# Anchoring Inflation Expectations in the Face of Oil Shocks & in the Proximity of ZLB: A Tale of Two Targeters

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## Abstract

This paper applies a N-ARDL framework to two longstanding inflation targeting policy regimes in order to assess the relation between oil prices dynamics and inflation expectations and the further consequences created by a proximal ZLB situation. The application is based on data from January 1994 to June 2018 for New Zealand and the UK. We focus on oil price shocks as a variable of interest and this was found to have an asymmetric effect on inflation expectations. One further key finding is that the real effective exchange rate has significant impacts on inflation expectations and this is indicative of an exchange rate pass-through to inflation via an inflation expectations channel. In general, we find that inflation, exchange rate, money supply, output growth, unemployment and fiscal deficit/surplus have significant implications for inflation expectations. Inflation expectations are also influenced by their past behaviour indicating adaptive inflation expectations. This study contributes to the debate on the inflation targeting at ZLB.

**Key Words:** Inflation Targeting, Oil Shocks, Zero Lower Bound, Monetary Policy, Money supply, Inflation, Inflation Expectations, Nonlinear ARDL, NKPC.
**JEL Classification:** E24, E31, E43, E52, E58, E61, E62, D84.

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## 1. Introduction:

In this paper we explore the effects of zero lower bound interest rates (ZLB) on inflation targeting policy regimes. A key purpose of central bank independence is to achieve price stability based on a rules and discretion compromise in the context of a delegated committee-based decision making process (Svensson, 1996; Bernanke et al. 2001; Mishkin, 2000).[2] The committee is given an inflation target (subject to parameters) and empowered to use tools such as short term nominal interest rates to achieve the target. A primary intention is to "anchor" inflationary expectations (Williams, 2014) through continuity, coherency and consistency in policy and through strategic communication (providing an iterative development of decision making through policy) as the economic environment evolves (Bernanke, 2001 and 2003; Morgan, 2009). Transparency and accountability are considered core institutional features for credible guidance. However, since the financial crisis, inflation targeting has been the subject of multiple critiques.[3] For example, it has been argued that a primary focus on price stability and frequent small adjustments to short term interest rates led to neglect of other factors that may cause price and financial stability to diverge, and this was *one* reason why asset price inflation could create the pricing problems and default contagions that contribute to an escalating banking crisis (Borio and White, 2004). The subsequent development of macro-prudential policy is intended to rectify this problem. A macro-prudential policy orientation is intended to complement and not substitute for price stability policy tools. However, intuitively one would expect the efficacy of those tools to be affected by the environmental consequences that the new macro-prudentialism is intended to address (Schoenmaker, 2014). Analytically, one can distinguish between determinants of inflation and influences on inflationary expectations. In reality the two tend to bleed together in a purposive fashion via the anchoring effect.[4] A situation of long term zero lower bound interest rates (ZLB) creates a new environment for both determinants and expectations, and thus for the received and currently available monetary policy tools intended to affect these.[5] Clearly, there is a potential barrier or threshold effect at the zero lower bound, given that the IMF anticipates that interest rate cuts of 3-6% are necessary to address sudden major financial and economic recessions and ZLB implies an immediate shift to negative interest rates in such cases and a possible liquidity trap (see Agarwal and Krogstrup, 2019) . However, more generally and prior to any such problem of crisis, one would expect that ZLB affects the credibility of monetary policy and thus receptivity to attempts to influence price stability via expectations management.

Our purpose, therefore, for inflation targeting policy regimes, is to test how inflationary expectations respond to a ZLB environment and whether inflation expectations become *unanchored* and hence more responsive to shocks to standard inflation determinants in a (proximal) ZLB environment. We employ a *Nonlinear Autoregressive Distributed Lag (N-ARDL)* framework to explore data for the UK and New Zealand. These two were selected since both are longstanding inflation targeting policy regimes and so provide an extended duration for data. Moreover, each can be decomposed into two periods: a pre proximal ZLB period and a proximal ZLB period, though the interest rates indicative of proximal are

[2] *Inter alia*, proponents claim that inflation targeting is simple, transparent, flexible and makes policymakers more accountable to the public; it overcomes the problem of time-inconsistency (Mishkin, 2000), mitigates inflationary bias (Herrendorf, 1998), lowers risk premiums (Lee, 2011; Lanzafame, 2016), increases real wages (Seim and Zetterberg, 2013), reduces the output sacrifice (ratio) by increasing the credibility of monetary authority (Corbo et al. 2001; Chortareas et al. 2002), and contributes to fiscal discipline (Obstfeld (2014) Minea and Tapsoba, 2014).

[3] There are longstanding critiques of the desirability and efficacy of inflation targeting in general (Angeriz and Arestis, 2008; Alpanda and Honig, 2014), but also specific claims that it has been fatally undermined by the global financial crisis (Frankel, 2012; Quiggin, 2012; and Sumner, 2012); various counterclaims have been made (Reichlin and Baldwin, 2013; Andersen et al. 2015).

[4] For the evolution of theory see Phelps (1967) and Friedman (1968) and most recently Marfatia (2018).

[5] One might also note that Bank of Japan, European Central Bank (ECB) and the Riksbank have opted for negative rates (Nasir, 2017).

different. In New Zealand, the trigger was a cut to 2.5% and in the UK a cut to 0.5%. Drawing on monthly observations from January 1994 to June 2018 we apply a comprehensive empirical estimation exercise. Much of the analysis focus around oil price shocks as a variable of interest and this was found to have an asymmetric effect on inflation expectations that a N-ARDL framework is sufficiently sensitive to pick up. One key finding is that the real effective exchange rate has significant impacts on inflation expectations and this is indicative of an exchange rate pass-through to inflation via an inflation expectations channel. This is a *relatively* under-explored or researched avenue for statistical analysis and debate[6]. In general, our empirical results lead us to conclude that inflation, GDP, unemployment, the exchange rate and the state fiscal stance have significant implications for inflation expectations in the case of both countries. Moreover, inflation expectations appear to be influenced by their past behaviour, and this *does have* implications for anchoring based on adaptive inflation expectations. We provide further comment, explanation and findings in the subsequent analysis.

The paper proceeds in five sections: a brief reprise of standard determinants of inflation and some comment on how inflationary expectations are shaped (Section 2), methodology and data (Section 3), analysis and findings (Section 4), and policy implications (Section 5).

## 2. Determinants of inflation expectations and anchoring

In the aftermath of the global financial crisis, radicalised monetary policy has maintained historic low interest rates for an unprecedented period, and during that time inflation has also remained relatively low and fairly stable (Haldane, 2015; Nasir, 2017). Proximal ZLB conditions have been part of a new "normal". Despite positive signalling through "forward guidance", the UK (unlike the USA) has not begun the return to a prior historic "normal" range for interest rates. Arguably, communicative signalling has become ambiguous in the context of interest rate policy for the shaping of expectations-related behaviour in the UK, and yet the breakdown in convention has not passed through to manifest consequences in terms of elevated inflation. This is a curious situation based on the assumed efficacy of past practice emanating from the Bank of England Monetary Policy Committee (if we again refer to Bernanke 2001, Obstfeld, 2014 etc). Clearly, ZLB is a relevant issue here. Once one approaches ZLB, then the expectations relation of interest rates becomes a matter of ambiguity since the behavioural response of market participants may be ambivalent. As such, in hypothesis terms, there is scope to test whether inflation expectations become *more* responsive to shocks in proximal ZLB conditions for longstanding inflation targeting countries. Put another way, in what sense can one refer to anchoring?

Factors that define the dynamic of actual inflation are widely considered to influence inflationary expectations. Accordingly, this study focuses on the factors which are typically deemed to account for inflation and inflation expectations dynamics. There is extensive literature on the many determinants of inflation, but less for inflation expectations. Logically, what determines inflation must also influence the expectations of inflation, since information regarding the former feeds the latter (Armantier et al. 2016). Determinants extend to encompass past inflation and aggregate demand and supply pressure (Gali and Gertler, 1999). This has tended to vary between countries. For example, Canova et al. (2007) report significant demand shocks in the US and supply shocks in the Euro Zone. A number of studies report mixed results for demand and supply shocks as determinants of inflation (contrast, McAdam and Willman, 2004; Boschia and Girardi, 2007; Norkute, 2015; and Lagoa, 2017).

There is also contrasting evidence regarding the role and relevance of the state's fiscal stance, the past behaviour of inflation ("inertia"), inflation expectations, money supply, and exchange rates in determining the dynamics of inflation expectations. Clearly, this creates scope for further study and this extends into a context of ZLB. In terms of relevant literature, Mehra and Herrington (2008) report that inflation and inflation expectations were affected by past inflation, expected inflation, supply (oil price) shocks and demand (unemployment) shocks. Similarly, Fuhrer (2011) reports only a short-run nexus

[6] See Nasir et al (2019)

between inflation and inflation expectations in the US. In contrast, Lagoa (2017) and Marfatia (2018) report an enduring nexus between inflation and inflation expectations in Europe. Posen (2011) provides further specifications focused on the UK. However, ZLB creates a new context. One might argue that if inflation expectations are and have continued to be well-anchored then recent exchange rate shocks in the UK would have caused neither inflation nor weak performance of Bank of England forecasts (Broadbent, 2017; Haldane, 2017 and Nasir, 2017b). We return to this in our findings.

A number of studies have suggested that the money supply has important implications for inflation. For instance, Lu et al. (2017) report a positive impact of money supply on inflation. However, Su et al. (2016) reported mixed results and Hung and Thompson (2016) observe little relation. More pertinently we were unable to identify any work specifically focused on the link as a determinant of inflation or ZLB conditions.

Exchange Rate Pass-Through (ERPT) to inflation can pose significant challenges to a monetary authority (Fraga et al. 2003, Nasir et al. 2019)[7]. Focusing on the Pre-GFC period, Mishkin and Savastano (2001), Eichengreen (2002) and Schmidt-Hebbel and Werner (2002), argue that increased credibility due to the adoption of inflation targeting might lead to a reduction of ERPT, keeping inflation expectations anchored in the face of depreciation. However, Forbes and various others (2015; 2016; Forbes et al. 2017; Nasir and Simpson, 2018; Nasir, 2018) find that ERPT persists in inflation targeting regimes. In a recent study on the Czech Republic, Nasir et al. (2019) reported that the ERPT has a significant impact on inflation expectations.

One must also consider the potential inflationary consequences of the state's fiscal stance and this too has undergone evolution during the period of ZLB. The empirical evidence regarding an enduring relation to fiscal stance is mixed (Fischer et al. 2002; Catao and Terrones, 2005; and Lin and Chu, 2013). Intuitively one might expect fiscal discipline to be a precondition for well-managed expectations and thus for effective inflation targeting (Mikek, 2004; Alpanda and Honig, 2014; Minea and Tapsoba, 2014). This too warrants further exploration in a period of ZLB.[8] Of similar interest is observable "inertia" or persistence in the periodization of inflation. Again, the evidence is mixed (contrast Corbo et al. 2001 and Gali and Gertler, 1999). Yigit (2010) reports a significant reduction once inflation targeting is adopted. However, ZLB may change the context in which this arises.

So, there are multiple factors to consider as determinants of inflation that may be relevant for inflation expectations and that may be operative in inflation targeting regimes. ZLB provides a particular environment for these. Our question is whether inflation expectations remains anchored in the face of shocks experienced in a monetary policy condition proximal to ZLB.

## 3.1 Methodology

A Nonlinear Auto-Regressive Distributed Lag (ARDL) framework is employed to analyse the shocks to inflation and inflation expectations caused by their potential determinants. This relationship can be specified in the form of an open economy *New-Keynesian Phillips Curve* (*NKPC*); -

$$\pi_t = \beta_\pi \pi_{t-i} + \beta_{E\pi} E\pi_{t+i} + \beta_{Oil}(Oil)_{t-i} + \beta_{OG} OG_{t-i} + \beta_{LMS} LMS_{t-i} + \beta_{Fiscal} Fiscal_{t-i} + \beta_{Ex} EX_{t-i} + \beta_{MS} MS_{t-i} + e_t \qquad (1)$$

[7] See, Engel and West (2005) for insightful discussion on the exchange rate role in predicting output, inflation, money supply and interest rates.

[8] In a couple of remarkable studies on Brazil, Minella et al. (2003) and later Cerisola and Gelos (2009) find that fiscal policy is an important factor in influencing inflation expectations. Importantly, they claim that since the adoption of inflation targeting, inflation expectations have been anchored and this has extended into a period of uncertainty.

Where the inflation ($\pi_t$) is determined by its past values (persistence element,$\pi_{t-i}$), its expectations ($E\pi$), output or GDP growth ($OG$), labour market slack or spare capacity ($LMS$), fiscal stance (deficit/surplus), supply/cost (Oil) shocks, Money Supply (MS) and exchange rate pass-through ($EX$). Given that these factors are standard theory and often empirically established as the main determinants of inflation, we highlight these as influencers of inflationary expectations and their dynamics[9]. Hence,

$$E\pi_{t+i} = \beta_{\pi}\pi_{t-i} + \beta_{E\pi}E\pi_{t-i} + \beta_{Oil}(oil)_{t-i} + \beta_{OG}OG_{t-i} + \beta_{LMS}LMS_{t-i} + \beta_{Fiscal}Fiscal_{t-i} + \beta_{Ex}EX_{t-i} + \beta_{Ms}MS_{t-i} + e_t \qquad (2)$$

Where the inflation expectations ($E\pi_t$) are influenced by its past values (persistence element,$E\pi_{t-i}$), actual prevailing inflation ($\pi$), output or GDP growth ($OG$), labour market slack or spare capacity ($LMS$), fiscal stance (deficit/surplus), supply/cost (Oil) shocks, Money Supply (MS) and exchange rate pass-through ($EX$)[10]. We employ a N-ARDL model because such an approach takes into account both asymmetries and nonlinearities (Pesaran and Shin, 1999; Pesaran et al. 2001; Shin et al. 2011). We take the potential for these to be important in exploring ZLB and inflation targeting. As such, N-ARDL is an appropriate framework of analysis. To begin, we specify the Eq. (1 & 2) in the following long-run model of inflation and inflation expectations:

$$\pi_t = a_0 + a_1Oil_t^+ + a_2Oil_t^- + a_3E\pi_t + a_4OG_t + a_5LMS_t + a_6Fiscal_t + a_7EX_t + a_8MS_t + e_t \qquad (3)$$

$$E\pi_{t+i} = a_0 + a_1Oil_t^+ + a_2Oil_t^- + a_3\pi_t + a_4OG_t + a_5LMS_t + a_6Fiscal_t + a_7EX_t + a_8MS_t + e_t \qquad (4)$$

Where $\pi_t$ is inflation and $E\pi_t$ are inflation expectations and their determinants are as specified in equation (1 & 2), $a = (a_0 - a_8)$ is a co-integrating vector of long-run parameters. Supply-side or cost shocks arise most clearly in terms of oil prices, since these are fundamental to economic activity. In Eq. (3 & 4) the $Oil_t^+$ and $Oil_t^-$ are partial sums of positive and negative changes in oil prices (expressed for crude in the representative West Texas Intermediate pricings). This can be specified as:

$$Oil_t^+ = \sum_{i=1}^{t} \Delta Oil_i^+ = \sum_{i=1}^{t} \max(\Delta Oil_i, 0) \qquad (5)$$

and

$$Oil_t^- = \sum_{i=1}^{t} \Delta Oil_i^- = \sum_{i=1}^{t} \min(\Delta Oil_i, 0) \qquad (6)$$

Given the formulation presented above (Eq. 3 & 4), the relationship between oil price shocks ($OP$) and inflation expectations ($E\pi_t$) is expected to be positive ($a_1$). However, $a_2$ captures the association between oil prices and inflation expectations when there are reductions in those oil prices. As the oil price and its expectations are expected to show co-movement, estimates of $a_2$ are expected to have positive signs. Furthermore, we also posit that the increasing relation is greater than the decreasing one. That is, an increase in the oil price will lead to a more pronounced increase in inflation expectations when contrasted with the dampening effect on expectations of a decrease in the oil price. In simple terms, the asymmetry is expressed as: positive shocks will have a greater impact than negative shocks

[9] Given that the focus of the paper is inflation expectations rather actual inflation, we did not report the estimation result of equation 1. However, despite the fact that the Equation 1 is empirically and theoretically well explored and established, we still performed the estimation of equation 1 using System GMM to make sure that the nexus between inflation expectations → inflation is robust in the subject case. The results are not presented here to conserve the space, but are available on request.

[10] To empirically establish the link between inflation expectations and real exchange rate i.e. exchange rate pass through to inflation expectation, we employed the system-GMM and VAR Granger causality test. Both approaches empirical demonstrated that real exchange rate causes inflation expectations at 1% significance level. To conserve the space, these results are also not presented here but are available on request.

i.e. $a_1 > a_2$. This implies downward price rigidity, reflected in inflation expectations. Concomitantly, the long run relationship presented in Eq. (3 & 4) is expected to reflect an asymmetric pass through. At this juncture, we can frame Eq. 3 and 4 in a N-ARDL setting (see, Shin et al. (2011) Pesaran and Shin (1999) and Pesaran et al. (2001) as follows:

$$\Delta\pi_t = a + \beta_1\pi_{t-1} + \beta_2 OP^{+}_{t-1} + \beta_3 OP^{-}_{t-1} + \beta_4 E\pi_{t-1} + \beta_5 OG_{t-1} + \beta_6 LS_{t-1} + \beta_7 Fiscal_{t-1} + \beta_8 EX_{t-1} + \beta_9 MS_{t-1} + \sum_{i=1}^{p}\emptyset_i\Delta\pi_{t-i} + \sum_{i=0}^{q}(\theta_i^{+}\Delta OP^{+}_{t-i} + \theta_i^{-}\Delta OP^{-}_{t-i}) + \sum_{i=0}^{s}\gamma_i\Delta OG_{t-i} + \sum_{i=0}^{v}\delta_i\Delta LMS_{t-i} + \sum_{i=0}^{w}\Omega_i\Delta Fiscal_{t-i} + \sum_{i=0}^{x}\varphi_i\Delta E\pi_{t-i} + \sum_{i=0}^{z}\delta_i\Delta EX_{t-i} + \sum_{i=0}^{m}\psi_i\Delta MS_{t-i} + e_t \qquad (7)$$

And

$$\Delta E\pi_{t+i} = a + \beta_1 E\pi_{t-1} + \beta_2 OP^{+}_{t-1} + \beta_3 OP^{-}_{t-1} + \beta_4\pi_{t-1} + \beta_5 OG_{t-1} + \beta_6 LS_{t-1} + \beta_7 Fiscal_{t-1} + \beta_8 EX_{t-1} + \beta_9 MS_{t-1} + \sum_{i=1}^{p}\emptyset_i\Delta E\pi_{t-i} + \sum_{i=0}^{q}(\theta_i^{+}\Delta OP^{+}_{t-i} + \theta_i^{-}\Delta OP^{-}_{t-i}) + \sum_{i=0}^{s}\gamma_i\Delta OG_{t-i} + \sum_{i=0}^{v}\delta_i\Delta LMS_{t-i}\sum_{i=0}^{w}\Omega_i\Delta Fiscal_{t-i} + \sum_{i=0}^{x}\varphi_i\Delta\pi_{t-i} + \sum_{i=0}^{z}\delta_i\Delta EX_{t-i} + \sum_{i=0}^{m}\psi_i\Delta MS_{t-i}\ e_t \qquad (8)$$

All the variables are as previously defined, whilst $p, \mathrm{q}, \mathrm{s}, \mathrm{v}, \mathrm{w}, \mathrm{x}, z, m$ are lag orders and $a_1 = -\beta_2/\beta_1$ $a_2 = -\beta_3/\beta_1$ are the earlier mentioned long run impacts of increase/decrease oil shocks on inflation (Eq. 7) and the impact of increase/decrease in oil prices on inflation expectations (Eq.8). In Eq. 7, $\sum_{i=0}^{q}\theta_i^{+}$measures the short-run impacts of an increase in oil prices on inflation whereas $\sum_{i=0}^{q}\theta_i^{-}$ measures the short run impacts of a decrease in oil prices on inflation. In Eq. 8 $\sum_{i=0}^{q}\theta_i^{+}$measures the short-run impacts of an increase in oil prices on inflation expectations whereas $\sum_{i=0}^{q}\theta_i^{-}$ measures the short run impacts of a decrease in oil prices on inflation expectations. In this setting, we capture the asymmetric long-run as well as asymmetric short run relationship between oil prices and inflation expectations.

We implement this N-ARDL framework following several steps. First, we perform a unit root test to determine the order integration of the underlying data series. Whilst the N-ARDL approach to co-integration *is* valid whether the series are $I$ (0) or $I$ (1), it is *still* important to perform a unit root test to confirm that there is no $I$ (2) variable. This is because $I$ (2) invalidates the computation of F-statistics to test co-integration (Ibrahim, 2015). We perform a standard ADF unit root test but with structural break to find the order of integration. Thereafter, we estimate Equation 7 & 8 using the OLS method. After estimation of our N-ARDL model, we apply the bound testing approach proposed by Pesaran et al. (2001) and Shin et al. (2011) to test for the presence of co-integration of the underlying data series. In so doing, we perform the Wald F-test with the null hypothesis, $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$. In a final step we examine the long and short run asymmetries in the relationship between oil price shocks and inflation expectations, which provides the grounds for subsequent discussion of the impact of other explanatory variables in the model. With specific reference to inflation expectations, we derive the asymmetric cumulative dynamic multiplier effects of a 1% change in the oil prices i.e. $OP^{+}_{t-1}$ and $OP^{-}_{t-1}$ as;-

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{OP_{t-1}^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{OP_{t-1}^-}, h = 0,1,2 \dots \dots .. \quad (10)$$

A point to note here is that as $h \rightarrow \infty, m_h^+ \rightarrow a_1 \, and \, m_h^- \rightarrow a_2$ .

## 3.2 Data

As stated in the introduction, we selected data for the UK and New Zealand. These two were chosen since both are longstanding inflation targeting policy regimes and so provide an extended duration for data. We draw on monthly observations extending from January 1994 to June 2018 and apply a comprehensive empirical estimation exercise. However, the two data sets are not entirely synchronous. Based on availability, the time horizon of study for New Zealand is January 1994 to June 2017, whilst for the UK, December 1999 to June 2018. To match frequency, we performed linear interpolation for the monthly observations where necessary. Details of each proxy is as follows:

**Inflation Expectations:** For New Zealand, we used monthly data collected through Business Surveys, including all sectors inflation expectations. The data is collected by the Australia and New Zealand Banking Group. For the UK, we collected data from the Bank of England's survey on inflation expectations.

**Inflation:** Both the Bank of England and Reserve Bank of New Zealand measure inflation using the monthly Consumer Price Index and we used the year on year percentage change in CPI.

**Supply /Cost (oil) Shocks:** For oil prices, we collected data on crude oil prices (West Texas Intermediate, WTI). We used the spot crude oil price which is in US$ per Barrel and internationally reported in the dominant currency. The data was retrieved from the Federal Reserve Bank of St. Louis.

**Output growth:** We used data on real GDP growth for both New Zealand and the UK. The data was collected from the UK Office for National Statistics (ONS) and Statistics New Zealand.

**Labour Market (Unemployment):** For the labour market and employment outlook we used data on the unemployment rate from the ONS and Statistics New Zealand.

**Fiscal Stance (Surplus/Deficit):** Monthly data was used from the ONS public sector current budget deficit (excluding public sector banks) for the UK and the central government Deficit/Surplus published by the New Zealand Treasury.

**Real Exchange Rate:** To represent the exchange rate, we used monthly data on the real effective exchange rate, collected from the Bank for International Settlements (BIS).

**Money supply:** M3 was selected as the longest duration available monthly measure of broad money for both New Zealand and the UK. The reason to choose M3 is that it provides a more comprehensive and inclusive measure of the money supply. Nonetheless, it is also observed that despite the *Large-Scale Asset Purchases* (A.k.a. Quantitative Easing or Q.E.) by the Bank of England, contrary to the high-powered money balances (M0), there was not a huge shift in the broad money supply M3. The data was collected from the ONS and Statistics New Zealand.

## 4.1 Analysis, Findings and Discussion

As previously stated, we performed an ADF unit root test with structural break to determine the order of integration of the series. Accounting for a structural break is important, since in the presence of a structural break, a confirming unit root test is prone to be biased towards the null of random walk (Ranganathan and Ananthakumar, 2010; Nasir et al. 2018). We let the date of the break be determined endogenously (allowing the data to speak). We chose the alternative minimize and maximise options to allow for evaluation of one-sided alternatives. This produces different critical values for the final Dickey-Fuller test statistic, appropriate in these circumstances since it tests with greater power than the non-directional alternatives[11]. The ADF tests for unit roots in the presence of breaks with both innovative outliers (IO) and additive outliers (AO)[12]. In order to choose the optimal number of lags for the ADF test, we used the Schwarz Information Criteria (SIC) which is particularly appropriate in the presence of a structural break (Asghar and Abid 2007). The results are presented in Table 1:

**Table 1: ADF Test with Structural Break: Additive & Innovative Outliers**

| | *Variables* | *ADF Test Statistic (IO)* | *P-Values* | *ADF Test Statistic (AO)* | *P-Values* |
|---|---|---|---|---|---|
| ***Level*** | **New Zealand** | | | | |
| | Inflation | -4.088 | 0.144 | -5.632* | 0.014 |
| | Inflation Expectations | -4.674 | 0.165 | -4.650 | 0.173 |
| | GDP | -5.302** | 0.035 | -5.305** | 0.035 |
| | Unemployment | -4.625 | 0.183 | -4.217 | 0.383 |
| | REER | -3.895 | 0.591 | -3.858 | 0.612 |
| | Oil Shocks | -5.096 | 0.06 | -5.011 | 0.076 |
| | Money Supply | -4.114 | 0.447 | -4.192 | 0.399 |
| | Fiscal Deficit/Surplus | -5.037 | 0.072 | -5.075 | 0.065 |
| | **United Kingdom** | | | | |
| | Inflation | -3.657 | 0.734 | -3.801 | 0.648 |
| | Inflation Expectations | -4.912 | 0.095 | -5.262** | 0.039 |
| | GDP | -6.019* | < 0.01 | -6.375 | < 0.01 |
| | Unemployment | -7.073* | < 0.01 | -7.101* | < 0.01 |
| | REER | -3.718 | 0.696 | -3.718 | 0.696 |
| | Oil Shocks | -4.093 | 0.459 | -4.141 | 0.431 |
| | Money Supply | -3.935 | 0.564 | -3.657 | 0.733 |
| | Fiscal Deficit/Surplus | -9.216 | < 0.01 | -9.290* | < 0.01 |
| ***1st Difference*** | **New Zealand** | | | | |
| | Inflation | -7.127* | < 0.01 | -7.250* | < 0.01 |
| | Inflation Expectations | -14.811* | < 0.01 | -14.911* | < 0.01 |
| | GDP | -7.921* | < 0.01 | -10.185* | < 0.01 |
| | Labour Market | -7.992* | < 0.01 | -9.274* | < 0.01 |
| | REER | -13.463* | < 0.01 | -13.564* | < 0.01 |
| | Oil Shocks | -12.401* | < 0.01 | -12.468* | < 0.01 |
| | Money Supply | -16.695* | < 0.01 | -17.330 | < 0.01 |
| | Fiscal Deficit/Surplus | -6.285* | < 0.01 | -5.638** | 0.024 |
| | **United Kingdom** | | | | |
| | Inflation | -13.254* | < 0.01 | -13.360* | < 0.01 |
| | Inflation Expectations | -6.466* | < 0.01 | -8.536* | < 0.01 |
| | GDP | -5.632* | 0.014 | -4.607** | 0.032 |
| | Unemployment | -7.114* | < 0.01 | -7.182* | < 0.01 |
| | REER | -14.141* | < 0.01 | 14.272* | < 0.01 |
| | Oil Shocks | -11.767* | < 0.01 | -11.878* | <0.01 |
| | Money Supply | 13.588* | < 0.01 | -14.356* | < 0.01 |
| | Fiscal Deficit/Surplus | -19.791 | < 0.01 | -22.745 | < 0.01 |

*1% level of significance ** 5% level of significance ***Vogelsang (1993) asymptotic one-sided p-values.

[11] See, Zivot and Andrews (1992), Banerjee *et al.* (1992) and Vogelsang and Perron (1998).

[12] See, Fox (1972) and Tsay (1988).

The results of the stated ADF unit root test indicate that the null of "no root" could not be rejected at a 5% level of statistical significance. However, at the first difference, *all* the series for *both* countries were found to be stationary i.e. I (*1*)[13]. We now turn to the estimation of N-ARDL model (Eq. 8) for inflation expectations in New Zealand and the UK.

## 4.2 New Zealand

Table 2 presents the results of bounds testing for nonlinear co-integration for New Zealand:

**Table 2: Bounds test for the Nonlinear Co-integration New Zealand (1994M1 – 2017M06)**

| Dependent variable | F-statistics | Lower-Bound (95%) | Upper-Bound (95%) | Conclusion |
|---|---|---|---|---|
| Inflation Expectations ($E\pi$) | 8.523* | 2.11 | 3.15 | Cointegration |

*1% level of significance ** 5% level of significance ***10% level of significance: Null hypothesis is that there is not cointegration i.e. $H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$, whereas the alternative hypothesis is that there is cointegration i.e. $H_1 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 \neq 0$.

Bound testing finds that the critical values of the F-statistics were greater than upper bound at a 95% level of confidence, indicating *strong* evidence of co-integration in modelled inflation expectations (Eq. 8). This implies that there is a *long-run* relationship between the variables under analysis. We, therefore, proceeded with the estimation and further analysis. We split the sample, April 2009. This was the point in time that the Reserve Bank of New Zealand decreased the policy rate (official cash) to an unprecedented level of 2.5%.[14] Splitting the sample here allows us to differentiate between the response of inflation expectations to its explanatory factors in a pre-ZLB and proximal ZLB period. We estimated the model for the two sub-periods (January 1994 to March 2009 and April 2009 to June 2017). The results of our N-ARDL model for inflation expectations for the full and sub-samples are presented in Table 3:

**Table 3 Nonlinear- ARDL Estimation NZ Inflation Expectations**

| | Full Sample | | Pre-ZLB (1994M1-2009M03) | | | Proximal ZLB(2009M04-2017M06) | | |
|---|---|---|---|---|---|---|---|---|
| **Panel A: Short Run Estimates** | | | | | | | | |
| **Variables** | **Coefficient** | **Prob.** | **Variables** | **Coefficient** | **Prob.** | **Variables** | **Coefficient** | **Prob.** |
| $E\pi_{t-1}$ | -0.294* | 0.000 | $E\pi_{t-1}$ | -0.308* | 0.000 | $E\pi_{t-1}$ | -0.365* | 0.006 |
| $OP^+_{t-1}$ | 0.223* | 0.000 | $OP^+_{t-1}$ | 0.324* | 0.000 | $OP^+_{t-1}$ | -0.015 | 0.873 |
| $OP^-_{t-1}$ | 0.274* | 0.000 | $OP^-_{t-1}$ | 0.409* | 0.000 | $OP^-_{t-1}$ | -0.041 | 0.719 |
| $\pi_{t-1}$ | 0.046* | 0.000 | $\pi_{t-1}$ | 0.013 | 0.355 | $\pi_{t-1}$ | 0.033 | 0.341 |
| $MS_{t-1}$ | 0.0006 | 0.276 | $MS_{t-1}$ | 0.001 | 0.066 | $MS_{t-1}$ | 0.006* | 0.006 |
| $GDP_{t-1}$ | 0.0005 | 0.912 | $^*GDP_{t-1}$ | -0.0005 | 0.922 | $GDP_{t-1}$ | -0.062 | 0.111 |
| $Unemp_{t-1}$ | -0.011 | 0.267 | $Unemp_{t-1}$ | -0.016 | 0.359 | $Unemp_{t-1}$ | 0.299* | 0.001 |
| $Fiscal_{t-1}$ | 2.95E-11 | 0.310 | $^*Fiscal_{t-1}$ | 1.73E-10** | 0.045 | $Fiscal_{t-1}$ | 1.13E-10** | 0.048 |
| $EX_{t-1}$ | -0.371* | 0.000 | $^*EX_{t-1}$ | -0.573* | 0.000 | $^*EX_{t-1}$ | 0.491 | 0.217 |
| $\Delta E\pi_{t-1}$ | 0.154* | 0.007 | $\Delta E\pi_{t-1}$ | 0.109 | 0.120 | $\Delta E\pi_{t-1}$ | -0.114 | 0.301 |
| $\Delta E\pi_{t-2}$ | -0.011 | 0.837 | $\Delta E\pi_{t-2}$ | -0.035 | 0.597 | $\Delta E\pi_{t-2}$ | -0.118 | 0.247 |
| $\Delta E\pi_{t-3}$ | 0.279* | 0.000 | $\Delta E\pi_{t-3}$ | 0.133** | 0.040 | $\Delta E\pi_{t-3}$ | 0.304* | 0.002 |

[13] Though the inflation and GDP for New Zealand and inflation expectation, unemployment, GDP and fiscal deficit/surplus for UK were stationary even at level. We also did the unit-root testing on the sub-periods and the series were either stationary at level or first difference. To conserve the space the results are not presented here but can be made available upon request.

[14] Note, 2.5% can be considered proximal ZLB based on recognition in standard discourse and analysis of monetary policy and with reference to historic contrast. However, this is substantively different in terms of quantity if not significance from the UK case, where the base rate has varied between 0.25 and 0.75 with consistency around 0.5% beginning March 2009. Indeed, since April 2009 the Official Cash rates did show some movement i.e. initial increase to 3.5% and then decrease to 1.5% but this change remained around the proximal ZLB of 2.5% which we are considering in context of historical stance of Reserve Bank of New Zealand.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $\Delta OP_t^+$ | 0.081 | 0.473 | $\Delta E\pi_{t-4}$ | -0.079 | 0.245 | $\Delta OP_t^+$ | 0.057 | 0.830 |
| $\Delta OP_{t-1}^+$ | 0.060 | 0.620 | $\Delta E\pi_{t-5}$ | -0.129** | 0.057 | $\Delta OP_{t-1}^+$ | 0.310 | 0.245 |
| $\Delta OP_{t-2}^+$ | -0.272* | 0.022 | $\Delta OP_t^+$ | 0.036 | 0.817 | $\Delta OP_{t-2}^+$ | 0.115 | 0.673 |
| $\Delta \pi_t$ | 0.083* | 0.012 | $\Delta OP_{t-1}^+$ | -0.085 | 0.605 | $\Delta OP_{t-3}^+$ | -0.096 | 0.707 |
| $\Delta \pi_{t-1}$ | -0.167* | 0.000 | $\Delta OP_{t-2}^+$ | -0.459* | 0.006 | $\Delta OP_{t-4}^+$ | -0.149 | 0.519 |
| $\Delta \pi_{t-2}$ | 0.176* | 0.000 | $\Delta OP_t^-$ | 0.198 | 0.165 | $\Delta OP_{t-5}^+$ | 0.668* | 0.002 |
| $\Delta \pi_{t-3}$ | -0.002 | 0.941 | $\Delta OP_{t-1}^-$ | -0.119 | 0.433 | $\Delta OP_t^-$ | -0.086 | 0.656 |
| $\Delta \pi_{t-4}$ | -0.042 | 0.322 | $\Delta OP_{t-2}^-$ | -0.044 | 0.766 | $\Delta OP_{t-1}^-$ | 0.116 | 0.450 |
| $\Delta \pi_{t-5}$ | -0.046 | 0.182 | $\Delta OP_{t-3}^-$ | -0.504* | 0.000 | $\Delta OP_{t-2}^-$ | 0.404 | 0.057 |
| $\Delta MS_t$ | 0.001 | 0.192 | $\Delta \pi_t$ | 0.049 | 0.248 | $\Delta OP_{t-3}^-$ | 0.298 | 0.169 |
| $\Delta MS_{t-1}$ | -0.002* | 0.003 | $\Delta \pi_{t-1}$ | -0.158* | 0.001 | $\Delta \pi_t$ | -0.063 | 0.263 |
| $\Delta MS_{t-2}$ | -0.0003 | 0.698 | $\Delta \pi_{t-2}$ | 0.256* | 0.000 | $\Delta MS_t$ | 0.0002 | 0.883 |
| $\Delta MS_{t-3}$ | -0.0021* | 0.019 | $\Delta MS_t$ | 0.003* | 0.008 | $\Delta MS_{t-1}$ | -0.008* | 0.001 |
| $\Delta MS_{t-4}$ | 0.0015 | 0.089 | $\Delta Unemp_t$ | 0.110 | 0.365 | $\Delta MS_{t-2}$ | -0.006* | 0.001 |
| $\Delta GDP_t$ | 0.008 | 0.578 | $\Delta Unemp_{t-1}$ | -0.493* | 0.001 | $\Delta MS_{t-3}$ | -0.007* | 0.000 |
| $\Delta GDP_{t-1}$ | -0.004 | 0.769 | $\Delta Unemp_{t-2}$ | 0.439* | 0.001 | $\Delta GDP_t$ | -0.093 | 0.068 |
| $\Delta GDP_{t-2}$ | -0.039* | 0.018 | $\Delta Unemp_{t-3}$ | 0.274** | 0.042 | $\Delta GDP_{t-1}$ | 0.113** | 0.037 |
| $\Delta GDP_{t-3}$ | 0.043* | 0.004 | $\Delta Unemp_{t-4}$ | -0.528* | 0.006 | $\Delta GDP_{t-2}$ | -0.081* | 0.001 |
| $\Delta Unemp_t$ | 0.087 | 0.309 | $\Delta Unemp_{t-5}$ | 0.375* | 0.001 | $\Delta GDP_{t-3}$ | -0.015 | 0.780 |
| $\Delta Unemp_{t-1}$ | -0.324* | 0.003 | Constant | 3.441* | 0.000 | $\Delta GDP_{t-4}$ | 0.182* | 0.001 |
| $\Delta Unemp_{t-2}$ | 0.381* | 0.000 | | | | $\Delta Unemp_t$ | 0.0951 | 0.501 |
| $\Delta Unemp_{t-3}$ | 0.081 | 0.411 | | | | $\Delta Unemp_{t-1}$ | -0.332** | 0.029 |
| $\Delta Unemp_{t-4}$ | -0.401* | 0.000 | | | | $\Delta Unemp_{t-2}$ | 0.137 | 0.234 |
| $\Delta Unemp_{t-5}$ | 0.289* | 0.000 | | | | $\Delta Unemp_{t-3}$ | -0.105 | 0.439 |
| $\Delta Fiscal_t$ | 1.32E-10 | 0.602 | | | | $\Delta Unemp_{t-4}$ | -0.223 | 0.079 |
| $\Delta Fiscal_{t-1}$ | - 4.91E-10 | 0.112 | | | | $\Delta Fiscal_t$ | 3.22E-11 | 0.923 |
| $\Delta Fiscal_{t-2}$ | 6.38E-10* | 0.037 | | | | $\Delta Fiscal_{t-1}$ | -7.01E-10** | 0.050 |
| $\Delta Fiscal_{t-3}$ | -4.51E-10 | 0.083 | | | | $\Delta Fiscal_{t-2}$ | 3.21E-10 | 0.360 |
| $\Delta EX_t$ | 0.399 | 0.169 | | | | $\Delta Fiscal_{t-3}$ | -9.89E-10E | 0.002 |
| Constant | 2.410* | 0.000 | | | | Constant | -3.101 | 0.193 |
| | | | | | | | | |
| **Panel B: Long-run Estimates** | | | | | | | | |
| $OP^+$ | 0.759* | 0.000 | 1.051* | | 0.000 | -0.043 | | 0.873 |
| $OP^-$ | 0.933* | 0.000 | 1.326* | | 0.000 | -0.112 | | 0.724 |
| $\pi$ | 0.158* | 0.000 | 0.043 | | 0.262 | 0.091 | | 0.297 |
| MS | 0.002 | 0.313 | 0.005** | | 0.048 | 0.017** | | 0.028 |
| GDP | 0.001 | 0.913 | -0.001 | | 0.916 | -0.170 | | 0.120 |
| *Unemp.* | -0.040 | 0.214 | -0.054 | | 0.296 | 0.818** | | 0.026 |
| *Fiscal* | 1.00E-10 | 0.288 | 5.60E-10** | | 0.023 | 3.08E-10 | | 0.087 |
| EX | -1.260* | 0.00 | -1.856* | | 0.000 | 1.343 | | 0.284 |
| **Panel C: Diagnostic Test** | | | | | | | | |
| $R^2$ | 0.980 | | 0.974 | | | 0.993 | | |
| DW | 2.003 | | 1.965 | | | 1.946 | | |
| ECT | -0.294* | 0.000 | -0.308* | | 0.000 | -0.365* | | 0.000 |
| JB test. | 13.945* | 0.009 | 0.483 | | 0.785 | 1.053 | | 0.590 |
| BG LM test | 1.161 | 0.559 | 0.460 | | 0.794 | 0.831 | | 0.659 |
| BPG test | 61.712* | 0.019 | 65.264* | | 0.000 | 45.264 | | 0.298 |
| Harvey test | 43.661 | 0.359 | 47.770** | | 0.027 | 47.239 | | 0.230 |
| Ramsey REST Test | 0.149429 | 0.824 | 0.452 | | 0.502 | 1.419 | | 0.239 |

*1% level of significance ** 5% level of significance ***10% level of significance, * interpreted as $z_t = z_{t-1} + \Delta z$ whereas the JB is Jarque-Bera test for the error normality. BG is Breusch-Godfrey LM test with two lags for autocorrelation, BPG is Breusch-Pagan-Godfrey Test and White-test were used for heteroskedastic. Note: White heteroskedasticity-consistent standard errors & covariance. Optimal lag selection based on AIC.

The estimation results for the full period for New Zealand show that in the short-run, the lagged values for inflation expectations $E\pi_{t-1}$ had a *negative and statistically significant impact* on inflation expectations. This is prima facie evidence of adaptive expectations and the adjustment of inflation expectations due to past deviations. In the short run, positive oil shocks $OP_t^+$ had a positive impact on inflation expectations, and negative oil shocks $OP_t^-$ *also* had a positive impact on inflation expectations. However, the positive shocks $\Delta OP_t^+$ were greater in magnitude than the negative oil price shocks $\Delta OP_t^-$ suggesting price stickiness. This confirms what is otherwise intuitive.

Moving on, inflation, GDP and money supply had positive impacts, which varied in magnitude and significance over different lags. Unemployment and fiscal consolidation exhibit negative impacts, which become more pronounced with lags. The real effective exchange rate also showed a significant lagged impact - negative one period - although the short-term impact was, by contrast, positive and this is consistent with the concept of a J-curve. The long-run estimates for the full period presented in Panel B establish that a positive oil shock had a positive impact on inflation expectations, and negative oil shocks also had a positive impact, indicating an *asymmetric relationship between oil prices and inflation expectations* over the duration for New Zealand. Other relations were of less relevance.

Diagnostic testing reported in Panel C suggests that there were no issues of autocorrelation or heteroscedasticity and the negative and significant values of the Error Correction Term (ECT) indicate the stability of the model. Finally, the Ramsey REST Test indicates that the null of no misspecification could not be rejected at the 5% statistical level of significance. As such, the model passes standard testing.

If we now look to the sub-period analysis, divided at the point of implementation of proximal ZLB, the estimation results of the first and second sub-period show that inflation expectations $E\pi_t$ were negatively but significantly affected by one period lagged values indicating adaptive expectations and adjustments. This follows a similar form to the full sample. Interestingly, in the first sub-period, both positive and negative oil shocks $OP_t^+$ and $OP_t^-$ had a positive impact on inflation expectations. However, in the second sub-period, the relation changed, exhibitng a negative impact, suggesting that oil prices have a greater deflationary impact in a context of proximal ZLB conditions. It should also be clear that short term coefficients for positive ($\Delta OP_t^+$) and negative $\Delta OP_t^-$ oil price shocks varied with lags but showed positive and negative impacts overall. Our later impact multiplier analysis (see Figure 2) provides further contextual significance for this.

Table 3 establishes that unemployment has greater negative impact on inflation expectations in the second sub-period suggesting that *unemployment may have greater deflationary impact on inflation expectations when monetary policy is approaching ZLB.* The money supply had a positive impact on inflation expectations in both sub-periods, though the impact was more pronounced and statistically significant in the second sub-period. Conversely, the real effective exchange rate exhibits a negative impact on inflation expectations in the first sub-period, and this reduces in significance for the second sub-period. The long run estimates for both sub periods suggest that oil price shocks had positive impacts on inflation expectations in the first sub-period while in the second sub-period the impact was negative (though the results were only significant in the first sub-period).[15] Interestingly, the exchange rate appreciation showed a negative impact on inflation expectations in the first sub-period. However, in the latter period the impact became positive and insignificant. *This implies that the exchange rate*

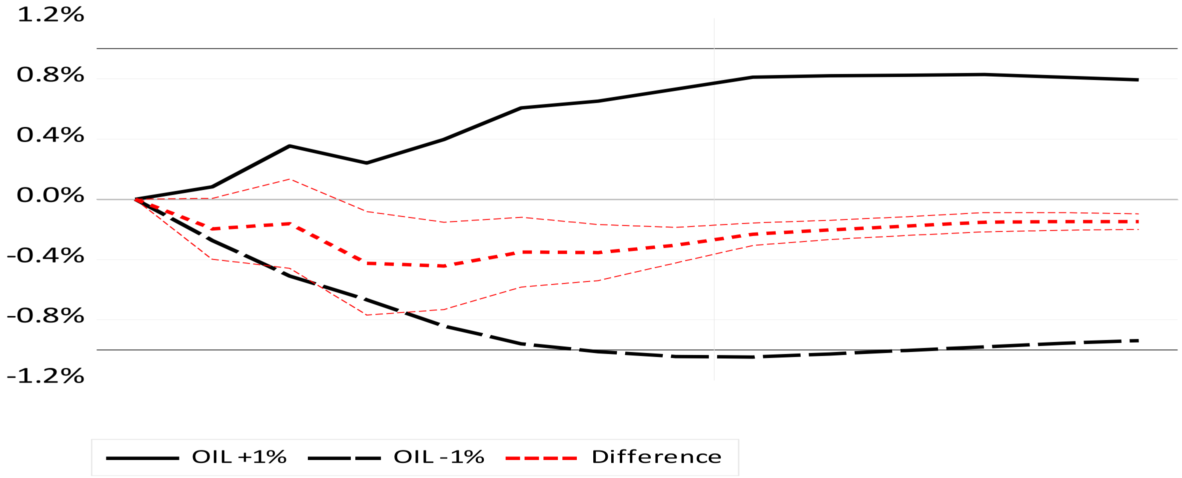
[15] Inter alia, inflation and money supply had positive impact on inflation expectation in both period though only the latter had statistically significant impact. GDP has negative but insignificant impact, while unemployment has negative and insignificant impacts on inflation expectations in the first sub-period and positive impact in the second.

*loses its ability to influence expectations in proximal ZLB conditions.* We comment more on cumulative findings in the conclusion.

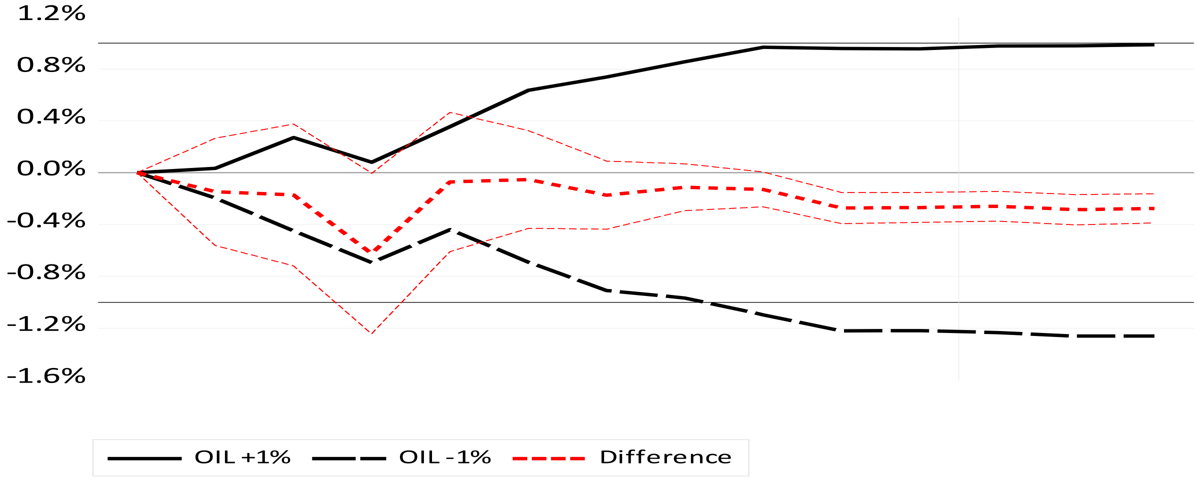
As with the full period, diagnostic testing performed for both sub-periods showed a significant value for the ECT. The Jarque-Bera test suggests that the null of normality of errors, no auto correlation and no misspecifications were *not* rejected at the standard statistical level of significance. To further test the stability of the estimates, we also performed the CUSUM and CUSUMSQ and the results are presented for the full and sub-samples in Figure 1 (See Appendix).

The CUSUM and CUSUMSQ parameter stability tests for inflation expectations show that for both the full and sub-periods the CUSUM and CUSUMSQ remained between the 5% significance bounds. Interestingly, the second sub-period *did* show comparatively higher oscillations. The CUSUM graph is sub-zero, though still in the significance bound, indicating the stability of estimates. Following stability tests, we estimate the multiplier impact of oil prices shocks on inflation expectations. The results of N-ARDL multiplier analysis are presented in Figure 2:

**Full Sample**




**1st Sub-Period**




**2nd Sub-Period**

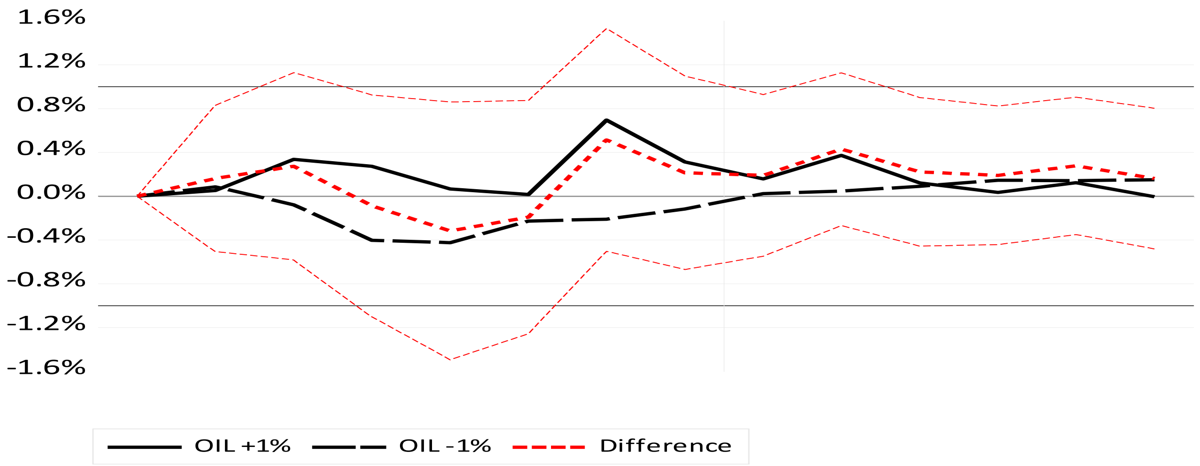



**Figure 2: NARDL Multiplier of Oil Shocks and response of Inflation Expectations in the NZ**

The results of the multiplier test for oil shocks on inflation expectation for New Zealand provide interesting results. In response to a 1% increase in oil prices inflation expectations showed a positive response in the full period as well as both sub-periods. Similarly, in response to negative oil price shocks inflation expectations showed a negative response in all of the periods. However, the *second sub-period* showed that *responsiveness* of inflation expectations to oil price shocks *decreases* in proximal ZLB conditions. In conjunction with earlier presented estimates the implication is that although inflation expectations are perennially influenced by oil price shocks, in proximal ZLB conditions expectations *converge* more promptly after oil shocks (see Figure 2 2nd period). We now move on to apply our N-ARDL framework to the UK case.

### 4.3 United Kingdom

We begin with bounds testing to determine the presence of co-integration. The results are presented in Table 4:

**Table 4: Bounds test for the Nonlinear Cointegration United Kingdom (1999M1-2018M06)**

| **Dependent variable** | **F-statistics** | **Lower-Bound (95%)** | **Upper-Bound (95%)** | **Conclusion** |
|---|---|---|---|---|
| Inflation Expectations ($E\pi$) | 4.879* | 2.17 | 3.21 | Cointegration |

*1% level of significance ** 5% level of significance ***10% level of significance: Null hypothesis is that there is no cointegration i.e. $H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$, whereas the alternative hypothesis is that there is cointegration i.e. $H_1 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 \neq 0$.

As with New Zealand, bounds testing indicates the presence of co-integration, with the same inference. As such, we proceeded to the estimate based on N-ARDL and, following the same format as previously the results for the full and sub-periods are presented in Table 5:

**Table 5 Nonlinear- ARDL Estimation UK Inflation Expectations**

| | **Full Sample** | | **Pre-ZLB (1999M1-2009M03)** | | | **Proximal ZLB(2009M04-2018M06)** | | |
|---|---|---|---|---|---|---|---|---|
| **Panel A: Short Run Estimates** | | | | | | | | |
| **Variables** | **Coefficient** | **Prob.** | **Variables** | **Coefficient** | **Prob.** | **Variables** | **Coefficient** | **Prob.** |
| $E\pi_{t-1}$ | -0.132* | 0.000 | $E\pi_{t-1}$ | -0.181* | 0.000 | $E\pi_{t-1}$ | -0.088** | 0.045 |
| $OP^{+}_{t-1}$ | 0.036** | 0.065 | $OP^{+}_{t-1}$ | 0.044 | 0.237 | $OP^{+}_{t-1}$ | -0.059 | 0.437 |
| $OP^{-}_{t-1}$ | 0.049** | 0.029 | $OP^{-}_{t-1}$ | 0.073 | 0.255 | $OP^{-}_{t-1}$ | 0.001 | 0.979 |
| $\pi_{t-1}$ | 0.035* | 0.006 | *$\pi_{t-1}$ | 0.054* | 0.006 | $\pi_{t-1}$ | -0.022 | 0.3777 |
| $GDP_{t-1}$ | 0.009 | 0.154 | $GDP_{t-1}$ | 0.010 | 0.166 | $GDP_{t-1}$ | 0.039 | 0.503 |
| *$MS_{t-1}$ | 0.0002 | 0.0669 | *$MS_{t-1}$ | 0.002 | 0.108 | $MS_{t-1}$ | 0.0007 | 0.636 |
| *$Unemp_{t-1}$ | -0.001 | 0.086 | *$Unemp_{t-1}$ | -0.003* | 0.003 | $Unemp_{t-1}$ | 0.003 | 0.380 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $EX_{t-1}$ | -0.478* | 0.001 | *$EX_{t-1}$ | -1.156* | 0.000 | $EX_{t-1}$ | -0.834* | 0.019 |
| $Fiscal_{t-1}$ | 3.68E-06* | 0.001 | *$Fiscal_{t-1}$ | 3.68E-07 | 0.851 | *$Fiscal_{t-1}$ | 3.59E-06* | 0.008 |
| $\Delta E\pi_{t-1}$ | 0.741* | 0.000 | $\Delta E\pi_{t-1}$ | 0.610* | 0.000 | $\Delta E\pi_{t-1}$ | 0.660* | 0.000 |
| $\Delta E\pi_{t-2}$ | -0.048 | 0.533 | $\Delta OP_t^+$ | -0.166 | 0.329 | $\Delta E\pi_{t-2}$ | -0.036 | 0.748 |
| $\Delta E\pi_{t-3}$ | -0.235* | 0.002 | $\Delta OP_t^-$ | 0.594* | 0.000 | $\Delta E\pi_{t-3}$ | -0.562* | 0.000 |
| $\Delta E\pi_{t-4}$ | 0.269* | 0.000 | $\Delta GDP_t$ | -0.064** | 0.49 | $\Delta E\pi_{t-4}$ | 0.416* | 0.000 |
| $\Delta E\pi_{t-5}$ | -0.112 | 0.070 | Constant | 5.910* | 0.005 | $\Delta E\pi_{t-5}$ | -0.122 | 0.199 |
| $\Delta OP_t^+$ | -0.078 | 0.540 | | | | $\Delta OP_t^+$ | 0.021 | 0.893 |
| $\Delta OP_{t-1}^+$ | 0.221 | 0.080 | | | | $\Delta OP_{t-1}^+$ | -0.246 | 0.134 |
| $\Delta OP_t^-$ | 0.0428* | 0.000 | | | | $\Delta OP_t^-$ | 0.039 | 0.777 |
| $\Delta OP_{t-1}^-$ | -0.059 | 0.641 | | | | $\Delta OP_{t-1}^-$ | 0.193 | 0.228 |
| $\Delta OP_{t-2}^-$ | 0.238** | 0.023 | | | | $\Delta OP_{t-2}^-$ | 0.184 | 0.221 |
| $\Delta\pi_t$ | 0.033 | 0.098 | | | | $\Delta OP_{t-3}^-$ | 0.058 | 0.685 |
| $\Delta\pi_{t-1}$ | 0.012 | 0.541 | | | | $\Delta OP_{t-4}^-$ | -0.251 | 0.068 |
| $\Delta\pi_{t-2}$ | -0.036 | 0.073 | | | | $\Delta OP_{t-5}^-$ | 0.333** | 0.018 |
| $\Delta\pi_{t-3}$ | 0.016 | 0.375 | | | | $\Delta\pi_t$ | -0.012 | 0.645 |
| $\Delta\pi_{t-4}$ | -0.045** | 0.020 | | | | $\Delta\pi_{t-1}$ | 0.089* | 0.000 |
| $\Delta GDP_t$ | 0.026 | 0.496 | | | | $\Delta\pi_{t-2}$ | 0.004 | 0.870 |
| $\Delta GDP_{t-1}$ | -0.080** | 0.039 | | | | $\Delta\pi_{t-3}$ | 0.060* | 0.009 |
| $\Delta EX_t$ | -1.0378* | 0.002 | | | | $\Delta GDP_t$ | -0.103 | 0.219 |
| Constant | 2.55* | 0.005 | | | | $\Delta GDP_{t-1}$ | -0.071 | 0.369 |
| | | | | | | $\Delta GDP_{t-2}$ | -0.026 | 0.745 |
| | | | | | | $\Delta GDP_{t-3}$ | -0.260* | 0.002 |
| | | | | | | $\Delta MS_t$ | -0.003 | 0.080 |
| | | | | | | $\Delta Unemp_t$ | 0.0004 | 0.920 |
| | | | | | | $\Delta Unemp_{t-1}$ | 0.001 | 0.784 |
| | | | | | | $\Delta Unemp_{t-2}$ | -0.004 | 0.374 |
| | | | | | | $\Delta Unemp_{t-3}$ | -0.001 | 0.839 |
| | | | | | | $\Delta Unemp_{t-4}$ | -0.009** | 0.032 |
| | | | | | | $\Delta Unemp_{t-5}$ | -0.005 | 0.157 |
| | | | | | | $\Delta EX_t$ | -0.445 | 0.284 |
| | | | | | | $\Delta EX_{t-1}$ | 0.530 | 0.221 |
| | | | | | | $\Delta EX_{t-2}$ | 0.954** | 0.027 |
| | | | | | | Constant | 4.265* | 0.001 |
| **Panel B: Long-run Estimates** | | | | | | | | |
| $OP^+$ | 0.276** | 0.044 | | 0.243 | 0.201 | | -0.677 | 0.556 |
| $OP^-$ | 0.376* | 0.014 | | 0.401 | 0.249 | | 0.020 | 0.979 |
| $\pi$ | 0.266* | 0.000 | | 0.300* | 0.006 | | -0.254 | 0.499 |
| GDP | 0.069 | 0.189 | | 0.057 | 0.170 | | 0.446 | 0.442 |
| MS | 0.002 | 0.661 | | 0.011 | 0.122 | | 0.008 | 0.643 |
| *Unemp.* | -0.007** | 0.046 | | -0.018* | 0.000 | | 0.037 | 0.348 |
| EX | -3.619* | 0.001 | | -6.357* | 0.000 | | -9.478 | 0.141 |
| *Fiscal* | 2.78E-05* | 0.000 | | 2.02E-06 | 0.852 | | 4.08E-05 | 0.172 |
| | | | | | | | | |
| $R^2$ | 0.989 | | | 0.985 | | | 0.996 | |
| DW | 2.059 | | | 2.005 | | | 1.927 | |
| ECT | -0.132* | 0.000 | | -0.181* | 0.000 | | -0.088* | 0.000 |
| JB test. | 185.677* | 0.000 | | 13.917* | 0.000 | | 1.486 | 0.475 |
| BG LM test | 1.501 | 0.220 | | 0.260 | 0.864 | | 0.932 | 0.627 |
| BPG test | 59.311* | 0.000 | | 51.683* | 0.000 | | 44.451 | 0.289 |
| Harvey test | 36.230 | 0.110 | | 29.324* | 0.005 | | 29.995 | 0.133 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ramsey REST Test | 0.875 | 0.350 | 0.103 | 0.748 | 0.032 | 0.857 |

*1% level of significance ** 5% level of significance ***10% level of significance, * interpreted as $z_t = z_{t-1} + \Delta z$ whereas the JB is Jarque-Bera test for the error normality. BG is Breusch-Godfrey LM test with two lags for auto-correlation, BPG is Breusch-Pagan-Godfrey Test and White-test were used for heteroskedastic. Note: White heteroskedasticity-consistent standard errors & covariance. Optimal lag selection based on AIC.

If we begin from the full period results, our estimation results indicate that in the short-run, the lagged values of inflation expectations $E\pi_{t-1}$ had a negative and statistically significant impact on inflation expectations. This outcome is similar to New Zealand and tends to confirm the general association. Notably, the short run coefficients of inflation expectations $\Delta E\pi_t$ also showed considerable impact which varied with lags, implying elements of adaptive inflation expectations. The one period lagged positive oil shocks $OP_t^+$ had a positive impact on inflation expectations, whilst the negative $OP_t^+$ also had a positive impact on inflation expectations. Importantly, the short-run coefficients establish positive shocks $\Delta OP_t^+$ were *greater* in magnitude than negative oil price shocks $\Delta OP_t^-$ , again suggesting price stickiness. This also confirms the general trend association suggested in the New Zealand case, and is of course, likewise intuitive.

Moving on, careful scrutiny of Table 4 highlights that inflation, GDP, money supply and fiscal (surplus) had positive impacts that varied in magnitude and significance over different lags. Unemployment and the real effective exchange rate exhibit negative impacts. The REER estimates suggest a very strong pass-through to inflation expectations. The long-run estimates for the full period (Panel B) indicate that positive oil shocks had a positive impact on inflation expectations while negative oil shocks also had a positive impact. Once more this confirms the association found in the New Zealand case. That is, an indication of an asymmetric relationship between oil prices and inflation expectations.[16] Overall, diagnostic testing (Panel C) suggests that there were no issues of autocorrelation or heteroskedasticity. The negative and significant values for ECT also indicate stability of the model and the Ramsey REST test establishes once more that the model passes standard testing.

The results for the first and second sub-period also indicate that adaptive expectations were operative. Inflation expectations $E\pi_t$ were negatively but significantly affected by the one period lagged values and so adjustments allow us to infer adaptive expectations. Interestingly, in the first sub-period, both positive and negative oil shocks $OP_t^+$ and $OP_t^-$ had a positive impact on inflation expectations. However, in the second sub-period, one period lagged positive oil price shocks ($OP_{t-1}^+$) had a negative impact, while a negative oil shock ($OP_{t-1}^-$) had a positive impact. The short-term coefficients of oil price changes $\Delta OP_t$ exhibited diminishing impacts in the second period – and so this was the case during a proximal ZLB situation.

If we consider other variables from Table 4, inflation, GDP, money supply and fiscal stance (surplus/deficit) exhibit positive impacts with lags. Unemployment had a contemporaneous positive and insignificant impact which lags changed to negative and significant. The real effective exchange rate had a strong negative impact suggesting that appreciation can have *very strong* deflationary impact on inflation expectations. This is rarely discussed in the literature. The first-sub period long-run estimates (Panel B) show that oil prices ($OP^+$ & $OP^-$), inflation, GDP, money supply, and fiscal consolidation have positive impacts, while unemployment and REER demonstrate negative impacts on inflation expectations. In the second period, positive oil shocks($OP^+$), inflation and REER had negative impacts, though the results lacked statistical significance.

Overall, the diagnostic tests establish some signs of heteroscedasticity for the first sub-period. However, there was no issue of autocorrelation or misspecification. Given we are employing a White approach

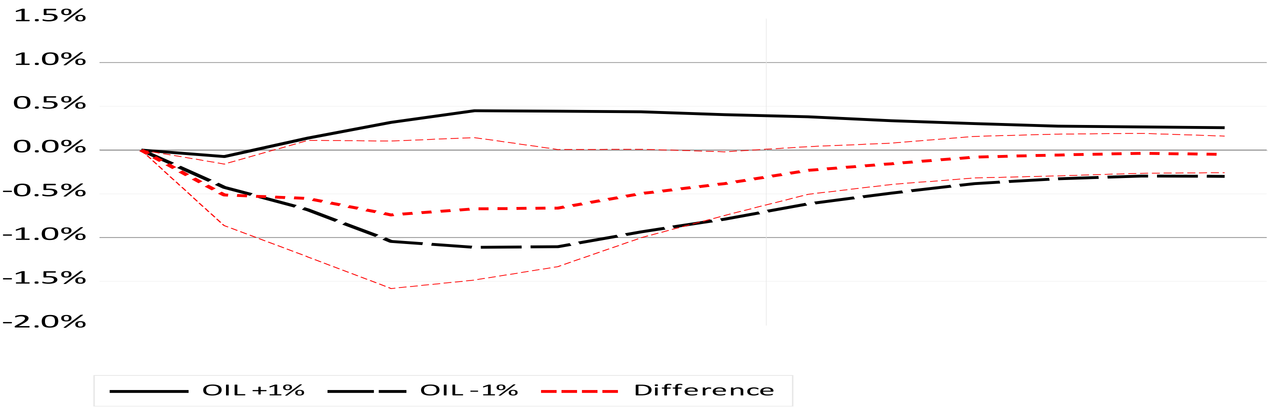
[16] Among the other variables, money supply GDP, money supply and fiscal consolidation had positive impacts and unemployment and REER had negative impacts on inflation expectations.

coefficient covariance matrix, able to account for heteroskedasticity-consistent standard errors & covariance, this is not a major issue from a statistical adequacy perspective. In any case, in the second sub-period, the diagnostic tests indicate no sign of heteroskedasticity or autocorrelation and the model passed specification testing.

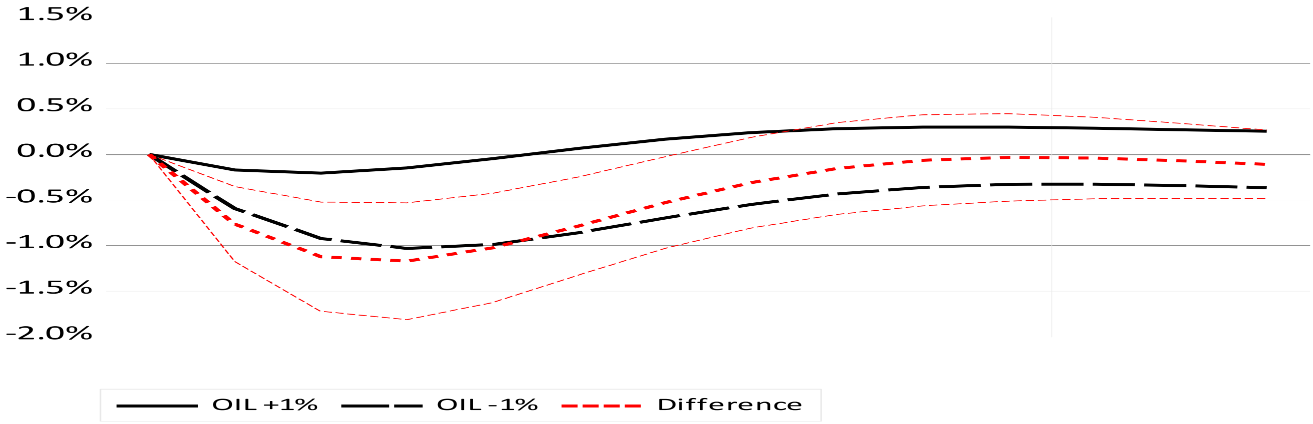
Following the same methodological approach applied to New Zealand by performing parameter stability tests for the periods and this is set out in Figure 3 (See appendix)

The CUSUM and CUSUMSQ parameter stability test for inflation establish that, aside from some temporary transgression in the first sub-period, our estimates for the full as well as sub-samples are stable. We estimate the multiplier effects of inflation expectations on inflation and the results are presented in Figure 4:

**Full sample**




**1st Sub-Period**




**2nd Sub-Period**

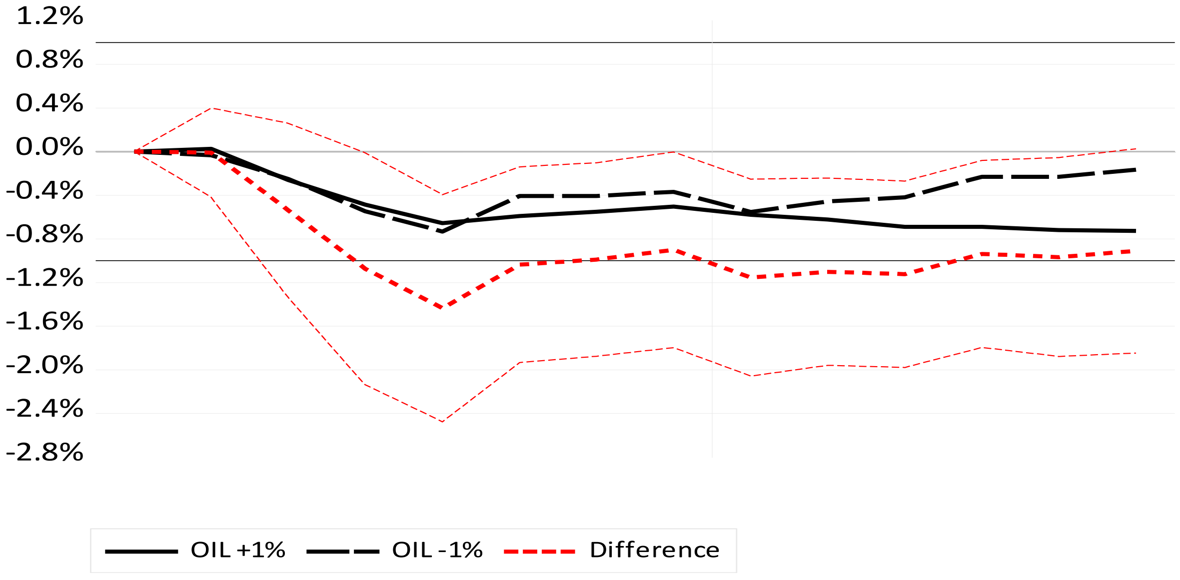



**Figure 4: NARDL Multiplier of Oil Shocks and response of Inflation expectations in the UK**

The results of the multiplier test of oil shocks on inflation expectations for the UK are interesting. In response to a 1% increase in oil prices inflation expectations demonstrate a positive response in the full period, which materialised after some lags. Similarly, in repose to negative oil price shocks inflation expectations showed a negative response in the full period. Thereafter, when we performed the sub-periods analysis, the positive oil shocks had a positive impact on the inflation with lag in the first sub-period. However, a positive oil shock did not have a positive impact, but rather a negative impact on inflation expectations in the second period. A negative oil price shock had a negative impact in both sub-periods. Furthermore, the responsiveness of inflation expectations to oil price shocks decreased in the second sub-period, and hence when monetary policy was in a proximal ZLB situation.

These findings in conjunction with the earlier presented N-ARDL estimates suggest that although inflation expectations have been influenced by oil prices shocks throughout the full period, in the proximal ZLB period the *pressure* on inflation expectations is perhaps best characterised as involving downward or deflationary risks to price stability.

## 5. Conclusion and Policy Implications

Central bank inflation targeting to achieve price stability has become a standard practice. Intuitively, policy strategy involves acknowledging a link between inflation and inflationary expectations. There is, therefore, an issue of anchoring. A proximal situation of ZLB interest rates poses an important set of challenges for monetary policy and price stability. In this study we focused on New Zealand and the UK as two longstanding inflation targeting policy regimes. We have analysed the implication of core factors affecting inflation expectations in an empirical framework designed to explore nonlinearities and asymmetries in the association between variables of interest. One key finding is that the real effective exchange rate has significant impacts on inflation expectations and this is indicative of an exchange rate pass-through to inflation via an inflation expectations channel. This is a *relatively* under-explored or researched avenue for statistical analysis and debate[17].

[17] Though in all fairness, we must acknowledge that in their seminal work, Engel and West (2005) did reflect on predictability of fundamentals including money supply, inflation, interest rates and output by the exchange rate dynamics.

More generally, our empirical results lead us to conclude that inflation, money supply, GDP, unemployment, the exchange rate and fiscal stance all have significant implications for inflation expectations. Inflation expectations are also influenced by their past behaviour and hence, there is considerable evidence to infer adaptive inflation expectations. As such, anchoring is clearly operative. This remained the case in the proximal-ZLB period for both countries.

However, we found oil shock asymmetries in the response of inflation expectations in both the first and second periods. In the case of New Zealand, inflation expectations showed a positive response to increasing oil prices in the full as well as both sub-periods. In response to negative oil price shocks inflation expectations showed a negative response in both periods. However, the *responsiveness* of inflation expectations to oil price shocks decreased in the second sub-period. The implication is that in a proximal ZLB situation expectations converge more promptly to oil shocks. By contrast, in the case of the UK, oil price shocks affected inflation expectations with lags and there was *symmetric* association between oil price shocks and inflation expectations. However, asymmetries emerge in the sub-period analysis. Furthermore, inflation expectations response to oil price shocks decreased in the proximal ZLB period. Overall, in the case of the UK, inflation expectations were influenced by oil price shocks in the full period, but in a proximal ZLB situation, to reiterate, the *pressure* on inflation expectations is perhaps best characterised as involving downward or deflationary risks to price stability.

As a final point and as a trigger for future research. One ought also to consider the combination of ZLB conditions and the effects created by quantitative easing, since it is ultimately self-limiting to consider the former in the absence of the latter. It is widely recognized that QE raised the price and lowered the yield on government bonds in policy applying countries. This in turn has fed through to lower long term interest rates and thus provides a further environmental factor to consider in future research.

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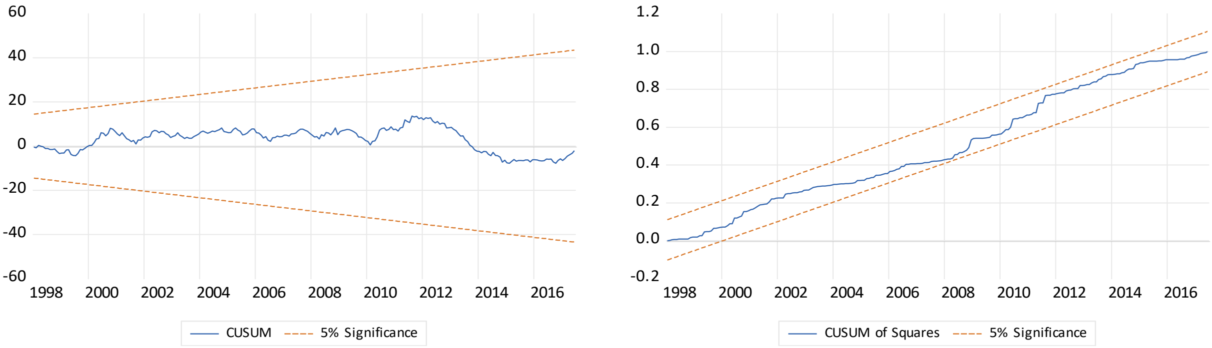
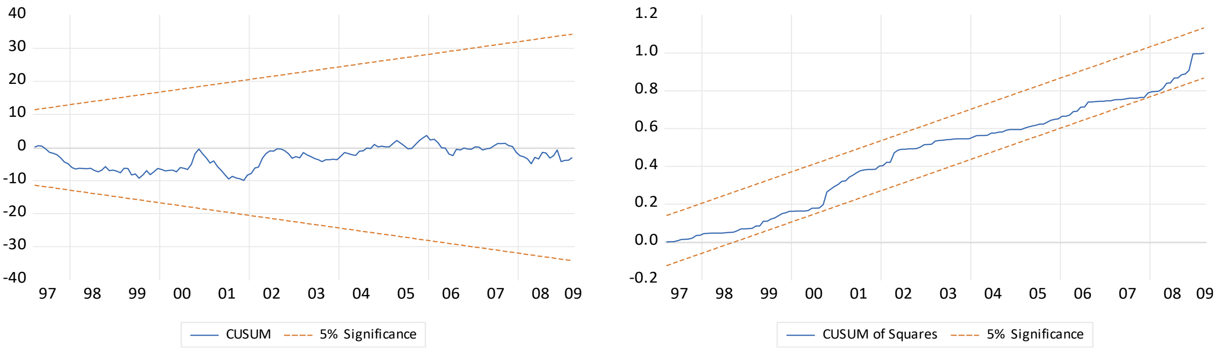
# Appendix

## Full sample




## 1st Sub Period




## 2nd Sub Period

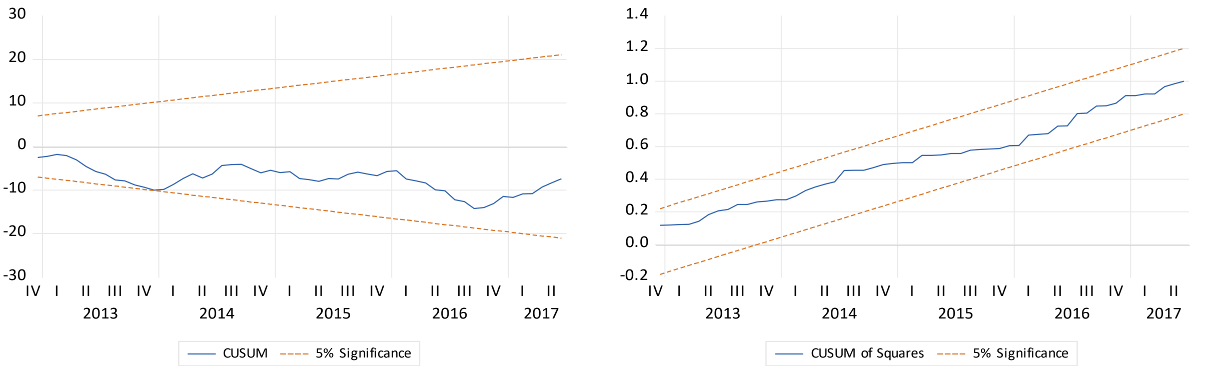
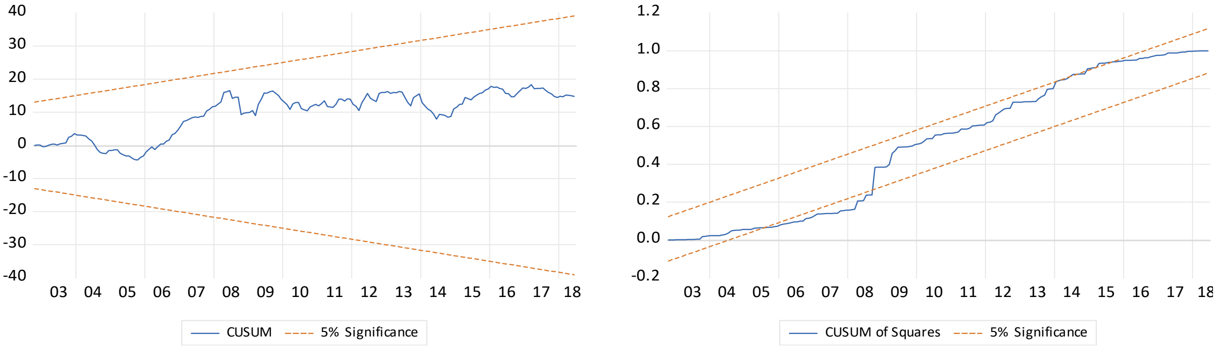
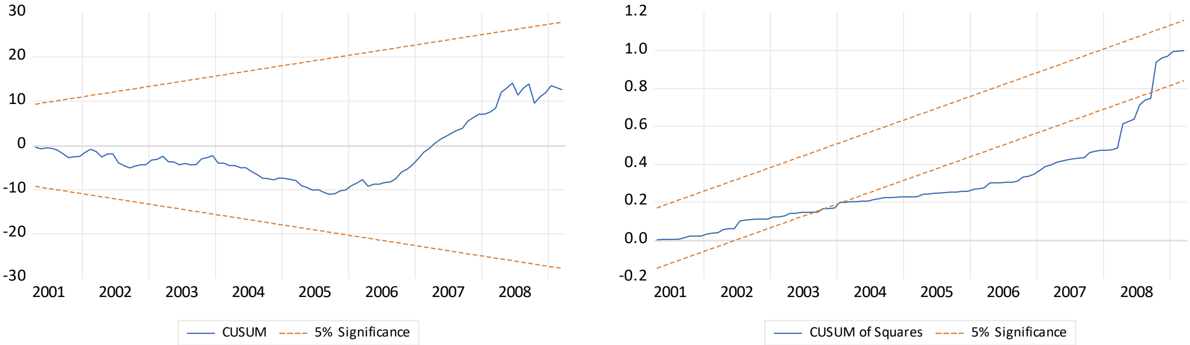



**Figure 1. CUSUM and CUSUMSQ Parameter Stability Test for Inflation Expectations in NZ**

**Full sample**




**1st Sub Period**

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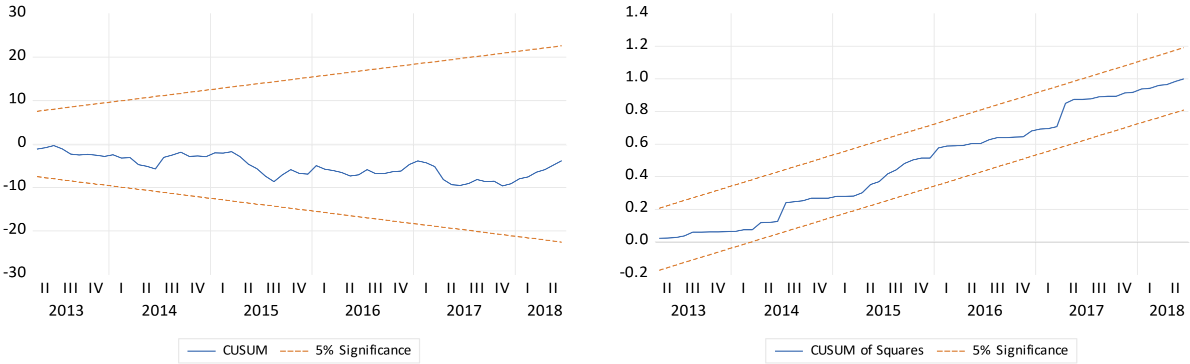


**Figure 3. CUSUM and CUSUMSQ Parameter Stability Test for Inflation Expectation in the UK**