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# Is the Bank of Canada Concerned about Inflation or the State of the Economy?

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**Abstract**

This paper examines the behaviour of the Bank of Canada (BoC) since the adoption of the inflation-targeting framework. We use a newly released dataset that contains quarterly vintages of real-time historical data and BoC staff forecasts, and we present the following novel empirical findings. First, the BoC appears to have increased its focus towards the state of the economy. Over the sample period, we find that the response to inflation weakens and the response to the real economy rises substantially. Second, the BoC appears to be responding to an alternative inflation measure: persistent expected future inflation deviations. We find that transitory or past inflation deviations do not elicit a response. Third, the BoC appears to respond asymmetrically to positive and negative persistent expected future inflation deviations. We find an aggressive response to positive inflation deviations that declines over time in favour of a modest response to negative inflation deviations, suggesting that persistent expected future inflation overshoots and undershoots elicit different responses and these responses are time-varying.

JEL classification: E42, E43, E52, E58

Key words: asymmetric monetary policy, expected inflation deviations, real-time data and forecasts, forward looking Taylor rule

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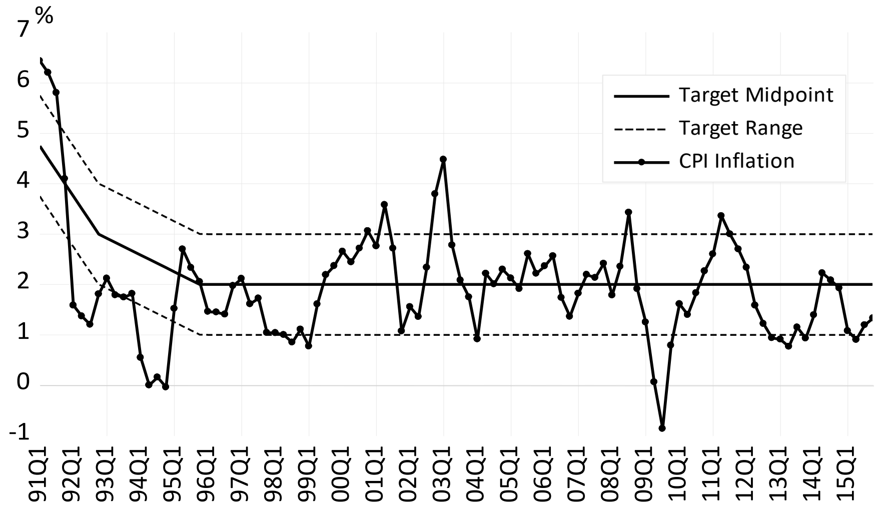
# 1 Introduction

As inflation rates around the world are climbing to levels not seen for decades, monetary authorities, including the Bank of Canada (BoC), are under the spotlight for their stance on inflation. The scrutiny has been particularly intense in Canada. Has the BoC been following a policy that responds to inflation or a different variable? Here, we investigate the behaviour of the BoC since inflation-targeting.

In 1991, the BoC adopted an inflation-targeting framework. The initial inflation target was set to be 3 percent by the end of 1992, and gradually declined to 2 percent by the end of 1995 as shown in Figure 1. Since 1995, the inflation target has remained at 2 percent, with a target range of 1 to 3 percent. The BoC focuses on price stability and its primary objective is to maintain low and stable inflation over time. The increased emphasis on inflation suggests that the BoC systematically responds to inflationary and deflationary pressures. However, has the BoC's response to inflation remained sufficiently strong over time? The BoC does not have a dual mandate targeting both inflation and employment, but the BoC supports maximum sustainable employment and economic growth (BoC, 2021). Has the BoC shifted its focus from inflation to the state of the economy even though the BoC does not have an explicit objective to stabilize the real economy?

One of the key features of the BoC's inflation targeting framework is symmetry. The BoC has repeatedly emphasized that it operates in a symmetric way. It is equally concerned about inflation rising above the target or falling below the target. Yet, between 1995 and 2015, the average inflation was below the 2 percent target, the inflation rate has been above 3 percent for a total of 6 quarters, and it has been below 1 percent for 12 quarters, twice as many quarters. Has the BoC's response to inflation deviations from the target been symmetric? Or does the BoC respond asymmetrically to positive and negative inflation deviations from the target? In this paper, we address all the aforementioned questions. We conduct an in-depth analysis of the Canadian monetary policy and present

Figure 1: CPI Inflation and the Target




novel empirical findings about the behaviour of the BoC.

Monetary policy reaction functions in the spirit of Taylor (1993) in which the interest rate responds to inflation and the real economy have been widely used to investigate the behaviour of central banks. Judd and Rudebusch (1997), Clarida et al. (1997, 2000) and Orphanides (2002) find that simple Taylor rules can describe the behaviour of the US monetary policy and also provide a reasonable empirical description of the behaviour of many other central banks, such as Germany, France, Italy, Japan, and the UK. Although early papers assumed that the interest rate responded to lagged or contemporaneous inflation and output gaps, it has now become common practice to estimate forward looking monetary policy rules, in which the interest rate responds to the forecast of inflation and output gaps because it takes time for monetary policy to affect the real economy and inflation.

To estimate forward looking monetary policy rules, Orphanides (2001, 2002, 2003) highlights the importance of using real-time data and central banks' forecasts – the data available to policymakers at the time the monetary policy decisions were made. He finds that monetary policy rules estimated using revised data – the data available now – yield misleading results as revised data contains information that was unavailable to policymakers at the time the interest rate decisions were made. Most of the empirical papers (Coibion and Goldstein, 2012, Coibion and Gorodnichenko, 2011, 2012) focus on the US monetary policy and use the Greenbook real-time data and forecasts. These forecasts are prepared by the Federal Reserve staff prior to the Federal Open Market Committee meetings. The availability of real-time data in the US has led to a large stream of empirical work that tackles various issues surrounding the US monetary policy. Outside the US, however, the availability of real-time data and forecasts is rather limited. In the absence of Canadian real-time data and central bank's forecasts, Curtis (2005) utilizes revised data, Nikolsko-Rzhevskyy (2011) constructs forward looking variables, while Hayo and Neuenkirch (2011) use alternative indicators or proxies of real-time forecasts, and Neuenkirch and Tillmann (2014) and Siklos and Neuenkirch (2015) use private sector forecasts to estimate monetary policy rules for Canada. Their results about the BoC's responsiveness to inflation and the state of economy are mixed.[1] In this paper, we demonstrate that the type of data and the sample period used can explain the differences in their results.

One of the contributions of this paper is the use of real-time data and forecasts to estimate forward looking monetary policy rules for Canada. Our paper uses the new BoC Staff Economic Projections (SEP) dataset that contains quarterly vintages of real-time historical data and the BoC staff forecasts. This data became publicly available recently, has a 5-year lag and is equivalent to the Greenbook real-time data. Champagne et al. (2020) introduce the new database and evaluate the BoC staff forecasts for GDP growth, inflation and policy rate, Champagne and Sekkel (2018) use the new real-time data to

[1] Curtis (2005) and Hayo and Neuenkirch (2011) find that the BoC responds to both inflation and the state of the economy. Nikolsko-Rzhevskyy (2011) finds that the BoC responds to inflation, but not the state of the economy, whereas Neuenkirch and Tillmann (2014) find that the BoC responds to the state of the economy, but not inflation. Siklos and Neuenkirch (2015) find that the BoC's response to inflation is weak as the long-run inflation coefficient is either below the value needed to maintain inflation at its target in the long-run, or statistically insignificant at the 5% level.

construct monetary policy shocks and estimate their effect on inflation and output, and Champagne et al. (2018) study the revision properties of the staff's output gap estimates and forecasts. While different parts of the new database have already been used, to the best of our knowledge, our paper is the first paper to use the new SEP data to estimate forward looking Taylor rules for Canada, explore the time variability of the monetary policy coefficients, and investigate whether the BoC responds asymmetrically to positive and negative persistent inflation deviations since adopting inflation-targeting.[2]

We find that the BoC responds strongly to both inflation and output gap over the full sample period (1991Q1-2015Q4). The long-run coefficient on inflation exceeds unity, thereby satisfying the Taylor principle. This result is robust to alternative measures of the inflation rate (headline and core), different measures for the real economy (output gap, real GDP growth and unemployment rate), alternative measures for the interest rate (actual policy rate and shadow rates), additional explanatory variables (such as a time-varying real interest rate, interest rate smoothing, exchange rates, and financial market conditions) and persistent monetary policy shocks. However, if we use revised data, we do not find evidence of a statistically significant response to inflation and the Taylor principle. The magnitude of the inflation coefficient has been extensively analyzed for its determinacy properties. Clarida et al. (2000), Bullard and Mitra (2002) and Woodford (2003) show that determinacy requires the long-run coefficient on inflation to be larger than one. That is, the nominal interest rates adjust more than one-for-one in response to inflation changes, implying that a rise in inflation yields an increase in the real interest rate, which then dampens inflationary pressures. This property has been labeled the Taylor principle. Clarida et al. (2000) argue that failure to satisfy the Taylor principle contributes to output and inflation volatility. Lubik and Schorfheide (2004) argue that failure to

[2] Verstraete and Suchanek (2018) use the BoC's staff forecasts to estimate backward and forward looking Taylor rules. However, they use a shorter sample period, which starts after 2001, and focus on the inclusion of the Business Outlook Survey indicator and the impact of monetary policy on firms. Our paper can be viewed as extending their sample size, providing time-varying estimates for the policy response coefficients, and documenting the asymmetric response of the BoC to persistent expected future inflation deviations.

respond strongly to inflation provides an explanation for the rise in inflation expectations. Our results suggest that the use of real-time data is crucial in finding evidence in favour of the Taylor principle. This finding is consistent with Orphanides (2001, 2002, 2003) who also finds that the results obtained with real-time data are considerably different from those obtained with revised data for the US.

Our second contribution is to present new evidence about the time variability of the monetary policy coefficients in response to inflation and output gaps. Curtis (2005) alludes that there is a shift in the BoC's focus from inflation to the real economy. However, he estimates a backward-looking monetary policy rule using revised data up to 2000 and only considers two sub-periods. The rest of the literature on Canadian monetary policy does not investigate the time variability of the monetary policy coefficients. Our paper fills this gap by providing an in-depth analysis of the stability of the monetary policy coefficients using various approaches. First, we slice our sample into various sub-periods, the disinflation period (1991Q1-1994Q4) and post-disinflation period (1995Q1-2015Q4), or divide the sample by the Governor's tenure, or use the Bai and Perron (1998) structural break test. Second, we use different types of rolling regressions in which either a fixed window size is rolled over the entire sample, or the starting date is anchored in 1991Q1 and the window size increases as the ending date moves towards 2015Q4, or the ending date is anchored in 2015Q4 and the window size decreases as the starting date moves from 1991Q1 towards the end of the sample. All the approaches yield similar results and suggest that there has been a change in the monetary policy coefficients. We find that during the early period, which includes the disinflation era, the BoC responded strongly to inflation but not to output gap. After the disinflation period, however, the response to inflation weakened, the Taylor principle disappeared, and the response to output gap rose substantially, suggesting that once the inflation rate became low and stable, the BoC shifted its emphasis from inflation to the real economic activity. Komlan (2013) argues that when inflation is low and near its target, policymakers could put more effort on stabilizing the economy, especially when the economy is navigating through recessions. We find that the coefficient on output gap increases after the disinflation period, and its magnitude experiences upward jumps once the estimation window includes the aftermath of the early 2000s downturn and the 2008 Global Financial Crisis (GFC). Kiley (2007), Ascari and Ropele (2009) and Coibion and Gorodnichenko (2011) show that the magnitude of the inflation coefficient required to maintain stability has to move in the same direction as trend inflation (i.e. inflation at the steady-state). They show that the coefficient on the inflation must increase as trend inflation rises, or equivalently it can decrease as the trend inflation declines without jeopardizing stability. Over our sample period, there is a decline in trend inflation from around 5 percent to 2 percent, and we find that the coefficient on inflation also declines and eventually becomes statistically insignificant, which puts the BoC's inflation control mandate in question. Next, we uncover that the BoC responds to an alternative inflation measure.

Our third contribution is that we unveil the following novel empirical findings: the BoC responds to *persistent expected future* inflation deviations from the target and these responses appear to be *asymmetric* and *time-varying*. Prior literature focuses on past inflation deviations. Corder and Eckloff (2011) identify episodes of persistent past inflation deviations, i.e., inflation that historically remained away from its target for an extended period, and find that these deviations affect inflation expectations in the same direction. Svensson (2015) finds that persistent inflation deviations from the target can yield large unemployment costs. Neuenkirch and Tillmann (2014) and Paloviita et al. (2021) augment the standard monetary policy rules with an additional term that captures persistent past inflation deviations and find that monetary authorities respond to this so called credibility term, suggesting history dependent monetary policy in which central banks make up for past misses.[3] Our paper considers both past and expected future inflation deviations. We

[3] Neuenkirch and Tillmann (2014) analyze the monetary authorities in Australia, Canada, New Zealand,

find that the BoC only responds to persistent expected future inflation deviations. In contrast to Neuenkirch and Tillmann (2014), we do not find evidence that the BoC responds to past inflation deviations. The novel result that the BoC considers only persistent future deviations and does not engage in makeup strategies has not been previously reported in the literature. Additionally, our paper is the first to uncover that the BoC responds asymmetrically to these deviations. We find that the BoC's response to *positive* and *negative* future inflation deviations is asymmetric, and the estimated coefficients and the statistical significance of these responses are time-varying. At the beginning of the post-disinflation period, we find an aggressive response to positive future inflation deviations that decreases over time in favour of a modest response to negative future inflation deviations.[4] The initial strong response to positive inflation deviations can be due to the central bank's asymmetric preferences as in Ruge-Murcia (2003), Surico (2007) and Komlan (2013), who argue that the monetary authority may respond more aggressively to positive inflation deviations (i.e. overshoots) than negative ones (i.e. undershoots), especially during periods in which the monetary authority is building up credibility and stabilizing inflation. The response to negative inflation deviations in the later part of our sample period can be due to the low neutral real rate and the risk of hitting the effective lower bound (ELB) as in Bianchi et al. (2021), Maih et al. (2021) and Clarida (2022). They argue that optimal monetary policy should be asymmetric and the monetary authority, recognizing the risk of encountering the ELB, should respond more aggressively to negative inflation deviations than to positive ones because the policy space available to counteract deflationary shocks is limited relative to the policy space to counteract inflationary shocks.[5]

This paper is organized as follows. Section 2 describes the baseline monetary pol-

Sweden, and the UK, and Paloviita et al. (2021) study the European Central Bank.

[4] Neuenkirch and Tillmann (2014) find that the BoC responds only to positive past inflation deviations.

[5] In the August 2020 speech at the Peterson Institute for International Economics, FED Vice Chair Clarida said that "... the aim to achieve *symmetric* outcomes for inflation (as would be the case under flexible inflation targeting in the absence of the ELB constraint) requires an *asymmetric* monetary policy reaction function in a low $r^*$ world with binding ELB constraints in economic downturns."

icy reaction function and presents the estimates for the full sample period. Section 3 investigates the time variability of the monetary policy coefficients. Section 4 augments the baseline function with a new inflation term to investigate whether the BoC responds asymmetrically to persistent inflation deviations. Conclusions are drawn in Section 5.

# 2 Monetary Policy Reaction Function

In this section, we describe the data, present our baseline monetary policy reaction function, report the baseline estimates, and investigate the robustness of our results.

## 2.1 Data

We employ the new BoC SEP database. The database contains quarterly vintages of historical real-time data and BoC staff forecasts for key macroeconomic variables. The real-time data and BoC staff forecasts are made publicly available with at least a 5-year lag. We focus on the period between 1991Q1 and 2015Q4. The BoC adopted inflation targeting in 1991Q1 and the last available vintage is 2015Q4. The vintages contain the data available to the policy makers at the time the policy decisions were made. Each vintage contains the historical real-time data for the periods prior to the vintage date, nowcast for the vintage date ($h = 0$), and forecasts up to 12 quarters ahead for the periods after the vintage date ($h = 1, \cdots, 12$). For example, the 2010Q1 vintage includes historical real-time data up until 2009Q4, nowcasts for 2010Q1, and forecasts for each quarter between 2010Q2 and 2013Q1.[6] Champagne et al. (2018, 2020) find that the root mean square error for the BoC staff forecasts have declined over time and that the BoC's staff forecasts outperform time series econometric forecasts.

[6]For the Consumer Price Index, the 1993Q3-1993Q4 vintages are missing some historical data and the 1991Q2, 1992Q2, 1993Q2, and 1995Q3 vintages are missing some forecasts. Following Champagne et al. (2020), we can either drop the vintages with missing values or impute values to the missing data. Our results are robust to both approaches. In the latter approach, we impute values for the missing quarters using the growth rates for these quarters from the previous vintage. In the paper, we report results using the second approach. Our results are almost identical if we drop the vintages with missing values.

## 2.2 Baseline Empirical Specification

Our baseline specification is a forward-looking policy rule that allows the policy rate to respond to the real-time forecasts of future macroeconomics variables, adds a time-varying real interest rate, and includes the lagged policy interest rate:

$$i_t \quad = \quad c + \rho i_{t-1} + \phi_r r_t + \phi_\pi E_t(\pi_{t+h_\pi} - \pi^*_{t+h_\pi}) + \phi_x E_t(x_{t+h_x}) + \epsilon_t \tag{1}$$

where $i_t$ is the actual nominal policy rate at time $t$.[7] $E_t$ denotes the central bank's forecasts formed at time $t$, $\pi$ is the year-over-year CPI inflation rate, $\pi^*$ is the inflation target, $x$ is the output gap, $h_\pi$ and $h_x$ are the forecast horizons for inflation and output gap, respectively, and $\epsilon$ represents the monetary policy shocks. Our baseline specification includes the lagged interest rate to capture policy inertia.[8] The parameter $\rho$ measures the degree of interest rate smoothing, and the parameters $\phi_\pi$ and $\phi_x$ can be interpreted as the short-run responses to the expected inflation and output gap, respectively. The long-run response to expected inflation is given by $\frac{\phi_\pi}{1-\rho}$. If $\frac{\phi_\pi}{1-\rho} > 1$, the Taylor principle is satisfied.

Early formulations of monetary policy rules assume that the neutral real interest rate is constant. Carlstrom and Fuerst (2016), Clarida (2008, 2012), Dorich et al. (2017), Negro et al. (2018) and Williams (2018) argue that the neutral real interest rate varies over time and suggest that it takes the following form $r^*_t = r^* + \phi_r r_t$, where $r^*$ is the time-invariant component of the neutral rate and is part of $c$ in equation (1), and $\phi_r r_t$ is the time-varying component that depends on the long-run real interest rate, denoted by $r_t$, and is an additional variable in equation (1). Following Clarida (2012), the real interest rate, $r_t$, is based on the 10-year real government bond returns.[9] Figure 2 illustrates that

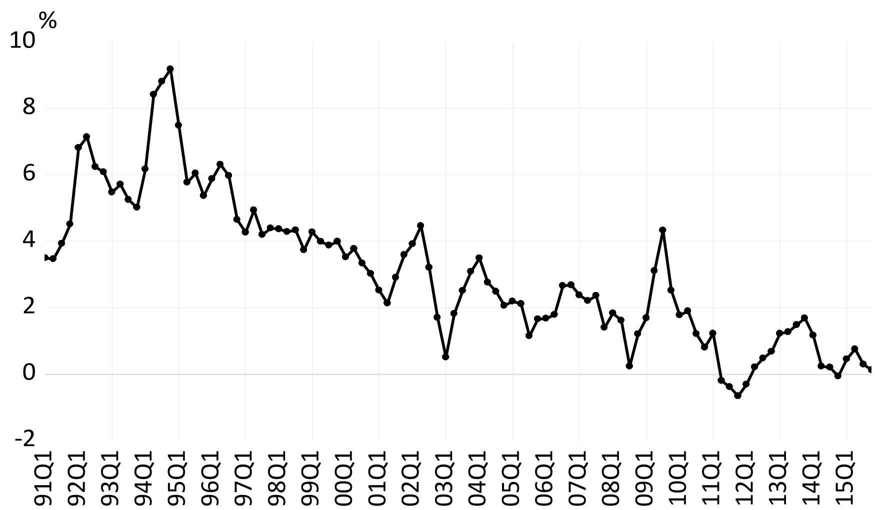
[7] We use the average interest rate over the quarter as in Champagne et al. (2020). Our results are almost identical, and our key conclusions are robust when we use the average interest rate over the two meetings closest to the staff forecasts, or the interest rate in the month that the staff forecasts are produced, or the interest rate in the month after the staff forecasts. The results are presented in Section 2.10 of the Appendix.

[8] Wooford (1999, 2001), Bernanke (2004), Carlstrom and Fuerst (2008) and Coibion and Gorodnichenko (2012) have demonstrated that an inertial Taylor rule outperforms rules without inertia both theoretically and empirically.

[9] We subtract the nowcast (contemporaneous forecast) of inflation from the 10-year government bond

the Canadian real interest rate increased in the early-1990s and remained elevated until the mid-1990s. Since the mid-1990s, the real interest rate has been trending downwards and even turned negative towards the end of our sample period.

Figure 2: Long-Term Real Interest Rate




Our baseline specification also allows the target level of inflation to be time-varying to capture the decline in the inflation targets at the beginning of our sample period.[10] In February 1991, the BoC and the Ministry of Finance jointly set the inflation targets as follows: 3 percent by the end of 1992, 2.5 percent by the middle of 1994, and 2 percent by the end of 1995. The initial objective was to reduce inflation from around 5 percent to 2 percent by the end of 1995. The focus then shifted towards maintaining inflation at around 2 percent. In December 1993, the BoC and the Ministry of Finance announced that the inflation target will stay at 2 percent with a target range of 1 to 3 percent after 1995. Based on the 1991 and 1993 announcements, we know that the inflation targets for

yield. Our results are robust to using yields on government bonds with alternative maturities (e.g., 3-year, 5-year, 7-year and 10-plus-year government bonds).

[10]Most of the recent empirical literature assumes that the inflation target is constant.

1992Q4, 1994Q2 and 1995Q4 were 3%, 2.5% and 2%, respectively. Following the BoC's Background Information for Renewal of the Inflation-Control Target (BoC, 2021), we use linear interpolation to construct the inflation target for the remaining quarters between 1991Q1 and 1995Q4. Figure 1 shows the inflation target and the CPI inflation between 1991Q1 and 2015Q4.[11]

We set the baseline forecast horizons for inflation and output gap at $h_\pi = 4$ and $h_x = 2$, respectively. Orphanides (2001, 2002, 2003, 2004), Coibion and Gorodnichenko (2011, 2012), Boivin (2006), Coibion and Goldstein (2012), Bunzel and Enders (2010), Nikolsko-Rzhevskyy (2011), Neuenkirch and Tillmann (2014), Bauer and Neuenkirch (2017) and Bennania et al. (2018) use forecast horizons up to a year ($h_\pi \leq 4$ and $h_x \leq 4$) and allow the inflation forecast horizon to be greater than or equal to the output gap forecast horizon ($h_\pi \geq h_x$). The BoC's communication also states that monetary policy affects first the real economy and then inflation, suggesting shorter forecast horizon for the real economy than the forecast horizon for inflation in the monetary policy reaction function. Additionally, Champagne et al. (2018, 2020) show that the BoC staff inflation forecasts are reliable regardless of the horizon, but the accuracy of the forecasts for the real economy variables can be poor at longer horizons. We, therefore, consider all possible combinations of forecast horizons ($h = 0, \cdots, 7$) for the forward looking variables and we compute the AIC, BIC and HQIC criteria for each specification. All the information criteria favour the $h_\pi = 4$ and $h_x = 2$ specification as it achieves the lowest AIC, BIC and HQIC scores.[12]

[11] We also consider an alternative inflation target measure for the period between 1991Q1 and 1995Q4. We assume that the inflation target decreases in a stepwise fashion based on the announced target goals by the BoC. Table 1 in the Appendix reports the two inflation target measures employed in this paper. Our results are robust to both measures.

[12] See Table 2 in the Appendix for the detailed results.

## 2.3 Baseline Estimates

Following Orphanides (2001, 2002, 2003, 2004), Coibion and Gorodnichenko (2011, 2012) and Carvalho et al. (2021), we estimate equation (1) by Ordinary Least Squares.[13] Results over the period between 1991Q1 and 2015Q4 are contained in Table 1.[14] The Newey-West HAC standard errors are reported in parentheses.

Column 1 of Table 1 shows the estimates of our baseline specification. All coefficients are statistically significant at the 1% level and have the expected signs. The estimated degree of interest rate smoothing of 0.889 is high, as commonly found in the literature.[15] Its high value implies that the BoC adjusts gradually to changes in expected macroeconomic conditions. The BoC also raises the interest rate in response to higher expected inflation. We find that the BoC responds strongly to inflation and the implied long-run response ($\frac{0.304}{1-0.889} \approx 2.74$) is greater than one, thereby satisfying the Taylor principle over the full sample period.[16] We also find that the BoC is responding with higher interest rates to rising output gap with an estimated coefficient of 0.098. Although we find a modest response to output gap, the implied long-run response of $\frac{0.098}{1-0.889} \approx 0.88$ is similar to the

[13] When using ex-post revised data, endogeneity is a major concern and OLS could potentially produce inconsistent estimates, but not when using real-time data and forecasts. In the absence of real time data and forecasts, the earlier literature had to rely on ex-post revised data to proxy future expected values of macroeconomic variables, and thus pursued different estimation methodologies to account for the endogeneity. With the newly available BoC SEP data, there is no longer an endogeneity problem because the data is in real time and most importantly the staff forecasts are produced under the assumption that the current monetary policy rate will remain unchanged. The staff forecasts are not correlated with the monetary policy shock, satisfying the orthogonality condition required by OLS. Therefore, OLS is an appropriate methodology. Carvalho et al. (2021) also argue in favour of using OLS to estimate monetary policy rules. They show that even when the orthogonality condition is not satisfied, the bias of the OLS estimates is very small, and that the OLS estimation bias (if any) is of "economic irrelevance". They find that the impulse response functions obtained from OLS are very close to the true impulse response functions. Additionally, they show that OLS can outperform GMM in the absence of good instrumental variables.

[14] Our estimates are almost identical if we use the period between 1992Q1 and 2015Q4 as in Champagne and Sekkel (2018). See the reverse recursive regression in Figure 6.

[15] Our estimate is similar to the estimated interest rate smoothing parameter of 0.9 used in the BoC's ToTEM II Model (Dorich et al., 2013), and in line with those found in Nikolsko-Rzhevskyy (2011), Neuenkirch and Tillmann (2014) and Siklos and Neuenkirch (2015).

[16] In the BoC's ToTEM II Model, the long-run response to inflation is 2.14, which is slightly smaller than our estimate.

estimate in Siklos and Neuenkirch (2015), but larger than the long-run response of 0.08 used in the BoC's ToTEM II Model and the no response to output gap assumed in the BoC's Quarterly Projection Model (QPM).[17] Lastly, we find that the response to the real interest rate of 0.112 is comparable to those found in the literature[18] and the long-run response of $\frac{0.112}{1-0.889} \approx 1$ implies that the nominal policy rate and the real interest rate move together in the steady state.

## 2.4 Robustness Analysis

We next explore the robustness of our results. We consider alternative measures for the real economy, inflation and interest rates, different forecast horizons, the inclusion of additional control variables, higher orders of interest rate smoothing and persistent monetary policy shocks. We find that our results are robust to all the alternative specifications. We then compare our results to those that use ex-post revised data.

### 2.4.1 Alternative Measures

We begin by considering different measures for the real side of the economy. We replace the output gap with the unemployment rate gap, as in Orphanides (2002), Boivin (2006) and Coibion and Goldstein (2012). In Column 2 of Table 1, we use the cyclical component of the contemporaneous ($h = 0$) unemployment rate obtained by applying the HP filter to each vintage.[19] The estimated coefficient for the unemployment rate gap is statistically significant at the 1% level and it has the expected negative sign, suggesting that the

[17] The QPM was the BoC's primary model until December 2005. Since then, the ToTEM II became the main projection and policy-analysis model.

[18] The estimated short-run response to the real interest rate is between 0.036 and 0.078 in Neuenkirch and Tillmann (2014) and between 0.211 and 0.234 in Siklos and Neuenkirch (2015).

[19] There are no unemployment rate forecasts ($h = 1, \cdots, 12$) available for the vintages between 2005Q4 and 2009Q1 and the SEP database does not contain any data for the natural rate of unemployment. We use the real-time data and forecasts available in each vintage and employ the HP filter to create an unemployment rate gap series for each vintage. We then use the cyclical value of the contemporaneous ($h = 0$) unemployment rate from each vintage to construct the final series. Our results are robust to alternative cyclical measures, such as the difference of the unemployment rate to the average of the last eight quarters in each vintage.

BoC will lower the interest rate as unemployment rate rises above its trend to ward off deflationary pressures. The signs and magnitudes for the remaining coefficients are mostly unchanged, implying that our results are robust to the use of the unemployment rate gap.

We then replace the output gap forecast with the real GDP growth forecast, as in Orphanides (2003), Coibion and Gorodnichenko (2011), Neuenkirch and Tillmann (2014), and Bauer and Neuenkirch (2017). In Column 3, we use the two quarters ahead real GDP year-over-year growth rate. The results indicate that the BoC responds strongly to inflation and the real economy, and the Taylor principle holds. In Column 4, we include both the real GDP growth rate and the output gap as in Coibion and Gorodnichenko (2012), and in Column 5, we include both the real GDP growth rate and the unemployment rate gap as in Coibion and Goldstein (2012). The use of the real GDP growth rate does not affect the response to inflation or the interest rate smoothing parameter. However, including the real GDP growth rate in the Taylor rule renders the response to the real interest rate insignificant.[20]

Next, we investigate if our results are sensitive to core inflation, which excludes highly volatile categories such as food and energy. In Column 6, we replace the headline inflation with the core inflation. Our results are qualitatively unchanged. Overall, we find that the Taylor principle holds regardless of which measure of inflation we use.[21]

In Column 7, we re-estimate our baseline specification using the Canadian shadow rates constructed by MacDonald and Popiel (2020). During the GFC, some central banks have been at or near the ELB and engaged in unconventional monetary policy to further stimulate the economy. The true policy stance during the GFC could have been more accommodative than what the actual nominal policy rate demonstrated. The BoC has been at the ELB only briefly between 2009Q2 and 2010Q2 and did not engage in quantitative easing. The BoC, however, used forward guidance and credit easing. Thus, the Canadian

[20] This is driven by the relatively high correlation between the real interest rate and the real GDP growth rate.

[21] Table 10 in the Appendix reports additional results using the core inflation instead of headline inflation.

shadow rates are slightly lower than the actual policy rate during that period, and the results in Column 7 are very similar to those of the baseline case (Column 1), implying that the use of the actual policy rate or shadow rate does not affect our key findings.[22]

### 2.4.2 Different Forecast Horizons

In our baseline regression, we assume that the BoC responds to four quarters ahead inflation and two quarters ahead output gap. The forecast horizons $h_\pi = 4$ and $h_x = 2$ are selected because they yield the lowest AIC, BIC and HQIC values. As shown in Table 2 in the Appendix, our key findings remain the same and the Taylor principle holds as long as (i) $h_\pi \geq h_x$, (ii) $0 \leq h_x \leq 6$, and (iii) $3 \leq h_\pi \leq 6$. These findings align with the BoC's communication (Murray, 2013), which states that it typically takes about 4 to 6 quarters for the monetary policy to affect the real economy and about 6 to 8 quarters for the monetary policy to affect inflation.

Furthermore, our results are robust if we use the average forecast over a number of periods as in Coibion and Gorodnichenko (2011). Column 8 reports the result when we use the average forecast of inflation over $t+1$, $t+2$, $t+3$ and $t+4$, and the average forecast of the output gap over $t+1$ and $t+2$. This is an example of average forward looking inflation targeting. Our estimates in Column 8 are similar to those in Column 1. Overall, our results are robust to alternative forecast horizons.

[22] During the GFC, the BoC lowered its policy rate to the ELB after other central banks did. However, the BoC was at the ELB for a much shorter period compared to other major central banks and engaged in modest unconventional monetary policy.

Table 1: Monetary Policy Reaction Function: 1991Q1 – 2015Q4

| **Variables** | (1) Baseline | (2) Unemployment Gap | (3) GDP Growth | (4) Output Gap & GDP Growth | (5) Unemployment Gap & GDP Growth | (6) Core Inflation | (7) Shadow Rate |
|---|---|---|---|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.889*** | 0.874*** | 0.892*** | 0.900*** | 0.895*** | 0.875*** | 0.891*** |
| | (0.028) | (0.021) | (0.030) | (0.027) | (0.023) | (0.032) | (0.029) |
| $\phi_r$ : *Real Int. Rate* | 0.112*** | 0.094*** | 0.022 | 0.054 | 0.040 | 0.147*** | 0.111*** |
| | (0.031) | (0.031) | (0.039) | (0.041) | (0.039) | (0.034) | (0.031) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.304*** | 0.332*** | 0.339*** | 0.299*** | 0.301*** | 0.325*** | 0.309*** |
| | (0.106) | (0.095) | (0.111) | (0.113) | (0.104) | (0.096) | (0.106) |
| $\phi_x$ : *Exp. Output Gap* | 0.098*** | | | 0.060* | | 0.077* | 0.101*** |
| | (0.036) | | | (0.032) | | (0.041) | (0.037) |
| $\phi_{ue}$ : *Exp. Unemp. Gap* | | −0.325*** | | | −0.258*** | | |
| | | (0.116) | | | (0.087) | | |
| $\phi_{gy}$ : *Exp. GDP Growth* | | | 0.150*** | 0.113** | 0.127*** | | |
| | | | (0.040) | (0.043) | (0.038) | | |
| *N* | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| *Adj.* $R^2$ | 0.950 | 0.950 | 0.952 | 0.953 | 0.954 | 0.950 | 0.950 |
| *S.E. of Regression* | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| **Variables** | (8) Averaging | (9) Exchange Rate | (10) TSX | (11) Interest Rate Smoothing | (12) AR(1) | (13) AR(1) & AR(2) | (14) Revised Data |
| $\rho$ : *Lagged Int. Rate* | 0.849*** | 0.894*** | 0.871*** | $\rho_1 : i_{t-1}$ 0.952*** | 0.888*** | 0.890*** | 0.867*** |
| | (0.037) | (0.031) | (0.033) | (0.161) | (0.044) | (0.042) | (0.025) |
| | | | | $\rho_2 : i_{t-2}$ − 0.064 | | | |
| | | | | (0.143) | | | |
| $\phi_r$ : *Real Int. Rate* | 0.153*** | 0.129*** | 0.077** | 0.110*** | 0.112*** | 0.111*** | 0.096*** |
| | (0.040) | (0.036) | (0.032) | (0.032) | (0.042) | (0.041) | (0.036) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.275** | 0.283** | 0.318*** | 0.295*** | 0.303** | 0.310*** | 0.004 |
| | (0.120) | (0.115) | (0.108) | (0.105) | (0.116) | (0.115) | (0.096) |
| $\phi_x$ : *Exp. Output Gap* | 0.080** | 0.113*** | 0.120*** | 0.090*** | 0.098** | 0.097** | 0.167*** |
| | (0.038) | (0.041) | (0.036) | (0.030) | (0.041) | (0.041) | (0.049) |
| $\phi_{er}$ : *Exchange Rate* | | 0.005 | | | | | |
| | | (0.006) | | | | | |
| $\phi_{tsx}$ : *TSX* | | | −0.003 | | | | |
| | | | (0.002) | | | | |
| *AR*(1) | | | | | 0.010 | 0.008 | |
| | | | | | (0.094) | (0.094) | |
| *AR*(2) | | | | | | −0.046 | |
| | | | | | | (0.122) | |
| *N* | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| *Adj.* $R^2$ | 0.949 | 0.950 | 0.950 | 0.950 | 0.949 | 0.949 | 0.945 |
| *S.E. of Regression* | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |

Note: [1] Estimation of equation (1) and robustness analysis. [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

### 2.4.3 Additional Control Variables

We consider the role of exchange rates as they may have affected the interest rate decisions. In small open economies such as Canada, central banks may react to exchange rate movements. Following Clarida et al. (1997, 2000), Curtis (2005) and Nikolsko-Rzhevskyy (2011), we augment our baseline monetary policy reaction function with the year-over-year percentage change in the nominal Canadian-US dollar exchange rate. The results are presented in Column 9. Similar to Nikolsko-Rzhevskyy (2011) and Champagne and Sekkel (2018), we find that the coefficient on the exchange rate is not statistically different from zero, implying that the BoC does not respond to exchange rate fluctuations over the inflation-targeting period.[23]

We then explore the role of the financial markets. We follow Coibion and Gorodnichenko (2012) and augment equation (1) with the log of quarterly average of the Toronto Stock Exchange (TSX) index and report the results in Column 10. We find that the coefficient on TSX is statistically insignificant and the estimates for the other parameters remain almost unchanged. The financial market coefficient remains statistically insignificant when we use the year-over-year growth rate of the TSX or when we use the quarterly standard deviation of the TSX daily returns to capture financial market volatility. Our results suggest that there is no evidence that the BoC systematically responds to the financial markets beyond their impact on inflation and output gap.

### 2.4.4 Interest Rate Smoothing

Our baseline specification allows for an interest rate smoothing of order one. In Column 11, we allow for an interest rate smoothing of order two as in Coibion and Gorodnichenko (2011, 2012). Woodford (2003) shows that the optimal monetary policy reaction function in New Keynesian models should have an interest rate smoothing of order two. We find

[23] The exchange rate coefficient remains statistically insignificant when we use the logarithm of the nominal exchange together with the level of the US federal funds rate as in Champagne and Sekkel (2018) or when we use quarterly growth rate of the nominal exchange rate.

that the lagged one interest rate coefficient ($\rho_1$) is statistically significant, but the lagged two interest rate coefficient ($\rho_2$) is not. The results for the remaining coefficients are very similar to our baseline specification (Column 1).[24]

### 2.4.5 Persistent shocks

Most of the theoretical and empirical literature represents the inertia in the policy-making process with interest rate smoothing. Rudebusch (2002), however, suggests that the policy inertia could reflect persistent monetary policy shocks. In Column 12, we re-estimate our baseline specification allowing for AR(1) errors as in Coibion and Gorodnichenko (2012). We find that the autoregressive parameter of the error term is not statistically different from zero.[25] The inclusion of AR(1) errors does not alter the estimates of the other parameters. Instead, allowing for persistent errors deteriorates the fit of the empirical reaction function. We obtain similar results when we considered nested specifications with higher order processes for both interest smoothing and persistent shocks. All the information criteria favour the specification with lagged one interest rate and no persistence in monetary policy shocks.[26]

### 2.4.6 Revised Data

Finally, we estimate our baseline specification using ex-post revised data. We use the revised CPI and real GDP data from Statistics Canada and compute the output gap as the cyclical component of log real GDP using the HP filter. Column 14 reports the results. The inflation coefficient is not statistically different from zero and the implied long-run response of interest rate to inflation is less than one, suggesting that the Taylor principle is not satisfied when we use the ex-post revised data. This finding is in sharp

[24]Our results remain the same when we allow for higher order of interest rate smoothing.

[25]We also test for the presence of serial correlation in the errors using the Ljung–Box Q-statistic test and the Breusch–Godfrey Lagrange multiplier test, and we find no evidence of first-order or higher orders of serial correlation in the errors.

[26]See Table 3 in the Appendix.

contrast to the one obtained when we use the real-time data. Our results are similar to the findings of Orphanides (2001, 2002, 2003) who argues that the use of revised data may lead to completely different and misleading results about the US monetary policy. Our results highlight the importance of using real-time data and forecasts for finding evidence in favour of the Taylor principle in Canada.

# 3 Stability of the Baseline Monetary Policy Coefficients

In this section, we examine the time variation of the monetary policy coefficients. During our sample period, the BoC adopted a new monetary policy framework, credibility got established, and the economy navigated through recessions, suggesting that the BoC could have altered its responses over the sample period. Curtis (2005) alludes that there could have been a change in the monetary policy coefficients, but he and the rest of the literature on the Canadian monetary policy do not explicitly test if the coefficients have changed over time. We conduct an extensive analysis of the stability of the monetary policy coefficients using various approaches.

## 3.1 Disinflation vs Post-disinflation Period

We begin by dividing our sample into two sub-periods: the disinflation period and the post-disinflation period. The disinflation period is the initial phase following the adoption of inflation targeting, during which the BoC set moving targets to reduce inflation. Once inflation was brought down, the BoC shifted to target inflation at 2 percent within the 1 to 3 percent control range. Following Roger (2009), we set the disinflation period to be between 1991Q1 and 1994Q4 and the post-disinflation period to be after 1995Q1. Results are contained in Table 2.

All four coefficients point to important differences between the two sub-periods. First, we find that the inflation coefficient is positive and statistically significant at the 5% level only in the disinflation period. During this initial period, the BoC is responding

Table 2: Disinflation vs. Post-disinflation Periods

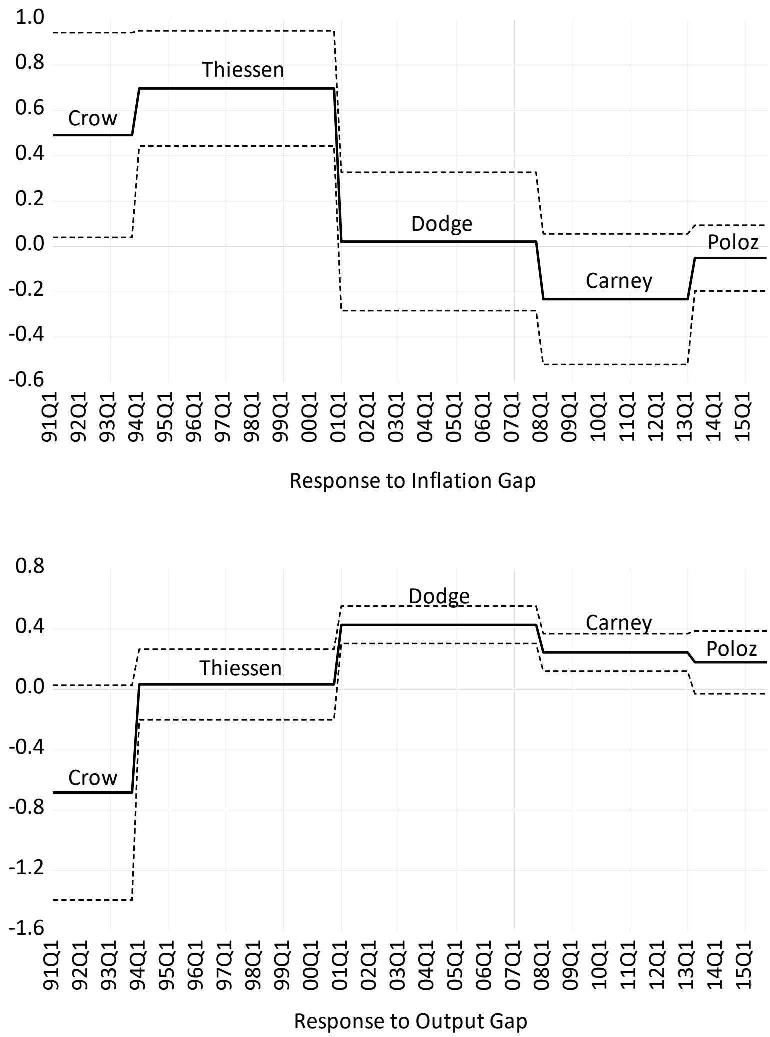
| **Variables** | 1991Q1 - 1994Q4 | 1995Q1 - 2015Q4 |
|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.554** | 0.899*** |
| | (0.179) | (0.027) |
| $\phi_r$ : *Real Int. Rate* | 0.028 | 0.091** |
| | (0.120) | (0.039) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.927** | 0.329 |
| | (0.414) | (0.219) |
| $\phi_x$ : *Exp. Output Gap* | −0.493 | 0.204*** |
| | (0.328) | (0.045) |
| $N$ | 16 | 84 |
| *Adj.* $R^2$ | 0.777 | 0.962 |
| *S.E. of Regression* | 0.009 | 0.004 |

Note: [1] Estimation of equation (1) for the disinflation period and the post-disinflation period. [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

strongly to inflation, the implied long-run response to inflation is larger than one and the Taylor principle is satisfied. The Taylor principle, however, disappears in the later period as the inflation coefficient declines and becomes statistically insignificant. Second, the sign and the significance of the output gap coefficient change between the two sub-periods. The estimated output gap coefficient is negative and insignificant in the disinflation period, but it is positive and statistically significant at the 5% level in the later period. Third, the coefficient on lagged interest rate is statistically significant at the 5% level in both periods, but its magnitude increases substantially in the post-disinflation period, suggesting higher persistent in the interest rate decisions in the later period. Finally, the real interest rate coefficient is statistically significant at the 5% level only in the later period.

Overall, our results suggest that there is a change in the behaviour of the BoC between the two sub-periods. We find that during the disinflation period, monetary policy exhibits modest persistence and responds strongly to inflation. But once inflation becomes low and stable, the BoC shifts its emphasis from inflation to the state of the economy. During the post-disinflation period, BoC responds to output gap and real interest rate, and also exhibits substantial inertia in the policy-making process.[27]

Figure 3: Governor Specific Response to Inflation and Output Gap




### 3.2 Governors' Tenure

Next, we divide the sample by the tenure of the BoC Governors and investigate if the parameters of our baseline specification vary across their tenure. During the period of

[27]Our key findings remain the same if the standard errors are constructed using bootstrapping, or if we modify the disinflationary period to end in 1995Q4 and the post-disinflation period to start in 1996Q1.

1991Q1-2015Q4, there were five Governors: John Crow (1991Q1 – 1993Q4), Gordon Thiessen (1994Q1 – 2000Q4), David Dodge (2001Q1 – 2007Q4), Mark Carney (2008Q1 – 2013Q1), and Stephen Poloz (2013Q2 – 2015Q4).[28] Figure 3 plots the point estimates and the 95% confidence interval of the inflation and output gap coefficients for each Governor between 1991Q1 and 2015Q4.[29] Our results suggest that there are important differences between the periods of the first two Governors (Crow and Thiessen) and the later three Governors (Dodge, Carney and Poloz). As shown in Table 3, the inflation coefficient is positive and statistically significant at the 1% level during the tenures of Crow and Thiessen, but it is not statistically different from zero during the tenures of Dodge, Carney and Poloz. In contrast, we find that the output gap coefficient is insignificant during the tenures of Crow and Thiessen, but it is positive and statistically significant at the 1% level during the tenures of Dodge, Carney and Poloz.[30] These findings are generally in line with our findings in Table 2 as the disinflation period overlaps with Crow's full tenure and a portion of Thiessen's tenure.

### 3.3 Structural Break Test

We use the Bai and Perron (1998) structural break test in which the break date is considered unknown and is chosen endogenously by the data. We use their sequential procedure and allow for one break and a 20% trimming. At the 5% significance level, we find the presence of a structural break in 1999Q3.[31] The structural break test divides the sample into two sub-periods. The first one contains the disinflation era and is associated with the tenures of Crow and Thiessen, while the later period includes the tenures of Dodge, Carney and Poloz. Table 4 reports the results for our monetary policy reaction function

[28] Since the change of Governors usually takes place within a particular quarter, we assign the quarter in which there is a leadership changeover to the incoming Governor. Our results are almost identical if we assign the quarter in which there is a leadership changeover to the departing Governor.

[29] Table 4 in the Appendix contains the detailed results.

[30] Our findings remain the same if the standard errors are constructed using bootstrapping.

[31] We find the same break date if we use a trimming percentage of 15 and 25, or if we use the Quandt-Andrews breakpoint test.

with the breakpoint at 1999Q3. Our results suggest that in the first sub-period there is modest policy inertia, and we find evidence of a strong response to inflation. In the later period, we do not find evidence that the BoC responds to inflation as the coefficient is not statistically significant. Instead, the BoC responds strongly to the output gap and there is substantial inertia in the policy-making process.[32]

Table 3: Baseline Monetary Policy Reaction Function

Governor Groups

| **Variables** | Crow-Thiessen | Dodge-Carney-Poloz |
|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.732*** | 0.834*** |
| | (0.090) | (0.029) |
| $\phi_r$ : *Real Int. Rate* | 0.011 | 0.020 |
| | (0.070) | (0.033) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.586*** | −0.109 |
| | (0.115) | (0.128) |
| $\phi_x$ : *Exp. Output Gap* | −0.025 | 0.310*** |
| | (0.084) | (0.045) |
| *N* | 40 | 60 |
| *Adj.* $R^2$ | 0.845 | 0.968 |
| *S.E. of Regression* | 0.007 | 0.003 |

Note: [1] Estimation of equation (1) for different governor groups between 1991Q1 and 2015Q4: Crow-Thiessen (1991Q1 – 2000Q4) and Dodge-Carney-Poloz (2001Q1 - 2015Q4). [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

### 3.4 Rolling Regressions

We further investigate the effects of the disinflation period and the aftermath of the GFC on the monetary policy coefficients using different types of rolling regressions. We begin by re-estimating equation (1) using a fixed rolling window of 60 observations over the entire sample. Figure 4 plots the coefficient estimates for the lagged interest rate, real interest rate, inflation and the output gap and their 95% confidence intervals. The date

[32] If we allow for two breaks in the Bai and Perron sequential test, then we find two dates: 1999Q3 and 2008Q1. In addition to the first break in 1999Q3, we find that there is a second potential break during the GFC. Table 5 in the Appendix reports the results for the monetary policy reaction function with these two breakpoints. Since the results between 1999Q3 and 2007Q4 are similar to those between 2008Q1 and 2015Q4, we present the results with one break in the paper.

Table 4: Breakpoint Regression

| **Variables** | 1991Q1 - 1999Q2 | 1999Q3 - 2015Q4 |
|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.696*** | 0.845*** |
| | (0.099) | (0.031) |
| $\phi_r$ : *Real Int. Rate* | 0.028 | 0.031 |
| | (0.072) | (0.033) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.613*** | −0.092 |
| | (0.111) | (0.129) |
| $\phi_x$ : *Exp. Output Gap* | −0.082 | 0.321*** |
| | (0.097) | (0.044) |
| *N* | 34 | 66 |
| *Adj.* $R^2$ | 0.850 | 0.975 |
| *S.E. of Regression* | 0.007 | 0.003 |

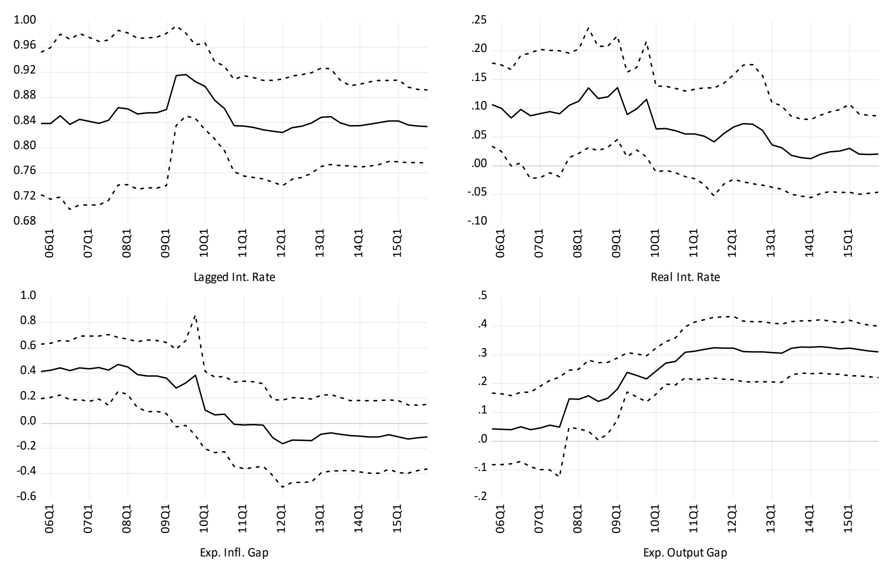
Note: [1] Estimation of equation (1) with breakpoint detected by Quandt-Andrews breakpoint test and Bai and Perron sequential test. [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

on the horizontal axis refers to the end of the fixed window. The first estimate on the left side of each chart in Figure 4 is for the period between 1991Q1 and 2005Q4, which includes the disinflation era. Each period, the fixed window moves one quarter ahead. The last rolling estimate on the right side of each chart in Figure 4 covers the period between 2001Q1 and 2015Q4, which includes the fallout of the GFC.[33] The results confirm that all four monetary policy coefficients vary as the estimation window moves over time. The degree of interest rate smoothing sharply increases after the 1994Q2 – 2009Q1 rolling window, suggesting higher policy inertia, but then the policy inertia declines as the rolling window moves out of the disinflation era and through the aftermath of the GFC. The estimated coefficient for the real interest rate remains insignificant at the 5% level after the 1995Q2 – 2010Q1 rolling window. The inflation coefficient gradually declines and eventually becomes statistically insignificant at the 5% level after the 1994Q3-2009Q2 rolling window, implying that the BoC's responsiveness to inflation weakens as the fixed window exits the disinflation period and rolls over the GFC. In contrast, we find that the

[33]The last rolling window also aligns with the tenures of the last three Governors.

output gap coefficient rises and becomes statistically significant at the 5% level after the 1993Q1-2007Q4 rolling window, suggesting an increased emphasis by the BoC on the real side of the economy when the estimation window includes the GFC. The first takeaway from the fixed window rolling analysis is that the early disinflation period is crucial in finding a statistically significant inflation coefficient and evidence in favour of the Taylor principle. The second takeaway is that the period after the GFC is important for the magnitude and the significance of the output gap coefficient.[34]

Figure 4: Baseline Monetary Policy Reaction Function: Rolling Window with 60 Observations, Short-Run Coefficients with Confidence Bands




Since the disinflation era is at the beginning of our sample, while the aftermath of the GFC is towards the end of the sample, we use recursive rolling regressions and reverse recursive rolling regressions to further investigate the time variation of the monetary policy

[34]Our results are robust if we use a rolling window of 40 observations.

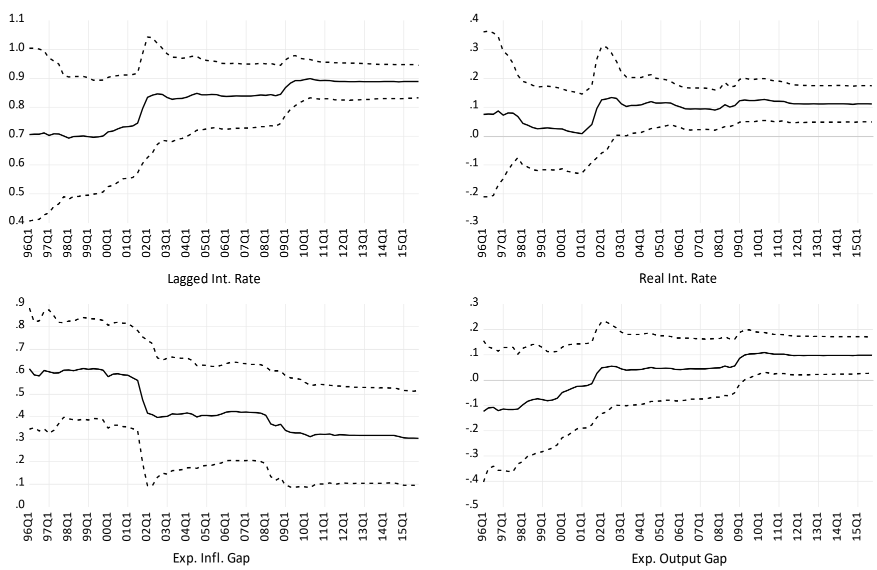
coefficients. In the recursive rolling regressions, we anchor the starting date at the beginning of the sample and increase the window size by a quarter each time until the entire sample is used. Figure 5 plots the point estimates and the 95% confidence intervals for the four coefficients when the starting date is anchored in 1991Q1. The date on the horizontal axis shows the end of each recursive rolling window. The first estimate on the left side of each chart in Figure 5 is for the period between 1991Q1 and 1996Q1, while the last estimate on the right side of each chart in Figure 5 is for the full sample between 1991Q1 and 2015Q4. The disinflation period is included in all the recursive rolling estimations reported in Figure 5.

We find that as more observations are added in the recursive rolling regressions, the coefficients for the lagged interest rate, real interest rate and output gap increase. These three coefficients appear to experience two upward jumps. In contrast, the inflation coefficient experiences two downward jumps. These jumps occur in synchronization, with the first one happening once the window includes the early 2000s downturn and the second one occurring once the window includes the onset of the GFC, suggesting that recessions cause an increase in the BoC's responsiveness to the real side of the economy and a decrease in the BoC's responsiveness to inflation. We find that despite the decrease in the inflation coefficient, it remains statistically significant at the 5% level and the Taylor principle always holds, whereas the response to output gap becomes statistically significant once the recursive rolling window includes the observations of the GFC. These results hold as long as a portion of the disinflation era is included in the recursive rolling regressions. If the starting date is anchored prior to 1995Q1, then the inflation coefficient is almost always statistically significant and the output gap coefficient becomes statistically significant once the window includes the observations of the GFC. But if the starting date is anchored after 1995Q1, then the inflation coefficient is almost never significant at the 5% level, whereas the output gap coefficient is almost always significant at the 5% level.[35] The results from

[35]In Section 2.5 of the Appendix, we present the results when the starting date is anchored in 1994Q1

the recursive rolling regressions confirm that the inclusion of the disinflation period is essential for finding a statistically significant inflation coefficient and for the presence of the Taylor principle. Additionally, the results confirm that if the estimation includes part or all the disinflation era, then the period after the GFC is necessary for the existence of a statistically significant output gap coefficient.

Figure 5: Baseline Monetary Policy Reaction Function: Recursive Regression Anchor in 1991Q1, Short-Run Coefficients with Confidence Bands




We further explore the implications of including the period after the GFC in the estimations. In the reverse recursive rolling regressions, we anchor the end date of the estimation window in 2015Q4 and decrease the window size by a quarter each time as the starting date advances from 1991Q1 towards the end of the sample. Figure 6 plots the point estimates and the 95% confidence intervals for the four coefficients. The horizontal

(to include part of the disinflation period) and in 1996Q1 (a date after the disinflation period).

axis displays the starting date of each reverse recursive rolling window. The estimates on the left side of each chart in Figure 6 utilize the entire sample, while the estimates on the right side of each chart use the period between 2010Q4 and 2015Q4. The aftermath of the GFC is included in all the reverse recursive estimations.

We find that the inflation coefficient declines and becomes insignificant at the 5% level once the starting date of the reverse recursive rolling window does not include the disinflation period. Additionally, we find that the output gap coefficient is almost always significant, confirming that the inclusion of the period after the GFC is critical for finding a significant response to the real side of the economy. If the ending date is anchored prior to the GFC, then the output gap coefficient is significant only if the starting date of the window does not include the disinflation period.[36]

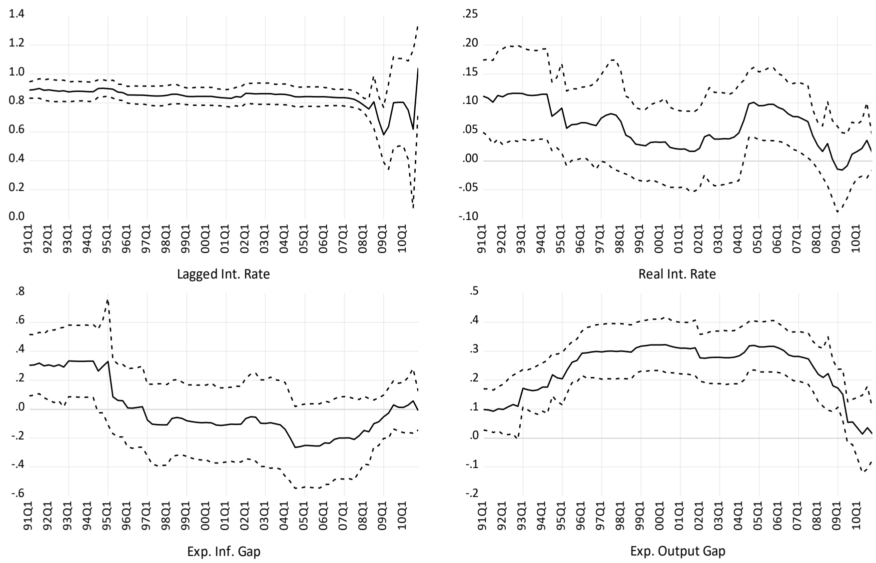
All the results from the rolling regression are robust when we drop the output gap from our baseline monetary policy rule in equation (1), use the real GDP growth rate instead of the output gap, include both the real GDP growth rate and output gap, use different forecast horizons for inflation and output gap, use alternative policy rate measures or use core inflation instead of headline inflation.[37]

Our results shed some light about the mixed results for the Canadian monetary policy. The inclusion of certain episodes in the estimation periods could yield different conclusions about the BoC's responsiveness to inflation and the state of economy. In Neuenkirch and Tillmann (2014) and Siklos and Neuenkirch (2015), the sample periods start after the disinflation era and include part of the GFC, and they find that the inflation coefficient is not statistically significant, but the real economy coefficients are statistically significant at the 5% level. In Nikolsko-Rzhevskyy (2011), the sample period includes the full disinflation era, but ends prior to the GFC, and he does not find a statistically significant output gap coefficient but he confirms the existence of the Taylor principle.

[36] In Section 2.5 of the Appendix (Figure 3), we present the results when the ending date is anchored in 2006Q4 (a date prior to the GFC).

[37] See Sections 2.6 - 2.10 and 4 of the Appendix for the detailed results.

Figure 6: Baseline Monetary Policy Reaction Function: Reverse Recursive Regression Anchor in 2015Q4, Short-Run Coefficients with Confidence Bands




In summary, when we use the full sample period, we find that both the inflation and output gap coefficients are positive and statistically significant. However, when we slice our sample into various sub-periods, all the approaches reveal a change in the inflation and output gap coefficients over time. We find that as trend inflation declined, the BoC's response to inflation also declined, while the BoC's response to output gap increased, suggesting that the BoC shifted its focus from inflation to the state of the economy. While our sample ends in 2015, our findings align with the BoC's behaviour in 2021 (out of sample). Despite the rising inflation pressures in 2021, the BoC did not raise the interest rates or conduct quantitative tightening to tame inflation. Instead, the BoC continued to emphasize the state of the economy and the recovery from the pandemic.[38]

[38]In the October 2021 monetary policy report press conference opening statement, Governor Macklem said that "Slack remains in the labour market. ... In view of the continued excess capacity in the economy,

# 4 Persistent Inflation Deviations

The decline of the inflation coefficient and the disappearance of the Taylor principle in the later period of our sample can be viewed as undesirable and a cause for concern. First, a monetary policy rule with coefficients similar to the post-disinflation period estimates could induce indeterminacy. Determinacy depends on both the coefficient on inflation and output gap. Bullard and Mitra (2002) show that under a zero-trend inflation there is a trade-off between the coefficient of inflation and output, and they show that a monetary policy rule with a long-run coefficient on inflation less than one could still be consistent with a unique stationary equilibrium if the monetary authority responds more aggressively to output. However, this trade-off between the two coefficients disappears when trend inflation is positive. Kiley (2007), Ascari and Ropele (2009), Coibion and Gorodnichenko (2011) show that even for small positive levels of trend inflation, the coefficient on inflation should be sufficiently large, and the coefficients on inflation and output gap should be moving in the same direction. A central bank that becomes more aggressive towards the state of the economy should also become more aggressive with inflation. Second, the insignificant inflation coefficient during the post-disinflation period could suggest that the BoC has stopped responding to inflation. The BoC refutes that it deviates from its mandate and continues to highlight that it focuses on price stability and follows an inflation-targeting framework. An inflation targeting central bank is expected to respond to inflation.

## 4.1 New Inflation Measure

In this section, we investigate if the BoC responds to an alternative inflation measure: *persistent* inflation deviations. Perhaps responding to inflation at a specific period ahead is a narrow price-stability mandate. Instead, the BoC is responding to deviations that are

my fellow Governing Council members and I judged that the economy still needs considerable monetary policy support."

more persistent, i.e., inflation that remains away from its target for an extended period. In a low inflation environment, temporary deviations from the target may not elicit a response by the BoC. However, persistent deviations from the target could prompt a policy intervention as it puts the inflation performance at risk.

The persistent inflation deviations can be backward or forward looking. Corder and Eckloff (2011), Davis (2012), Neuenkirch and Tillmann (2014), Svensson (2015), and Paloviita et al. (2021) focus only on *past* inflation deviations. The Federal Reserve's new average inflation targeting framework has some history dependence as it seeks to maintain the average inflation rate at the target, implying that periods of below-target inflation will be offset with periods of above-target inflation, thereby making up for past deviations. In contrast, the BoC emphasizes that it is always conducting monetary policy in a forward-looking manner, thereby focusing on *expected future* inflation deviations.

The response to these persistent inflation deviations could be *asymmetric*. An asymmetric response could be stemming from the central bank's asymmetric preferences around the inflation target. When the central banker's loss function is not quadratic, the loss associated with positive inflation deviations from the target could be different from the loss associated with negative inflation deviations. Ruge-Murcia (2003), Surico (2007) and Komlan (2013) depart from the conventional quadratic loss function and show that central banks do not weigh positive and negative inflation deviations equally. They all use data prior to the GFC and provide evidence that monetary authorities, such as the Federal Reserve and the BoC, weight positive deviations more severely than negative ones, especially during periods in which the monetary authority is building up credibility and stabilizing inflation. Therefore, if the monetary authority is more concerned about inflation overshooting than undershooting, it may respond more forcefully to positive inflation deviations than negative ones. However, as the environment changes, the type of asymmetric response could also change. The Federal Reserve's new framework alludes to an asymmetric strategy with a stronger response to inflation when it is below the target than above the target. Bianchi et al. (2021), Maih et al. (2021) and Clarida (2022) argue that when the neutral real interest rate is low and the economy is near the ELB, optimal monetary policy should follow an asymmetric strategy in which the monetary authority responds more aggressively to negative inflation deviations than positive ones as it corrects the deflationary bias and reduces the risk of deflationary spirals.

Asymmetric objectives yield nonlinear policy rules. When the central bank's preferences are asymmetric around the inflation target, optimal monetary policy responds nonlinearly to inflation (Surico, 2007). A nonlinear response to inflation also captures the idea that small deviations from the target may be tolerated as they fall within a central bank's "comfort zone" (Mishkin, 2008), but large deviations prompt a policy response.

We draw from Surico (2007), Neuenkirch and Tillmann (2014), Paloviita et al. (2021) and Bianchi et al. (2021) and augment our baseline monetary function with a new inflation term, which has four features. It captures *persistent* inflation deviations as it averages deviations over an extended period of time. It encompasses *past* or *expected future* inflation deviations, thereby allowing us to test if policy decisions are history dependent or forward looking. It includes both positive and negative inflation deviations, hence allowing us to test if the BoC has *asymmetric* responses to positive and negative deviations. It changes *nonlinearly* as inflation moves away from its target. We, therefore, specify the new inflation term as the average inflation deviation multiplied by its absolute value:

$$\tilde{\pi}_t|\tilde{\pi}_t| \tag{2}$$

where $\tilde{\pi}_t$ can be backward looking and equal the average of past inflation deviations over the last $P$ quarters,

$$\tilde{\pi}_t \quad = \quad \frac{\sum\limits_{p=1}^{P}(\pi_{t-p} - \pi^*_{t-p})}{P}. \tag{3}$$

Alternatively, $\tilde{\pi}_t$ can be forward looking and equal the average of the contemporaneous and future forecasts of inflation deviations over the next $Q$ quarters,[39]

$$\tilde{\pi}_t = \frac{\sum_{q=0}^{Q} E_t(\pi_{t+q} - \pi^*_{t+q})}{1+Q}. \tag{4}$$

We augment the monetary policy reaction function (1) with the new inflation term

$$\begin{aligned} i_t &= c + \rho i_{t-1} + \phi_r r_t + \phi_\pi E_t(\pi_{t+h_\pi} - \pi^*_{t+h_\pi}) + \phi_x E_t(x_{t+h_x}) \\ &\quad + \phi_{id}\tilde{\pi}_t|\tilde{\pi}_t| + \epsilon_t \end{aligned} \tag{5}$$

where a positive and significant coefficient for $\phi_{id}$ would indicate that the BoC responds to persistent inflation deviations. Equation (5) allows for the same response to inflation deviations regardless of inflation being above or below the target. We also investigate the possibility of an asymmetric response to positive and negative inflation deviations and estimate the following equation

$$\begin{aligned} i_t &= c + \rho i_{t-1} + \phi_r r_t + \phi_\pi E_t(\pi_{t+h_\pi} - \pi^*_{t+h_\pi}) + \phi_x E_t(x_{t+h_x}) \\ &\quad + \phi_{id}^{pos} D_t^{pos}\tilde{\pi}_t|\tilde{\pi}_t| + \phi_{id}^{neg} D_t^{neg}\tilde{\pi}_t|\tilde{\pi}_t| + \epsilon_t \end{aligned} \tag{6}$$

where $\tilde{\pi}_t|\tilde{\pi}_t| > 0$ captures positive inflation deviations (i.e., overshoots) and $\tilde{\pi}_t|\tilde{\pi}_t| < 0$ captures negative inflation deviations (i.e., undershoots). $D_t^{pos}$ is a dummy variable that is equal to 1 if $\tilde{\pi}_t|\tilde{\pi}_t| > 0$ and 0 otherwise, and $D_t^{neg}$ is a dummy variable that is equal to 1 if $\tilde{\pi}_t|\tilde{\pi}_t| < 0$ and 0 otherwise. Positive and significant coefficients for $\phi_{id}^{pos}$ and $\phi_{id}^{neg}$ would indicate that the BoC responds to inflation-overshooting by raising the interest rate and to inflation-undershooting by lowering the interest rate.

Figure 7 plots the BoC's policy rate (left vertical axis) between 1995Q1 and 2015Q4, the past inflation deviations with a memory of 16 quarters, $P = 16$ (right vertical axis),

[39] Our paper can be viewed as extending Corder and Eckloff (2011), Davis (2012), Neuenkirch and Tillmann (2014), Svensson (2015), and Paloviita et al. (2021) by investigating the effects of both historical inflation deviations and expected future inflation deviations.

and the expected future inflation deviations with a forecast horizon of 9 quarters, $Q = 9$ (right vertical axis). During this period, the negative deviations tend to be larger and more frequent than the positive ones.[40] Also, after 2000Q1 the backward-looking and forward-looking inflation deviation terms tend to move in the opposite direction.[41]

Figure 7: Policy Rate, Forward looking and Backward looking Inflation Deviations

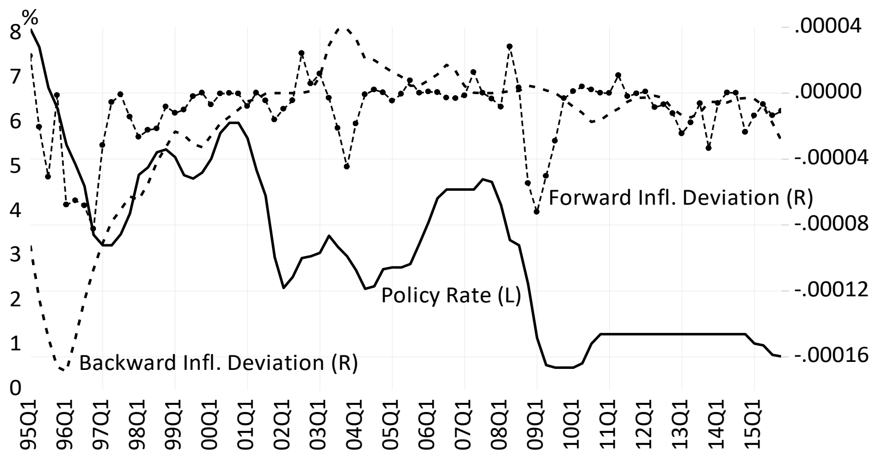



Table 5 contains the results for the new specifications between 1995Q1 and 2015Q4. We use the period after 1995 for two primary reasons. First, we would like to investigate if the BoC responds to persistent inflation deviations during the post-disinflation period as the BoC's responsiveness to inflation in this period is in doubt. Second, to construct the past inflation deviation term in equation (3) we need to use observations at the beginning of the sample, thereby reducing the estimation window.

We begin by investigating whether the BoC responds to past inflation deviations. Using $P = 16$ in the backward-looking term, equation (3), the results for the specifications in (5) and (6) are reported in Columns 1 and 3 of Table 5.[42] The estimated coefficients

[40] There are about three times as many negative deviations as positive ones throughout our sample as well as during various subsamples (i.e., the disinflation period, the post-disinflation period and the post-GFC period).

[41] Tables 7 and 8 in the Appendix report the descriptive statistics of the past and expected future inflation deviations and their correlation coefficients with the other variables.

[42] To estimate the new specifications between 1995Q1 and 2015Q4, $P = 16$ is the maximum number of

Table 5: Monetary Policy Reaction Function with Persistent Inflation Deviations
1995Q1 - 2015Q4

| **Variables** | (1) Backward | (2) Forward | (3) Backward | (4) Forward |
|---|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.888*** | 0.886*** | 0.887*** | 0.886*** |
| | (0.025) | (0.028) | (0.024) | (0.027) |
| $\phi_r$ : *Real Int. Rate* | 0.064 | 0.131*** | 0.053 | 0.131*** |
| | (0.040) | (0.045) | (0.047) | (0.045) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.348 | 0.069 | 0.369 | 0.069 |
| | (0.220) | (0.147) | (0.222) | (0.118) |
| $\phi_x$ : *Exp. Output Gap* | 0.235*** | 0.140** | 0.237*** | 0.140*** |
| | (0.047) | (0.055) | (0.047) | (0.051) |
| $\phi_{id}$ : *Infl. Deviation* | $-23.116$ | 90.294*** | | |
| | (15.791) | (29.305) | | |
| $\phi_{id}^{pos}$ : *Pos. Infl. Deviation* | | | 16.339 | 92.585 |
| | | | (43.475) | (161.109) |
| $\phi_{id}^{neg}$ : *Neg. Infl. Deviation* | | | $-30.631$ | 89.991*** |
| | | | (23.321) | (28.514) |
| *N* | 84 | 84 | 84 | 84 |
| *Adj.* $R^2$ | 0.962 | 0.964 | 0.962 | 0.964 |
| *S.E. of Regression* | 0.004 | 0.004 | 0.004 | 0.004 |

Note: [1] Estimation of equations (5) and (6). [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

for the past inflation deviation terms in both specifications (5) and (6) are insignificant at the 5% level and some of them have the wrong signs, whereas the other monetary policy coefficients remain similar to the ones reported in Table 2. The results in Columns 1 and 3 of Table 5 suggest that the BoC follows a "bygone" strategy in which it does not appear to make up for past inflation misses.[43]

Next, we consider whether the BoC responds to expected future inflation deviations. Using $Q = 9$ in the forward-looking term in equation (4), Column 2 of Table 5 reports the results for the specification in equation (5).[44] The estimated coefficient on the persistent inflation deviation term has the expected sign and is statistically significant at the 1% level, suggesting that in the post-disinflation period the BoC is responding to persistent expected future inflation deviations. The estimated coefficient of 90.294 suggests that if the average inflation over the current and the next 9 quarters is expected to overshoot (undershoot) its target by 1 percentage point,[45] then the BoC will increase (decrease) the interest rate by 0.90294 percentage points.[46] The quadratic feature of the new term indicates that larger deviations prompt even larger interest rate changes. If inflation is expected to overshoot (undershoot) its target by 2 percentage points, then the interest rate will increase (decrease) by 3.61176 percentage points.[47]

The coefficient $\phi_{id}$ remains statistically significant at the 5% level as long as the forward-looking term in equation (4) includes the average of at least 6 quarters ahead

lags that can be used to construct the backward-looking inflation deviation term. We obtain similar results when we use smaller values of $P$.

[43] Our result is in contrast to Neuenkirch and Tillmann (2014) who use ex-post revised data and private sector forecasts, they find that the BoC responds to positive persistent past inflation deviations. Even when we use the same monetary policy specification with the same forecast horizons, same variables, and the same sample period as them, we find that the past inflation deviations terms remain statistically insignificant.

[44] The specification with $Q = 9$ is selected based on the information criteria AIC, BIC and HQIC. In Section 3.2 of the Appendix, we report the results for $Q = 6, 7, \ldots, 12$.

[45] One standard deviation of the expected future inflation deviation variable, equation (4), is equivalent to inflation overshooting (or undershooting) its target by 0.766 percentage points.

[46] $0.01 \times 0.01 \times 90.294 \times 100 = 0.90294$, i.e., 90.294 basis points.

[47] $0.02 \times 0.02 \times 90.294 \times 100 = 3.61176$, i.e., 361.176 basis points.

inflation forecasts ($Q \geq 6$), implying that persistent deviations appear to elicit a response by the BoC, but the transitory ones do not. Although our sample ends in 2015, our results align with the BoC's behaviour in 2021 and 2022. In 2021, the BoC did not respond to the rising inflation as it was perceived to be transitory.[48] But in 2022, when the expected inflation deviations from the target appeared to be more persistent than originally forecasted, the BoC started raising the policy rate, admitting elevated persistent inflation pressures.[49]

Next, we explore if the BoC has an asymmetric reaction to the positive and negative expected future inflation deviations. The results are contained in Column 4 of Table 5. Although both coefficients $\phi_{id}^{pos}$ and $\phi_{id}^{neg}$ have the expected sign, only the negative inflation deviation term is statistically significant at the 1% level. The BoC appears to respond only to persistent negative expected future inflation deviations, suggesting that between 1995Q1 and 2015Q4 the BoC appears to be more concerned about inflation undershooting than overshooting. The asymmetric response is robust to alternative values of $Q$.[50] When we use $Q = 6, \ldots, 12$ in equation (4), the coefficient $\phi_{id}^{neg}$ is always statistically significant at least at the 5% level, whereas the coefficient $\phi_{id}^{pos}$ is never statistically significant at conventional statistical significance levels.

We then investigate the effects on the asymmetric responses when using a sub-sample that excludes the period after the GFC as this period was dominated by sizeable negative inflation deviations. We re-estimate equations (5) and (6) using the period between 1995Q1 and 2007Q4. The results are contained in Table 6. When we exclude the GFC period from the estimation, the negative inflation deviations coefficient, $\phi_{id}^{neg}$, remains statistically significant at the 5% level and its magnitude declines slightly. We also find

[48] In the July 2021 monetary policy report press conference opening statement, Governor Macklem said that "We expect the factors pushing up inflation to be temporary."

[49] In the April 2022 monetary policy report press conference opening statement, Governor Macklem said that "... inflation is too high. It is higher than we expected, and it's going to be elevated for longer than we previously thought. ... we need higher interest rates."

[50] See Table 9 in the Appendix.

that the exclusion of the GFC period makes the positive inflation deviations coefficient, $\phi_{id}^{pos}$, statistically significant at the 10% level and its magnitude increases substantially. During this period, the BoC appears to respond to both positive and negative inflation deviations, but the response to positive inflation deviations is almost four times as big as the response to negative inflation deviations. The aggressive response to persistent positive inflation deviations aligns with the BoC's multiple rate hikes in 2022. Between March and December 2022, there were 7 consecutive interest rate hikes and the policy rate increased by 4 percentage points. The BoC stated that interest rates could rise further, and the ongoing quantitative tightening is complementing policy rate hikes to ensure that inflation eventually returns to its 2% inflation target.

Table 6: Monetary Policy Reaction Function with Persistent Inflation Deviations
1995Q1 – 2007Q4

| **Variables** | (1) | (2) |
|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.911*** | 0.923*** |
| | (0.045) | (0.047) |
| $\phi_r$ : *Real Int. Rate* | 0.177** | 0.165** |
| | (0.082) | (0.068) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.206 | 0.136 |
| | (0.169) | (0.160) |
| $\phi_x$ : *Exp. Output Gap* | 0.189** | 0.213** |
| | (0.083) | (0.082) |
| $\phi_{id}$ : *Infl. Deviation* | 94.509** | |
| | (39.707) | |
| $\phi_{id}^{pos}$ : *Pos. Infl. Deviation* | | 287.270* |
| | | (164.130) |
| $\phi_{id}^{neg}$ : *Neg. Infl. Deviation* | | 75.280** |
| | | (33.345) |
| *N* | 52 | 52 |
| *Adj.* $R^2$ | 0.914 | 0.917 |
| *S.E. of Regression* | 0.004 | 0.004 |

Note: [1] Estimation of equations (5) and (6). [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

## 4.2 Stability of the Persistent Inflation Deviation Terms

In this section, we investigate the time variation of the BoC's response to the persistent deviations using recursive rolling regressions. We anchor the starting date in 1995Q1 and increase the estimation window by one quarter each time. Figures 8 and 9 plot the point estimates and the 95% confidence intervals for all the coefficients in specifications (5) and (6), respectively. The date on the horizontal axis shows the end date of each recursive rolling window.

The results in Figure 8 reveal that during the post-disinflation period the BoC is shifting its responsiveness from the four-quarters ahead expected inflation to the persistent inflation deviations and the output gap. We find that once the estimation window includes 2001Q4, the persistent inflation deviations and the output gap coefficients become statistically significant at the 5% level, whereas the four-quarters ahead expected inflation coefficient declines and becomes insignificant.

The results in Figure 9 confirm the BoC's asymmetric responses to persistent inflation overshoots and undershoots and also reveal that the asymmetric responses are time-varying. As more observations are added in the recursive rolling regressions, the estimated coefficients for the positive and negative inflation deviations are moving in the opposite direction. We find that the positive inflation deviations coefficient is large and statistically significant at the 5% level when the estimation window includes data up until 2005Q3, implying that during the first half of the post-disinflation period there is evidence that the BoC is responding aggressively to persistent expected inflation overshoots. The coefficient on the positive inflation deviations is considerably larger than the coefficient on the negative inflation deviations.[51] But as the estimation window increases beyond 2005Q3, the coefficient on the positive inflation deviations declines and eventually be-

[51] During the period 1995Q1 and 2005Q3, we find that positive inflation deviations coefficient is statistically different from the negative one at the 10% significance level, and we fail to reject the hypothesis that the positive inflation deviations coefficient is four times larger than the negative one at conventional statistical significance levels.

Figure 8: Monetary Policy Reaction Function with Symmetric Response to Inflation Deviation: Recursive Regression (Anchor in 1995Q1), Short-Run Coefficients

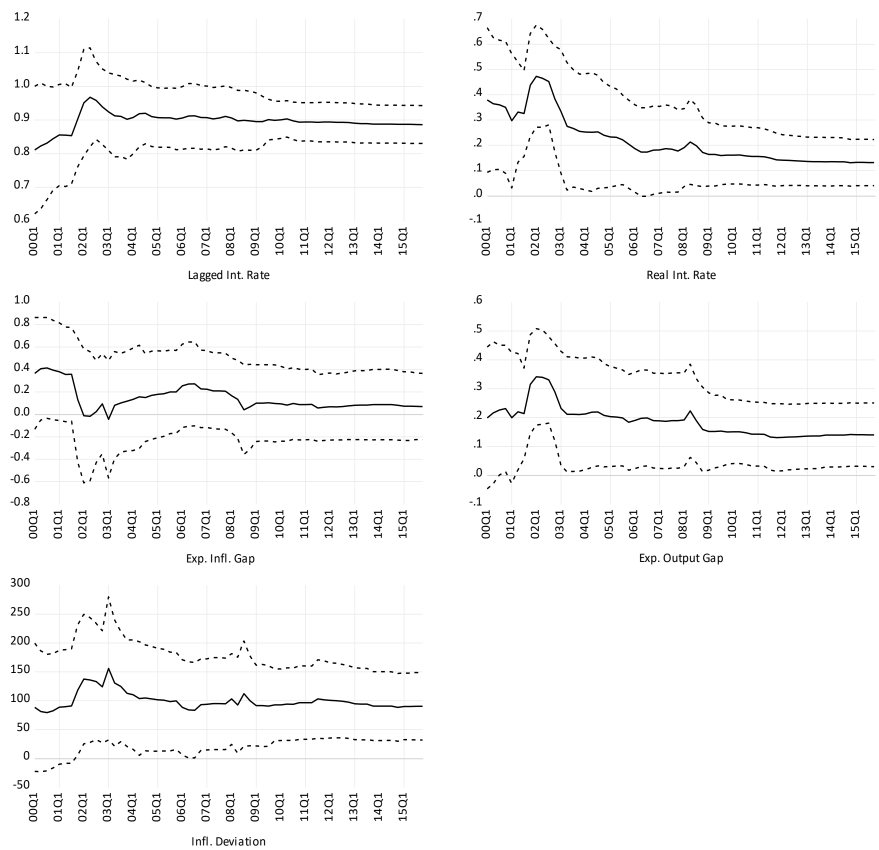
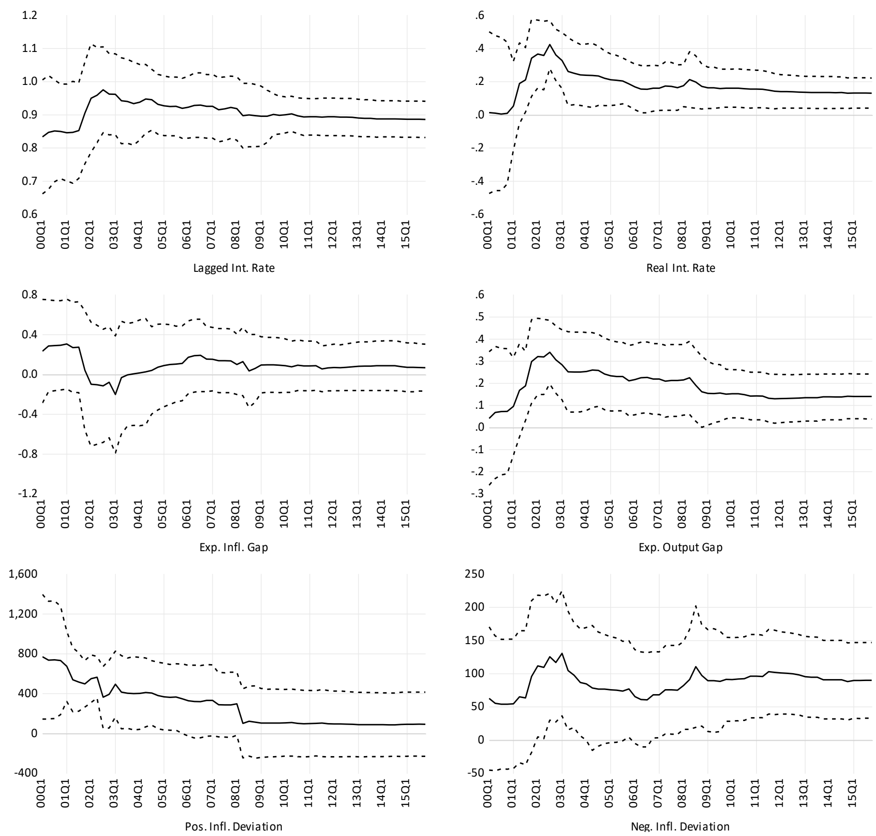


Figure 9: Monetary Policy Reaction Function with Asymmetric Response to Inflation Deviation: Recursive Regression (Anchor in 1995Q1), Short-Run Coefficients



comes statistically insignificant. In contrast, the negative inflation deviations coefficient rises and becomes statistically significant at the 5% level once the estimation window includes 2002Q1. The negative inflation deviations coefficient remains statistically significant as the estimation window expands towards the end of our sample period. The initial strong response to positive inflation deviations can be partly due to the central bank's asymmetric preferences as in Ruge-Murcia (2003), Surico (2007) and Komlan (2013). The shift in the asymmetric responses and the increased emphasis on the negative inflation deviations, especially after the GFC period, align with the findings of Bianchi et al. (2021), Maih et al. (2021) and Clarida (2022). In an environment with ELB and a low neutral real rate, the optimal monetary policy rule calls for asymmetric responses to inflation, that is, more aggressive response to negative inflation deviations than to positive inflation deviations. The asymmetry arises because the ELB and the low neutral real rate reduce the policy space available to counteract recessionary shocks while central banks have plenty of policy space to counteract inflationary shocks.

Overall, the results in Figure 9 suggest that there are two key changes in the BoC's behaviour during the post-disinflation period. First, the BoC stops responding to the four-quarters ahead expected inflation and starts responding to persistent expected future inflation deviations and the output gap. Second, the BoC responds asymmetrically to *positive* future inflation deviations (i.e. overshoots) and *negative* future inflation deviations (i.e. undershoots), and that the estimated coefficients and the statistical significance of the asymmetric responses are time-varying.

## 5 Conclusion

Our paper provides insights on how the BoC is conducting monetary policy. The BoC is forward looking. It appears that the state of the economy has become an important consideration in the BoC's decision-making process. The BoC is always responding to an inflation measure; initially, it was the one-year ahead inflation, but later it was persistent expected future inflation deviations, that is the average of at least a year and half of expected future inflation deviations. The BoC is also responding asymmetrically to persistent future inflation overshoots and undershoots.

Although our in-depth analysis of the Canadian monetary policy ends in 2015, our key findings are consistent with the BoC's behaviour in 2021 and 2022. Inflation started to rise in Canada in the second quarter of 2021, but the BoC chose not to raise the policy rate. Instead, the BoC kept emphasizing the state of the economy as the Canadian economy was operating below its capacity for most of 2021. Another reason that the BoC did not respond to the higher inflation in 2021 was because the inflationary pressures were deemed transitory. These actions are consistent with our findings that the BoC responds to the output gap, and that transitory inflation deviations do not elicit a response. In early 2022, the BoC started raising the policy rate admitting that the inflation pressures were stronger and more persistent than originally forecasted. This is again consistent with our finding that the BoC responds to persistent expected future inflation deviations. Furthermore, the aggressive interest rate-hiking cycle in 2022 aligns with our finding that the BoC responds aggressively to persistent expected future inflation overshoots when the risk of hitting deflationary spirals is low.

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# Is the Bank of Canada Concerned about Inflation or the State of the Economy?
# Appendix

December 16, 2022

# 1 Inflation Targets

Table 1: Inflation Targets

| | Target 1 | Target 2 |
|---|---|---|
| 1991Q1 | 4.75 | 3 |
| 1991Q2 | 4.5 | 3 |
| 1991Q3 | 4.25 | 3 |
| 1991Q4 | 4 | 3 |
| 1992Q1 | 3.75 | 3 |
| 1992Q2 | 3.5 | 3 |
| 1992Q3 | 3.25 | 3 |
| **1992Q4** | **3** | **3** |
| 1993Q1 | 2.92 | 2.5 |
| 1993Q2 | 2.83 | 2.5 |
| 1993Q3 | 2.75 | 2.5 |
| 1993Q4 | 2.67 | 2.5 |
| 1994Q1 | 2.58 | 2.5 |
| **1994Q2** | **2.5** | **2.5** |
| 1994Q3 | 2.42 | 2 |
| 1994Q4 | 2.33 | 2 |
| 1995Q1 | 2.25 | 2 |
| 1995Q2 | 2.17 | 2 |
| 1995Q3 | 2.08 | 2 |
| **1995Q4** | **2** | **2** |

# 2 Additional Results: Baseline

## 2.1 Alternative Forecast Horizons

Table 2: Baseline Monetary Policy Reaction Function with Different Forecast Horizons
1991Q1 - 2015Q4

| $(h_\pi, h_x)$ | $(0,0)$ | $(1,0)$ | $(2,0)$ | **(3,0)** | **(4,0)** | **(5,0)** | **(6,0)** |
|---|---|---|---|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.828*** | 0.830*** | 0.849*** | 0.859*** | 0.876*** | 0.876*** | 0.879*** |
| *Short − Run Coefficients* | | | | | | | |
| $\phi_r$ : *Real Int. Rate* | 0.198*** | 0.189*** | 0.162*** | 0.146*** | 0.127*** | 0.139*** | 0.146*** |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.118 | 0.158** | 0.131 | 0.188* | 0.306*** | 0.280*** | 0.250*** |
| $\phi_x$ : *Exp. Output Gap* | 0.091*** | 0.084** | 0.090*** | 0.087*** | 0.085*** | 0.087** | 0.084** |
| *Long − Run Coefficients* | | | | | | | |
| $\frac{\phi_r}{1-\rho}$ : *Real Int. Rate* | 1.154*** | 1.107*** | 1.076*** | 1.035*** | 1.023*** | 1.126*** | 1.202*** |
| $\frac{\phi_\pi}{1-\rho}$ : *Exp. Infl. Gap* | 0.686* | 0.925*** | 0.866* | 1.331** | 2.460*** | 2.262** | 2.060** |
| $\frac{\phi_x}{1-\rho}$ : *Exp. Output Gap* | 0.530* | 0.494* | 0.595** | 0.618** | 0.680* | 0.701* | 0.690* |
| *Adj.* $R^2$ | 0.946 | 0.948 | 0.947 | 0.948 | 0.950 | 0.949 | 0.948 |
| *AIC* | −7.612 | −7.637 | −7.622 | −7.639 | −7.674 | −7.667 | −7.654 |
| *SIC* | −7.481 | −7.507 | −7.491 | −7.508 | −7.544 | −7.537 | −7.524 |
| *HQIC* | −7.559 | −7.584 | −7.569 | −7.586 | −7.621 | −7.614 | −7.601 |
| $(h_\pi, h_x)$ | $(7,0)$ | $(1,1)$ | $(2,1)$ | **(3,1)** | **(4,1)** | **(5,1)** | **(6,1)** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.879*** | 0.839*** | 0.859*** | 0.867*** | 0.884*** | 0.885*** | 0.887*** |
| *Short − Run Coefficients* | | | | | | | |
| $\phi_r$ : *Real Int. Rate* | 0.150*** | 0.175*** | 0.150*** | 0.135*** | 0.117*** | 0.129*** | 0.136*** |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.191* | 0.148** | 0.119 | 0.179* | 0.306*** | 0.285*** | 0.253*** |
| $\phi_x$ : *Exp. Output Gap* | 0.087*** | 0.085** | 0.091*** | 0.088** | 0.087** | 0.091** | 0.087** |
| *Long − Run Coefficients* | | | | | | | |
| $\frac{\phi_r}{1-\rho}$ : *Real Int. Rate* | 1.235*** | 1.091*** | 1.061*** | 1.017*** | 1.009*** | 1.126*** | 1.207*** |
| $\frac{\phi_\pi}{1-\rho}$ : *Exp. Infl. Gap* | 1.571 | 0.923*** | 0.842 | 1.349* | 2.637** | 2.482** | 2.243** |
| $\frac{\phi_x}{1-\rho}$ : *Exp. Output Gap* | 0.715* | 0.531* | 0.647* | 0.665* | 0.752* | 0.788* | 0.771 |
| *Adj.* $R^2$ | 0.947 | 0.948 | 0.947 | 0.948 | 0.950 | 0.950 | 0.949 |
| *AIC* | −7.623 | −7.637 | −7.622 | −7.640 | −7.681 | −7.677 | −7.663 |
| *SIC* | −7.493 | −7.506 | −7.492 | −7.510 | −7.551 | −7.547 | −7.532 |
| *HQIC* | −7.571 | −7.584 | −7.569 | −7.587 | −7.628 | −7.625 | −7.610 |
| $(h_\pi, h_x)$ | (7, 1) | (2, 2) | **(3,2)** | **(4,2)** | **(5,2)** | **(6,2)** | (7, 2) |
| $\rho$ : *Lagged Int. Rate* | 0.887*** | 0.865*** | 0.872*** | 0.889*** | 0.891*** | 0.893*** | 0.893*** |
| *Short − Run Coefficients* | | | | | | | |
| $\phi_r$ : *Real Int. Rate* | 0.140*** | 0.143*** | 0.129*** | 0.112*** | 0.124*** | 0.131*** | 0.134*** |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.195* | 0.112 | 0.173 | 0.304*** | 0.288*** | 0.255*** | 0.199* |
| $\phi_x$ : *Exp. Output Gap* | 0.090*** | 0.103*** | 0.099*** | 0.098*** | 0.103** | 0.099** | 0.101*** |
| *Long − Run Coefficients* | | | | | | | |
| $\frac{\phi_r}{1-\rho}$ : *Real Int. Rate* | 1.242*** | 1.058*** | 1.012*** | 1.005*** | 1.133*** | 1.221*** | 1.257*** |
| $\frac{\phi_\pi}{1-\rho}$ : *Exp. Infl. Gap* | 1.727 | 0.827 | 1.354* | 2.736** | 2.640** | 2.387* | 1.859 |
| $\frac{\phi_x}{1-\rho}$ : *Exp. Output Gap* | 0.795* | 0.761* | 0.776* | 0.885* | 0.942* | 0.925 | 0.950* |
| *Adj.* $R^2$ | 0.947 | 0.947 | 0.948 | 0.950 | 0.950 | 0.949 | 0.948 |
| *AIC* | −7.631 | −7.626 | −7.644 | −7.687 | −7.687 | −7.672 | −7.641 |
| *SIC* | −7.501 | −7.496 | −7.513 | −7.557 | −7.557 | −7.542 | −7.510 |
| *HQIC* | −7.579 | −7.573 | −7.591 | −7.635 | −7.634 | −7.620 | −7.588 |
| $(h_\pi, h_x)$ | **(3,3)** | **(4,3)** | **(5,3)** | **(6,3)** | (7, 3) | **(4,4)** | **(5,4)** |
| $\rho$ : *Lagged Int. Rate* | 0.874*** | 0.891*** | 0.893*** | 0.895*** | 0.896*** | 0.891*** | 0.893*** |
| *Short − Run Coefficients* | | | | | | | |
| $\phi_r$ : *Real Int. Rate* | 0.122*** | 0.104*** | 0.116*** | 0.124*** | 0.127*** | 0.098*** | 0.109*** |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.173 | 0.306*** | 0.291*** | 0.261*** | 0.206* | 0.310*** | 0.295*** |
| $\phi_x$ : *Exp. Output Gap* | 0.107** | 0.107** | 0.113** | 0.108** | 0.111*** | 0.117** | 0.123** |
| *Long − Run Coefficients* | | | | | | | |
| $\frac{\phi_r}{1-\rho}$ : *Real Int. Rate* | 0.966*** | 0.954*** | 1.085*** | 1.179*** | 1.218*** | 0.893*** | 1.021*** |
| $\frac{\phi_\pi}{1-\rho}$ : *Exp. Infl. Gap* | 1.373* | 2.799** | 2.723** | 2.487* | 1.971 | 2.838** | 2.755** |
| $\frac{\phi_x}{1-\rho}$ : *Exp. Output Gap* | 0.850 | 0.978 | 1.052 | 1.035 | 1.062 | 1.071 | 1.154 |
| *Adj.* $R^2$ | 0.948 | 0.950 | 0.950 | 0.950 | 0.948 | 0.950 | 0.950 |
| *AIC* | −7.637 | −7.681 | −7.682 | −7.669 | −7.637 | −7.676 | −7.677 |
| *SIC* | −7.507 | −7.551 | −7.552 | −7.538 | −7.506 | −7.546 | −7.546 |
| *HQIC* | −7.584 | −7.629 | −7.629 | −7.616 | −7.584 | −7.624 | −7.624 |
| $(h_\pi, h_x)$ | **(6,4)** | (7, 4) | **(5,5)** | **(6,5)** | (7, 5) | **(6,6)** | (7, 6) |
| $\rho$ : *Lagged Int. Rate* | 0.895*** | 0.896*** | 0.890*** | 0.893*** | 0.894*** | 0.888*** | 0.889*** |
| *Short − Run Coefficients* | | | | | | | |
| $\phi_r$ : *Real Int. Rate* | 0.117*** | 0.121*** | 0.101*** | 0.110*** | 0.113*** | 0.105*** | 0.109*** |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.266*** | 0.213* | 0.310*** | 0.285*** | 0.238** | 0.307*** | 0.266** |
| $\phi_x$ : *Exp. Output Gap* | 0.119** | 0.122** | 0.123* | 0.118* | 0.120** | 0.110 | 0.110 |
| *Long − Run Coefficients* | | | | | | | |
| $\frac{\phi_r}{1-\rho}$ : *Real Int. Rate* | 1.121*** | 1.161*** | 0.917*** | 1.024*** | 1.071*** | 0.930*** | 0.984*** |
| $\frac{\phi_\pi}{1-\rho}$ : *Exp. Infl. Gap* | 2.545* | 2.053 | 2.820** | 2.665** | 2.246 | 2.730** | 2.403 |
| $\frac{\phi_x}{1-\rho}$ : *Exp. Output Gap* | 1.141 | 1.170 | 1.119 | 1.107 | 1.131 | 0.981 | 0.996 |
| *Adj.* $R^2$ | 0.949 | 0.947 | 0.948 | 0.948 | 0.946 | 0.947 | 0.945 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *AIC* | −7.664 | −7.633 | −7.652 | −7.642 | −7.610 | −7.617 | −7.586 |
| *SIC* | −7.534 | −7.502 | −7.522 | −7.512 | −7.480 | −7.487 | −7.455 |
| *HQIC* | −7.612 | −7.580 | −7.599 | −7.589 | −7.557 | −7.565 | −7.533 |

Note: [1] Estimation of equation (1) with different forecast horizons. [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The standard errors (available upon request) for the coefficients are estimated with a Newey-West HAC estimator.

## 2.2 AR Error Terms

Table 3: Baseline Monetary Policy Reaction Function with AR Error Terms
1991Q1-2015Q4

| **Variables** | Baseline | AR(1) | AR(1) & AR(2) | AR(1) & AR(2) & AR(3) | AR(1) & AR(2) & AR(3) & AR(4) |
|---|---|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.889*** | 0.888*** | 0.890*** | 0.889*** | 0.889*** |
| | (0.028) | (0.044) | (0.042) | (0.053) | (0.053) |
| $\phi_r$ : *Real Int. Rate* | 0.112*** | 0.112*** | 0.111*** | 0.110** | 0.110** |
| | (0.031) | (0.042) | (0.041) | (0.046) | (0.046) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.304*** | 0.303** | 0.310*** | 0.274** | 0.263* |
| | (0.106) | (0.116) | (0.115) | (0.131) | (0.135) |
| $\phi_x$ : *Exp. Output Gap* | 0.098*** | 0.098** | 0.097** | 0.102** | 0.098** |
| | (0.036) | (0.041) | (0.041) | (0.045) | (0.043) |
| *AR*(1) | | 0.010 | 0.008 | 0.018 | 0.033 |
| | | (0.094) | (0.094) | (0.098) | 0.097 |
| *AR*(2) | | | −0.046 | -0.039 | -0.044 |
| | | | (0.122) | (0.160) | (0.165) |
| *AR*(3) | | | | 0.147 | 0.149 |
| | | | | (0.125) | (0.123) |
| *AR*(4) | | | | | −0.089 |
| | | | | | (0.152) |
| *Adj.* $R^2$ | 0.950 | 0.949 | 0.949 | 0.949 | 0.949 |
| *AIC* | −7.687 | −7.647 | −7.629 | −7.630 | −7.617 |
| *SIC* | −7.557 | −7.465 | −7.421 | −7.395 | −7.357 |
| *HQIC* | −7.635 | −7.574 | −7.545 | −7.535 | −7.512 |

Note: [1] Estimation of equation (1) with AR error terms. [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

## 2.3 Governor's Tenure

Table 4: Baseline Monetary Policy Reaction Function

Governor Specific Effects

| Variables | | | |
|---|---|---|---|
| $\rho^{Crow}$ : *Lagged Int. Rate* | 0.414 | $\rho^{Thiessen}$ : *Lagged Int. Rate* | 0.759*** |
| | (0.265) | | (0.089) |
| $\phi_r^{Crow}$ : *Real Int. Rate* | −0.402 | $\phi_r^{Thiessen}$ : *Real Int. Rate* | −0.007 |
| | (0.270) | | (0.119) |
| $\phi_\pi^{Crow}$ : *Exp. Infl. Gap* | 0.491** | $\phi_\pi^{Thiessen}$ : *Exp. Infl. Gap* | 0.697*** |
| | (0.230) | | (0.130) |
| $\phi_x^{Crow}$ : *Exp. Output Gap* | −0.684* | $\phi_x^{Thiessen}$ : *Exp. Output Gap* | 0.032 |
| | (0.363) | | (0.119) |
| $\rho^{Dodge}$ : *Lagged Int. Rate* | 0.804*** | $\rho^{Carney}$ : *Lagged Int. Rate* | 0.764*** |
| | (0.031) | | (0.028) |
| $\phi_r^{Dodge}$ : *Real Int. Rate* | −0.122*** | $\phi_r^{Carney}$ : *Real Int. Rate* | 0.021 |
| | (0.041) | | (0.017) |
| $\phi_\pi^{Dodge}$ : *Exp. Infl. Gap* | 0.021 | $\phi_\pi^{Carney}$ : *Exp. Infl. Gap* | −0.233 |
| | (0.156) | | (0.147) |
| $\phi_x^{Dodge}$ : *Exp. Output Gap* | 0.428*** | $\phi_x^{Carney}$ : *Exp. Output Gap* | 0.245*** |
| | (0.063) | | (0.063) |
| $\rho^{Poloz}$ : *Lagged Int. Rate* | 0.880*** | | |
| | (0.194) | | |
| $\phi_r^{Poloz}$ : *Real Int. Rate* | 0.072 | | |
| | (0.047) | | |
| $\phi_\pi^{Poloz}$ : *Exp. Infl. Gap* | −0.052 | | |
| | (0.074) | | |
| $\phi_x^{Poloz}$ : *Exp. Output Gap* | 0.180* | | |
| | (0.106) | | |
| *N* | 100 | | |
| *Adj.* $R^2$ | 0.960 | | |
| *S.E. of Regression* | 0.005 | | |

Note: [1] Estimation of equation (1) for different governor tenures between 1991Q1 and 2015Q4: John Crow (1991Q1 – 1993Q4), Gordon Thiessen (1994Q1 - 2000Q4), David Dodge (2001Q1 - 2007Q4), Mark Carney (2008Q1 - 2013Q1), and Stephen Poloz (2013Q2 - 2015Q4). [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

## 2.4 Two Breakpoints

Table 5: Baseline Monetary Policy Reaction Function

Breakpoint Regression with Two Breakpoints

| **Variables** | 1991Q1 - 1999Q2 | 1999Q3 - 2007Q4 | 2008Q1 - 2015Q4 |
|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.696*** | 0.837*** | 0.783*** |
| | (0.099) | (0.036) | (0.024) |
| $\phi_r$ : *Real Int. Rate* | 0.028 | −0.068* | 0.026 |
| | (0.072) | (0.038) | (0.020) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.613*** | 0.057 | −0.148 |
| | (0.111) | (0.139) | (0.118) |
| $\phi_x$ : *Exp. Output Gap* | −0.082 | 0.480*** | 0.220*** |
| | (0.097) | (0.046) | (0.047) |
| *N* | 34 | 34 | 32 |
| *Adj.* $R^2$ | 0.850 | 0.950 | 0.963 |
| *S.E. of Regression* | 0.007 | 0.003 | 0.002 |

Note: [1] Estimation of equation (1) with breakpoints detected by Bai and Perron sequential test. [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

## 2.5 Different Anchor Dates

Figure 1: Baseline Monetary Policy Reaction Function: Recursive Regression

Anchor in 1994Q1, Short-Run Coefficients with Confidence Bands

Figure 2: Baseline Monetary Policy Reaction Function: Recursive Regression

Anchor in 1996Q1, Short-Run Coefficients with Confidence Bands

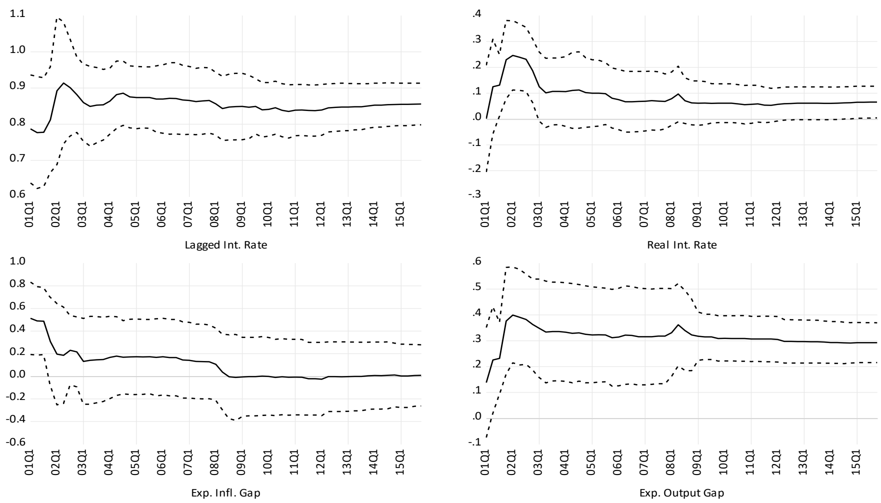
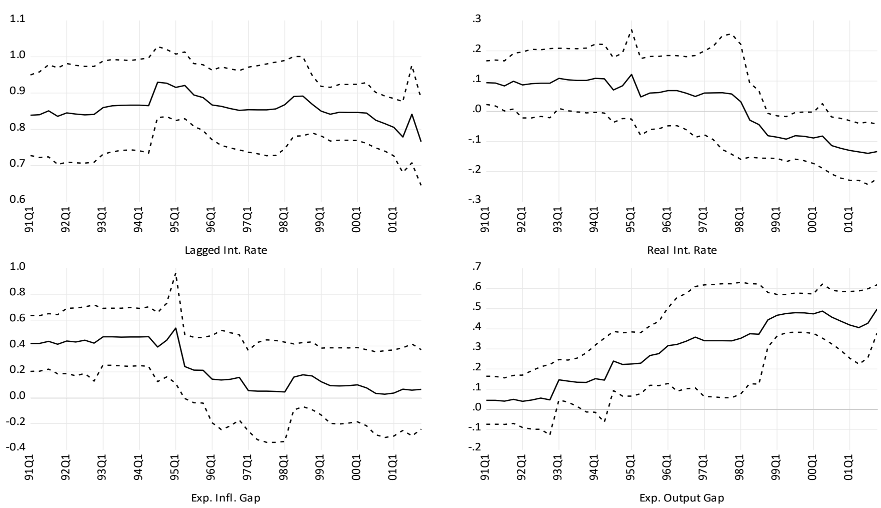



Figure 3: Baseline Monetary Policy Reaction Function: Reverse Recursive Regression

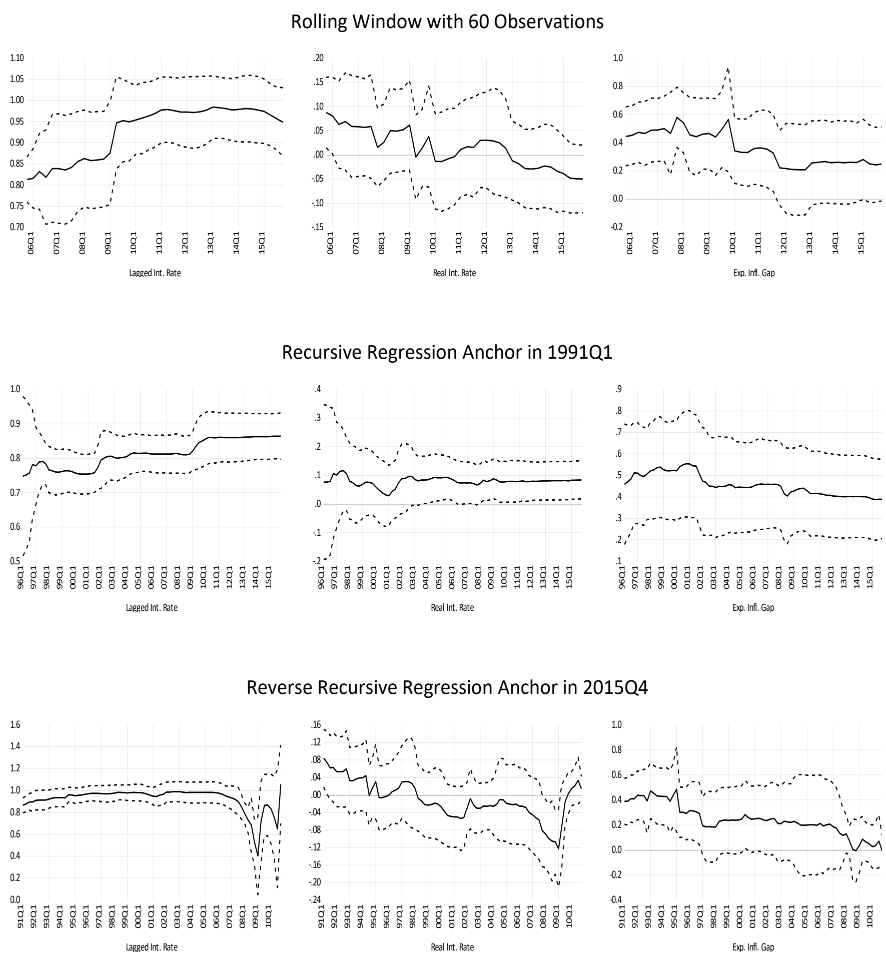
Anchor in 2006Q4, Short-Run Coefficients with Confidence Bands



## 2.6 Drop Output Gap

Figure 4: Monetary Policy Reaction Function without Output Gap

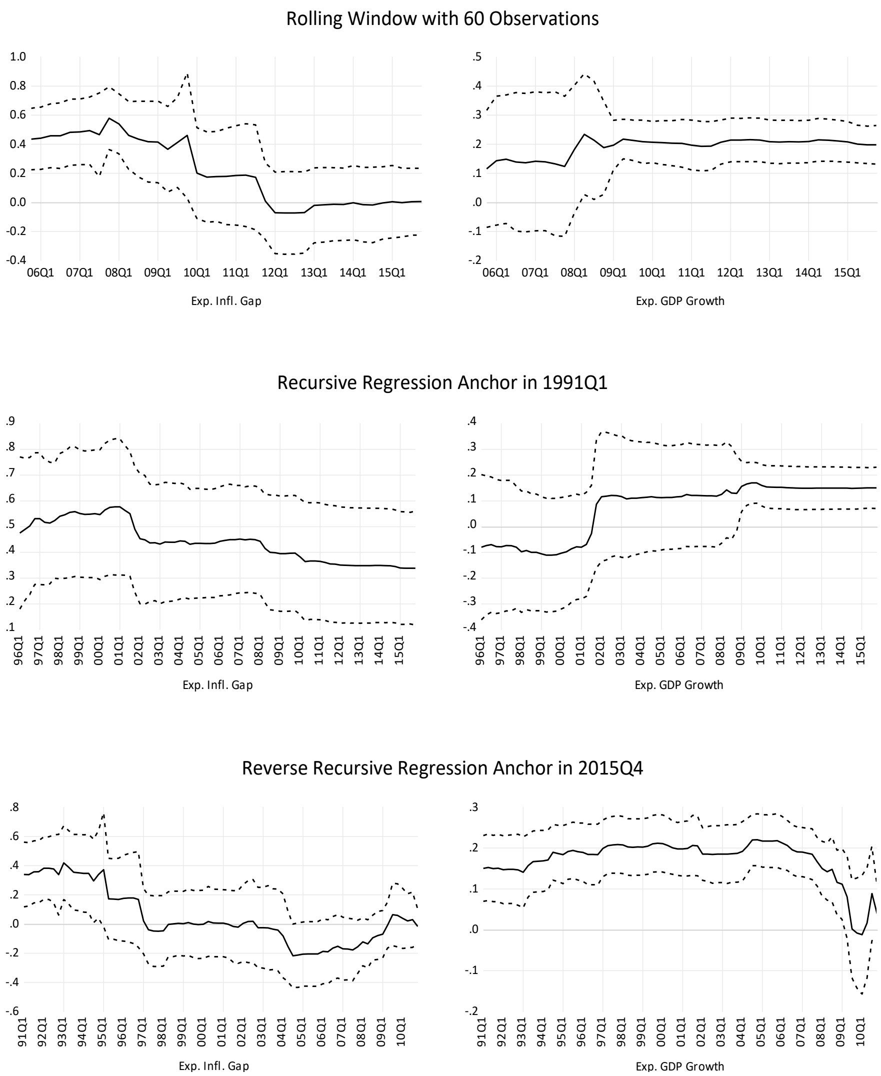
Rolling Regressions, Short-Run Coefficients with Confidence Bands



## 2.7 Use Real GDP Growth Rate Instead of Output Gap

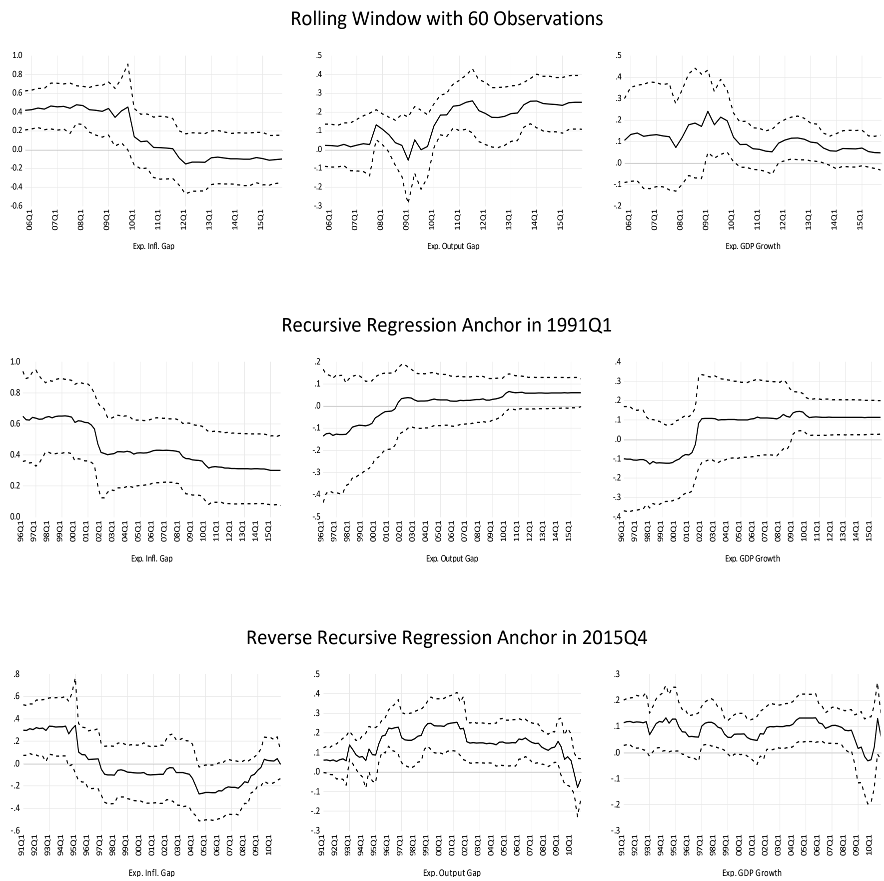
Figure 5: Monetary Policy Reaction Function Using Real GDP Growth Rate

Rolling Regressions, Short-Run Coefficients with Confidence Bands



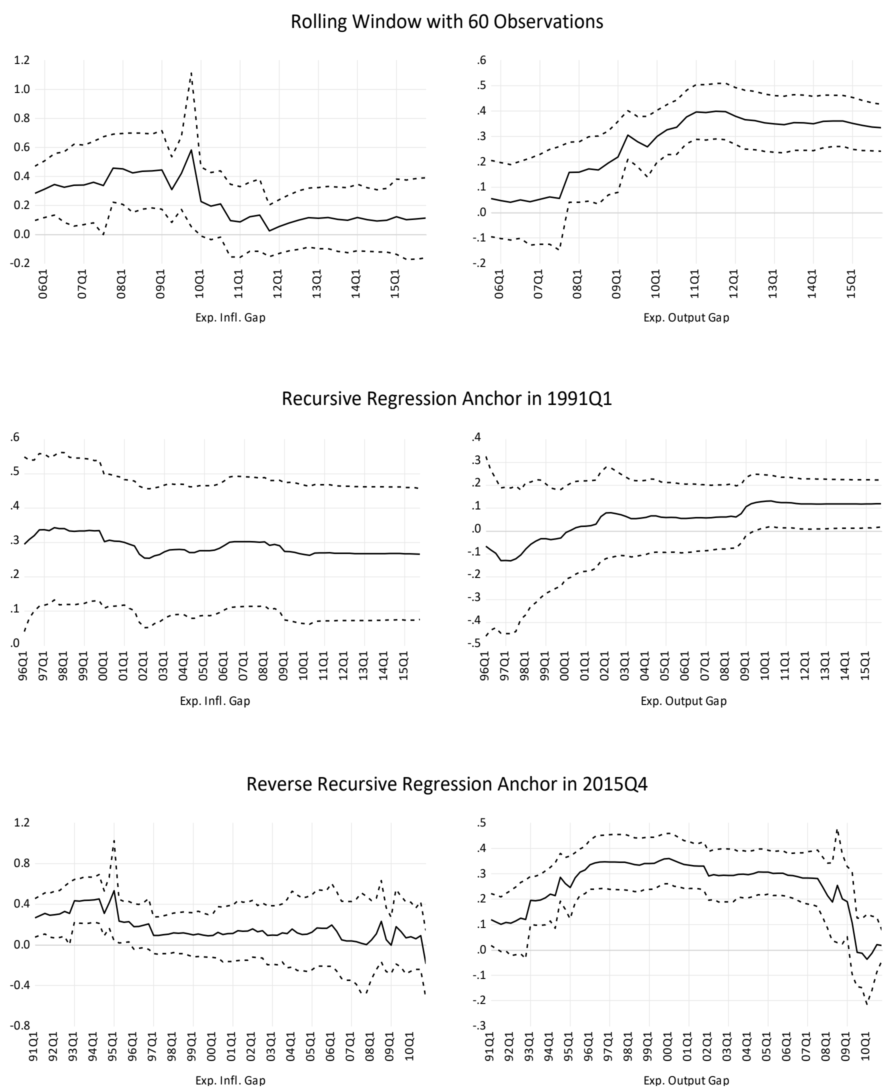
## 2.8 Include Both Real GDP Growth Rate and Output Gap

Figure 6: Monetary Policy Reaction Function Using Both Real GDP Growth Rate and Output Gap, Rolling Regressions, Short-Run Coefficients with Confidence Bands



## 2.9 Alternative Forecast Horizons for Inflation and Output Gap

Figure 7: Baseline Monetary Policy Reaction Function with Alternative Forecast Horizons $h_\pi = 6$ and $h_x = 4$, Rolling Regressions, Short-Run Coefficients with Confidence Bands



## 2.10 Alternative Policy Rates

In our baseline case, we use the average interest rate over the quarter (with the results repeated in Column 1 below). Our key results are robust when we use the average interest rate over the two meetings closest to the staff forecasts (reported in Column 2), or the interest rate in the month that the staff forecasts are produced (reported in Column 3), or the interest rate in the month after the staff forecasts (reported in Column 4).

Table 6: Baseline Monetary Policy Reaction Function Using

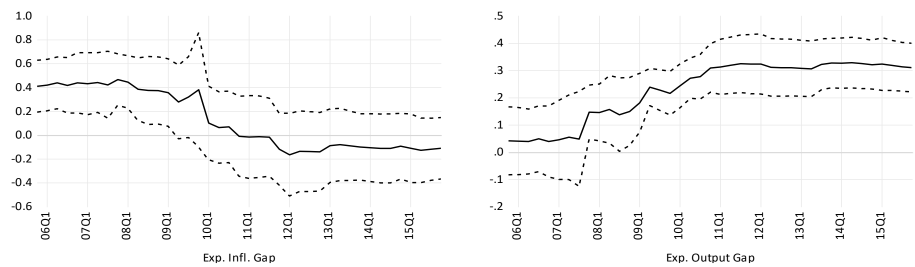
Different Policy Rate Measures, 1991Q1 - 2015Q4

| **Variables** | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.889*** | 0.878*** | 0.862*** | 0.871*** |
| | (0.028) | (0.027) | (0.034) | (0.033) |
| $\phi_r$ : *Real Int. Rate* | 0.112*** | 0.128*** | 0.136*** | 0.133*** |
| | (0.031) | (0.032) | (0.034) | (0.039) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.304*** | 0.304*** | 0.358*** | 0.248* |
| | (0.106) | (0.107) | (0.096) | (0.143) |
| $\phi_x$ : *Exp. Output Gap* | 0.098*** | 0.100*** | 0.097** | 0.097*** |
| | (0.036) | (0.030) | (0.038) | (0.030) |
| *N* | 100 | 100 | 100 | 100 |
| *Adj.* $R^2$ | 0.950 | 0.952 | 0.936 | 0.940 |
| *S.E. of Regression* | 0.005 | 0.005 | 0.006 | 0.005 |

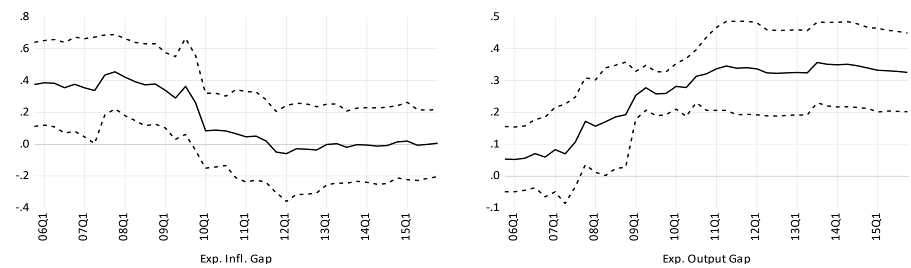
Note: [1] Estimation of equation (1). [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

Figure 8: Baseline Monetary Policy Reaction Function Using Different Policy Rate Measures, Rolling Window with 60 Observations

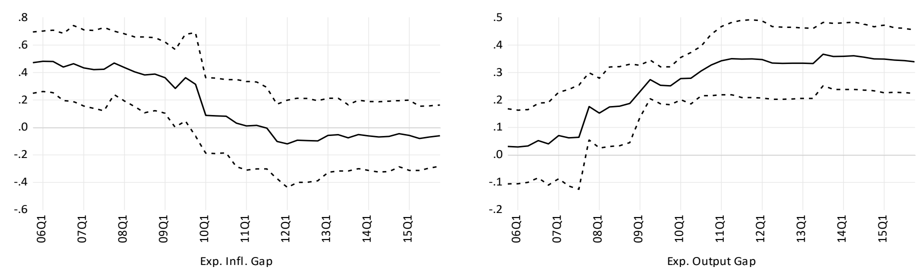
(1)




(2)




(3)




(4)

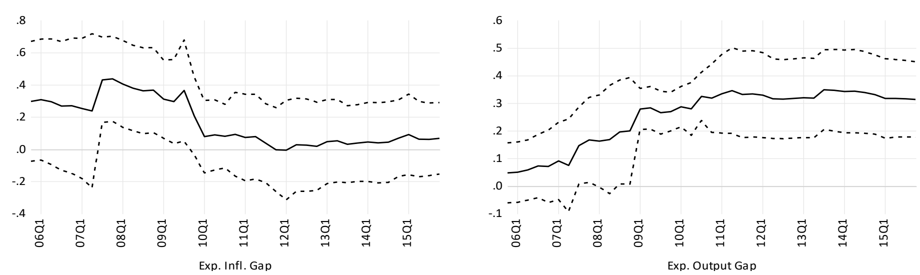


Figure 9: Baseline Monetary Policy Reaction Function Using Different Policy Rate Measures, Recursive Regression Anchor in 1991Q1

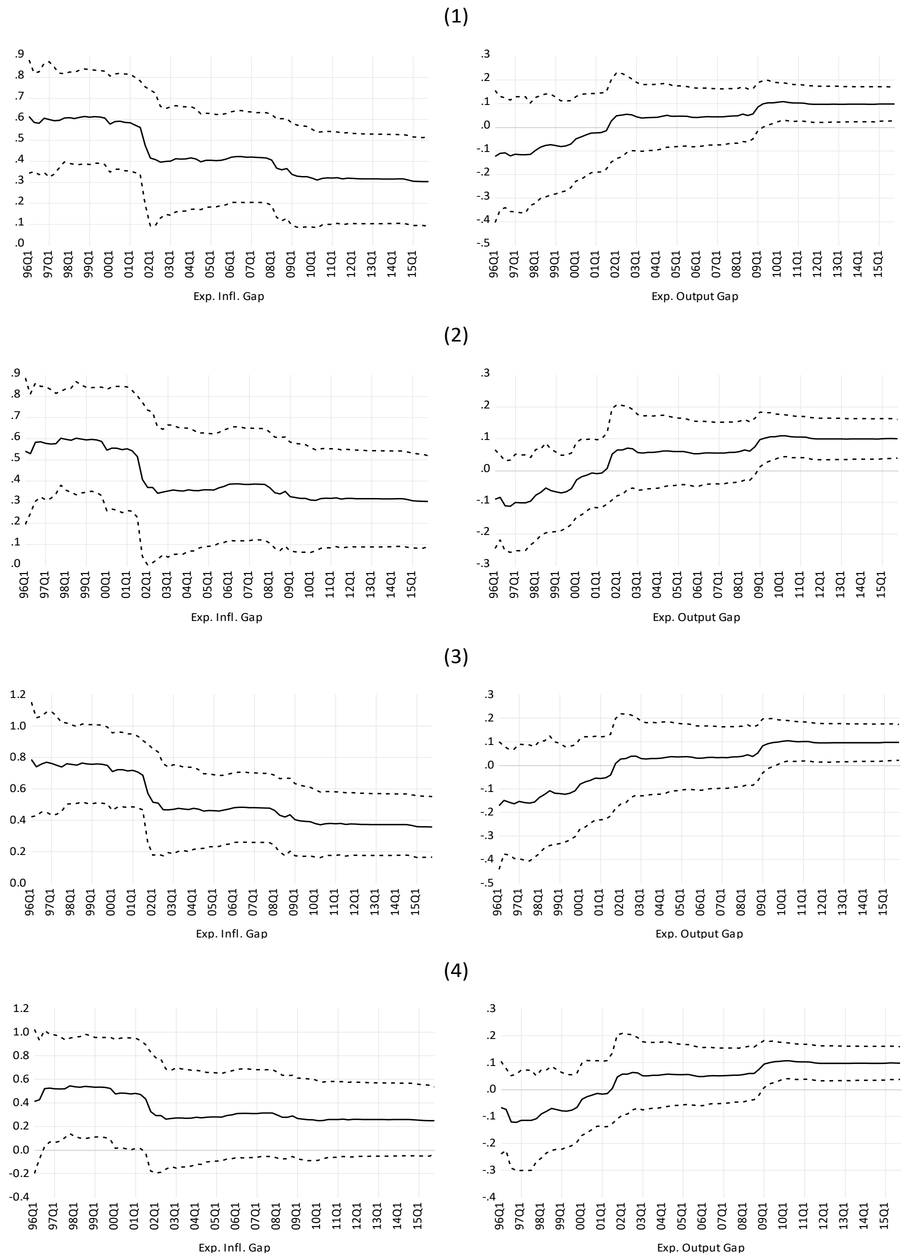
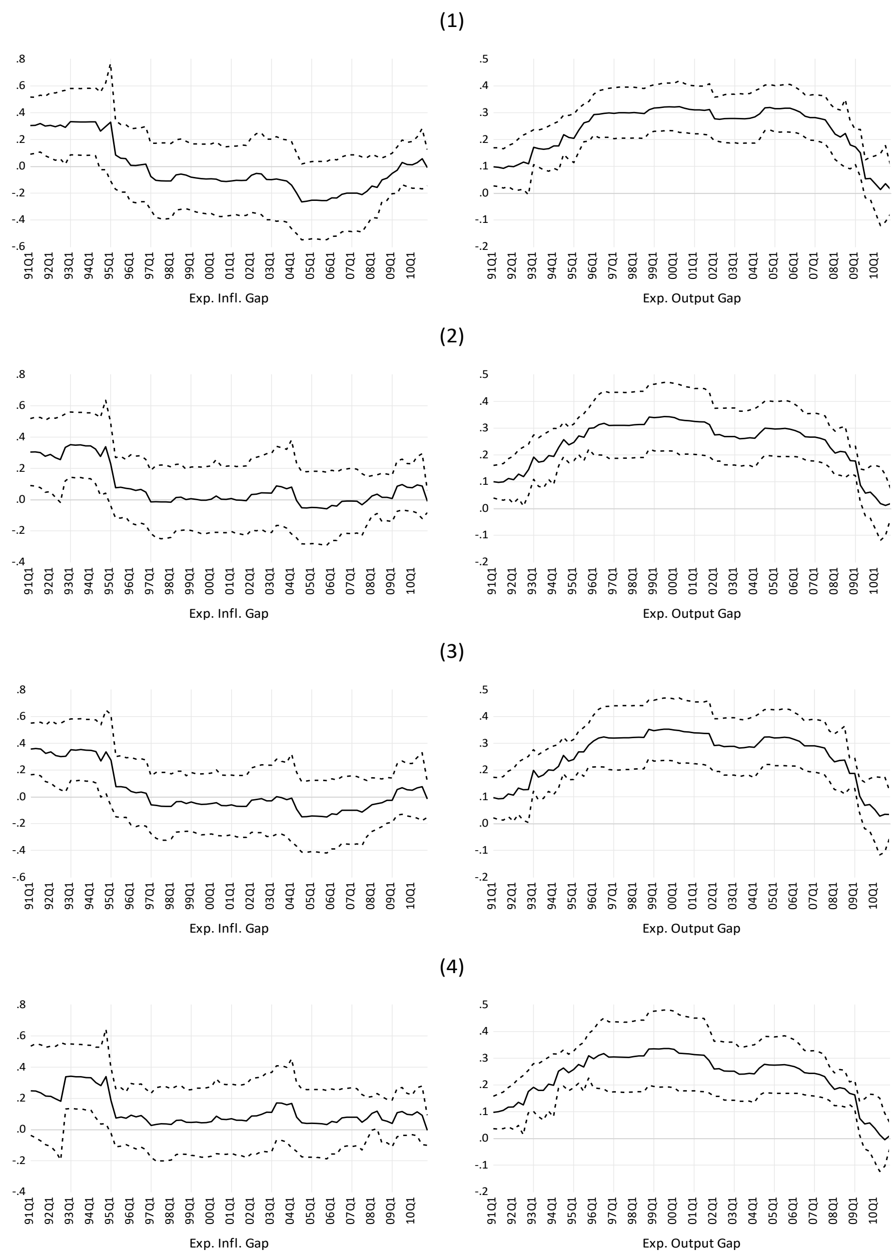


Figure 10: Baseline Monetary Policy Reaction Function Using Different Policy Rate Measures, Reverse Recursive Regression Anchor in 2015Q4



# 3 Additional Results: Persistent Inflation Deviation

## 3.1 Backward vs. Forward Inflation Deviations 1995Q1 - 2015Q4

Table 7: Backward and Forward Inflation Deviations: Basic Statistics

| **Variables** | *Backward Infl. Deviation* ($P = 16$) | *Forward Infl. Deviation* ($Q = 9$) |
|---|---|---|
| *Mean* | −0.000020 | −0.000011 |
| *Median* | −0.000005 | −0.000005 |
| *Maximum* | 0.000039 | 0.000028 |
| *Minimum* | −0.000169 | −0.000082 |
| *Std. Dev.* | 0.000045 | 0.000021 |

Table 8: Backward and Forward Inflation Deviations: Correlation Coefficients

| **Variables** | *Int. Rate* | *Lagged Int. Rate* | *Real Int. Rate* | *Exp. Infl. Gap* | *Exp. Output Gap* | *Backward Infl. Deviation* ($P = 16$) | *Forward Infl. Deviation* (Q=9) |
|---|---|---|---|---|---|---|---|
| *Int. Rate* | 1 | | | | | | |
| *Lagged Int. Rate* | 0.969 | 1 | | | | | |
| *Real Int. Rate* | 0.705 | 0.707 | 1 | | | | |
| *Exp. Infl. Gap* | 0.030 | −0.080 | −0.010 | 1 | | | |
| *Exp. Output Gap* | 0.205 | 0.089 | −0.165 | 0.255 | 1 | | |
| *Backward Infl. Deviation* (P=16) | −0.482 | −0.512 | −0.671 | 0.180 | 0.408 | 1 | |
| *Forward Infl. Deviation* (Q=9) | −0.020 | −0.153 | −0.354 | 0.655 | 0.590 | 0.447 | 1 |

## 3.2 Inflation Deviation with Different Forecast Horizons

Figure 11: Forward-looking Inflation Deviation

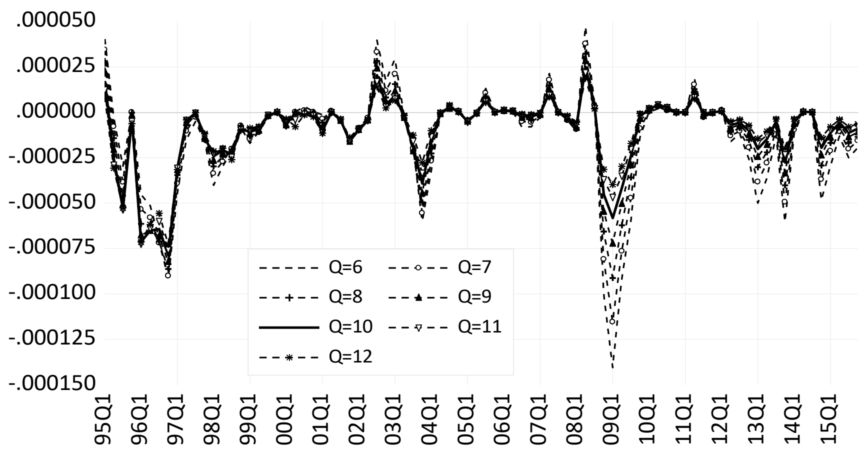



Table 9: Monetary Policy Reaction Function with Persistent Inflation Deviation
Different Forecast Horizons 1995Q1 - 2015Q4

| | $Q=6$ | $Q=7$ | $Q=8$ | $Q=9$ | $Q=10$ | $Q=11$ | $Q=12$ |
|---|---|---|---|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.879*** | 0.878*** | 0.881*** | 0.886*** | 0.892*** | 0.897*** | 0.900*** |
| | (0.025) | (0.027) | (0.027) | (0.028) | (0.029) | (0.029) | (0.030) |
| $\phi_r$ : *Real Int. Rate* | 0.111*** | 0.119*** | 0.126*** | 0.131*** | 0.132*** | 0.131*** | 0.127*** |
| | (0.042) | (0.043) | (0.044) | (0.045) | (0.046) | (0.047) | (0.047) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.172 | 0.122 | 0.086 | 0.069 | 0.077 | 0.101 | 0.138 |
| | (0.170) | (0.157) | (0.150) | (0.147) | (0.150) | (0.156) | (0.165) |
| $\phi_x$ : *Exp. Output Gap* | 0.161*** | 0.151*** | 0.144*** | 0.140** | 0.141** | 0.146** | 0.154** |
| | (0.053) | (0.053) | (0.054) | (0.055) | (0.057) | (0.058) | (0.059) |
| $\phi_{id}$ : *Infl. Deviation* | 41.828** | 59.902*** | 77.116*** | 90.294*** | 96.693*** | 96.492** | 89.296** |
| | (16.116) | (20.306) | (24.898) | (29.305) | (33.330) | (36.821) | (40.181) |
| *Adj.* $R^2$ | 0.963 | 0.964 | 0.964 | 0.964 | 0.964 | 0.964 | 0.963 |
| *AIC* | −8.344 | −8.364 | −8.377 | −8.380 | −8.374 | −8.360 | −8.343 |
| *SIC* | −8.171 | −8.191 | −8.203 | −8.207 | −8.200 | −8.187 | −8.170 |
| *HQIC* | −8.274 | −8.295 | −8.307 | −8.311 | −8.304 | −8.291 | −8.274 |

| | $Q=6$ | $Q=7$ | $Q=8$ | $Q=9$ | $Q=10$ | $Q=11$ | $Q=12$ |
|---|---|---|---|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.878*** | 0.878*** | 0.881*** | 0.886*** | 0.893*** | 0.898*** | 0.903*** |
| | (0.025) | (0.026) | (0.027) | (0.027) | (0.027) | (0.028) | (0.028) |
| $\phi_r$ : *Real Int. Rate* | 0.111*** | 0.119*** | 0.126*** | 0.131*** | 0.133*** | 0.131*** | 0.126*** |
| | (0.041) | (0.042) | (0.044) | (0.045) | (0.046) | (0.047) | (0.047) |
| $\phi_\pi$ : *Exp. Infl. Gap* | 0.166 | 0.114 | 0.081 | 0.069 | 0.083 | 0.116 | 0.162 |
| | (0.142) | (0.126) | (0.119) | (0.118) | (0.121) | (0.130) | (0.144) |
| $\phi_x$ : *Exp. Output Gap* | 0.164*** | 0.154*** | 0.146*** | 0.140*** | 0.138** | 0.142** | 0.149** |
| | (0.048) | (0.048) | (0.049) | (0.051) | (0.054) | (0.056) | (0.059) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\phi_{id}^{pos}$ : *Pos. Infl. Deviation* | 53.680 | 77.985 | 90.328 | 92.585 | 75.630 | 44.000 | −6.235 |
| | (89.157) | (114.315) | (138.226) | (161.109) | (180.185) | (193.476) | (199.897) |
| $\phi_{id}^{neg}$ : *Neg. Infl. Deviation* | 39.621** | 56.917*** | 75.117*** | 89.991*** | 98.969*** | 100.803** | 94.846** |
| | (16.066) | (19.500) | (23.756) | (28.514) | (33.725) | (38.786) | (43.289) |
| *Adj.* $R^2$ | 0.963 | 0.963 | 0.964 | 0.964 | 0.964 | 0.963 | 0.963 |
| *AIC* | −8.321 | −8.342 | −8.353 | −8.357 | −8.351 | −8.339 | −8.325 |
| *SIC* | −8.119 | −8.139 | −8.151 | −8.154 | −8.148 | −8.137 | −8.123 |
| *HQIC* | −8.240 | −8.261 | −8.272 | −8.275 | −8.269 | −8.258 | −8.244 |

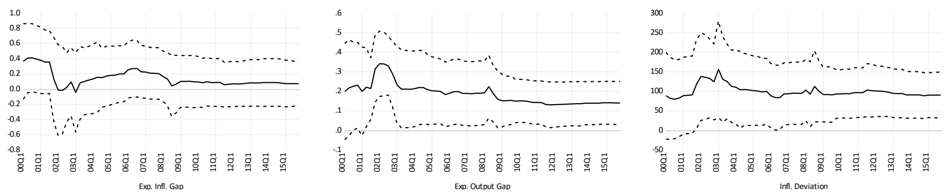
Note: [1] Estimation of equations (5) and (6) with different forecast horizons (Q). [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The standard errors (available upon request) for the coefficients are estimated with a Newey-West HAC estimator.

### 3.3 Alternative Policy Rates

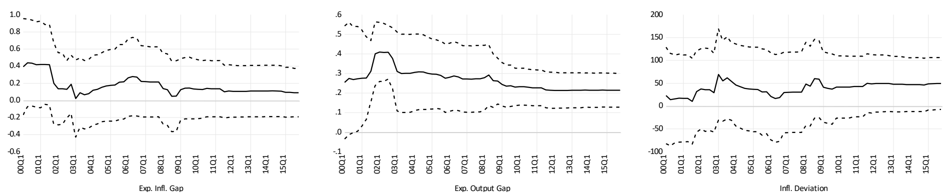
In the paper, we report the results using the average interest rate over the quarter (case 1 below). Our key results are robust when we use the average interest rate over the two meetings closest to the staff forecasts (case 2), or the interest rate in the month that the staff forecasts are produced (case 3), or the interest rate in the month after the staff forecasts (case 4).

Figure 12: Monetary Policy Reaction Function with Symmetric Response to Inflation Deviation Using Different Policy Rates: Recursive Regression (Anchor in 1995Q1)

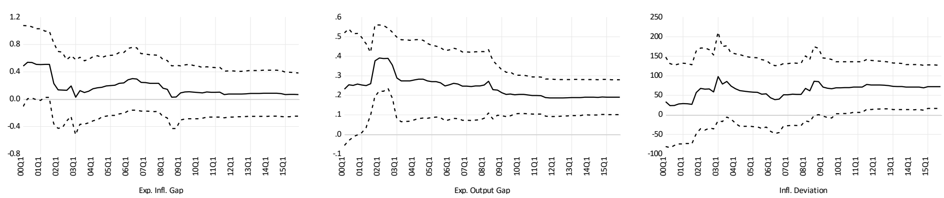
(1)




(2)




(3)




(4)

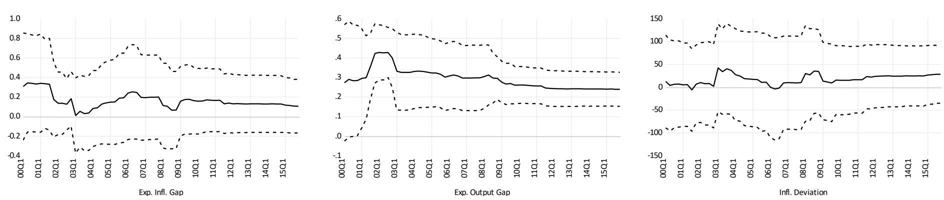
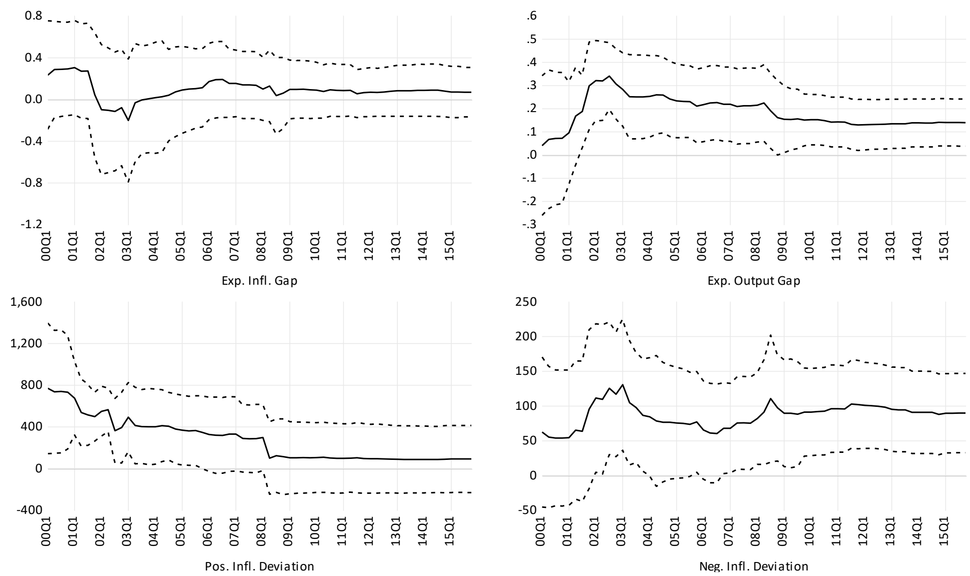
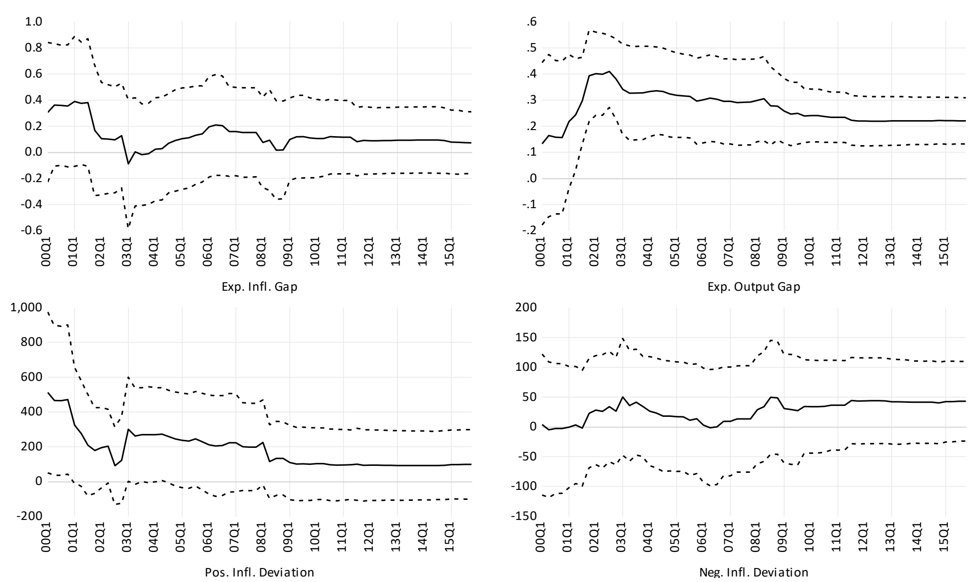


Figure 13: Monetary Policy Reaction Function with Asymmetric Response to Inflation Deviation Using Different Policy Rates: Recursive Regression (Anchor in 1995Q1)

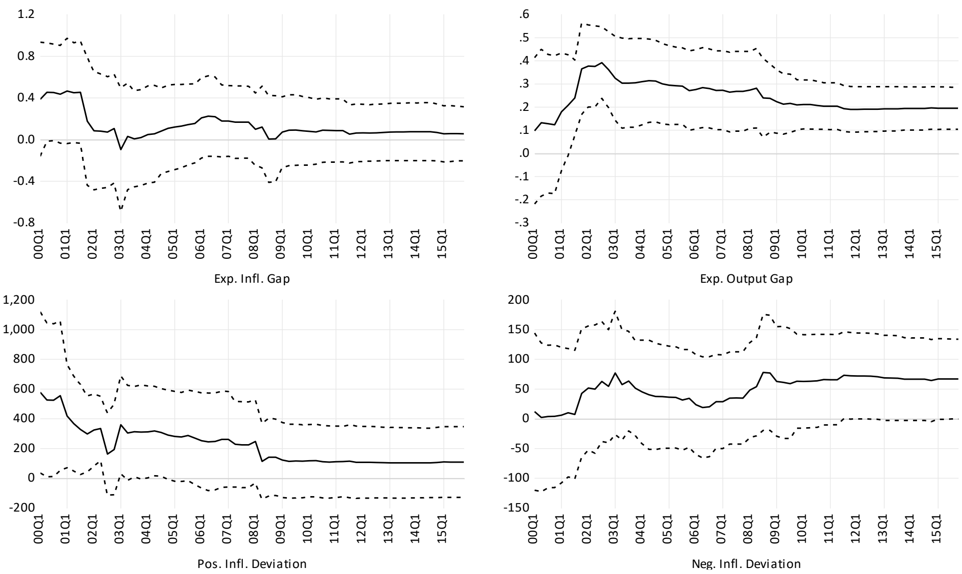
(1)



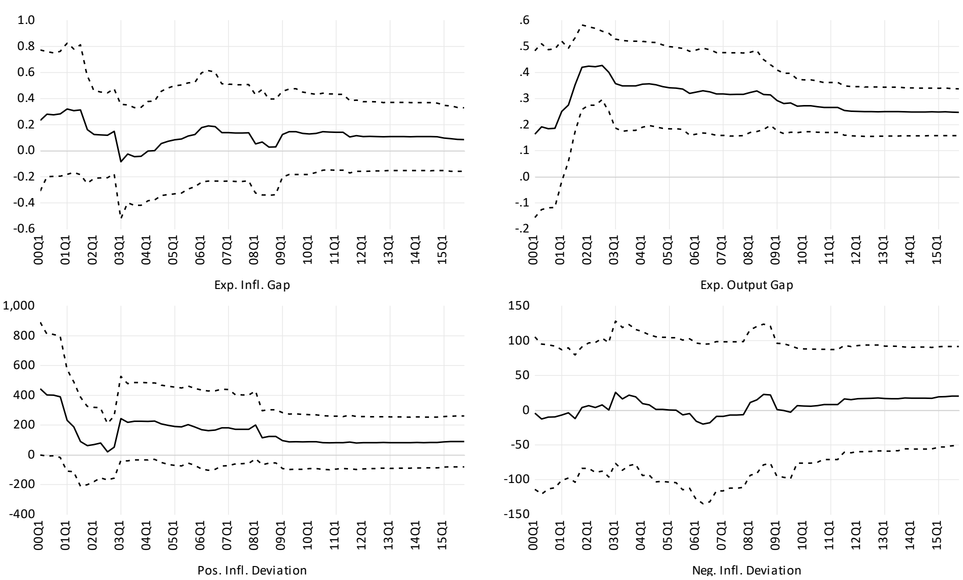

(2)



(3)


Exp. Infl. Gap
Exp. Output Gap
Pos. Infl. Deviation
Neg. Infl. Deviation

(4)


Exp. Infl. Gap
Exp. Output Gap
Pos. Infl. Deviation
Neg. Infl. Deviation

# 4 Using Core Inflation Instead of Headline Inflation

## 4.1 Baseline

Figure 14: Monetary Policy Reaction Function Using Core Inflation

Rolling Window with 60 Observations

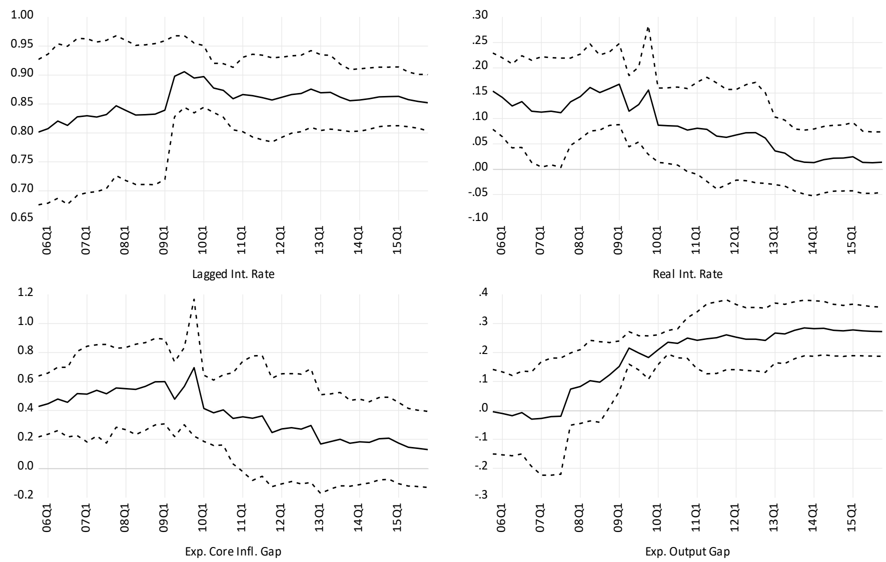


Figure 15: Monetary Policy Reaction Function Using Core Inflation

Recursive Regression Anchor in 1991Q1

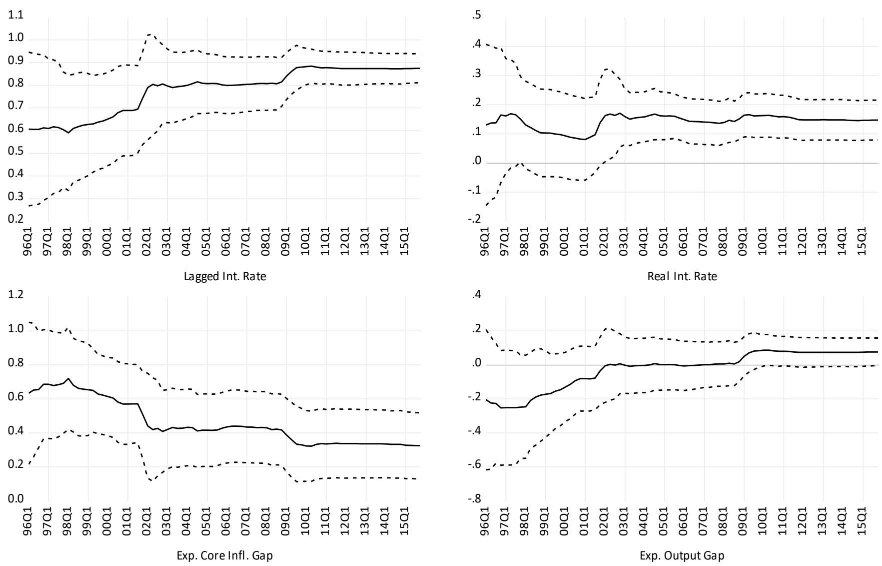


Figure 16: Monetary Policy Reaction Function Using Core Inflation

Reverse Recursive Regression Anchor in 2015Q4

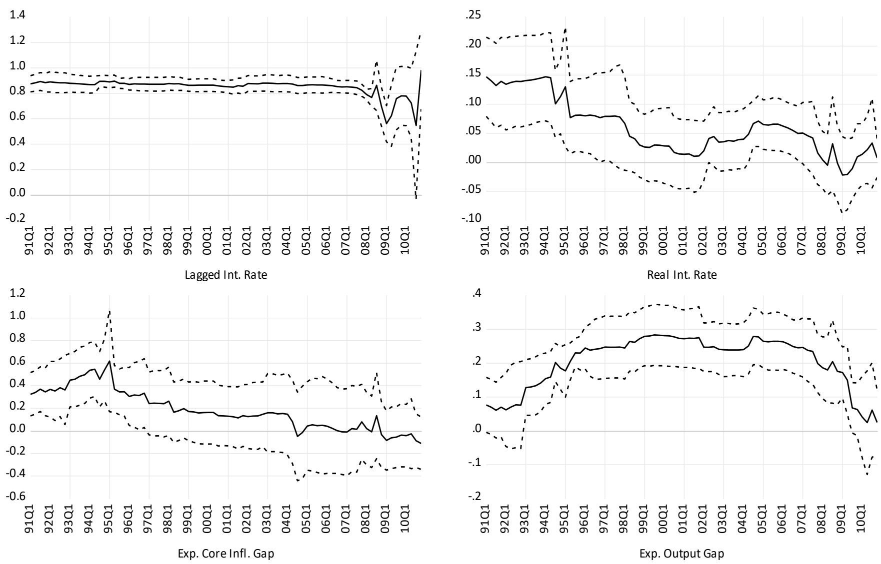


Table 10: Monetary Policy Reaction Function with Core Inflation: 1991Q1 - 2015Q4

| **Variables** | (1) Unemployment Gap | (2) GDP Growth | (3) Output Gap & GDP Growth | (4) Unemployment Gap & GDP Growth | (5) Exchange Rate | (6) TSX |
|---|---|---|---|---|---|---|
| $\rho$ : *Lagged Int. Rate* | 0.862*** | 0.884*** | 0.888*** | 0.887*** | 0.882*** | 0.858*** |
| | (0.024) | (0.030) | (0.030) | (0.023) | (0.034) | (0.037) |
| $\phi_r$ : *Real Int. Rate* | 0.137*** | 0.071* | 0.079* | 0.076* | 0.166*** | 0.116*** |
| | (0.032) | (0.042) | (0.041) | (0.041) | (0.035) | (0.036) |
| $\phi_\pi$ : *Exp. Core Infl. Gap* | 0.354*** | 0.413*** | 0.380*** | 0.348*** | 0.304*** | 0.337*** |
| | (0.095) | (0.097) | (0.105) | (0.094) | (0.096) | (0.098) |
| $\phi_x$ : *Exp. Output Gap* | | | 0.022 | | 0.095** | 0.096** |
| | | | (0.039) | | (0.044) | (0.042) |
| $\phi_{ue}$ : *Exp. Unemp. Gap* | −0.257** | | | −0.181* | | |
| | (0.124) | | | (0.094) | | |
| $\phi_{gy}$ : *Exp. GDP Growth* | | 0.152*** | 0.140** | 0.138*** | | |
| | | (0.031) | (0.037) | (0.034) | | |
| $\phi_{er}$ : *Exchange Rate* | | | | | 0.006 | |
| | | | | | (0.005) | |
| $\phi_{tsx}$ : *TSX* | | | | | | −0.003 |
| | | | | | | (0.002) |
| *N* | 100 | 100 | 100 | 100 | 100 | 100 |
| *Adj.* $R^2$ | 0.950 | 0.954 | 0.954 | 0.955 | 0.950 | 0.950 |
| *S.E. of Regression* | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |

Note: [1] Robustness analysis of equation (1) with core inflation. [2] The dependent variable is the monetary policy rate ($i_t$). [3] The symbols *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Newey-West HAC standard errors are reported in parentheses.

## 4.2 With Persistent Inflation Deviation

Figure 17: Monetary Policy Reaction Function with Symmetric Response to Inflation Deviation Using Core Inflation, Recursive Regression Anchor in 1999Q1

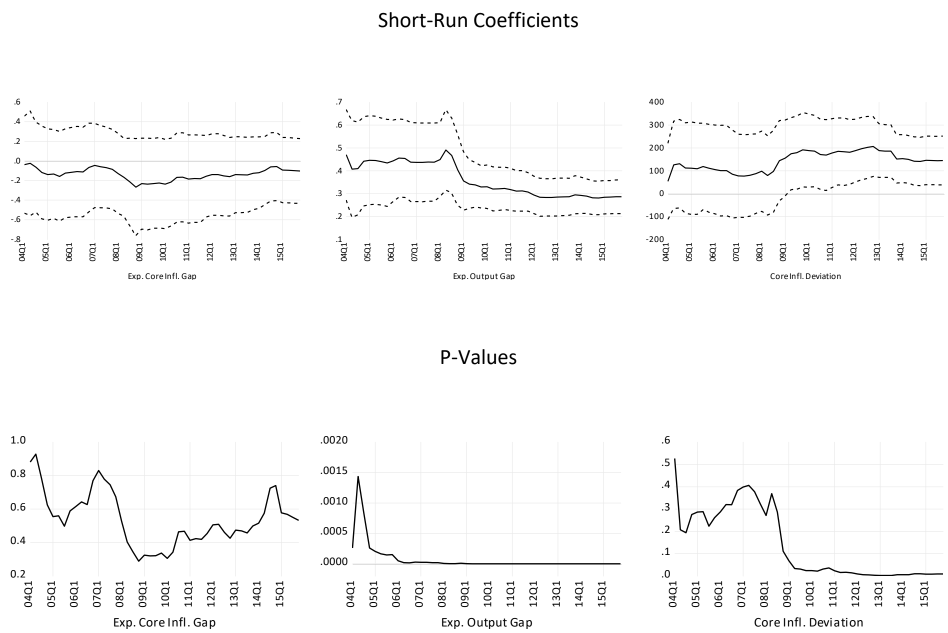


Figure 18: Monetary Policy Reaction Function with Asymmetric Response to Inflation Deviation Using Core Inflation, Recursive Regression Anchor in 1999Q1

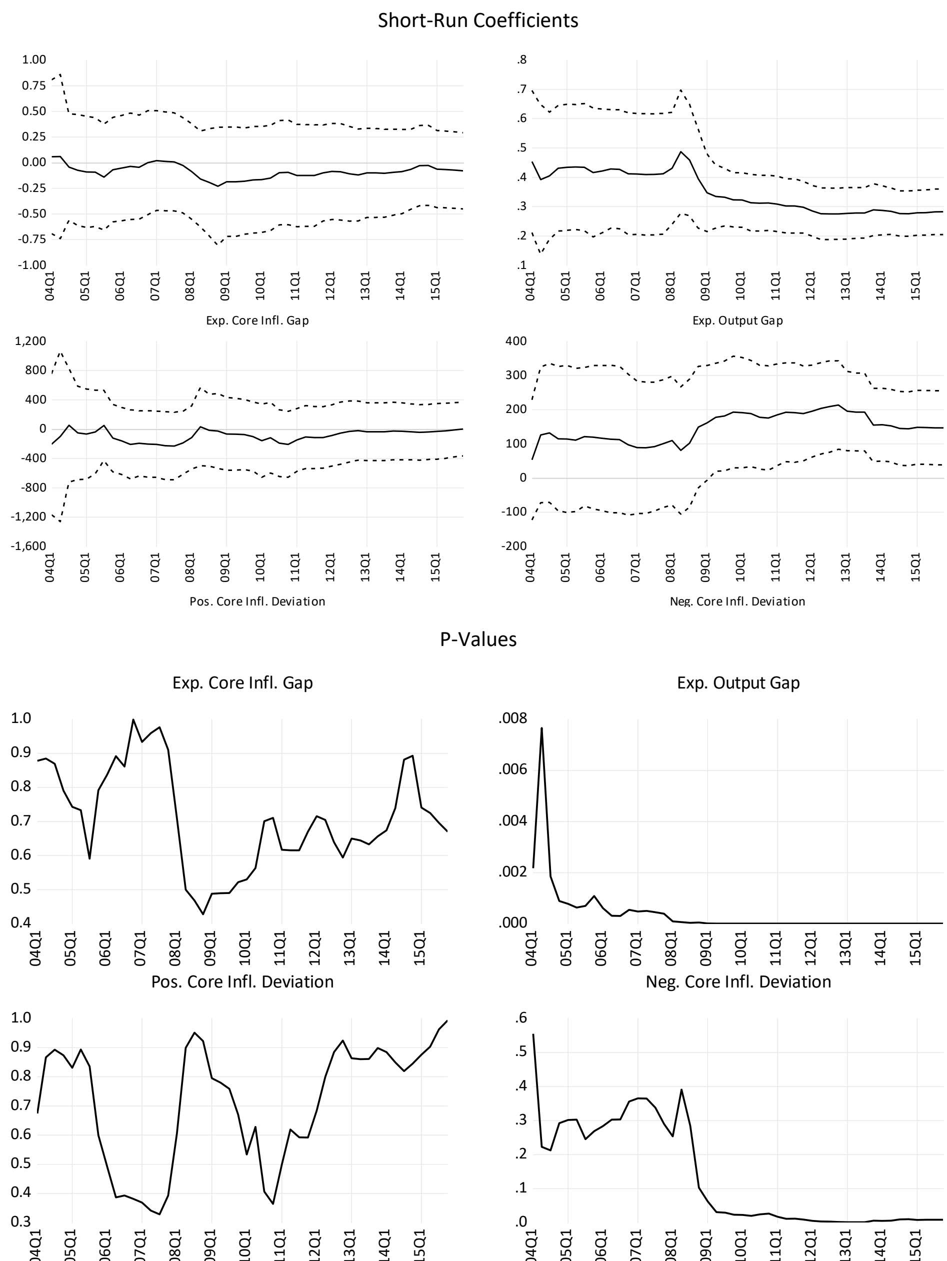


Figure 19: Monetary Policy Reaction Function with Symmetric Response to Inflation Deviation Using Core Inflation, Reverse Recursive Regression Anchor in 2015Q4

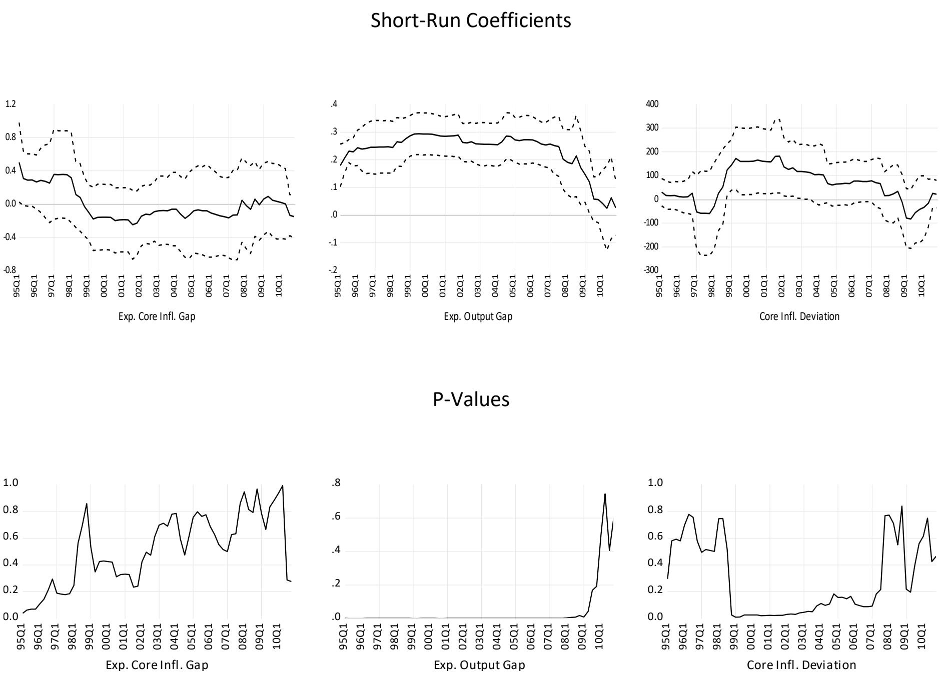


Figure 20: Monetary Policy Reaction Function with Asymmetric Response to Inflation Deviation Using Core Inflation, Reverse Recursive Regression Anchor in 2015Q4