve the fitness of our model.

6.3 Differences for output gap between the two sub-periods

From untabulated results and also the large coefficient estimates β_1, output gap in New Zealand may have become unstable over our cut-off point in 2006. To make sure that the effect of lagged output gap on current output gap is significantly different between the two sub-periods, we use a t-test for difference to test the null hypothesis that the two samples ($1991 - 2005$ and $2006 - 2015$) are significantly different. The result from the t-test shows statistical evidence in favour of the alternative that the two samples are statistically significantly different. An alternative to t-test is the Wilcoxon test, which is a non-parametric test with the null hypothesis that the two samples have the same median. In contrast to the t-test, the Wilcoxon test suggests that we do not reject the null hypothesis at the 10% level and therefore the two sub-periods are not significantly different from one another. The tests show that we do not have sufficient evidence to infer that the behaviour of output gap has changed significantly between the two sub-periods.

7 Viable solutions for a deterministic economy

7.1 What is viability theory?

Viability theory is an area of mathematics concerned with viable evolutions of dynamic systems subjected to constraints on states (Kim and Krawczyk, 2009). This theoretical approach is fundamentally different from the more popular Taylor rule in which the central bank is assumed to minimise a loss function. Viability theory does not subject the central bank to minimise its loss function and keep the economy at an optimal level at any given point in time. It simply specifies regions that the central bank should avoid and keep the economy from moving into those regions by using available policy instruments.

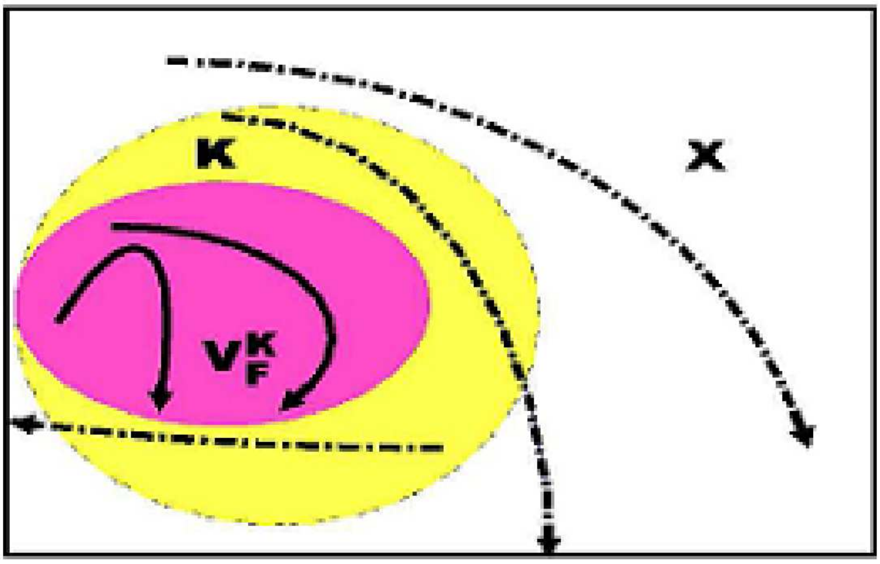
An analogy can be made to explain the intuition behind viability theory. Imagine that the central bank is a kayak sailor sailing down the river to further explore the beautiful scenery. There is a waterfall downstream where the nearby current is very strong. The sailor is constrained by her strength and stamina. If the current is slow, she can reverse her kayak and avoid the waterfall. However, if the current is too fast, then she will not be able to reverse. The closer the sailor gets to the waterfall, the harder it becomes for her to resist the fast current and she is then constantly pulled towards the waterfall despite any effort she makes. The solution to her problem is if she knows where the current speed is excessively fast for her, she can avoid sailing further from that point onwards and therefore spare herself from dropping down the waterfall. In this picture, the waterfall can be a symbol for the boundaries on inflation, output gap or exchange rate. The strength and stamina of the sailor is the policy instrument that the central bank has, which is the policy interest rate. The "point of no return" in this case is where the speed of the current becomes faster than the speed at which she can sail her kayak upstream.

This “point of no return” is the boundary for our viability kernels.

We can establish qualitatively here the ”waterfall” or the constrained set for the Reserve Bank. The objectives of the Reserve Bank can be summarised simply as to keep the New Zealand economy within certain boundaries. The Policy Targets Agreement states that the Reserve Bank must maintain inflation rate within 1%-3% on average in the medium term. Additionally, the bank also seeks to avoid unnecessary instability in output, interest rates and the exchange rate. The level of output can be high or low and the Reserve Bank will attempt to bring this output level to the full employment level in the medium term using available policy instruments. This also introduces some boundaries for interest rate and exchange rate that we will calibrate in the next part of this section.

The viability kernel that we will compute in the next sub-section will assist the Reserve Bank in determining the ”point of no return”. The concept of a viability kernel can be explained by looking at Figure 6. The yellow circle denoted K is the constraint set while the pink area V is the viable region. The set K (yellow) is the normative bounds that can be interpreted from the PTA and realistic assumptions about the behavior of the central bank, and we will calibrate these constraints later in this paper. The goal of viability theory is to solve for a given initial condition of the economy such that the central bank can use its policy instrument to keep the economic system within the normative bounds of the constraint set for a certain period of time. The viability kernel V (pink section) for the set K is then the largest subset of K which contains all initial conditions for such a strategy (Krawczyk & Sethi, 2007). It can be observed that trajectories starting inside this viability kernel V (pink section) can be kept inside the viable region using the policy interest rate. Any trajectories in the yellow area cannot be controlled to remain inside the viable area and will therefore escape the constraint set. The white area X is considered to be non-viable and is analogous to the waterfall that the central bank would clearly want to avoid.

Figure 6: Viability kernel illustration



7.2 Viability Constraints, Controls and Instrument

In order to compute the viability kernel for New Zealand, we will now calibrate the constraint set or the edges of the "waterfall" that the Reserve Bank wants to confine New Zealand within. As in the Policy Targets Agreement, the Reserve Bank is charged with maintaining inflation within the 1%-3% band on average over the medium term. In our viability analysis, we assume that this target must be met every quarter rather than as a multi-period average.

In a similar spirit to Krawczyk and Sethi (2007), we assume a wide interval for output gap of -0.04 to 0.04. The real exchange rate has a wide bound of $[-0.10, 0.10]$ which allows for up to 10% undervaluation or overvaluation of the NZ currency. We assume nominal interest rate to be between 0% and 7%. It has a zero lower bound as it is theoretically impossible to have negative nominal interest rates. Even though a few countries such as Japan have adopted zero interest rate policy, the lower bound remains appropriate for New Zealand as the current official cash rate (OCR) is 2% as at October 2016. The upper bound for nominal interest rate is historically justified as it is only infrequently violated in countries like the U.S. or Japan (Krawczyk & Kim, 2014). It is important to note that when we communicate π and i terms, they are considered as deviations from an average equilibrium level of 0.02 and 0.04, respectively. Therefore, in the viability analysis section we will add 0.02 and 0.04 to π and i respectively below. It then follows that the viability kernel plots will be displayed in terms of level inflation rate ($\Pi = \pi + 0.02$) and level interest rate ($I = i + 0.04$) which better reflects the actual variables being observed and targeted by the Reserve Bank. The constraint set K can therefore be summarised as:

$$\text{K}\equiv \{(y_t,\, \pi_t,\, i_t,\, q_t) : -0.04 \leq y_t \leq 0.04, \quad 0.01 \leq \pi_t + 0.02 \quad \leq 0.03, 0.0 \leq i_t + 0.04 \leq 0.07, -0.10 \leq q_t \leq 0.10\}$$

7.3 Viability Analysis of the Closed Economy Model

We used the VIKAASA[4] package in Matlab in order to conduct our viability analysis[5]. Calibrating the results for the full sample period closed economy model that we have estimated in Section 5.1, our dynamic system is characterized by equations 16 to 18.[6]

$$\frac{dy}{dt} = -0.07152y - 0.010046(i - \pi) \tag{16}$$

$$\frac{d\pi}{dt} = 0.022482y \tag{17}$$

$$\frac{di}{dt} = i \in U = [-0.005, 0.005] \tag{18}$$

Figure 7 shows a 3D plot of the viability kernel for New Zealand under the assumption that New Zealand is a closed economy. Note that the viability area V is quite large relative to the constraint set K (the box outside the green region). For us to gain a better understanding of the viability kernel, it is useful to take a closer look at several cuts of the whole region. Figure 8a slices the kernel through $I = 0.00$ (blue) and $I = 0.07$ (pink) and superimposes the two

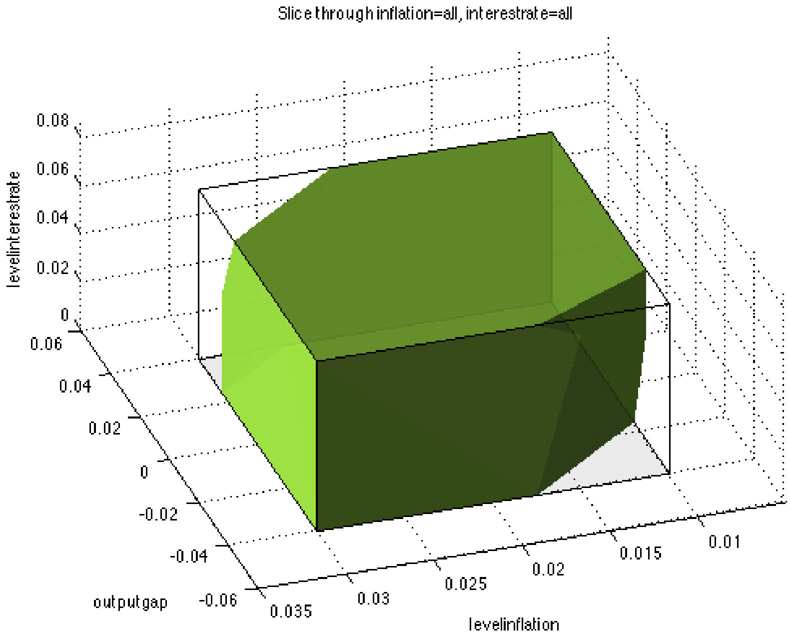
[4]VIKAASA is a specialised MATLAB application that can compute viability kernel approximations for rectangular constraint and control sets

[5]An online appendix is available for access to our VIKAASA inputs and computation

[6]When converting our model from discrete-time to continuous-time, the coefficient on output gap is α, where $\alpha = \beta_1 - 1$

slices. This plot shows that at very high level of output gap and at any level of interest rate, the Reserve Bank should avoid high inflation. At very negative output gap and at any level of interest rate, the Reserve Bank should avoid very low level inflation.

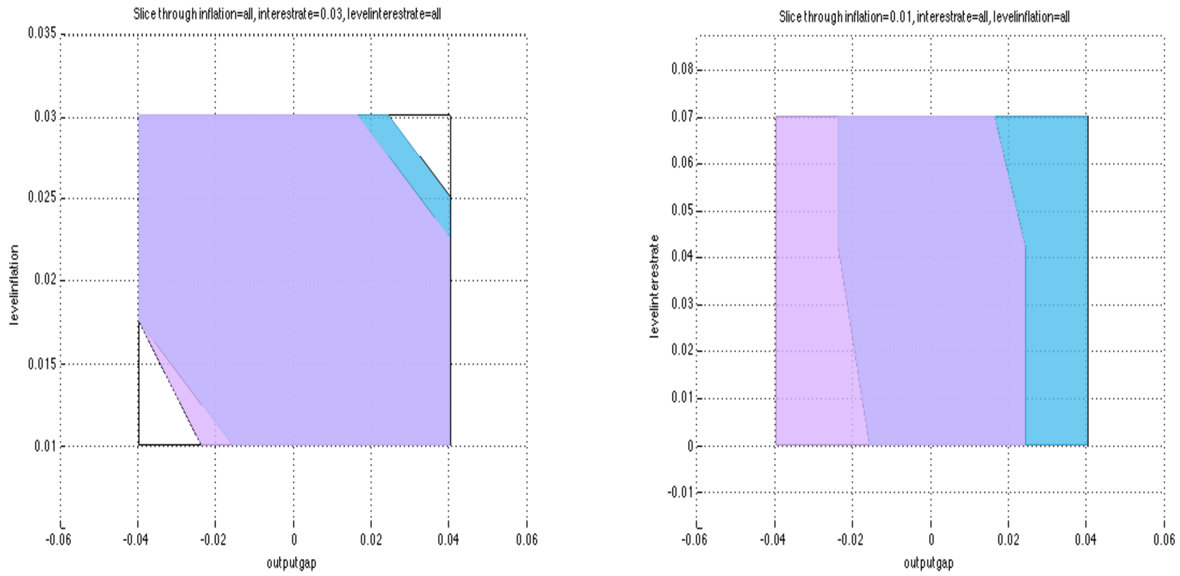
Figure 7: The 3D kernel for closed economy viability kernel



In Figure 8b, we plot two slices of level inflation: $\Pi = 0.01$ (blue) and $\Pi = 0.03$ (pink). This plot is consistent with conventional monetary policy. When output gap is low or negative, at any level interest rate, the Reserve Bank should target for a higher level of inflation to keep the New Zealand economy viable. When output gap is high and the economy is overheating, the Reserve Bank should target a low level of inflation to slow the economy down.

7.4 Viability Analysis of the Open Economy Model

Next, we look at the open economy model for the full sample period (1991-2015) that we have estimated using OLS regressions in Section 5. The model can be characterized by the following continuous-time equations:



(a) The plane of level inflation rate and output gap for $I = 0.00$ (blue) and $I = 0.07$ (pink)

(b) The plane of level interest rate and output gap for $\Pi = 0.01$ (blue) and $\Pi = 0.03$ (pink)

Figure 8: Closed Economy Viability Kernel Slices

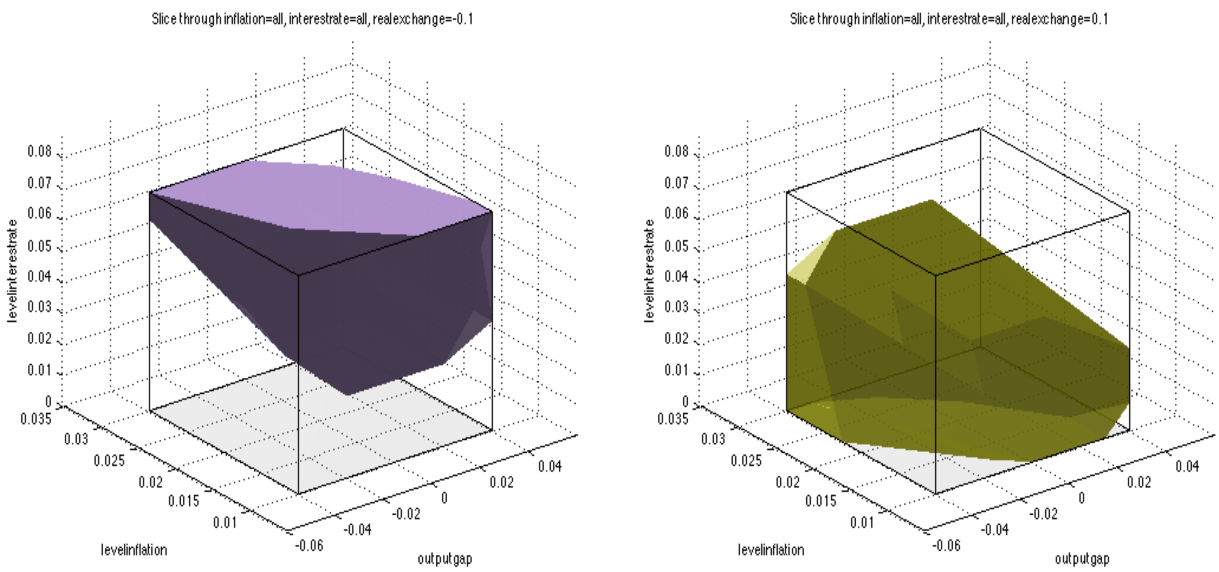
$$\frac{dy}{dt} = -0.06167y - 0.022286(i - \pi) + 0.0011955q \tag{19}$$

$$\frac{d\pi}{dt} = 0.044964y \tag{20}$$

$$\frac{dq}{dt} = (i - \pi) - 0.23369u \tag{21}$$

$$\frac{di}{dt} = i \in U = [-0.005, 0.005] \tag{22}$$

Figure 9a and 9b again show that the viability kernel V is quite large and similar in volume to the viability kernel for a closed economy model (see Figure 7). To see Figure 9 at a more detailed level, Figure 10 plots the viability kernels for the two extremes of level interest rates: $I = 0.00$ (pink) and $I = 0.07$ (blue). When New Zealand is in a recession with negative output gap and low inflation, a low nominal interest rate is needed to keep the economy within the viability kernel. Specifically, when New Zealand is operating close to full employment but with low inflation rate as high as $1.1\% - 1.2\%$, a relatively low interest rate policy is also needed to keep the economy viable. According to the August 2016 Monetary Policy Statement, the



(a) NZD overvalued by 10%

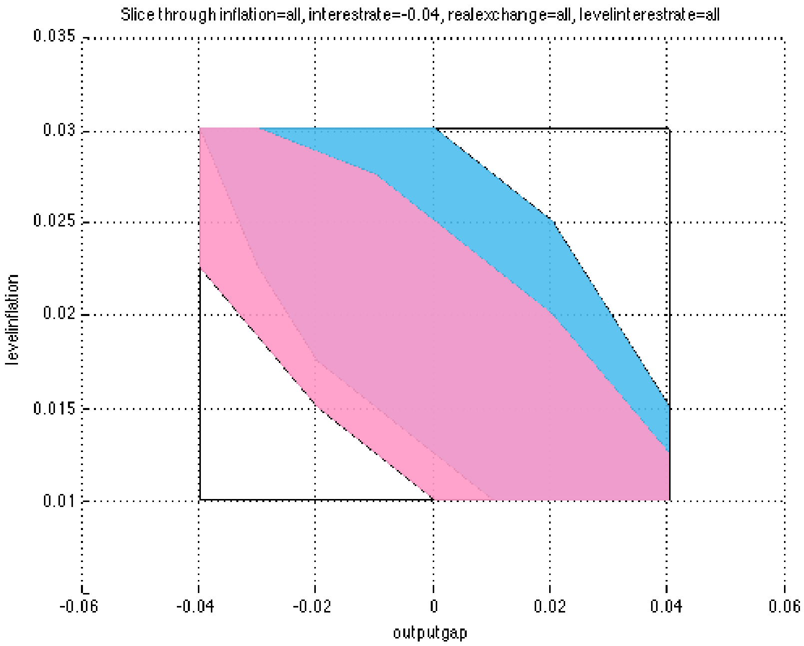
(b) NZD undervalued by 10%

Figure 9: Viability kernel 3D slices for open-economy model (full)

New Zealand economy is operating near capacity or full employment (RBNZ, 2016). With the annual CPI inflation currently sitting at 0.4% and OCR at 2% (RBNZ, 2016), New Zealand is likely to be outside the viability kernel that we have computed in Figure 10 and 9. By lowering the interest rate further, the central bank can get the economy back inside the viability region.

At very negative output gap, the central bank should avoid annualised inflation rate less than around 2%. The bottom left hand corner of Figure 10 represents an economy being in a liquidity trap whereby the nominal interest rate cannot be lowered any further to stimulate economic activity. When the economy is in a liquidity trap, the central bank should target a high level of inflation to keep the economy viable or attempt to boost the output gap level. Central banks want to avoid the liquidity trap because due to the zero lower bound, real interest rate may not be small enough to stimulate the economy and this will not guarantee a recovery without prompting a slide into deflation (Krawczyk & Sethi, 2007). This observation can support several arguments from a number of economists on increasing the inflation mid-point target above 2% and using fiscal policy to directly target output level. On the other hand,

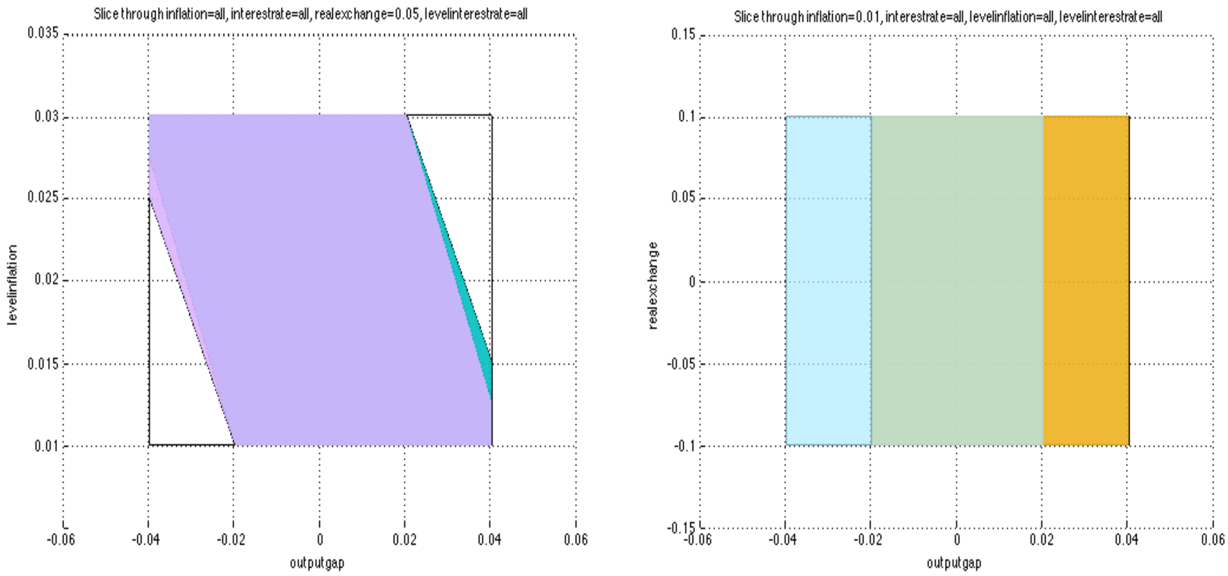
Figure 10: The plane of interest rate and output gap sliced at $I = 0.0$ (colour pink) and $I = 0.07$ (colour blue)



when the economy is overheating with very positive output gap and very high inflation, the central bank should increase nominal interest rate which will help keeping the economy viable and cooling down the economy.

Figure 11a plots the viability kernels for the two cases of real exchange rate: when the New Zealand dollar is overvalued by 5% (pink) and when the New Zealand dollar is undervalued by 5% (blue). The two viability kernels largely overlap each other. This prescribes similar policy for the central bank regardless of whether the New Zealand dollar is undervalued or overvalued in order for the economy to remain viable. To gain another perspective at this result, Figure 11b plots the viability kernels of output gap against real exchange rate for the two extremes of level inflation. The two viability kernels in Figure 11b show that for there is no significant effect from varying the real exchange rate on the state of the economy or the viable inflation rate and therefore has no significant policy implication according to our viability analysis.

We are also interested in how the viability kernels look like for the most recent period. In



(a) The plane of output gap and level inflation rate sliced at $q = -0.05$ (pink) and $q = 0.05$ (blue)

(b) Output gap & exchange rate sliced at $\Pi = 0.01$ (blue) & $\Pi = 0.03$ (orange)

Figure 11

the final part of this section, we examine the viability kernels for the sample period 2006-2015. We input the following system of continuous-time equations into VIKAASA:

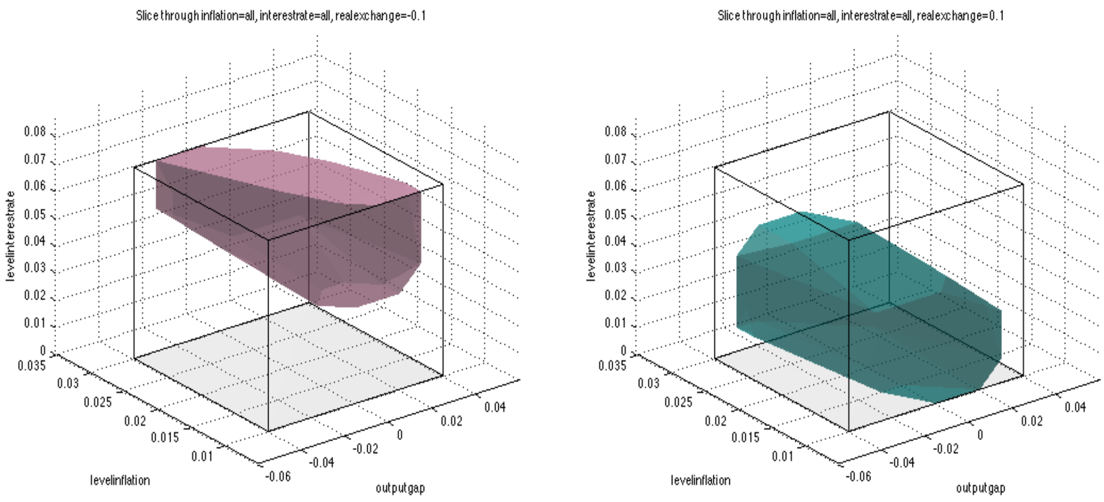
$$\frac{dy}{dt} = -0.06445y - 0.016467(i - \pi) - 0.0034191q \tag{23}$$

$$\frac{d\pi}{dt} = 0.073464y \tag{24}$$

$$\frac{dq}{dt} = (i - \pi) + 0.32073u \tag{25}$$

$$\frac{di}{dt} = i \in U = [-0.005, 0.005] \tag{26}$$

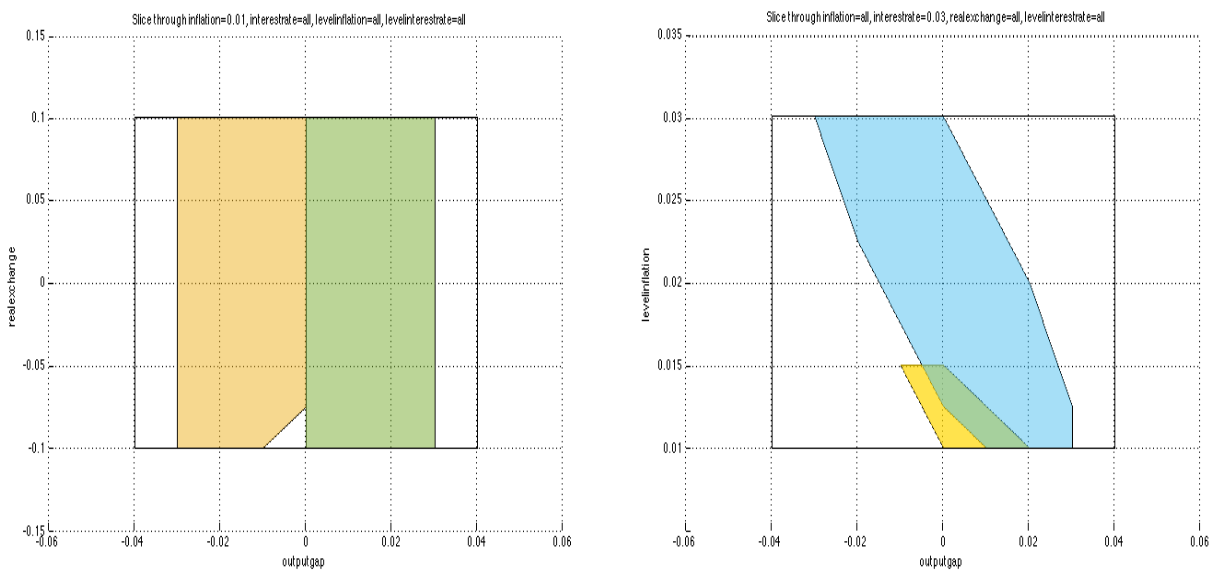
The four panels in Figure 13 shows that any output gap outside the interval -0.03 to 0.03 will lead the economy outside the viable region. This displays the increasing difficulty for the Reserve Bank to keep the economy viable should a significant shock on output gap occurs. Figure 13a and 13d show that the real exchange rate has no significant policy implication for the Reserve Bank. In Figure 13a, inflation has been shown to be the main variable that the Reserve Bank should target to keep the economy viable. These kernels are consistent with the



(a) NZD overvalued by 10%

(b) NZD undervalued by 10%

Figure 12: Viability kernel 3D slices for open-economy model (2006-2015)

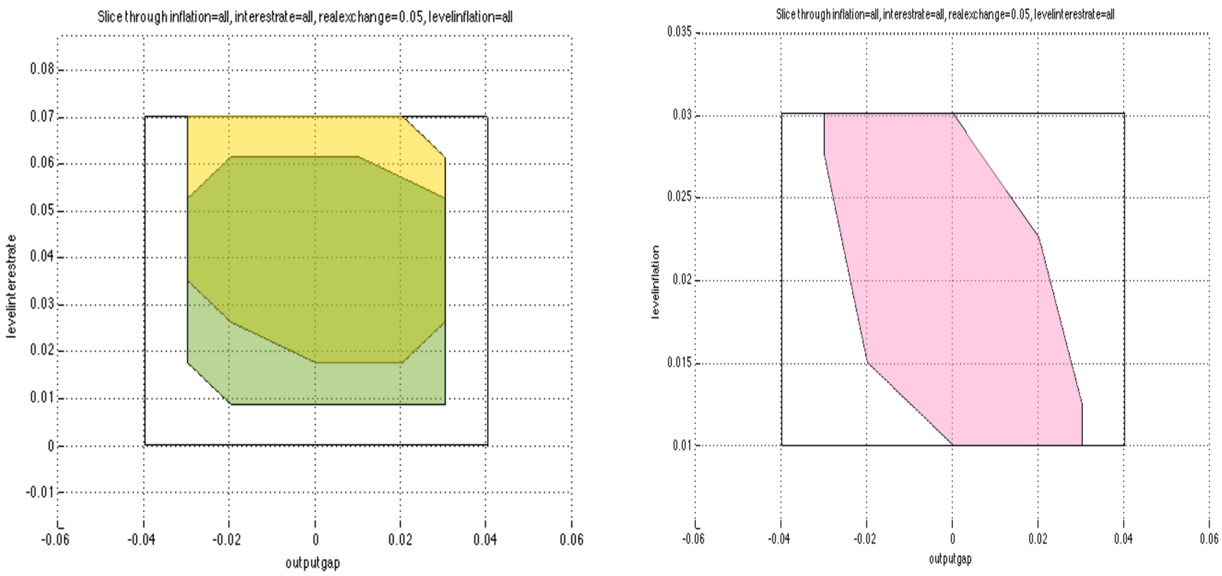


(a) Plane of output gap and real exchange rate for $\Pi = 0.01$ (green) and $\Pi = 0.03$ (orange)

(b) Plane of output gap and level inflation for $I = 0.00$ (yellow) and $I = 0.07$ (blue)

Figure 13: Viability kernel 3D slices for open-economy model (2006-2015)

full period as an economy operating below full capacity requires the central bank to target a higher level of inflation for any level of real exchange rate. Figure 13b shows that a low interest



(c) Plane of output gap and level interest rate for $q = -0.05$ (yellow) and $q = 0.05$ (green)

(d) Plane of output gap and level inflation for $q = -0.05$ and $q = 0.05$

Figure 13: Viability kernel 3D slices for open-economy model (2006-2015)

rate gives the economy a very small viable region. For very negative output gap, the economy can only return to the viability kernels if output is increased using fiscal policy or a very high level of inflation is achieved. This also shows the downside by a low interest rate regime whereby a large shock can destabilize the domestic economy. Figure 13c shows that when the interest rate is below 2% and for any level of output gap between −3% to 3%, the economy can stay viable if the real exchange rate decreases by a small percentage. However, it is noted that the effect from the real exchange rate is very insignificant.

8 Policy Recommendations

The findings from this paper suggest a number of recommendations to the Reserve Bank of New Zealand and interested government agencies:

- The concern regarding the overvaluation of the local currency cannot be justified using our approach. From (1) the positive correlation between exports and real exchange rate, (2) rising consumption demand from China, (3) insignificant difference between our closed and open economy models, and (4) large overlap in our viability kernels, it is recommended that the Reserve Bank as well as news correspondence should not be worried about the exchange rate as they have been for many years and should not change the focus of monetary policy to target the exchange rate

- From our viability kernels, it is also recommended that the Reserve Bank continue its accommodative monetary policy and possibly further lower the OCR to keep the economy within the viable region. However, it is also noted that we have not endogenise the Reserve Bank's concern regarding the Auckland region housing market. In spite of this, the Reserve Bank should avoid zero-interest rate policy which has been shown by our viability analysis to destabilise the economy.

- New Zealand government institutions should develop more and better mechanisms for fiscal policy to share the large burden with the Reserve Bank in contributing to the growth and stability of the economy.

9 Conclusion

In this paper, we have estimated a simple monetary policy model for New Zealand and used the estimated parameters for our viability analysis.

From our OLS estimation, we have found output gap to be persistent across our sample period. There is weak evidence of a downward sloping IS curve and an upward sloping Phillips curve which is consistent with Krawczyk and Sethi (2007) and Rudebusch and Svensson (1999). Our results on the effect of the real exchange rate on output gap and the behavior of the uncovered interest rate parity do not confirm theoretical predictions. It follows from our paper that our open economy model and the additional 10 years of data are not significant improvements from the closed economy model of Krawczyk and Sethi (2007).

An analysis based on viability theory has enabled us to propose how a central bank's monetary policy can be established. In particular, we have endogenously derived boundaries that should be observed, if the economy is to remain inside the constraint set K. These findings combined with our viability kernels suggest that the Reserve Bank should not worry about the exchange rate. Our viability analysis also suggests that the OCR be lowered further but above the zero lower bound for New Zealand to remain in the viability region.

References

Batini, Nicoletta and Andrew Haldane (1999). "Forward-looking rules for monetary policy". In: *Monetary policy rules*. University of Chicago Press, pp. 157–202.

Brookes, Andy et al. (2000). "Can hedging insulate firms from exchange rate risk?" In: *Reserve Bank of New Zealand Bulletin* 63.1, pp. 21–34.

Conway, Paul, Ben Hunt, et al. (1997). *Estimating potential output: a semi-structural approach.* Tech. rep. Reserve Bank of New Zealand.

Eisenhauer, Joseph G (2003). "Regression through the origin". In: *Teaching Statistics* 25.3, pp. 76–80.

Fabling, Richard and Lynda Sanderson (2015). "Export Performance, Invoice Currency and Heterogeneous Exchange Rate Pass-through". In: *The World Economy* 38.2, pp. 315–339.

Goldberg, Linda S and Cédric Tille (2008). "Vehicle currency use in international trade". In: *Journal of international Economics* 76.2, pp. 177–192.

Ha, Yuong (2016). Personal Communication.

Hargreaves, David, Bruce White, et al. (1999). "Measures of New Zealand's effective exchange rate". In: *Reserve Bank of New Zealand Bulletin* 62.3, pp. 3–15.

Karagedikli, Ozer et al. (2013). "Inflation expectations and low inflation in New Zealand". In: *Reserve Bank of New Zealand Discussion Papes, DP2016/09.*

Klau, Marc and San Sau Fung (2006). "The new BIS effective exchange rate indices". In: *BIS Quarterly Review, March.*

Krawczyk, Jacek B and Kunhong Kim (2014). "Viable stabilising non-Taylor monetary policies for an open economy". In: *Computational Economics* 43.2, pp. 233–268.

Krawczyk, JB and R Sethi (2007). *Satisficing solutions for New Zealand monetary policy. Reserve Bank of New Zealand Discussion Paper Series, No. DP2007/03.*

Mabin, Gemma et al. (2011). *New Zealand's exchange rate cycles: Impacts and policy.* Tech. rep. New Zealand Treasury Wellington.

Manuca, Radu and Robert Savit (1996). "Stationarity and nonstationarity in time series analysis". In: *Physica D: Nonlinear Phenomena* 99.2, pp. 134–161.

McDermott, John (2013). "Understanding the New Zealand exchange rate". In: *Address to Federated Farmers Meat and Fibre Council, Wellington, November.*

RBNZ (2016). *Monetary Policy Statement.* Reserve Bank of New Zealand.

Richardson, Adam, Rebecca Williams, et al. (2015). "Estimating New Zealand's neutral interest rate". In: *Reserve Bank of New Zealand Analytical Note, AN2015/05.*

Rudebusch, Glenn and Lars EO Svensson (1999). "Policy rules for inflation targeting". In: *Monetary policy rules.* University of Chicago Press, pp. 203–262.

Snijders, Tom AB and Roel J Bosker (1994). "Modeled variance in two-level models". In: *Sociological methods & research* 22.3, pp. 342–363.

Steenkamp, Daan et al. (2014). "Measuring New Zealand's effective exchange rate". In: *Reserve Bank of New Zealand Bulletin* 77.6.