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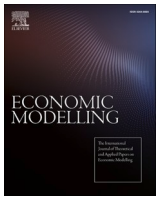

Nexus between inflation and inflation expectations at the zero lower bound: A tiger by the tail

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ABSTRACT

Ultra-low policy rates and zero lower bounds (ZLB) have been major issues for monetary policy formulation. In this context, we investigate the nexus between inflation and inflation expectations. Employing a non-linear ADRL framework on UK and Canadian datasets, we find significant asymmetries in the nexus among inflation and inflation expectations and their determinants, including labour market slack, output gap, oil shocks, fiscal deficit and exchange rates. Heterogeneities are explicit in the short and long-term as well as in the pre-and post-ZLB regimes. Inflation and inflation expectations become more responsive to their determinants as key policy rates approach the ZLB. There is strong evidence of persistence in inflation and inflation expectations in both regimes manifesting the importance of keeping expectations well anchored. Robustness testing with Time-Varying Parameter Vector Auto-Regression and Network Analysis confirms our findings. To mitigate the persistence of a high inflation regime, it would be vital to keep the inflation expectations well anchored.

1. Introduction

Managing and containing inflation is delicate yet a challenging business and for this reason, Hayek (1972) called it to have a *Tiger by the Tail.* To deliver on the objective of price stability, operationalised in the form of steady and stable inflation, some of the central banks have embarked on the explicit inflation targeting strategy since the early 1990s. The strategy of explicit inflation targeting entails, publicly announced inflation targets which an independent central bank is often mandated to achieve through monetary policy instruments e.g., policy rates. With the element of both the rule (target which acts as a nominal anchor) and discretion (instrument independence), inflation targeting is quite intuitively called "*constrained discretion*" by Bernanke (2003). An independent central bank that is committed to achieving the objective of price stability endeavours to keep inflation at target, its perceived commitment and credibility lead to anchoring inflation expectations, which in results complements its core objective of inflation targeting.

The benefit of inflation targeting has been widely discussed in the literature. For instance, Bernanke et al., (2001), argued that it is a transparent, flexible and simple strategy that leads to an increase in the policymaker's accountability. Mishkin (2010) argued it can overcome time-inconsistency issues, Herrendorf (1998) found it useful in mitigating inflation bias, Lee (2011) and Lanzafame (2016) reported that it leads to lowering risk premiums,[1] Seim and Zetterberg (2013) found that it results in higher real wages, Corbo et al. (2001) showed that it leads to lower sacrifice ratios, to Svensson (1997) it simplifies the

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[1] Financial markets' volatility and term premium can have implications for the monetary policy through economic activity and inflation nexus (See, recent work by Kumar et al., 2023).

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formulation and monitoring of monetary policy, Ftiti (2010) concluded that it generates a stable monetary environment, Obstfeld (2014) and Minea and Tapsoba (2014) argued that it leads to well-disciplined fiscal policy. In Williams's (2014) view, inflation targeting can help to achieve price stability and anchor inflation expectations. So, in a nutshell, there is ample support in the literature for inflation targeting. However, even the proponents of this strategy have acknowledged that it is neither a *panacea* (Bernanke et al., 2001) nor one size fits all (Mishkin, 2010). In this regard, Angeriz and Arestis (2008) and later Alpanda and Honig (2014) argued that there is little evidence on the role of inflation targeting in taming inflation. Nevertheless, critics of inflation targets have argued that it has serious drawbacks and in fact, it is a dead strategy in the Post-Global Financial Crisis (GFC) world (see, Quiggin, 2012; Frankel, 2012). A claim strongly refuted by Reichlin and Baldwin (2013) as they declared the inflation targeting strategy *alive* and effective.

In the context of the GFC and the associated Great Recession, Andersen et al. (2015) have claimed that inflation-targeting economies performed a lot better during the crisis than those that did not adopt it. Williams (2014) has declared the inflation targeting strategy successful, though acknowledged that there are vital challenges faced by the monetary authorities including the *Zero Lower Bound (ZLB)* and financial instability. On the issue of ZLB, it is obvious that ZLB constraints the policy rate instrument and hence the monetary policy ability. Undoubtedly, there have been central banks that have defied the ZLB by adopting negative rates e.g., the European Central Bank (ECB), Sveriges Riksbank and Bank of Japan (Nasir, 2021), yet they did not go too far below Zero. Nevertheless, Post-Covid-19 there has been a sharp surge in inflation which has led central banks including the ECB to increase the policy rates to a little above zero. However, the logical question manifested in the Williams (2014) concern, stands that when the monetary policy isn't or is at ZLB, what implications could it have for the inflation targeting? We will revert to it, but for those who are in favour of inflation targeting, one of the main reasons given is that the accountability, transparency and associated characteristics of inflation targeting are effective not only for inflation but also for inflation expectations (see Morgan, 2009; Bernanke et al., 2001; 2003). Thus, the inflation expectations of the firms and households are anchored through the credibility that is associated with the adoption of inflation targeting.

Despite these institutional arrangements made by the various monetary authorities to pave the way for successful inflation targeting, some critiques declared them insufficient, particularly in the Post-GFC era (see e.g. Frankel 2012, Quiggin (2012) and Sumner (2012). Contrarily, Reichlin and Baldwin (2013, p. 29) contradicted the notion of the death of inflation targeting and argued that we need inflation targeting more than ever before so it can keep the inflation expectations anchored. Concomitantly, there are two sides to the argument on inflation targeting and the debate stands which necessitates drawing on the empirical facts to answer the question of the effectiveness of inflation targeting while monetary authorities are constrained by the ZLB. Intuitively, if the ZLB has led to diminishing the credibility of monetary authorities and inflation targeting, the inflation expectations and inflation should have become *unguarded and hence more* responsive to shocks from determinants. Most recently, particularly Post-Covid-19, across the world there has been a sharp surge in inflation accompanied by low growth. Several central banks including the Federal Reserve, ECB and the Bank of England have missed their targets by great margins (IMF, 2023). This scenario poses a question on the effectiveness of inflation targeting as a strategy.

Literature on the determining factor of inflation suggests that aggregate demand and supply, labour market outlook, cost shocks, exchange rate dynamics, past inflation or element of persistence in inflation, fiscal discipline, and expectations about inflation define the inflation dynamics. In this regard, the nexus between inflation and inflation expectation is a crucial one (see e.g., Friedman (1968) or Phelps (1967) to most recent studies by Marfatia (2018) and Nasir et al. (2020a). The strategy of inflation targeting is to exploit this nexus by anchoring the expectations about inflation through increased transparency, accountability and credibility, (Morgan, 2009). However, the ZLB constraint poses a significant challenge to the monetary authorities and this raises the question of whether the constraint influences their credibility and ability to stabilize inflation. Inflation targeting is not only about managing inflation but it's also a "*Game of managing inflation expectation*". Among its proponents, e.g. most prominently Bernanke et al. (2001) and Williams (2014), the most frequently given reason for the adoption of inflation targeting is anchoring expectation. Now given that the monetary policy has faced ZLB constraints in recent years, how the inflation and inflation expectations have responded to different shocks? As we have witnessed a sharp increase in inflation recently where inflation has overshoot targets in many countries including the US, UK and Eurozone. Contextualising this question, this study contributes to the existing literature in several ways. First, this study analyses the nexus between inflation and inflation expectations in inflation-targeting economies. Second, we focus on the Pre- and Post-ZLB periods and hence were able to analyse the implications of ZLB for inflation targeting and specifically for inflation and inflation expectations. Third, this study employs a framework which accounts for the nonlinearity and asymmetry and accounts for the long and short-term heterogeneities in the relationships. Fourth, this study provides evidence on the hysteresis or persistence of inflation expectations in the underlying economies. Last but not least, this study analyses the implications of determinants of inflation for not only inflation but also for inflation expectations and this includes, labour market slack, output gap, oil shocks, fiscal deficit and pass-through of real exchange rate. A Nonlinear Autoregressive Distributed Lag (N-ARDL) framework is employed on data from the UK (December 1999 to December 2017) and Canada (June 2001 to December 2017). A very comprehensive estimation exercise was performed which gave us an in-depth insight into the tie between inflation and inflation expectations and their determining factors. The key empirical findings suggest significant asymmetries in the nexus between inflation and inflation expectations and their determinants including, output growth, unemployment, fiscal policy, exchange rate and cost shocks. These heterogeneities were explicit in the short and long term as well as in the Pre- and Post-ZLB regimes. There was significant evidence of persistence in the inflation and inflation expectations in both regimes which reflected the significance of hysteresis in the inflation and inflation expectations. The overarching conclusion of our analysis was that the inflation and inflation expectations seemed to have become more responsive to each other as well as other explanatory factors in the regime when the monetary policy in the UK and Canada were close to the ZLB. Our findings have profound implications for the monetary authorities and debate on the adoption of inflation targeting strategy to pursue the objective of price stability. The results are also valid in monetary policy formulation in the Post-Covid-19 era and a high inflation regime.

The rest of the paper proceeds as follows: Section 2 discusses the evidence on inflation targeting, ZLB and determinants of inflation and inflation expectations Section 3 lays out the N-ARDL model. Section 4 entails the presentation of empirical results and discussion. In section 5 we conclude and draw policy implications.

2. Literature review

The strategy of explicit inflation targeting was first adopted by New Zealand in 1990 and soon followed by the Canada and UK. Since then, several central banks followed and almost every year one central bank chose to adopt the inflation targeting strategy, lately Argentina in 2016. Though some of the big players like the ECB and Fed were not among the early adopters of inflation targeting, there was some support that they shall go for inflation targeting,[2] most prominently by Bernanke et al. (2001) and Bernanke (2003). In their support of inflation targeting,

[2] In case of ECB, there were some logical concerns around the country level inflation differentials and their implications for the ECB's credibility and success in inflation targeting (Artis and Kontolemis, 1998).

Bernanke et al. (2001) analysed the evidence on several countries and reported that *lower inflation and inflation expec*tations have been witnessed in the inflation-targeting countries. However, they also cautioned that the inflation Target is *not a Panacea* and is contingent on the operational details. Perhaps, as Obstfeld (2014) suggested the inflation-targeting framework entailing a *well-anchored inflation target* is helpful in achieving price stability. An intuitive question one may ask is what would be the case when the anchor is lifted? The success of any strategy is dependent on the quality of intuitions, and so is the successful inflation targeting for price stability, it is the institutional architect of monetary authorities (Huang and Wei, 2006). The economies which have adopted the strategy of inflation targeting and those considered in this study are developed countries with well-developed intuitional frameworks and established influential central banks (Caproasia Institute, 2017). However, the benefits could also be for the developing economies, for instance, Lee (2011), Lanzafame (2016) and Aslanoğlu and Deniz (2016) argued that inflation targeting could increase the credibility of monetary authorities and decrease the interest rate, particularly in emerging economies. Drawing on the Brazilian experience, Minella et al. (2003) argued that inflation targeting has played a major role in macroeconomic stabilisation. Similarly, Balima et al. (2017) argued that inflation targeting can improve the sovereign debt risk in emerging countries as well as their access to international financial markets. If we look at the evidence to judge the effectiveness of inflation targeting, despite the fact that it had condoned the aspect of financial stability, the inflation target has been successful in contributing to price stability (Williams, 2014). However, if that remains the case in the ZLB regime is the question that merits robust empirical testing. Perhaps, Williams (2014) acknowledged the fact that the ZLB can have implications for inflation targeting. In the period after the GFC, the interest rates have been unprecedentedly low, particularly across the developed world (Haldane, 2015; Nasir, 2021), until very recently, the inflation outlook has been very serene which could be due to several factors (including modest demand pressure, stagnation and low energy prices), so how much of it we can associate with inflation targeting? Particularly when the monetary authorities have been mostly focusing on output and financial stability. Is it down to the good policy or strategy of inflation targeting which kept the inflation and inflation expectations anchored or is it a deflationary stagnating economic regime? A good policy or good luck!

Demand and supply shocks define the dynamics of inflation and while the monetary policy may play an active role, it is a response to inflation or if forward-looking, to expected inflation. Furthermore, given that the policy rates are around ZLB since GFC, there is not much room to manoeuvre.[3] Hence, in this study, we focus on determinants of inflation dynamics found in the literature rather than the impact of policy. Among these, the positive demand and negative supply shocks are supposed to put upward pressure on inflation. As Gali and Gertler (1999) have argued, the prevailing rate of the inflation rate is affected by aggregate demand pressure but also the past behaviour of inflation, and inflation expectations. On the evidence from developed economies, Canova et al. (2007) have reported that the demand shocks in the US while supply shocks in the Euro-zone and UK are the most crucial determinants of inflation. Among other studies on the Euro-zone, McAdam and Willman (2004) and Lagoa (2017) found significant evidence of supply, whereas Boschia and Girardi (2007) reported the effects of both supply (cost) and demand shocks on inflation. On the contrary, another study on Euro-zone by Norkute (2015) employing country and sector-level data found no significant evidence of cost shocks' impact on inflation. In a recent study on inflation targeting in Scandinavian economies, Nasir et al. (2020a) reported country-wise heterogeneity in the impact of oil and shocks on inflation expectations. Similarly, in a study on the UK and New Zealand, Nasir et al. (2020b), reported asymmetries in the response of inflation expectations to oil shocks in the Pre- and Post-ZLB periods as well as between the NZ and UK. The evidence on the nexus between inflation and supply/cost shocks in developing countries is also mixed (contrast, e.g., Coe and McDermott, 1997; Domaç and Yucel, 2005; Mohanty and Klau, 2001; Mohanty and John, 2015; Unsal and Osorio, 2013). More recently, Later, Nasir et al. (2019) on GCC countries reported a positive impact of oil shocks on inflation, although Nasir et al. (2018) analysing BRICS data reported that the impact of oil shocks on inflation varied among countries. Concomitantly, the contrasting evidence from both developing and developed economies on the relationship between inflation and its determinants is intriguing and merits exploration of contextual factors and in the case of the subject study, it is the period with and without the ZLB.

Transparency is an important element of inflation targeting that leads to anchoring inflation expectations and resulting in actual inflation. Although transparency on its own may not be ample for price stability, it does influence inflation through expectation channels (Weber, 2016). The role of inflation in defining inflation dynamics is documented by Friedman (1968) and Phelps (1967). A bit more recently, several studies have explored the inflation-inflation expectations nexus, e.g., in evidence from the US, Mehra and Herrington (2008) analysed showed that inflation and inflation expectations are influenced by past inflation, oil shocks, expected inflation and unemployment. Comparing the US and Japan, Ueda (2010) found that inflation expectations have a higher pace of adjustment than inflation. The effects of exogenous prices on inflation expectations and inflation were found to be more pronounced and long-lasting in the US than in Japan. Similarly, in a study on the US, Fuhrer (2011) argued that inflation expectations have a significant impact on inflation in the short run, although the effects were not evident in the long term. In a study on Euro-zone, Lagoa (2017) argued that inflation expectations have a significant impact on inflation. However, while Aβhoff et al. (2021) reported a significant impact of unconventional monetary policy and inflation expectations in the short-term in the Eurozone, they failed to find a significant relationship between inflation and inflation expectations. Scharnagl and Stapf (2015) also reported a decrease in the responsiveness of inflation expectations to monetary policy decisions in the Eurozone. In a later study on the UK, Marfatia (2018) reported that inflation expectations (derived from the bond index) significantly explain the dynamics of inflation. Posen (2011) on the UK economy argued that considering inflation expectation as anchored leads to better forecasting of inflation. Though claims by Posen (2011) require empirical testing, if the expectations of inflation were anchored the Bank of England's forecast would be a lot better in the face of shocks (See, Nasir, 2020; Broadbent, 2017; Haldane, 2017).

The role of fiscal policy in influencing inflation is debatable, at least in the literature. Sargent and Wallace (1981) in their seminal work argued that fiscal policy can have crucial implications for inflation, although, in a later study, Fischer et al. (2002) reported that the link between fiscal deficit and inflation is not consistently found in the data of 133 countries they brought under-analysis. Furthermore, the relationship varied among countries and was mostly found in the economies having high inflation rates. This view was contradicted by Catao and Terrones (2005) study which employed data on 107 economies and found fiscal deficit as a cause of inflation in most of the countries. Their findings were supported by a later study on the inflation-fiscal deficit nexus by Lin and Chu (2013). A point to emphasise here is that if the fiscal policy plays an important part in inflation and inflation expectations as argued by Sargent and Wallace (1986), then by default the fiscal policy is also crucial for the effectiveness of inflation targeting (Alpanda and Honig, 2014; Mikek, 2004). On this aspect, Minea and Tapsoba (2014) have argued that successful inflation targeting requires a sound fiscal stance and discipline. Among other studies on this subject, Minella et al. (2003) and later Cerisola and Gelos (2009) employing a Brazilian

[3] With exception of Quantitative Easing which are unconventional and have been mostly focused on financial and output stabilisation rather inflation (see, e.g., Nasir, 2021; Haldane, 2015 for further discussion).

dataset reported that the inflation expectations have been anchored in uncertain times after the adoption of inflation targeting. They also argued for the importance of fiscal policy in influencing inflation expectations, although they suggested that inflation expectations are not affected by the past behaviour of inflation. Their argument on the lack of inertia in inflation is in line with the Corbo et al. (2001) position though contrary to the view held by Gali and Gertler (1999) and Nasir et al. (2020b). The study by Yigit (2010) showed that after the adoption of inflation targeting, there had been a decline in inflation expectations persistence. The contrasting evidence on the role of fiscal policy and persistence in inflation and inflation expectation is intriguing and in the subject study, we will revisit it in the context of ZLB and inflation targeting.

There are crucial implications of exchange rate pass-through (ERPT) for inflation targeting (Fraga et al., 2003). In recent years, there has been debate if the ERPT has declined after the adoption of inflation targeting by some economies, for instance, Goldfajn and Muinhos (2003) on Brazil reported a decline in ERPT. Similarly, studies by Mishkin and Savastano (2001), Eichengreen (2002) and Schmidt-Hebbel and Werner (2002) that focused on the Pre-GFC and Pre-ZLB regimes, associated with the potential decline in ERPT to keeping inflation expectations low post depreciation that could be increased credibility because of inflation targeting. In a later study, although Junior (2007) supported the notion of a decline in ERPT due to inflation targeting in emerging economies but also cautioned that this does not imply it has ceased to exist in the long term. Nonetheless, some studies argued that there is significant evidence of ERPT (See Forbes, 2016; Forbes et al., 2015; Nasir and Simpson, 2018; Forbes et al., 2017). There is also recent evidence that suggests an increase in ERPT in inflation-targeting regimes (Nasir et al., 2020, 2020b; Nasir and Vo, 2020). In a recent study, Pham et al. (2020) reported significant evidence of ERPT in ASEAN-5 countries, with varying intensity. Concomitantly, the contrasting evidence on the ERPT and inflation targeting require further exploration, particularly in the context of ZLB.[4] It raises the question of whether inflation targeting is an effective tool for anchoring inflation expectations and inflation against shocks from its determinants in the ZLB and non-ZLB regimes. The next section sets out the empirical framework used to answer this question.

3. Methodology

Nonlinear Auto-Regressive Distributed Lag (N-ARDL) is employed in this study. There are various reasons for this choice and the N-ARDL seems to be the most suitable framework for the subject analysis. Among its numerous merits, the N-ARDL take into account the non-linearity and asymmetry in the underlying causal relationships.[5] The model is dynamic and hence takes into account the current and past dynamics of the explanatory variable in determining the response variable's behaviour. The auto-regressive element of the model helps in analysing the persistence of inflation and inflation expectations. Last but not least, the model is also helpful in getting insight into both short and long-term relationships. Due to all these features, the N-ARDL seems to be the most suitable choice in this study. The relationship between inflation, inflation expectations and their determinants are expressed as an open economy New Keynesian Phillips model; -

$$\pi_t = \beta_\pi \pi_{t-i} + \beta_{E\pi} E\pi_{t+i} + \beta_{OG} OG_{t-i} + \beta_{LMS} LMS_{t-i} + \beta_{Fiscal} Fiscal_{t-i} + \beta_{Supp} Supp_{t-i} + \beta_{Ex} EX_{t-i} + e_t \; e_t \approx (0, \sigma^2) \quad (1)$$

Whereas the π_t is inflation that is affected by past inflation π_{t-i} implying hysteresis, the expectation of $E\pi$, OG is the output gap, LMS is labour market slack or unemployment, fiscal is fiscal deficit/surplus, $Supp$ is supply/cost shocks and EX is the exchange rate. The is e_t is the error term with independent and identical distribution (I.I. D). It is intuitive to postulate that what causes actual inflation also determines future inflation or expectations about it. Therefore,

$$E\pi_t = \beta_\pi \pi_{t-i} + \beta_{E\pi} E\pi_{t+i} + \beta_{OG} OG_{t-i} + \beta_{LMS} LMS_{t-i} + \beta_{Fiscal} Fiscal_{t-i} + \beta_{Supp} Supp_{t-i} + \beta_{Ex} EX_{t-i} + e_t e_t \approx (0, \sigma^2) \quad (2)$$

Eq. (1) & Eq. (2) for inflation and inflation expectations can also be specified in the following long-run form; - -

$$\pi_t = a_0 + a_1 E\pi_t^+ + a_2 E\pi_t^- + a_3 OG_t + a_4 LS_t + a_5 Fiscal_t + a_6 Supp_t + a_7 EX_t + e_t \quad e_t \approx (0, \sigma^2) \quad (3)$$

$$E\pi_t = a_0 + a_1 \pi_t^+ + a_2 \pi_t^- + a_3 OG_t + a_4 LS_t + a_5 Fiscal_t + a_6 Supp_t + a_7 EX_t + e_t \quad e_t \approx (0, \sigma^2) \quad (4)$$

Where π_t and $E\pi_t$ and other variables are as specified in Eq. (1) & Eq. (2), $a = (a_0 - a_7)$ is long-run parameters co-integrating vector. The $E\pi_t^+$ and $E\pi_t^-$ are partial sums of positive and negative changes in inflation expectations ($E\pi_t$) and π_t^+ and π_t^- are the partial sums of positive changes and negative changes in inflation (π_t), it can be specified as; -

$$E\pi_t^+ = \sum_{i=1}^{t} \Delta E\pi_i^+ = \sum_{i=1}^{t} \max(\Delta E\pi_i, 0) \quad (5)$$

and

$$E\pi_t^- = \sum_{i=1}^{t} \Delta E\pi_i^- = \sum_{i=1}^{t} \min(\Delta E\pi_i, 0) \quad (6)$$

For inflation (π_t), it would be as follows; -

$$\pi_t^+ = \sum_{i=1}^{t} \Delta \pi_i^+ = \sum_{i=1}^{t} \max(\Delta \pi_i, 0) \quad (7)$$

and

$$\pi_t^- = \sum_{i=1}^{t} \Delta \pi_i^- = \sum_{i=1}^{t} \min(\Delta \pi_i, 0) \quad (8)$$

Based on Eq. (3) & Eq. (4), the relationship between π_t and $E\pi_t$ is postulated to have a positive value of (a_1). The parameter a_2 that accounts for the relationship between inflation and inflation expectations when there is a decrease in them. Given the fact that we expect a co-movement between inflation and inflation expectations, it is expected that the a_2 will also yield positive signs. It is also hypothesised that an increase in inflation and inflation expectations will lead to increasing inflation expectations and inflation respectively than the other way round. This is due to the reason that we expect the positive shocks to have a bigger impact than the negative ones i.e., $a_1 > a_2$ or in other words, we expect downward rigidity in prices. Hence, the relationship presented in Eq. (3) & Eq. (4) is expected to manifest an asymmetric relationship. Eq. (3) and Eq. (4) can be specified into an N-ARDL framework as follows[6]; -

[4] In fact, the empirical evidence remains controversial and inconclusive, and several econometric methods and data have been used in the context of pass-through. Recent studies have proposed resolving the methodological issues using more appropriate econometric methods to test and identify the presence of nonlinear ERPT mechanism (see e.g., Anderl and Caporale, 2022; Baharumshah et al., 2017; Ben Cheikh and Ben Zaied, 2020; Donayre and Panovska, 2016).

[5] See Shin et al. (2011), Pesaran et al. (2001) and Pesaran and Shin (1999) for details.

[6] For details see, Pesaran and Shin (1999), Shin et al. (2011) and Pesaran et al. (2001).

$$\Delta\pi_t = a+\beta_1\pi_{t-1}+\beta_2 E\pi^{+}_{t-1}+\beta_3 E\pi^{-}_{t-1}+\beta_4 OG_{t-1}+\beta_5 LS_{t-1} + \beta_6 Fiscal_{t-1}+\beta_7 Supp_{t-1}+\beta_8 EX_{t-1}+\sum_{i=1}^{p}\varnothing_i\Delta\pi_{t-i}+\sum_{i=0}^{q}(\theta_i^{+}\Delta E\pi^{+}_{t-i} + \theta_i^{-}\Delta E\pi^{-}_{t-i})+\sum_{i=0}^{s}\gamma_i\Delta OG_{t-i}+\sum_{i=0}^{v}\delta_i\Delta LS_{t-i} + \sum_{i=0}^{w}\Omega_i\Delta Fiscal_{t-i}+\sum_{i=0}^{x}\varphi_i\Delta Supp_{t-i}+\sum_{i=0}^{z}\delta_i\Delta EX_{t-i}+e_t\, e_t \approx (0,\sigma^2) \quad (9)$$

And

$$\Delta E\pi_t = a+\beta_1 E\pi_{t-1}+\beta_2\pi^{+}_{t-1}+\beta_3\pi^{-}_{t-1}+\beta_4 OG_{t-1}+\beta_5 LS_{t-1}+\beta_6 Fiscal_{t-1} + \beta_7 Supp_{t-1}+\beta_8 EX_{t-1}+\sum_{i=1}^{p}\varnothing_i\Delta E\pi_{t-i}+\sum_{i=0}^{q}(\theta_i^{+}\Delta\pi^{+}_{t-i} + \theta_i^{-}\Delta\pi^{-}_{t-i})+\sum_{i=0}^{s}\gamma_i\Delta OG_{t-i} + \sum_{i=0}^{v}\delta_i\Delta LS_{t-i}\sum_{i=0}^{w}\Omega_i\Delta Fiscal_{t-i}++\sum_{i=0}^{x}\varphi_i\Delta Supp_{t-i}+\sum_{i=0}^{z}\delta_i\Delta EX_{t-i}+e_t e_t \approx (0,\sigma^2) \quad (10)$$

The variables are defined earlier and here we have lag orders p *to* z and $a_1 = -\beta_2/\beta_1$ $a_2 = -\beta_3/\beta_1$ are the long-run coefficients indicating the effects of positive or negative shocks of inflation expectations on inflation (Eq. (9)) as well as the impact of increase or decrease in inflation on inflation expectations (Eq. (10)). In Eq. (9), the $\sum_{i=0}^{q}\theta_i^{+}$ accounts for the short-term effect of an increase in expected inflation on the actual inflation whereas $\sum_{i=0}^{q}\theta_i^{-}$ accounts for the short-term effect of a decrease in expected inflation on actual inflation. In Eq. (10), $\sum_{i=0}^{q}\theta_i^{+}$ measures the short-term effects of increased inflation on inflation expectations whereas $\sum_{i=0}^{q}\theta_i^{-}$ measures the short-term effect of decreasing inflation on the expected rate of inflation. In this framework, we account for both the asymmetric long and short-term relationships.

The following steps are followed in the application of the NARDL framework. First, to find the order of integration of underlying data series, unit root testing is performed. The chosen approach to co-integration is valid if the series are $I(0)$ or $I(1)$ as the $I(2)$ could lead to invalid results (Ibrahim, 2015). Second, the OLS approach is used for the estimation of Eq. (9) & Eq. (10). To check the presence of co-integration, the bound testing approach drawing on the work by Pesaran et al. (2001) and Shin et al. (2011) is used. For this purpose, we used the Wald F-test with null $\beta_1 = \ldots = \beta_8 = 0$. Lastly, the long-term short-term asymmetries in the nexus between inflation and inflation expectations are analysed as well as the impact of other determinants. The asymmetric cumulative dynamic multiplier impact of a 1% change in the inflation expectations i.e. $E\pi^{+}_{t-1}$ and $E\pi^{-}_{t-1}$ and inflation i.e. π^{+}_{t-1} and π^{-}_{t-1} respectively is also analysed through the following specification; -

$$m_h^{+} = \sum_{j=0}^{h}\frac{\partial y_{t+j}}{E\pi^{+}_{t-1}}, m_h^{-} = \sum_{j=0}^{h}\frac{\partial y_{t+j}}{E\pi^{-}_{t-1}}, h = 0,1,2\ldots\ldots\ldots \quad (11)$$

and

$$m_h^{+} = \sum_{j=0}^{h}\frac{\partial y_{t+j}}{\pi^{+}_{t-1}}, m_h^{-} = \sum_{j=0}^{h}\frac{\partial y_{t+j}}{\pi^{-}_{t-1}}, h = 0,1,2\ldots\ldots\ldots \quad (12)$$

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

3.1. Data

We collected data on inflation, fiscal stance, inflation expectations, labour market, output growth, real exchange rate and cost shocks. We focused on two economies i.e., UK and Canada in this study. The reason for this choice is that these were the early adopters of inflation targeting and hence it provides a sufficient time horizon to perform the analysis. Furthermore, the availability of reliable estimates and data is also one of the reasons for choosing these economies. Both economies are large and developed and hence merit as good candidates to be used in this case. The linear interpolation is performed on the quarterly data where necessary to match the frequencies. Details of each variable and source are as follows:

Inflation: We collected the monthly data on the Consumer Price Index (CPI) which is also the targeted measure used by the Bank of England and Bank of Canada to target inflation at the annual rate of 2%. For Canada, we collected data from Statistics Canada while for the UK we obtained it from the Office for National Statistics (ONS).

Inflation Expectations: The data on inflation expectations were collected from the Bank of England for the UK. We used the BoE inflation expectations survey which captures the attitude toward inflation and inflation expectations for the next 12 months. For Canadian inflation expectations, we collected data on the inflation expectations in the survey carried out by the Bank of Canada. The survey captures the expectations about the CPI in the next two years.[7] The data on inflation expectations was the shortest series available for both the UK and Canada. Hence, it determined the time horizon of our analysis. There are some studies that extracted the inflation expectations data from the terms structure of interest rates or bond's yield (e.g. Balfoussia and Wickens (2006) and Marfatia (2018), however, this study employed the direct approach to avoid any limitations associated with the indirect way of deriving the inflation expectations. It is preferred to directly use the inflation expectations data from the survey and through the most reliable sources! In the case of the UK, the data on inflation expectation was available from 1999Q4 to 2017Q whereas, in the case of Canada, it was available from 2001Q2 to 2017Q4.

Output Gap: Data on the real GDP growth rate for the UK was collected from the Office for National Statistics (ONS), to estimate the output gap, we followed the procedure used by the Bank of England and employed the HP filter to obtain the long-term rate of output growth (See Carney, 2017). Thereafter we calculated the output gap as the deviation of output from its long-term level.[8] Similarly, for Canada, we collected data on the real GDP growth which was also seasonally adjusted. Analogous to the UK, the Canadian output gap was estimated as the deviation of output growth from its long-term level.

Labour Market Slack: For the Labour market, we collected the data from the Labour Force Survey (LFS) carried out by the ONS**.** The unemployment rate is used as a proxy based on the International Labour Organization's (ILO) definition of unemployed at the age of 16–64. The quarterly and seasonally adjusted data was obtained and similar to the output Gap estimation we estimated the labour market slack as the deviation of unemployment from its long-term rate. For Canada, we also used the Canadian unemployment rate data which was standardised and seasonally adjusted to account for the seasonal variation in the labour market statistics.

Fiscal Stance: The data on the quarterly GDP and current budget deficit were collected from the ONS. Using these observations, we calculated the deficit to GDP ratio. To exclude the seasonal shortfall and surpluses in the public deficit, we deseasonalised the data. For Canada, we collected the data on the central government Deficit/Surplus, year on year which was also standardised.

Real Effective Exchange Rate: For the real effective exchange rate,

[7] Specially, it has asked respondent firms that "Over the next two years, what do you expect the annual rate of inflation to be, based on the consumer price index? We took the proportion of respondents which suggest the inflation to be more than 2% target.

[8] We followed approach by the Bank of England (See Nasir and Morgan, 2018).

Table 1
ADF unit root test incorporating structural break.

		Test Stat. (IO)	Sig.	*Test Stat. (AO)*	Sig.
At level I(0)	United Kingdom				
	Inflation	−3.301	0.894	−3.491	0.816
	Inflation Expectations	−4.100	0.141	−5.160	0.052
	Output Gap	−6.422*	<0.01	−17.181*	<0.01
	Labour Market Slack	−4.832	0.115	−4.728	0.147
	Real Exchange Rate	−3.855	0.615	−3.850	0.618
	Cost (oil) Shocks	−4.853	0.114	−4.886*	0.010
	Fiscal Deficit/Surplus	−5.932	<0.01*	−3.869	0.606
	Canada				
	Inflation	−4.706	0.015	−4.862	0.108
	Inflation Expectations	−5.066	0.067	−4.035	0.497
	Output Gap	−6.417*	<0.01	−5.972*	<0.01
	Labour Market Slack	−4.731	0.146	−4.775	0.131
	Real Exchange Rate	−3.613	0.758	−3.607	0.762
	Cost (oil) Shocks	−4.681	0.163	−4.729	0.147
	Fiscal Deficit/Surplus	−11.106*	<0.01	−11.209*	<0.01
At 1st difference I(1)	**United Kingdom**				
	Inflation	−13.292*	<0.01	−13.397*	<0.01
	Inflation Expectations	−5.109**	0.02	−8.422*	<0.01
	Output Gap	−9.630*	<0.01	−92.013*	<0.01
	Labour Market Slack	−6.219*	<0.01	−6.577*	<0.01
	Real Exchange Rate	−13.730*	<0.01	−13.859*	<0.01
	Cost (oil) Shocks	−10.772*	<0.01	−10.857*	<0.01
	Fiscal Deficit/Surplus	−4.853*	<0.02	−5.688*	<0.01
	Canada				
	Inflation	−13.013*	<0.01	−13.572*	<0.01
	Inflation Expectations	−4.103**	0.054	−5.833*	<0.01
	Output Gap	−4.373**	<0.05	−5.052*	<0.01
	Labour Market Slack	−14.761*	<0.01	−14.902*	<0.01
	Real Exchange Rate	−11.716*	<0.01	−11.800*	<0.01
	Cost (oil) Shocks	10.194*	<0.01	−10.288*	<0.01
	Fiscal Deficit/Surplus	−17.100*	<0.01	−17.646*	<0.01

***Vogelsang and Perron (1998) asymptotic one-sided p-values, *1% and ** 5% level of significance.

we used data from the Bank for International Settlement's (BIS) Real Broad Effective Exchange Rate Index. These are weighted averages of bilateral exchange rates adjusted for inflation for both the UK and Canada.

Supply/Cost shocks: To proxy the supply or cost shocks we chose oil price data. Specifically, we chose the data on the crude oil prices, West Texas Intermediate (WTI). The monthly observations were collected from the Federal Reserve Bank of St. Louis.

3.2. Analysis and empirical findings

To start with, we carried out the Unit root testing and for this purpose, the ADF Unit root approach is followed which also accounted for the structural break in the data set. This strategy of accounting for the structural break is vital to avoid potential bias (for discussion see Perron, 1989; Hansen, 2001; Perron, 2006; Nasir et al., 2018a). The date of break is endogenously determined[9] based on data employing both Additive Outliers (AO) and Innovative Outliers (IO)[10]. The results of unit root testing are summarised in Table 1.

The ADF unit testing that accounted for the structural break and both additive and innovation outliers showed that at level, null of not unit root could not be rejected for most of the series. Interestingly, two of the variables (output gap and fiscal) were stationary even at the level, this suggested that the fiscal stability and economic stability of these economies in the long-term. Data was found to be stationary at first difference i.e. I (*1*) which implied that we could advance with the application of the N-ARDL model (Eq. (9) & Eq. (10)) for the UK and Canada.

[9] See Zivot and Andrews (1992) and Nasir et al. (2018).
[10] We followed classification by Fox (1972) and later by Tsay (1988).

Table 2
Nonlinear Cointegration - Bounds testing.

	F-stat.	Lower-Bound (95%)	Upper-Bound (95%)	Outcome
Inflation (π_t)	4.417*	2.17	3.21	Cointegration
Inflation Expectation ($E\pi$)	4.544*	2.17	3.21	Cointegration

*1%, ** 5% and ***10% significance level.

3.3. United Kingdom

The Bounds testing for the nonlinear Cointegration in the case of the UK is performed and the results are summarised in the following Table 2:

The results indicate the critical values i.e., F-statistics to be greater than the upper bound at the statistical level of 1% suggesting the presence of Cointegration in both models (Eq. (9) & Eq. (10)). Hence, we infer the presence of a long-run relationship and proceed with further analysis. To differentiate between the Pre-ZLB and ZLB periods, we also used the sub-sample when policy rates were lowered to 0.5% in March 2009. The two sub-periods include i.e. December 1999 to March 2009 and April 2009 to December 2017. The findings are summarised in Table 3.

The results on the inflation for the UK for the entire sample showed that there was a strong element of persistence and past inflation was a strong influencing factor on the inflation at present. The results were also highly significant ($P < 0.01$). The inflation expectations also seemed to play an important part in determining the dynamics of inflation, although there was evidence of asymmetry in the relationship. The positive shocks to the inflation expectations ($\Delta E\pi_t^+$) had a negative but insignificant contemporaneous effect, which became significant and positive with lag. This implied that the inflation expectations do influence the actual inflation through adjustment may take a period which in

Table 3
Estimation of NARDL- inflation UK.

	Full Period			Pre-ZLB (1999M12-2009M03)			ZLB (2009M04-2017M12)	
A: Short-run estimates								
	Coefficient	Sig.		Coefficient	Sig.		Coefficient	Sig.
$\Delta\pi_{t-1}$	0.85407	0.000*	$\Delta\pi_{t-1}$	0.683	0.000*	$\Delta\pi_{t-1}$	0.685	0.000*
$\Delta E\pi_t^+$	−0.43418	0.182	$\Delta\pi_{t-2}$	0.131	0.258	$\Delta\pi_{t-2}$	−0.242	0.056**
$\Delta E\pi_{t-1}^+$	0.61129	0.055**	$\Delta E\pi_t^+$	0.606	0.002*	$\Delta\pi_{t-3}$	0.141	0.241
$\Delta E\pi_t^-$	1.06081	0.000*	$\Delta E\pi_t^-$	0.599	0.311	$\Delta\pi_{t-4}$	−0.074	0.558
$\Delta E\pi_{t-1}^-$	−0.83367	0.001*	$\Delta E\pi_{t-1}^-$	0.102	0.914	$\Delta\pi_{t-5}$	0.249	0.066**
ΔOG_t	0.00006	0.617	$\Delta E\pi_{t-2}^-$	−0.602	0.479	$\Delta\pi_{t-6}$	−0.391	0.000*
ΔOG_{t-1}	0.00002	0.918	$\Delta E\pi_{t-3}^-$	−1.924	0.085***	$\Delta E\pi_t^+$	−1.296	0.018*
ΔOG_{t-2}	−0.00015	0.499	$\Delta E\pi_{t-4}^-$	3.008	0.001*	$\Delta E\pi_{t-1}^+$	1.682	0.001*
ΔOG_{t-3}	0.00031	0.129	ΔOG_t	0.002	0.004*	$\Delta E\pi_t^-$	1.174	0.031**
ΔOG_{t-4}	−0.00024	0.029**	ΔOG_{t-1}	−0.002	0.009*	$\Delta E\pi_{t-1}^-$	0.127	0.890
ΔLMS_t	0.02235	0.430	ΔOG_{t-2}	0.001	0.104***	$\Delta E\pi_{t-2}^-$	−1.324	0.152
ΔLMS_{t-1}	0.00529	0.918	ΔOG_{t-3}	−0.002	0.033**	$\Delta E\pi_{t-3}^-$	1.305	0.012*
ΔLMS_{t-2}	−0.03915	0.176	ΔLMS_t	0.068	0.059**	ΔOG_t	0.0002	0.028**
ΔEX_t	0.01111	0.285	ΔLMS_{t-1}	−0.023	0.721	ΔOG_{t-1}	−0.0002	0.021**
ΔEX_{t-1}	−0.02427	0.027**	ΔLMS_{t-2}	−0.068	0.308	ΔLMS_t	0.068	0.150
$\Delta Fiscal_t$	0.01243	0.375	ΔLMS_{t-3}	0.089	0.173	ΔLMS_{t-1}	−0.060	0.506
ΔOP_t	0.00846	0.014*	ΔLMS_{t-4}	−0.069	0.064***	ΔLMS_{t-2}	−0.043	0.649
ΔOP_{t-1}	−0.00794	0.031**	ΔEX_t	0.017	0.066***	ΔLMS_{t-3}	0.090	0.386
Constant	1.83499	0.009*	$\Delta Fiscal_t$	0.408	0.045**	ΔLMS_{t-4}	−0.174	0.139
ECT	−0.14603	0.000*	$\Delta Fiscal_{t-1}$	−0.575	0.118	ΔLMS_{t-5}	−0.050	0.650
			$\Delta Fiscal_{t-2}$	−0.017	0.962	ΔLMS_{t-6}	0.178	0.004*
			$\Delta Fiscal_{t-3}$	0.579	0.107	ΔEX_t	0.029	0.042**
			$\Delta Fiscal_{t-4}$	−0.523	0.008***	ΔEX_{t-1}	−0.038	0.016*
			ΔOP_t	0.009	0.126	$\Delta Fiscal_t$	−0.208	0.495
			ΔOP_{t-1}	−0.002	0.748	$\Delta Fiscal_{t-1}$	0.825	0.110
			ΔOP_{t-2}	−0.005	0.529	$\Delta Fiscal_{t-2}$	−0.587	0.250
			ΔOP_{t-3}	0.001	0.868	$\Delta Fiscal_{t-3}$	0.709	0.142
			ΔOP_{t-4}	0.016	0.026**	$\Delta Fiscal_{t-4}$	−0.940	0.039**
			Constant	−2.641	0.033**	$\Delta Fiscal_{t-5}$	0.741	0.003*
			ECT	−0.183	0.000*	ΔOP_t	0.012	0.020**
						ΔOP_{t-1}	−0.013	0.067**
						ΔOP_{t-2}	0.007	0.336
						ΔOP_{t-3}	−0.009	0.183
						ΔOP_{t-4}	0.010	0.163
						ΔOP_{t-5}	−0.009	0.053**
						Constant	9.746	
						ECT	−0.632	0.000*
B: Long-run Estimates								
$E\pi^+$	1.2137	0.021**	3.284		0.028**	0.610		0.007*
$E\pi^-$	1.5564	0.001*	6.420		0.033**	2.029		0.000*
OG	0.00003	0.852	−0.008		0.062***	0.000005		0.932
LS	−0.07881	0.035**	−0.014		0.738	0.0126		0.506
EX	−0.09020	0.012*	0.097		0.158	−0.015		0.343
Fiscal	0.08520	0.378	−0.698		0.094***	0.855		0.000*
Oil Price	0.00352	0.739	0.103		0.125	−0.005		0.366
Diagnostic Testing								
R^2	0.959		0.962			0.983		
JB test.	0.913	0.633	0.130		0.937	8.789		0.012*
BG LM test	0.240	0.888	2.178		0.336	4.038		0.132
BPG test	27.289	0.073	33.402		0.221	25.669		0.875
White-test	177.882	0.572	28.489		0.438	44.322		0.134

Note: *1%, ** 5% and ***10% level of significance, whereas the BG is the Breusch-Godfrey LM test with two lags for autocorrelation, JB is Jarque-Bera test for the error normality, White-test and Breusch-Pagan-Godfrey (BPG) for heteroscedasticity testing.

this case was about a month. The negative shock to inflation expectations ($\Delta E\pi_t^-$) showed a positive impact, however, after a lag, the impact was negative and statistically significant. This again implied that the inflation expectations affect the inflation rate in the UK though the evidence supports the learning expectations. Among the other explanatory factors, the output gap (ΔOG) showed a positive impact which was initially insignificant. The labour market slack also appeared to have a positive yet insignificant effect on inflation which turned negative with lag and increased in statistical significance. The exchange rate also showed contemporaneous positive but insignificant but with the lag negative and significant results. This is intuitive, as the appreciation is often perceived to kick in with lag. The fiscal stance showed a positive though insignificant effect indicating that the fiscal policy was not the significant cause of inflation in the UK at least in the short run. The cost (oil) shocks showed positive contemporaneous effects on inflation which were significant. Negative and significant values are shown by the Error Correction Term (ECT) suggesting stability of the long-run relationship and estimated model. Panel B presents the long-run estimates of the relationship between inflation and its explanatory variables. It showed that the positive shocks to the inflation expectations had a positive and significant effect on inflation. Interestingly, the negative shocks to the inflation expectations also showed a positive effect on inflation which implied asymmetry in the relationship between the two. This indicates that the increase in the expected inflation may increase the inflation while the decrease in the expected inflation may not have negative effects on the actual inflation. This finding is intuitive if we see it through

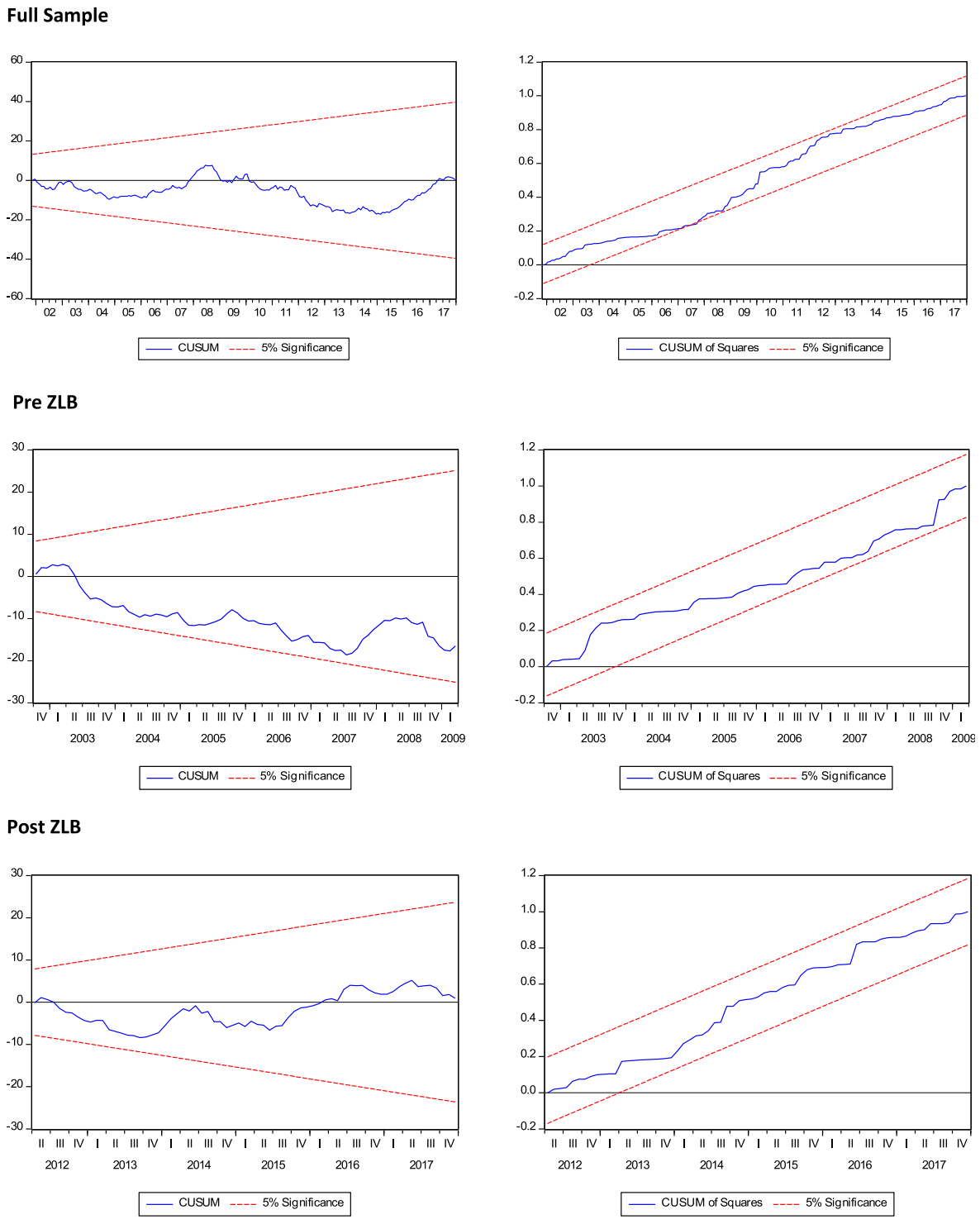

Fig. 1. Parameter stability test (cusum & cusumsq) UK inflation.

the lens of price stickiness. Among other variables, the output gap, fiscal (surplus) and oil price showed positive yet insignificant effects on inflation while labour market slack and exchange showed negative and significant effects on inflation. This suggested that the increase in the labour market slack could lead to a reduction of actual inflation as well as the real appreciation of the Sterling in the long run. The results of the diagnostic test presented in Panel C suggested no evidence of hetero-scedasticity, auto-correlation and non-normality of errors implying that the estimates were robust.

The short-run estimates for the first sub-periods showed that the inflation had some persistence as the past inflation showed significant and positive effects. The positive shock to the inflation expectations ($\Delta E\pi_t^+$) also displayed a positive and statistically significant effect on the inflation rate. On the other hand, the negative shock to the inflation expectation ($\Delta E\pi_t^-$) showed a positive but statistically insignificant short-term impact on inflation. This implied the asymmetry in the response of inflation to inflation expectations. Among the other explanatory variables, OG showed a significant positive effect on inflation implying demand-side inflationary pressure. The labour market slack initially showed a positive but statistically insignificant effect

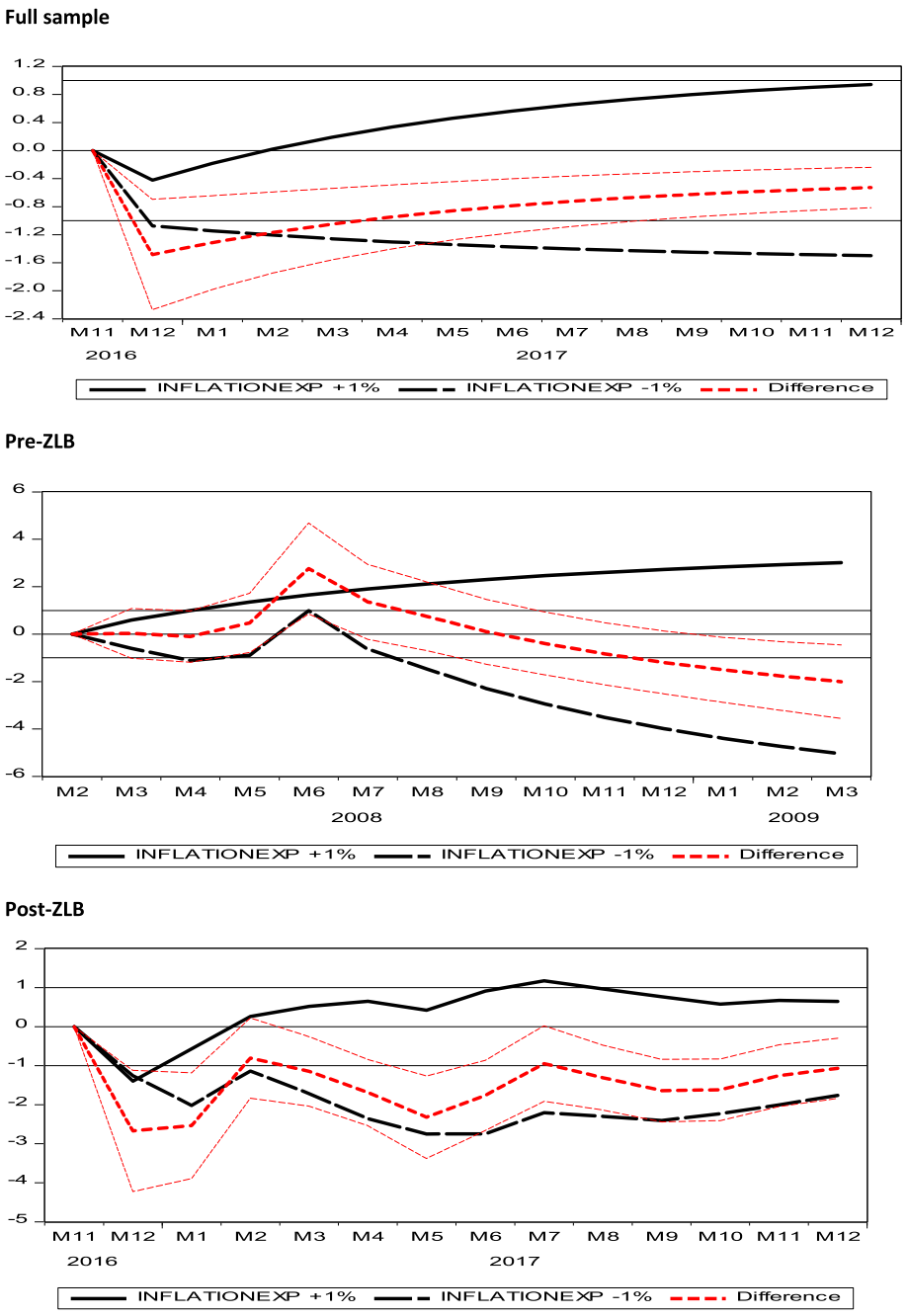

Fig. 2. Nardl cumulative multiplier inflation expectations and UK inflation response.

which changed into negative and significant impacts after some lags. Interestingly, the exchange only showed mild positive and not a highly significant impact on inflation in the short run. The fiscal (surplus/deficit) showed an initial positive impact which later turned negative and significant indicating the deflationary effects of fiscal (surplus) consolidation. The oil price (cost) shocks also showed positive effects which were not statistically significant in the beginning however, lagged effects were more significant. The long-term estimates for the first-sub sample showed that the positive inflation expectation had positive effects on inflation; however, the negative inflation expectation (decrease in inflation expectation) also had a positive effect, once again indicating the asymmetry in the relationship. Comparatively, the magnitude of the impact was greater than the full sample. The results of the output gap, labour market slack and fiscal consolidation showed negative effects on inflation, whereas the exchange rate and oil price shocks showed positive but insignificant results in the long run.

Lastly, we estimated the model for the sub-period associated with the ZLB. The short-run results suggest that inflation showed some persistence. The magnitude was equivalent to the first sub-sample for the counterpart lags, however, the impact later changed in magnitude and statistical significance. The contemporaneous impact of positive inflation expectations on inflation was negative; however, with lag it became positive. The negative inflation expectations shock also had a positive impact on inflation suggesting an asymmetry. Among the other variables, the OG showed a positive impact on inflation. The labour market slack and exchange rate showed initially positive but with the lag negative effects on inflation. The fiscal stance also showed a negative impact; this implied that the labour market slack and exchange rate appreciation and fiscal consolidation have deflationary effects, although they take time to kick in, particularly in the case of labour market slack

Table 4
Estimation of N-ARDL inflation expectations UK.

	Full Period		Pre-ZLB (1999M12-2009M03)			ZLB (2009M04-2017M12)		
A: Short-run estimates								
	Coefficient	Sig.		Coefficient	Sig.		Coefficient	Sig.
$\Delta E\pi_{t-1}$	1.553	0.000*	$\Delta E\pi_{t-1}$	1.571	0.000*	$\Delta E\pi_{t-1}$	1.532	0.000*
$\Delta E\pi_{t-2}$	−0.721	0.000*	$\Delta E\pi_{t-2}$	−0.625	0.000*	$\Delta E\pi_{t-2}$	−0.845	0.000*
$\Delta E\pi_{t-3}$	−0.339	0.022**	$\Delta E\pi_{t-3}$	−0.481	0.004*	$\Delta E\pi_{t-3}$	−0.367	0.009*
$\Delta E\pi_{t-4}$	0.680	0.001*	$\Delta E\pi_{t-4}$	0.919	0.000*	$\Delta E\pi_{t-4}$	0.859	0.000*
$\Delta E\pi_{t-5}$	−0.448	0.001*	$\Delta E\pi_{t-5}$	−0.677	0.001*	$\Delta E\pi_{t-5}$	−0.496	0.003*
$\Delta E\pi_{t-6}$	0.133	0.020**	$\Delta E\pi_{t-6}$	0.266	0.027**	$\Delta E\pi_{t-6}$	0.149	0.078***
$\Delta\pi_t^+$	0.081	0.020**	$\Delta\pi_t^+$	0.111	0.003*	$\Delta\pi_t^+$	0.058	0.182
$\Delta\pi_{t-1}^+$	−0.066	0.068***	$\Delta\pi_{t-1}^+$	−0.1113	0.009*	$\Delta\pi_{t-1}^+$	−0.043	0.394
$\Delta\pi_t^-$	0.003	0.941	$\Delta\pi_t^-$	−0.0005	0.980	$\Delta\pi_{t-2}^+$	−0.094	0.106***
$\Delta\pi_{t-1}^-$	0.032	0.609	ΔOG_t	0.0017	0.000*	$\Delta\pi_{t-3}^+$	0.099	0.030**
$\Delta\pi_{t-2}^-$	−0.0162	0.745	ΔOG_{t-1}	−0.0030	0.000*	$\Delta\pi_t^-$	−0.019	0.694
$\Delta\pi_{t-3}^-$	0.077	0.144	ΔOG_{t-2}	0.00015	0.009*	$\Delta\pi_{t-1}^-$	0.184	0.006**
$\Delta\pi_{t-4}^-$	−0.140	0.009*	ΔOG_{t-3}	−0.002	0.001*	$\Delta\pi_{t-2}^-$	−0.123	0.034**
$\Delta\pi_{t-5}^-$	0.063	0.080***	ΔOG_{t-4}	0.0039	0.009*	$\Delta\pi_{t-3}^-$	0.102	0.086***
ΔOG_t	0.00013	0.004*	ΔOG_{t-5}	−0.001	0.102***	$\Delta\pi_{t-4}^-$	−0.177	0.000*
ΔOG_{t-1}	−0.0002	0.007*	ΔLMS_t	−0.010	0.147	$\Delta\pi_{t-5}^-$	0.056	0.110
ΔOG_{t-2}	0.00018	0.015*	ΔLMS_{t-1}	0.0137	0.061***	ΔOG_t	0.0001	0.000*
ΔOG_{t-3}	−0.00018	0.006*	ΔEX_t	−0.147	0.001*	ΔOG_{t-1}	−0.00029	0.000*
ΔOG_{t-4}	0.0001	0.000*	ΔEX_{t-1}	0.010	0.038**	ΔOG_{t-2}	0.0002	0.000*
ΔLMS_t	0.0005	0.699*	ΔEX_{t-2}	−0.0030	0.596	ΔOG_{t-3}	−0.0001	0.000*
ΔEX_t	−0.0053	0.000*	ΔEX_{t-3}	−0.005	0.313	ΔOG_{t-4}	0.0001	0.000*
$\Delta Fiscal_t$	−0.0057	0.915	ΔEX_{t-4}	0.0122	0.012*	ΔLMS_t	0.020	0.034**
$\Delta Fiscal_{t-1}$	−0.0059	0.958	ΔEX_{t-5}	−0.010	0.022*	ΔLMS_{t-1}	−0.047	0.015*
$\Delta Fiscal_{t-2}$	0.025	0.751	$\Delta Fiscal_t$	−0.179	0.018*	ΔLMS_{t-2}	0.041	0.050*
$\Delta Fiscal_{t-3}$	−0.167	0.015*	$\Delta Fiscal_{t-1}$	0.266	0.041**	ΔLMS_{t-3}	0.008	0.616
$\Delta Fiscal_{t-4}$	0.271	0.003*	$\Delta Fiscal_{t-2}$	0.003	0.972	ΔLMS_{t-4}	−0.025	0.009*
$\Delta Fiscal_{t-5}$	−0.121	0.010*	$\Delta Fiscal_{t-3}$	−0.314	0.001*	ΔEX_t	−0.002	0.483
ΔOP_t	0.0003	0.036**	$\Delta Fiscal_{t-4}$	0.358	0.004*	ΔEX_{t-1}	−0.005	0.178
ΔOP_{t-1}	−0.002	0.382	$\Delta Fiscal_{t-5}$	−0.124	0.037**	ΔEX_{t-2}	0.007	0.088***
ΔOP_{t-2}	0.002	0.345	ΔOP_t	0.004	0.020**	ΔEX_{t-3}	−0.010	0.009*
ΔOP_{t-3}	−0.00047	0.788	ΔOP_{t-1}	−0.003	0.059***	$\Delta Fiscal_t$	−0.024	0.275
ΔOP_{t-4}	−0.0042	0.020**	Constant	1.43	0.002*	ΔOP_t	0.0005	0.663
ΔOP_{t-5}	0.0049	0.005*	ECT	−0.053	0.000*	ΔOP_{t-1}	−0.0004	0.759
ΔOP_{t-6}	−0.002	0.042**				ΔOP_{t-2}	0.001	0.259
Constant	0.954	0.000*				ΔOP_{t-3}	0.0003	0.792
ECT	−0.140	0.000*				ΔOP_{t-4}	−0.0036	0.034**
						ΔOP_{t-5}	0.006	0.000*
						ΔOP_{t-6}	−0.004	0.0002*
						Constant	1.50	0.000*
						ECT	−0.167	0.000*
B: Long-run Estimates								
π^+	0.105	0.098***	0.0089		0.975	0.117		0.315
π^-	0.145	0.011*	−0.0107		0.980	0.140		0.053**
OG	0.0002	0.000*	0.0019		0.433	0.0002		0.000*
LS	0.0035	0.694	0.051		0.515	−0.015		0.526
EX	−0.0376	0.000*	−0.197		0.353	−0.060***		0.007*
Fiscal	−0.0257	0.259	0.177		0.481	−0.147		0.265
Oil Price	0.009	0.001*	0.019		0.507	0.006		0.102*
C: Diagnostic Testing								
R^2	0.990		0.991			0.996		
JB test.	127.267	0.000*	8.212		0.016**	0.392		0.821
BG LM test	4.52	0.103	5.865		0.053***	2.543		0.280
BPG test	65.632	0.000*	27.735		0.634	35.421		0.589
White-test	81.395	0.000*	30.946		0.468	36.287		0.548

Note: *1%, ** 5% and ***10% level of significance, whereas the BG is Breusch-Godfrey LM test with two lags for autocorrelation, JB is Jarque-Bera test for the error normality, White-test and Breusch-Pagan-Godfrey (BPG) for heteroscedasticity testing.

and appreciation. The oil price shocks also showed positive contemporaneous and short-term effects. The long-run estimates showed that positive inflation expectations lead to an increase in inflation whereas the negative inflation expectation (decrease in expected inflation) also leads to a positive impact on inflation pointing towards the asymmetric relationship. Comparatively, the magnitude of positive inflation expectations on the inflation was smaller in the second sub-sample. This also indicated the low inflation environment in the Post-GFC era. Among other variables, the Output gap, labour market slack and fiscal stance showed positive effects although the results were only statistically significant for the latter. The appreciation of the exchange rate also shocks displayed negative but insignificant results. The results of the diagnostic test implied robustness of results, however, we also performed the CUSUM and CUSUMSQ tests for parameter stability as presented in Fig. 1.

The parameter stability (CUSUM and CUSUMSQ) test results for full, as well as sub-samples presented in Fig. 1, suggest stability. Next, we analyse the multiplier effects of inflation expectations on inflation and the results are presented in Fig. 2:

The result of multiplier effects of increases and decreases in the

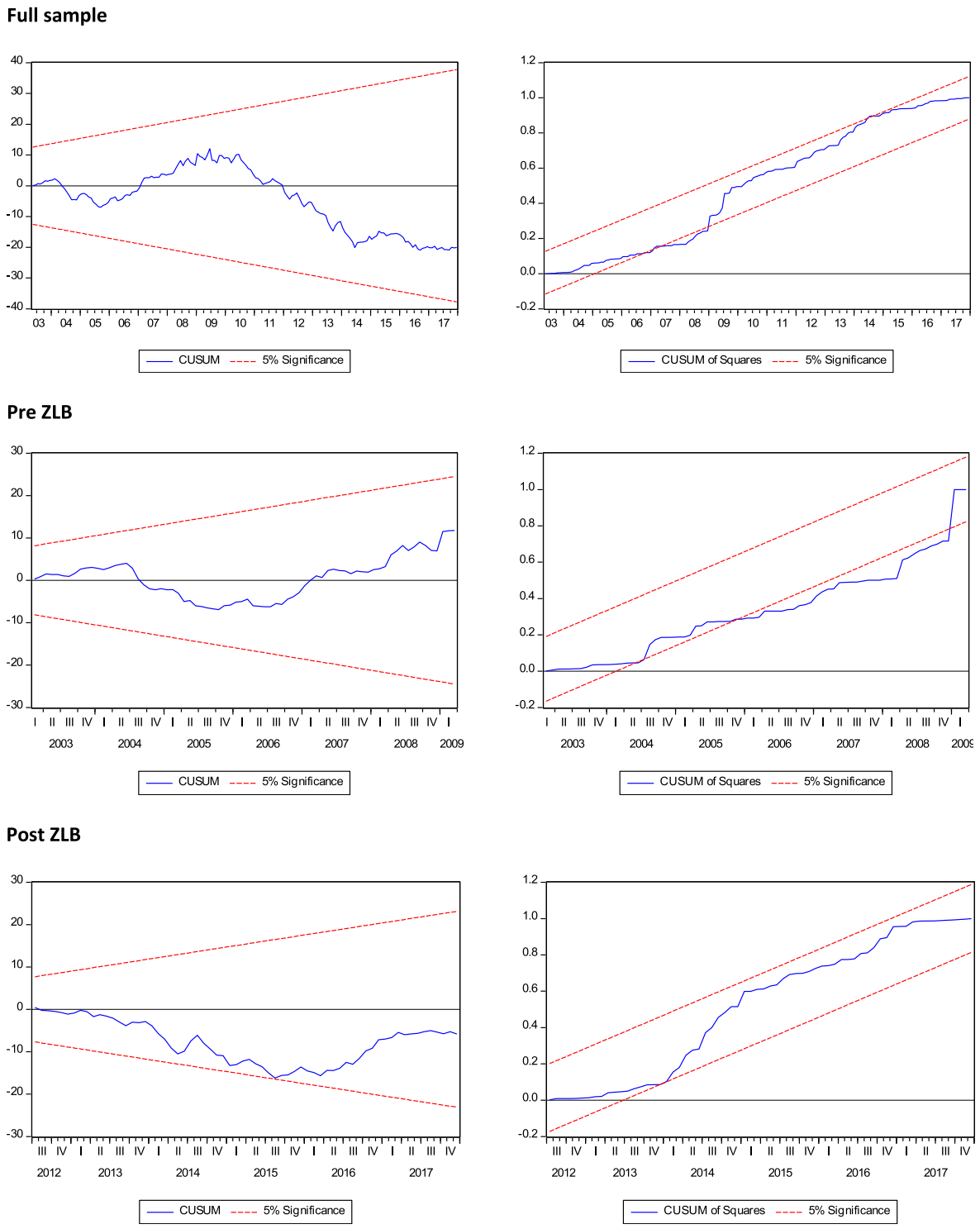

Fig. 3. Parameter stability test (cusum & cusumsq) UK inflation expectations.

inflation expectation on inflation presented in Fig. 2 gives some interesting insight into the link between inflation and inflation expectations.[11] For the full sample, it showed that the positive shock to inflation expectations (1%) lead to an increase in inflation of about 0.94% by the end of two years. The negative shock to the inflation expectation (−1%) led to a sharp decrease in inflation which persisted and very gradually further decreased inflation. This implied that inflation expectations do play an important role in inflation dynamics in the UK. We also analysed the multiplier effects for the sub-samples which showed significant differences. Specifically, it showed that in the first sub-period (Pre-ZLB), the positive shocks to the inflation expectations (1%) led to a considerable increase in inflation which was more than unity. Similarly, the negative shock to the inflation expectations (−1%) also led to a

[11] The thick black line is the response to the positive shock and the dashed black line is the response to the negative shock. The thick dashed red line is the difference between positive and negative. There are also two dashed red lines around the thick dashed red line. These two rather thin lines are confidence intervals, and they show significant evidence of asymmetry and statistical evidence.

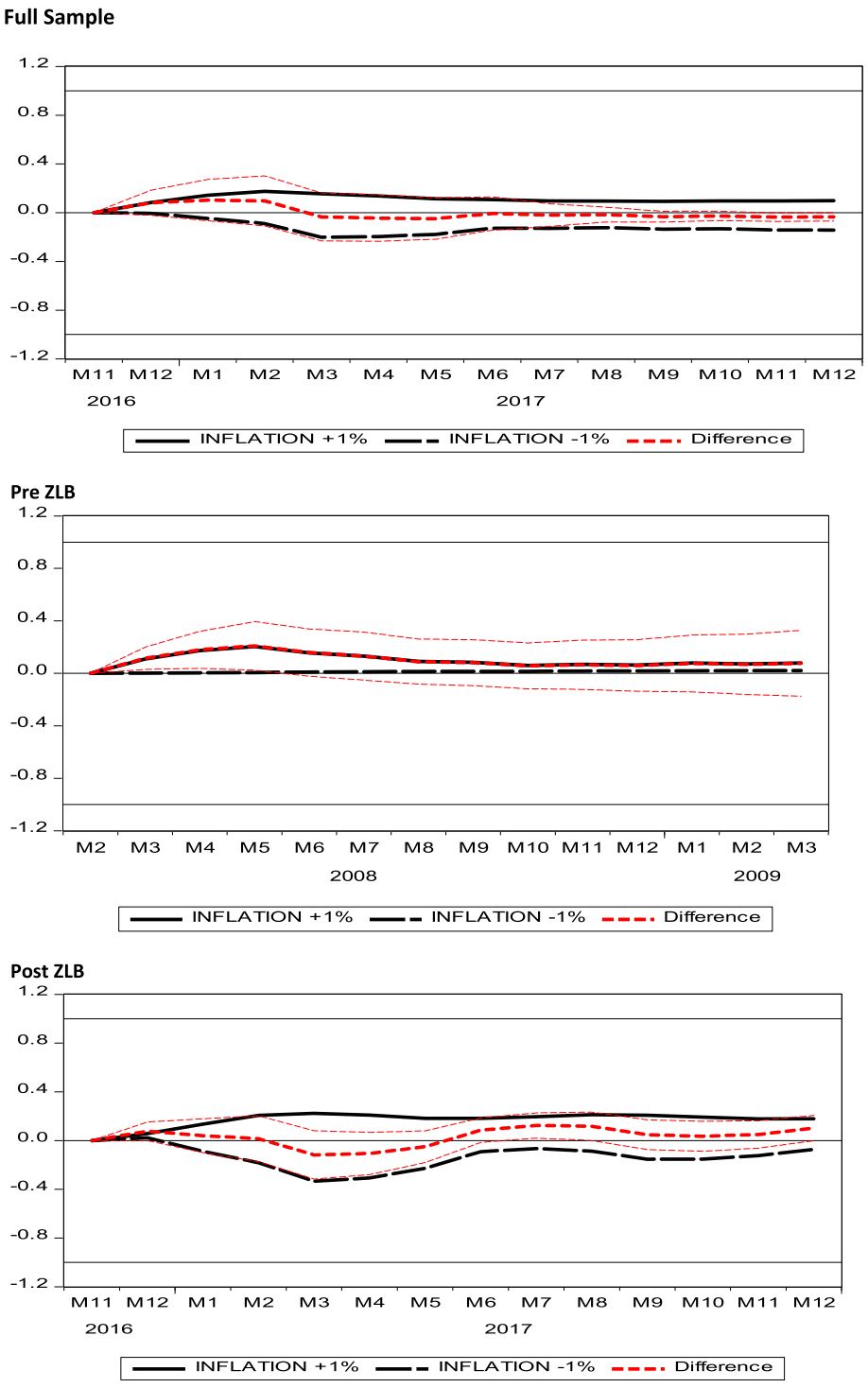

Fig. 4. Nardl cumulative multiplier inflation and UK inflation expectations response.

reduction in inflation in the medium term and the effects seemed to persist over two years. The results for the second sub-period showed contrary but interesting results. It showed that although the positive shocks to inflation expectations (1%) did lead to a positive response from the inflation in the UK, however, the effects were comparatively milder than in the Pre-ZLB period. On the other hand, it showed that the negative shock to the inflation expectations (−1%) had a greater negative impact on inflation than the Pre-ZLB period. This implies that the inflation response to the inflation expectation was asymmetric in the Pre and Post ZLB periods. Specifically, there was more risk of deflation than inflation in the Post-ZLB and Post-GFC periods which is very obviously associated with the period of low inflation.[12]

After inflation, we estimated the NARDL model for the UK inflation expectations. The results are summarised in Table 4:

Starting from the full sample and short-run estimates, it shows that the inflation expectations ($E\pi$) have a considerable amount of persistence effect which is statistically very significant ($P < 0.01$). The positive

[12] Between GFC-Brexit, the Inflation has been below its annual target rate of 2% for considerable amount of time in UK (See, Nasir and Simpson (2018).

shock to the inflation $\Delta\pi_t^+$ showed a statistically significant positive impact on inflation expectations. This implies that the actual and prevailing rate of inflation does affect inflation expectations for the future. The negative inflation shock initially showed a positive effect which changed into a negative effect with lag indicating that the decrease in inflation affects the inflation expectations after some time. Among the other explanatory factors, the output gap showed a positive contemporaneous effect which implied that the positive output gap can influence the inflation expectation i.e. demand-side pressure. The lagged output gap showed varying effects though the results were significant. The labour market slack showed a positive effect though the results were not significant implying that the labour market outlook does not influence the inflation expectations much in the short run. The appreciation of the real exchange rate however showed a statistically significant and negative effect, implying that the exchange rate pass-through even influences inflation expectations. The fiscal stance (surplus/deficit) showed initially positive but statistically insignificant effects which changed into negative and significant impacts after some lags. This implied that the fiscal consolidation might negatively affect or reduce the expected price level. The oil price (cost) shock showed positive contemporaneous effects on the inflation expectations which was significant. The long-run results suggest that a positive shock to inflation had positive effects on inflation expectations. Interestingly the negative shock to inflation also showed positive effects suggesting an asymmetric relationship. Among the other explanatory factors, the output gap showed a positive and significant effect on inflation expectations in the long run. The labour market slack showed a positive though insignificant impact suggesting that the inflation expectations are not strongly influenced by the labour market slack. The exchange rate (appreciation) and fiscal (surplus/deficit) showed negative effects on the inflation expectations which were significant only for the former. The oil price shocks also showed positive and significant effects on the inflation expectation. The diagnostic test results presented in Panel C suggested that although there was no autocorrelation the null of Heteroscedasticity and non-normality is not rejected. However, we used the White-coefficient covariance matrix and the results for the standard errors & covariance are Heteroscedasticity consistent. Nonetheless, when we employed the sub-sampling this issue disappeared.

The results for the first sub-sample showed that similar to the full sample, the inflation expectations were influenced by past expectations and hence inertia in the expectations of inflation. In a policy setting, this also implied that once the inflation expectations are tamed and moored they might be conveniently anchored due to their manifested inertia. The positive shock to inflation showed a positive contemporaneous effect on the inflation expectations which was also statistically significant, although the lagged effect was negative. On the other hand, the negative shock to inflation showed a negative contemporaneous effect on inflation expectations, which was statistically insignificant. This suggests a symmetric impact of inflation on expectations, though it lacked statistical significance. Among other explanatory factors, the output gap had a significant positive effect on inflation expectations, though the results vary with lags. The labour market slack had a negative contemporaneous effect on inflation expectations though the results were not very significant. The exchange rate (appreciation) and fiscal stance (surpluses/deficit) did show a significant negative contemporaneous effect on the inflation expectations, though the impact varies with the lags. The oil price also showed a significant positive effect on inflation expectations. The results of the long run suggest that inflation had a positive while deflation had a negative effect on inflation expectations. This suggested a symmetric impact, although, the results were not significant in this sub-sample. Among other factors, the output gap, labour market slack, fiscal stance and oil price had positive but insignificant effects whereas the exchange rate (appreciation) had negative and insignificant effects on the inflation expectation. Lastly, we re-estimated the NARDL model for the second sub-period. The results of the short-term estimates showed that similar to the full and first sub-period, inflation expectations were strongly influenced by past expectations, giving prima facie evidence of the inertia in inflation expectations. The positive shock to the inflation led to a positive response from the inflation expectations which were also statistically significant, though the results varied with the lags. The decreased or negative shock in the inflation led to a contemporaneous negative effect on the inflation expectations, though the results were not statistically significant until the second lag. Among other variables, the output gap, labour market slack and oil price shocks had contemporaneous positive effects on the inflation expectations, while the exchange rate (appreciation) and fiscal stance (surplus/deficit) had a negative effect. The long-run estimates suggested that both positive and negative inflation shocks had positive effects on inflation expectations, though only the results for the latter met the statistical significance level. Among other variables, the output gap and oil prices had a positive effect on inflation expectations, while the labour market slack, exchange rate (appreciation) and fiscal stance (surplus/deficit) had negative effects on inflation expectations. This implied that the demand and cost shock could influence inflation expectations positively, whereas the increasing labour market slack, appreciation of real exchange rates and fiscal (consolidation) can reduce the expected rate of inflation in the long run. Lastly, diagnostic testing is performed to check the robustness of the results. To check for the stability of the model the CUSUM and CUSUMSQ test is performed results are summarised in Fig. 3.

Table 5
Nonlinear Cointegration - Bounds testing.

	F-stat.	Lower-Bound (95%)	Upper-Bound (95%)	Outcome
Inflation (π_t)	6.042*	2.17	3.21	Cointegration
Inflation Expectations ($E\pi$)	3.822**	2.17	3.21	Cointegration

*1%, ** 5% and ***10% significance levels.

The parameter stability (CUSUM and CUSUMSQ) test for the inflation expectations showed interesting results. For the full sample, it showed that although the CUSUM graph remained between the bounds, there was some deviation beyond the bound near the 2008–9 periods which corresponded with the GFC and monetary policy hitting the ZLB. However, overall the results showed parameter stability. In the second subsample, the deviation around the later part became clearer in the CUSUMSQ, although the CUSUM showed the stability of estimates. The post-ZLB period showed the stability of estimates by both CUSUM and CUSUMSQ test graphs. Next, presented in Fig. 4, we analyse the multiplier impact of inflation on inflation expectations:

It showed that for the full period, the increase in inflation (1%) led to a higher rate of expected inflation. Similarly, the decrease in the actual inflation (1%) led to a decline in the expected rate of inflation, though the effects in the case of negative shocks were comparatively slow in transmission. The magnitude of both positive and negative effects was less than unity. The results of the sub-samples gave us some further insight into the association between inflation and inflation expectations. In fact, we saw an important shift in the nexus between the two. In the period preceding ZLB, the surge in the actual inflation had a positive effect on the expected rate of inflation, however, the negative inflation shock did not have much effect on the inflation expectation. Interestingly, during the ZLB period, it showed that where the increase in inflation (1%) had a positive impact on the expected rate of inflation, the deflation or fall in inflation rates also had a negative effect on the expected rate of inflation. Nonetheless, the negative inflation shock had a greater effect on the expected rate of inflation than the other two periods. This is a clear indication that while the monetary policy was at ZLB the negative shocks to inflation had a greater negative or deflationary effect on the inflation expectations.

Table 6
Nonlinear- ARDL estimation canadian inflation.

	Full Period		Pre-ZLB (2001M06-2009M03)			ZLB (2009M04-2017M12)		
A: Short-Run Estimates								
	Coefficient	Sig.		Coefficient	Sig.		Coefficient	Sig.
$\Delta\pi_{t-1}$	0.780	0.000*	$\Delta\pi_{t-1}$	0.632	0.000*	$\Delta\pi_{t-1}$	0.494	0.000*
$\Delta\pi_{t-2}$	−0.140	0.044**	$\Delta\pi_{t-2}$	−0.452	0.000*	$\Delta\pi_{t-2}$	0.087	0.494
$\Delta E\pi_t^+$	0.036	0.048**	$\Delta\pi_{t-3}$	0.182	0.163	$\Delta\pi_{t-3}$	0.130	0.255
$\Delta E\pi_{t-1}^+$	−0.064	0.093	$\Delta\pi_{t-4}$	0.054	0.665	$\Delta\pi_{t-4}$	−0.151	0.173
$\Delta E\pi_{t-2}^+$	0.089	0.041**	$\Delta\pi_{t-5}$	−0.242	0.043**	$\Delta\pi_{t-5}$	0.199	0.132
$\Delta E\pi_{t-3}^+$	−0.057	0.150	$\Delta\pi_{t-6}$	0.254	0.009*	$\Delta\pi_{t-6}$	−0.267	0.030*
$\Delta E\pi_{t-4}^+$	−0.022	0.566	$\Delta E\pi_t^+$	0.0008	0.978	$\Delta E\pi_t^+$	0.014	0.069***
$\Delta E\pi_{t-5}^+$	0.087	0.055**	$\Delta E\pi_{t-1}^+$	−0.015	0.754	$\Delta E\pi_t^-$	0.032	0.136
$\Delta E\pi_{t-6}^+$	−0.057	0.018*	$\Delta E\pi_{t-2}^+$	0.057	0.246	$\Delta E\pi_{t-1}^-$	−0.080	0.036**
$\Delta E\pi_t^-$	0.009	0.490	$\Delta E\pi_{t-3}^+$	−0.031	0.498	$\Delta E\pi_{t-2}^-$	0.071	0.005*
$\Delta E\pi_{t-1}^-$	−0.006	0.774	$\Delta E\pi_{t-4}^+$	−0.049	0.318	ΔOG_t	−0.002	0.579
$\Delta E\pi_{t-2}^-$	−0.024	0.405	$\Delta E\pi_{t-5}^+$	0.131	0.009*	ΔOG_{t-1}	0.004	0.454
$\Delta E\pi_{t-3}^-$	0.034	0.034**	$\Delta E\pi_{t-6}^+$	−0.053	0.063***	ΔOG_{t-2}	−0.001	0.834
ΔOG_t	0.001	0.012*	$\Delta E\pi_t^-$	0.054	0.003*	ΔOG_{t-3}	−0.006	0.212
ΔLMS_t	−0.012	0.465	$\Delta E\pi_{t-1}^-$	−0.035	0.072***	ΔOG_{t-4}	0.006	0.034**
ΔLMS_{t-1}	0.0193	0.269	ΔOG_t	0.003	0.038**	ΔLMS_t	0.002	0.876
ΔLMS_{t-2}	−0.029	0.097**	ΔLMS_t	−0.056	0.016*	ΔEX_t	−0.06	0.084***
ΔLMS_{t-3}	0.035	0.029**	ΔLMS_{t-1}	0.007	0.761	ΔEX_{t-1}	−0.003	0.949
ΔEX_t	−0.038	0.000*	ΔLMS_{t-2}	−0.064	0.012*	ΔEX_{t-2}	0.086	0.066***
$\Delta Fiscal_t$	2.74E-11	0.102***	ΔLMS_{t-3}	0.075	0.005*	ΔEX_{t-3}	−0.101	0.0008*
ΔOP_t	0.028	0.000*	ΔLMS_{t-4}	−0.051	0.036**	$\Delta Fiscal_t$	2.46E-11	0.319
ΔOP_{t-1}	−0.018	0.002*	ΔEX_t	−0.058	0.063**	$\Delta Fiscal_{t-1}$	5.90E-12	0.826
Constant	3.483	0.000*	ΔEX_{t-1}	0.005	0.887	$\Delta Fiscal_{t-2}$	−3.44E-11	0.185
ECT	−0.364	0.000	ΔEX_{t-2}	−0.034	0.332	$\Delta Fiscal_{t-3}$	4.61E-11	0.008*
			ΔEX_{t-3}	0.002	0.941	$\Delta Fiscal_{t-4}$	−4.24E-11	0.080***
			ΔEX_{t-4}	−0.078	0.013*	$\Delta Fiscal_{t-5}$	1.25E-11	0.516
			$\Delta Fiscal_t$	−4.08E-11	0.204	$\Delta Fiscal_{t-6}$	−4.37E-11	0.095***
			$\Delta Fiscal_{t-1}$	−1.84E-11	0.579	ΔOP_t	0.020	0.023**
			$\Delta Fiscal_{t-2}$	5.62E-11	0.108***	ΔOP_{t-1}	0.008	0.526
			ΔOP_t	0.020	0.036**	ΔOP_{t-2}	−0.036	0.008*
			ΔOP_{t-1}	−0.012	0.201	ΔOP_{t-3}	0.019	0.036**
			Constant	13.735	0.000*	Constant	7.716	0.000*
			ECT	−0.565	0.000*	ECT		0.000*
B: Long-run Estimates								
$E\pi^+$	0.034	0.003*	0.069		0.000*	0.027		0.014*
$E\pi^-$	0.033	0.001*	0.032		0.002*	0.045		0.000*
OG	0.003	0.005*	0.006		0.050**	0.002		0.045**
LMS	0.033	0.255	−0.157		0.002*	0.0053		0.875
EX	−0.107	0.000*	−0.285		0.000*	−0.155		0.000*
Fiscal	0.000	0.109	−0.000		0.965	−0.000		0.598
Oil Price	0.027	0.000*	0.014		0.161	0.024		0.005*
C: Diagnostic Testing								
R^2	0.844		0.889			0.884		
JB test.	2.199	0.332	0.758		0.684	0.294		0.863
BG LM test	9.163	0.162	1.760		0.414	1.860		3.944
BPG test	19.659	0.604	24.173		0.803	23.459		0.832
White-test	24.877	0.303	26.158		0.713	22.989		0.849

Note: *1%, ** 5%, ***10% level of significance, whereas the BG is the Breusch-Godfrey LM test with two lags for autocorrelation, JB is Jarque-Bera test for the error normality, White-test and Breusch-Pagan-Godfrey (BPG) for heteroscedasticity testing.

3.4. Canada

After the UK, the NARDL framework is applied to Canada. As presented in Table 5, we started with the cointegration analysis using bounds bounds-testing approach:

The bounds test results showed the presence of Cointegration in both specifications for Canada. Hence, we proceeded with the estimation of NARDL and the results are summarised in Table 6.

The full sample results (short-run estimates) showed that inflation has a significant element of persistence in Canada. The positive shocks to the inflation expectation ($E\pi_t^+$) had positive and significant while a negative shock to inflation expectations ($E\pi_t^-$) had a positive and insignificant impact on inflation. The output gap had a positive and statistically significant whereas the labour market slack showed a negative but insignificant effect on inflation which also varied with lags. The exchange rate appreciation had a statistically significant negative effect while the fiscal (surplus/deficit) had a positive yet insignificant effect on inflation. The oil shocks also showed positive and significant impacts. The long-run estimates suggested that the positive inflation and negative inflation expectations shocks had a positive and significant impact on inflation suggesting an asymmetry in the relationship. The output gap and oil prices had positive and significant effects suggesting the demand and cost-push phenomena. The labour market slack and fiscal (surplus/deficit) have positive but insignificant effects. The exchange rate (appreciation) had negative and significant effects on inflation.

After the estimation of the full sample, we divided the sample into two sub-periods. The results of the first sub-period cover the time horizon from June 2001 to March 2009. The short-run estimates for the first sub-period suggest that analogous to the full sample, there was an element of significant presentence. Interestingly, the positive inflation expectations did not have a significant impact until a few lags whereas

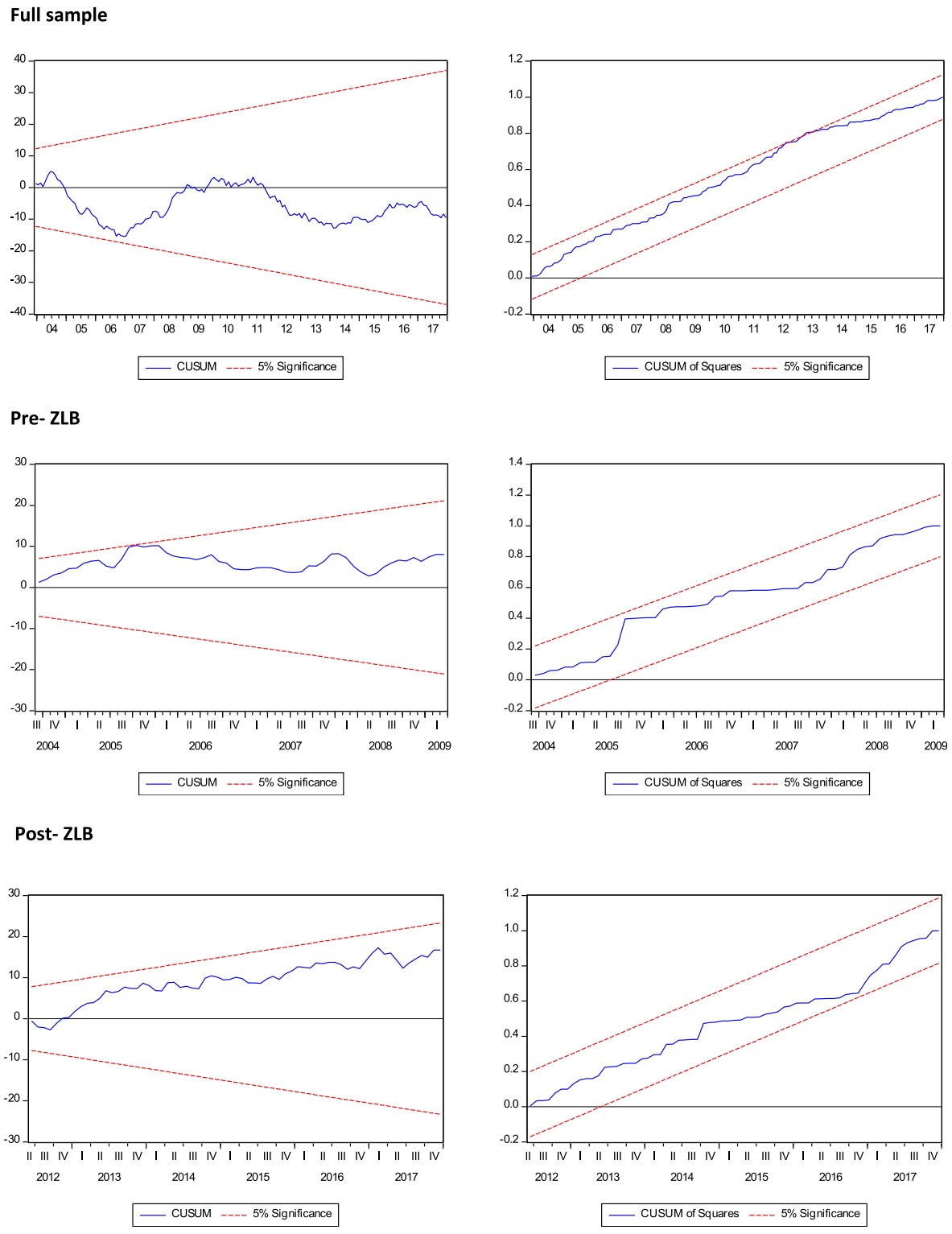

Fig. 5. Parameter stability test (cusum & cusumsq) canadian inflation.

the negative inflation expectations had a positive and significant impact which varied with a lag. The positive output gap and oil price had a positive effect while labour market slack had a significant negative impact. The exchange rate (appreciation) showed negative and significant effects on inflation but with lag. The fiscal (surplus/deficit) showed some mild positive but insignificant impact on inflation. The long-run estimates showed that most of the variables had a statistically significant impact. Specifically, both the positive and negative inflation expectation shocks had positive effects on inflation suggesting an asymmetry in the relationship. Among other variables, the output gap and oil shocks had a positive impact while the labour market slack and appreciation of the real exchange rate had deflationary effects. The fiscal (surplus/deficit) had a negative but insignificant impact. Lastly, we estimated the NARDL model for the second sub-period. The results for the short-term estimates showed that analogous to the previous two cases, there was an element of persistence in inflation. However, the

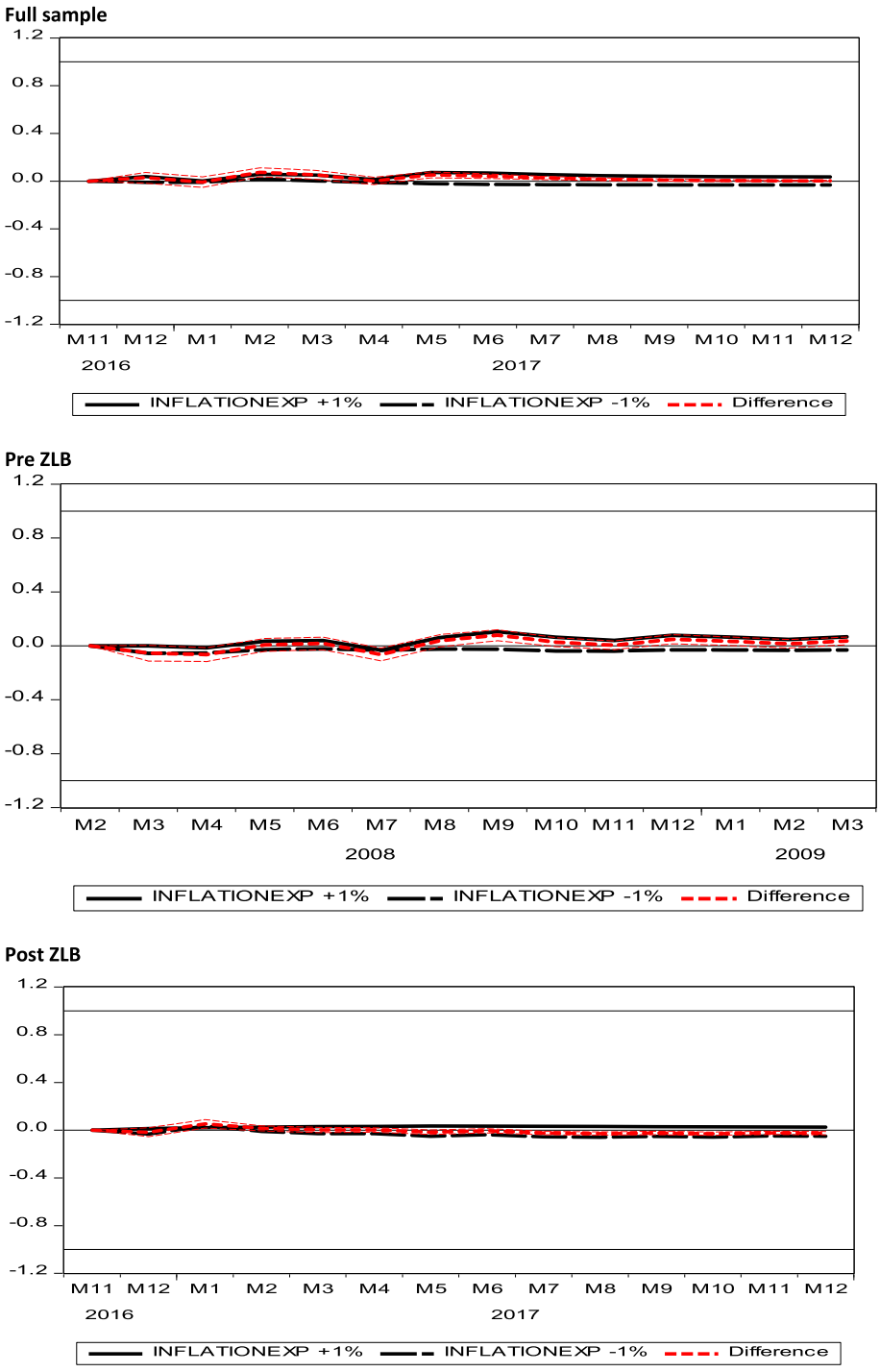

Fig. 6. Nardl cumulative multiplier inflation expectation and canadian inflation response.

effects on inflation expectations suggest that the positive inflation expectations shock had a positive and more significant impact on inflation compared to the first period. The negative shock or decline in inflation expectation initially had a positive and insignificant effect but it turned out to be a negative impact which was also significant after lags. Among other variables, the output gap initially showed a negative and insignificant effect that changed to a positive and significant effect with lags. This implied that the positive demand pressure did have a positive impact but with a lag. The labour market slack and fiscal (surplus/deficit) had positive and insignificant while the appreciation of the exchange rate had negative and significant and oil shocks had a positive and significant impact on inflation. The long-run estimates showed that both positive and negative inflation expectation shocks had a positive effect on inflation and implied an asymmetric relationship. Among other variables, the positive output gap and oil shocks had a positive and significant impact. The labour market slack had a positive while fiscal (surplus/deficit) had a deflationary effect. The exchange rate (appreciation) showed a negative and significant impact on inflation. Lastly, the diagnostic test results showed no evidence of non-normality, autocorrelation or heteroscedasticity. Next, we performed a parameter stability test as presented in Fig. 5.

Based on the Parameter Stability (CUSUM & CUSUMSQ) test for inflation in Canada, we can conclude that the estimates are stable. Thereafter, we analyse the multiplier impact of inflation expectations on

Table 7
Estimation of N-ARDL inflation expectations Canada.

	Full Period		Pre-ZLB (2001M06-2009M03)			ZLB (2009M04-2017M12)		
A: Short Run Estimates								
	Coefficient	Sig.		Coefficient	Sig.		Coefficient	Sig.
$\Delta E\pi_{t-1}$	1.572	0.000*	$\Delta E\pi_{t-1}$	1.118	0.000*	$\Delta E\pi_{t-1}$	1.504	0.000*
$\Delta E\pi_{t-2}$	−0.572	0.000*	$\Delta E\pi_{t-2}$	−0.317	0.046**	$\Delta E\pi_{t-2}$	−0.480	0.001*
$\Delta E\pi_{t-3}$	−0.611	0.000*	$\Delta E\pi_{t-3}$	−0.351	0.083***	$\Delta E\pi_{t-3}$	−0.754	0.000*
$\Delta E\pi_{t-4}$	0.885	0.000*	$\Delta E\pi_{t-4}$	0.352	0.162	$\Delta E\pi_{t-4}$	0.709	0.003*
$\Delta E\pi_{t-5}$	−0.302	0.009*	$\Delta E\pi_{t-5}$	−0.257	0.172	$\Delta E\pi_{t-5}$	−0.190	0.199
$\Delta E\pi_{t-6}$	−0.600	0.000*	$\Delta E\pi_{t-6}$	0.152	0.109***	$\Delta\pi_t^+$	0.566	0.648
$\Delta E\pi_{t-7}$	0.865	0.000*	$\Delta\pi_t^+$	2.139	0.020**	$\Delta\pi_{t-1}^+$	3.016	0.029**
$\Delta E\pi_{t-8}$	−0.330	0.000*	$\Delta\pi_t^-$	−0.123	0.942	$\Delta\pi_{t-2}^+$	−1.507	0.315
$\Delta\pi_t^+$	0.551	0.466	$\Delta\pi_{t-1}^-$	−1.798	0.358	$\Delta\pi_{t-3}^+$	2.044	0.202
$\Delta\pi_{t-1}^+$	0.350	0.744	$\Delta\pi_{t-2}^-$	0.338	0.817	$\Delta\pi_{t-4}^+$	−5.432	0.004*
$\Delta\pi_{t-2}^+$	0.571	0.598	$\Delta\pi_{t-3}^-$	−0.860	0.560	$\Delta\pi_{t-5}^+$	3.648	0.014*
$\Delta\pi_{t-3}^+$	−0.396	0.726	$\Delta\pi_{t-4}^-$	3.358	0.015*	$\Delta\pi_t^-$	1.380	0.353
$\Delta\pi_{t-4}^+$	−2.379	0.114	ΔOG_t	0.087	0.123	$\Delta\pi_{t-1}^-$	0.922	0.586
$\Delta\pi_{t-5}^+$	1.194	0.238	ΔOG_{t-1}	−0.032	0.778	$\Delta\pi_{t-2}^-$	−2.045	0.257
$\Delta\pi_t^-$	0.932	0.315	ΔOG_{t-2}	0.065	0.415	$\Delta\pi_{t-3}^-$	−0.268	0.865
$\Delta\pi_{t-1}^-$	−0.182	0.858	ΔOG_{t-3}	−0.191	0.011*	$\Delta\pi_{t-4}^-$	4.938	0.004*
$\Delta\pi_{t-2}^-$	−2.108	0.031**	ΔOG_{t-4}	0.157	0.002*	$\Delta\pi_{t-5}^-$	−2.422	0.064***
$\Delta\pi_{t-3}^-$	0.296	0.812	ΔLMS_t	−0.211	0.195	ΔOG_t	−0.001	0.770
$\Delta\pi_{t-4}^-$	3.267	0.007*	ΔLMS_{t-1}	0.082	0.617	ΔLMS_t	−0.079	0.707
$\Delta\pi_{t-5}^-$	−1.109	0.369	ΔLMS_{t-2}	0.099	0.589	ΔLMS_{t-1}	0.034	0.869
$\Delta\pi_{t-6}^-$	−1.080	0.233	ΔLMS_{t-3}	0.086	0.711	ΔLMS_{t-2}	0.209	0.249
ΔOG_t	0.028	0.316	ΔLMS_{t-4}	0.376	0.130	ΔLMS_{t-3}	−0.398	0.018*
ΔOG_{t-1}	−0.041	0.434	ΔLMS_{t-5}	0.056	0.768	ΔEX_t	0.249	0.089***
ΔOG_{t-2}	0.033	0.349	ΔLMS_{t-6}	0.341	0.082***	$\Delta Fiscal_t$	−5.51E-11	0.772
ΔOG_{t-3}	−0.022	0.533	ΔEX_t	0.212	0.473	ΔOP_t	−0.038	0.425
ΔOG_{t-4}	0.043	0.320	ΔEX_{t-1}	−0.705	0.009*	ΔOP_{t-1}	−0.057	0.433
ΔOG_{t-5}	−0.037	0.259	$\Delta Fiscal_t$	−4.06E-11	0.873	ΔOP_{t-2}	0.129	0.129
ΔOG_{t-6}	−0.027	0.331	$\Delta Fiscal_{t-1}$	−3.00E-10	0.203	ΔOP_{t-3}	0.087	0.214
ΔOG_{t-7}	0.039	0.013*	$\Delta Fiscal_{t-2}$	−2.21E-10	0.327	ΔOP_{t-4}	−0.276	0.000*
ΔLMS_t	0.109	0.330	$\Delta Fiscal_{t-3}$	4.54E-10	0.031**	ΔOP_{t-5}	0.096	0.059**
ΔLMS_{t-1}	−0.042	0.718	ΔOP_t	0.020	0.787	Constant	−11.866	0.351
ΔLMS_{t-2}	0.127	0.347	ΔOP_{t-1}	0.172	0.149	ECT	−0.220	0.000*
ΔLMS_{t-3}	−0.142	0.217	ΔOP_{t-2}	0.074	0.488			
ΔEX_t	0.197	0.317	ΔOP_{t-3}	−0.200	0.034**			
ΔEX_{t-1}	−0.406	0.112	Constant	47.455	0.000*			
ΔEX_{t-2}	0.325	0.04**	ECT	−0.299	0.000*			
$\Delta Fiscal_t$	−8.97E-11	0.517						
$\Delta Fiscal_{t-1}$	−2.04E-10	0.080***						
ΔOP_t	−0.018	0.630						
ΔOP_{t-1}	0.079	0.150						
ΔOP_{t-2}	−0.0007	0.991						
ΔOP_{t-3}	0.014	0.820						
ΔOP_{t-4}	−0.174	0.004*						
ΔOP_{t-5}	0.066	0.107***						
Constant	−1.093	0.791						
ECT	−0.093	0.000*						
B: Long-run Estimates								
π^+	−1.579	0.798	7.074		0.000*	10.971		0.000*
π^-	0.171	0.969	3.022		0.140	11.758		0.000*
OG	0.183	0.012*	0.284		0.000*	−0.008		0.759
LMS	0.548	0.600	2.746		0.008*	−1.099		0.098***
EX	1.239	0.024**	−1.631		0.038**	1.173		0.036**
Fiscal	−0.0000	0.157	−0.0000		0.813	−0.000		0.773
Oil Price	−0.347	0.068***	0.219*		0.216	−0.271		0.012*
C: Diagnostic Testing								
R^2	0.990		0.986			0.984		
JB test.	28.108	0.000*	2.275		0.320	0.327		0.848
BG LM test	0.142	0.931	0.342		0.842	1.773		0.411
BPG test	44.216	0.462	28.543		0.732	26.359		0.656
White-test	50.969	0.218	44.435		0.108	21.181		0.882

Note: *1%, ** 5% and ***10% level of significance, whereas BG is Breusch-Godfrey LM test with two lags for autocorrelation, the JB is Jarque-Bera test for the error normality, White-test and Breusch-Pagan-Godfrey (BPG) for heteroscedasticity testing.

inflation in Canada as presented in Fig. 6:

The effect of inflation expectations on inflation in Canada showed that for the full period, the positive shocks to inflation expectations had a positive while a negative shock to inflation expectations did not have much impact on inflation. Even in the case of the positive shocks, the impact was also less than unity. The first sub-sample showed that although the positive shock to inflation expectation had some positive impact on inflation, the negative shock had an even smaller impact than the full sample. Lastly, for the ZLB period, the multiplier results showed that the positive shock to inflation expectation had a milder impact on

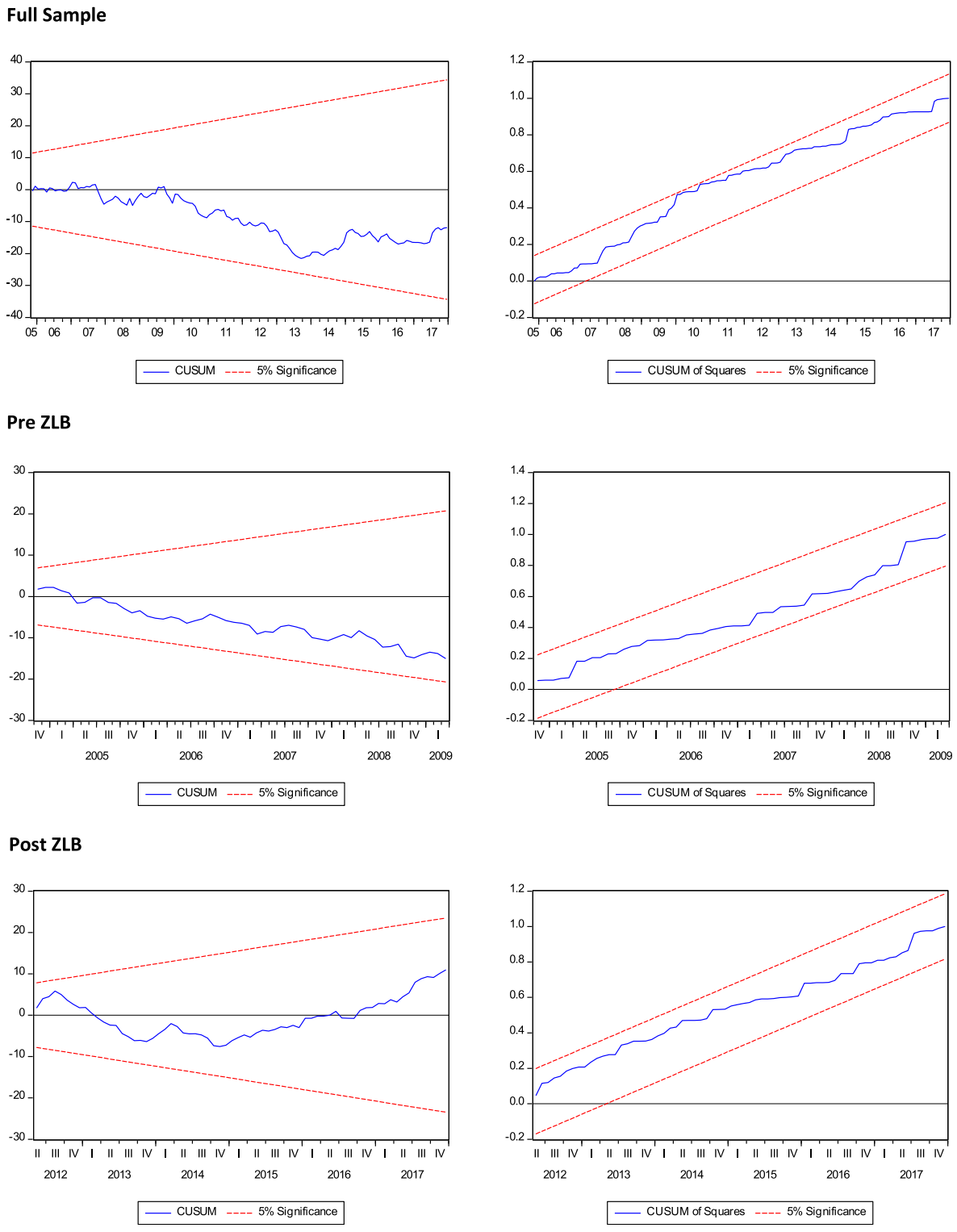

Fig. 7. Parameter stability test (cusum & cusumsq) test - canadian inflation expectations.

inflation which was smaller than the pre ZLB period. Interestingly, the negative inflation shock had a larger negative effect on inflation in the ZLB period indicating that the negative shocks to inflation expectation became more effective in the later period.

After inflation, we estimated the NARDL model for the Canadian Inflation Expectations and the results are summarised in Table 7:

The results on short-run estimates for the full sample suggest a very significant element of persistence or hysteresis in the inflation expectations. The increase in inflation ($\Delta\pi_t^+$) showed a positive though statistically insignificant effect on the expected rate of inflation. While decreasing inflation ($\Delta\pi_t^-$) also had a positive but insignificant effect on inflation expectations which change into negative and significant after some lags. The positive output gap, labour market slack and exchange rate (appreciation) had a positive but insignificant short-term effect on the inflation expectations, though the results varied with lags. The fiscal variable had a negative effect suggesting fiscal surplus or consolidation

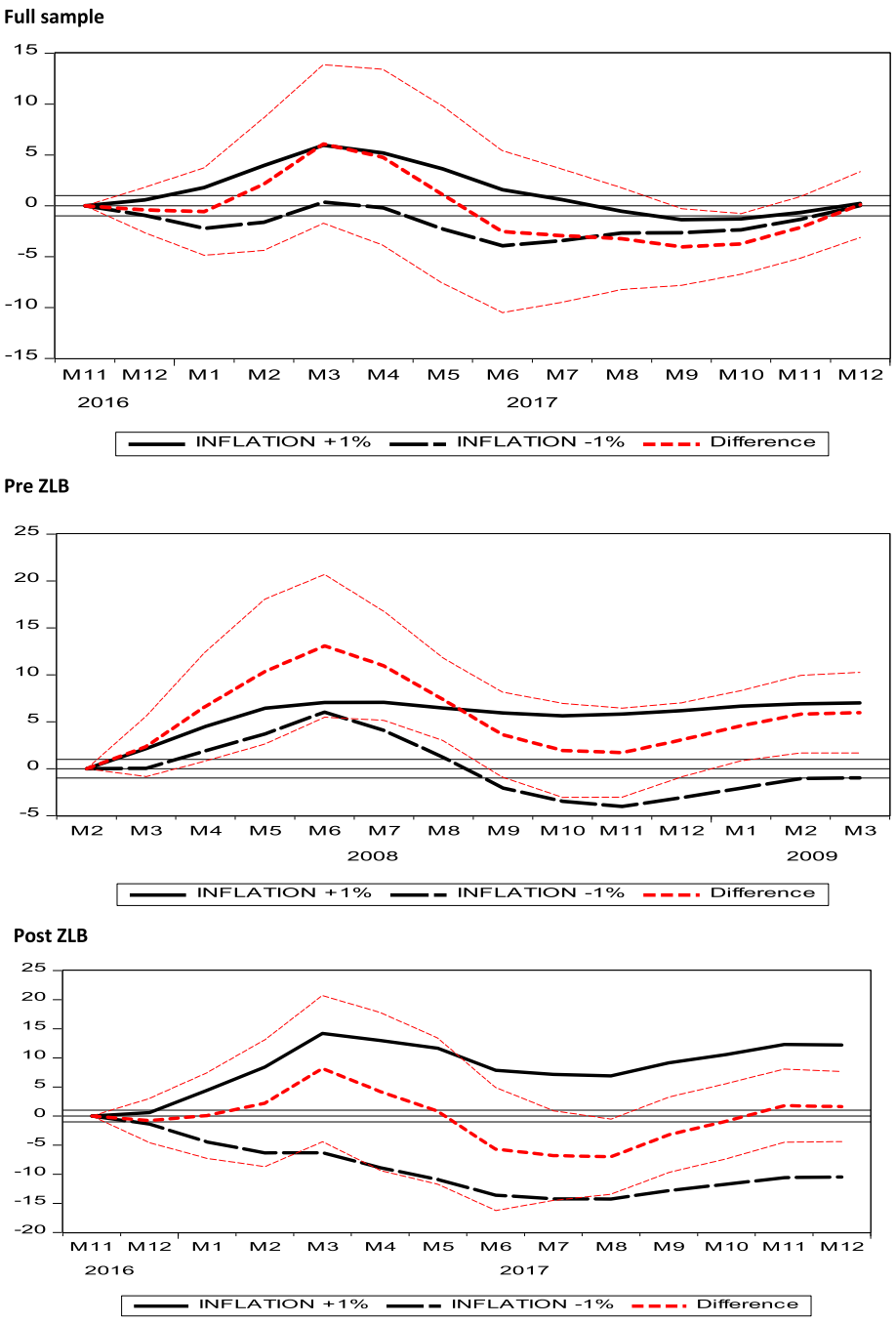

Fig. 8. Nardl cumulative multiplier inflation and canadian expectations inflation response.

can lead to a lower expected rate of inflation. Oil prices showed a negative though statistically insignificant effect on inflation expectations which varied with some lags. Estimates of long-term analysis for the full period showed that the increasing inflation had a negative and insignificant and while decreasing inflation had a positive and insignificant effect on the expected rate of inflation. The output gap, labour market slack and exchange rate had a positive effect on the expected rate of inflation, though the results were only significant for the real exchange rate and the output gap. Fiscal stance and oil prices had a negative effect on the expected rate of inflation, though the results were only significant for the latter.

After the estimation of the full sample, we divided the sample into two sub-periods. The results on the short-run estimates for the first subsample indicate a significant element of persistence in inflation expectations though less than the full sample. Increase in inflation $(\Delta\pi_t^+)$ leads to a positive and significant while decrease in inflation $(\Delta\pi_t^-)$ has a negative but insignificant impact on inflation expectations. Though the results varied and became significant with lags. The output gap, real exchange rate and oil shocks affect the expected rate of inflation while the labour market slack and fiscal stance had a negative impact. The results with lags varied for all the explanatory variables. The long-run estimates for the first sub-period showed an interesting result. It showed that the positive inflation shock had a positive but contrary to the full period, a statistically very significant effect on the expected rate of inflation. Decreasing inflation had a positive but insignificant effect on the expected rate of inflation, though significance increased as compared to the full sample. The output gap and labour market slack had a positive while the appreciation of the real exchange rate had a

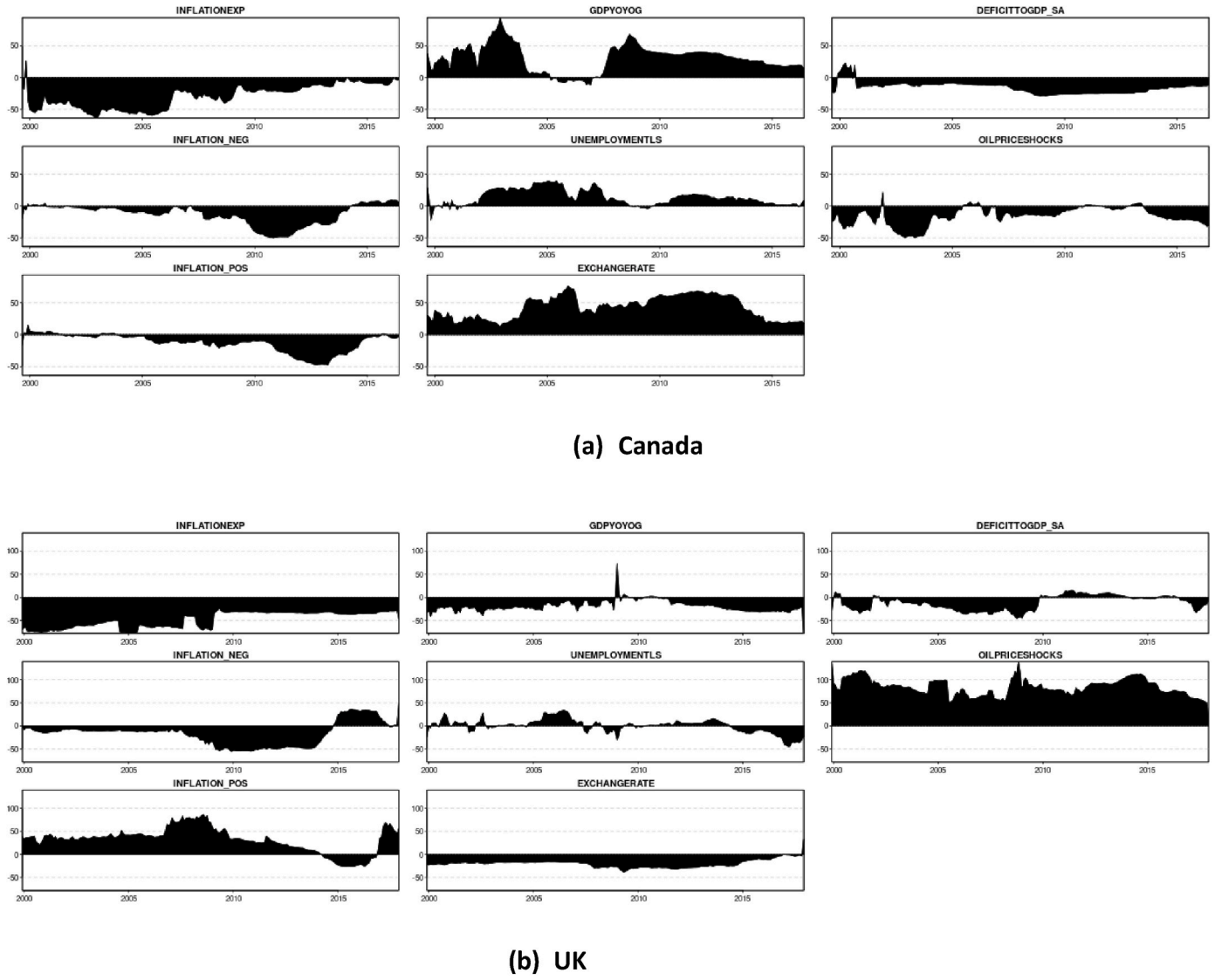

Fig. 9. The net 'sender' and 'receiver' of macroeconomic factors and inflation expectations.
Notes: The Inflation indicators (Positive and Negative dimensions) are retrieved from the Nonlinear ARDL in the estimations of Tables 4 and 7. After that, the 'sender' and 'receiver' effects from the Time-Varying Parameter Vector Auto-Regression models were calculated. Accordingly, the 'sender' variables exhibit a positive net spill-over number while the 'receiver' ones have the opposite values.

negative and significant effect on the expected rate of inflation. The fiscal stance had a negative and oil price had a positive impact on inflation expectations although the results were insignificant. Lastly, we estimated the NARDL model for the ZLB period. The results for the short-term estimates showed significant persistence in inflation expectations which was also more pronounced in magnitude and statistical significance than the pre-ZLB period. The increasing inflation ($\Delta\pi_t^+$) has a positive effect on the expected rate of inflation and the impact became significant with lags. The decrease in inflation ($\Delta\pi_t^-$) also had a positive and insignificant effect on inflation expectations the results varied with lags. Among other variables, the output gap, fiscal stance (surplus/deficit), oil price shocks and labour market slack had a negative effect on inflation though the results were insignificant and became significant with lags for the oil price and labour market slack. The exchange rate (appreciation) had a positive impact on the inflation expectation. The long-run estimates for the second sub-period showed that as compared with the full sample and first sub-period the inflation had a greater and more significant impact on inflation expectations. The increase as well as a decrease in inflation led to a positive effect on inflation expectations and the results were statistically significant. The output gap, fiscal stance, oil price shocks and labour market slack had a negative impact on inflation expectations though the results were only significant for the oil price shocks and labour market slack. The exchange rate had a positive and significant impact on inflation expectations. Diagnostic test results clearly suggest that there was no issue of non-normality of errors, auto-correlation or heteroscedasticity, an indication of the robustness of the model. However, we also performed a parameter stability test as presented in Fig. 7.

The results of stability test that our parameter estimates are stable. Thereafter, we performed the multiplier analysis as presented in Fig. 8.

The results of the multiplier effects of inflation on inflation expectations in Canada presented above entail some very interesting dynamics of the nexus between the two. For the full sample, it showed that a negative effect on inflation expectations although the positive shocks were more pronounced. However, the division of the period into the pre- and post-ZLB period gave some further insight into the link between inflation and future inflation expectations. It showed that in the pre-ZLB period, inflation shocks either positive or negative had a positive effect on the expected rate of inflation. The positive shocks were more pronounced and remained significant although the negative shocks faded

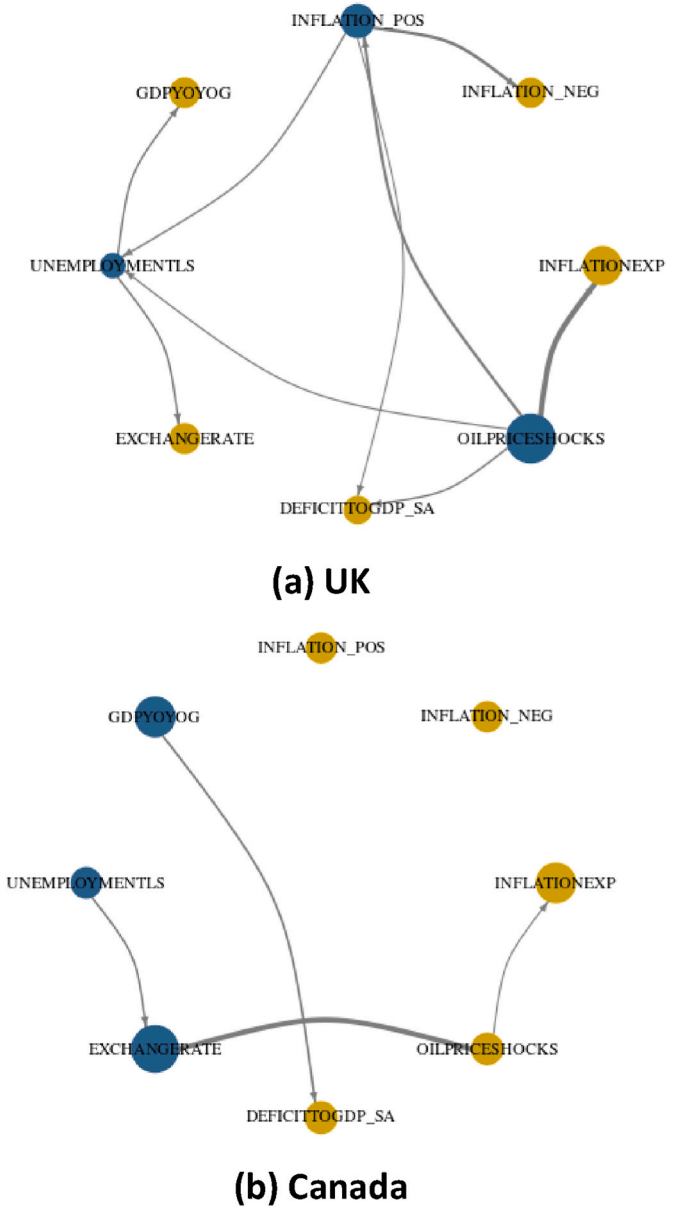

Fig. 10. A dynamic network of spill-over effects of all determinants of inflation and inflation expectations in both countries by using the TVP-VAR model.
Notes: The yellow and blue colour represents the 'receiver' and 'sender' determinants in the models, respectively. The light and bold lines highlight the level of shock transmission among factors. INF_EXP, INF_NEG, and INF_POS are the inflation expectations, inflation negative, and inflation positive in the respective orders.

after some periods and had a negative impact. Most interestingly the Post-ZLB period showed that the effect of inflation was more pronounced on the inflation expectation than the Pre-ZLB and full period. Specifically, the positive shock to inflation had a positive impact and a negative inflation shock had a negative impact on inflation expectations. The results for both types of shocks were statistically significant and implied a symmetric impact of inflation on the expected rate of inflation.

3.5. Robustness check: a network analysis of inflation expectations and inflation

In this section, we performed robustness testing through network analysis of inflation connectedness after controlling the rigorous variables, which are mentioned above. Accordingly, we employed Time-varying Parameter-Vector Auto-regression (TVP-VAR) model,[13] based on Antonakakis et al. (2020) to examine how these factors interconnect with each other. To be more precise, the two sets of inflation (positive and negative) and inflation expectations are our focus for this network analysis.[14] Fig. 9 manifests two different patterns in inflation expectations for the United Kingdom and Canada throughout the analysis. In particular, before 2012, Canadian inflation expectations are net receivers but then they showed a different position in the following years. In contrast, the UK expected indicators to show a slight 'sending' feature before 2007. After that, this variable turns into the 'receiver' of the major shocks from other determinants. Furthermore, the effects of inflation are heterogeneous across positive and negative shocks, which holds the same for fiscal deficit/surplus. In contrast, oil prices and output gaps significantly contribute shocks to inflation expectations while the exchange rate can be considered the pass-through channel of inflation expectations.

Fig. 10 summarizes the positioning of all variables in terms of their impacts on inflation expectations and inflation in both countries. Our robustness check with advanced techniques also confirms the Nonlinear ARDL estimates. Accordingly, the inflation and inflation expectations dynamic exhibit persistent and long-run effects on each other. More importantly, the other macroeconomic elements play an important role in driving actual inflation as well as inflation expectations. Therefore, this robustness check through network analysis confirms the previous findings and results as well as highlights the link between inflation and the expected rate of future inflation.

4. Conclusion

The strategy of inflation targeting and its logical and ontological roots are embedded in the notion of credibility, transparency and accountability which concomitantly leads to anchoring and mooring of expectations (e.g. Morgan, 2009). In so doing, the nexus between the actual inflation and expectations of inflation are exploited for the prime objective of price stability which has been the bread and butter of monetary policymakers in the last few decades. In this regard, a zero lower bound has important potential implications in terms of the capability of the central banks to deliver on any given promise as well as for the expectations of market participants in relation to the pattern of success of inflation targeting. Keeping all this in context, this study has analysed the nexus between inflation expectations and inflation in two of the major economies which have been early adopters and pursuers of inflation targeting strategies. In this endeavour, we have accounted for the policy rates being close to the ZLB and the asymmetries in the relationship between underlying variables. A Nonlinear- ARDL model was employed as a framework for analysis. Our key empirical findings lead us to draw a conclusion on considerable asymmetries in the nexus between inflation and expectation of inflation as well as their determinants, namely the output gap, labour market slack, exchange rate, fiscal stance and cost shocks (oil). Nonetheless, there is strong evidence that the nexus and association among these variables are influenced by the monetary policy positioned at ZLB. There is clear blue water between the parameters of the association in the two regimes of analysis.

Specifically, findings on inflation and inflation expectations dynamics lead us to conclude that in the short run, there is a very strong element of persistence. This element of persistence is of profound importance in terms of monetary policy formulation in the Post-Covid-

[13] Antonakakis et al. (2020) have employed a TVPVAR based connectedness approach by combining the Diebold and Yilmaz (2012) framework with the TVP-VAR proposed by Koop and Korobilis (2014).

[14] We choose the rolling window with 24 months ahead, presenting for two-year period. In addition, the dataset was transformed to n-th differences to ensure the stationary. Furthermore, the optimal lag selection was also chosen to validate the main results.

19 high inflation regime where there are substantial risks to long-term price stability. In the context of the recent surge in inflation, it would imply that the policymakers must deter the inflation and inflation expectations from becoming persistent leading to a permanently high inflation regime. We also conclude that the inflation expectations also seemed to play a crucial part in determining inflation dynamics although there are asymmetries in the relationship. Similarly, the actual and prevailing rate of inflation does affect inflation expectations for the future; however, there is an asymmetry in the relationship and results vary in magnitude between the UK and Canada. Other determinants also had a significant effect on inflation and inflation expectations, although the size and significance of the impact showed considerable heterogeneity and asymmetries with the period of analysis (long and short-term) and Pre and Post ZLB. The nexus between inflation and inflation expectations has shown substantial heterogeneities in the two regimes. In fact, we saw an important shift in the nexus between the two. There is prima facie evidence that while monetary policy was at ZLB the negative shocks to inflation had a greater negative or deflationary effect on the expected rate of inflation. However, as the results illustrate, in all regimens past inflation expectations strongly influenced the current period inflation expectations, providing prima facie evidence of inertia in inflation expectations. In policy setting, this also implied that once inflation expectations are tamed and moored, they might conveniently remain anchored due to this manifest inertia, so one can have the tiger by the tail! However, as we witnessed more recently, the surge in inflation and inflation expectations Post-Covid-19 can pose substantial challenges to long-term price stability and inflation targeting. On the whole, we conclude that for both the UK and Canada, the relationship between inflation expectation, actual inflation and their determinants have been influenced by ZLB, though the evidence also suggests that inflation and inflation expectations remained well anchored in both regimes. It would be cogent to also associate the taming of the tiger of inflation and inflation expectations with the deflationary pressures that prevailed since the adoption of inflation targeting and particularly since the GFC. The inflation targeting at the ZLB might have not been successful in their absence and the recent surge in inflation is prima facie evidence of it. These findings invite further research focusing on and contrasting other inflation-targeting and non-targeting countries in the Post-Covid-19 high inflation regime.

In this study, we focused on the UK and Canada for the earlier discussed reasons. However, as venues of further research, one can also focus on the other explicit inflation-targeting and non-targeting economies. Nevertheless, future research can also take into account different empirical frameworks and measures of inflation, such as deriving the expectations from the yield curve or different types of surveys.

Strong persistence in inflation and inflation expectations manifests risks to price stability.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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