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Using Functional Shocks to Assess Conventional and Unconventional Monetary Policy in Canada

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Abstract

We develop a new series of Canadian monetary policy shocks and analyze their impact on inflation and real GDP from 1996–2020. Our shocks are constructed as the daily change in the Nelson-Siegel yield curve factors after a monetary policy announcement. Because these shocks include information along the entire yield curve, they provide a more comprehensive view of Canadian monetary policy relative to the existing literature, which focuses on shocks to the short-run interest rate. We document that monetary policy shocks often twist the yield curve, which tends to make monetary policy less effective. Furthermore, we find that lower real interest rates have muted the overall impact of monetary policy over time. Looking at particular episodes, there is little evidence that forward guidance or quantitative easing had a significant impact on inflation or real GDP.

Keywords: Monetary Policy Shocks, Canada, Yield Curve, Local Projections, Unconventional Monetary Policy

JEL Classification: E52, E65, C58, G12

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1 Introduction

How effective were monetary policy actions in Canada over the last 25 years? For most of this period, the policy framework was well defined with an inflation target of 2% and the overnight rate as the main policy tool. Three particular issues, however, force one to take a more nuanced view to answer this question. First, policymakers have placed greater emphasis on communication as a way of influencing expectations about future policy actions, and hence influencing long-run interest rates. Second, real interest rates have trended downwards during this period and were consistently negative between 2010 and 2019. Third, when the policy rate has reached its lower bound, defined by the Bank of Canada as 0.25%, policymakers have turned to unconventional policy instruments such as forward guidance and quantitative easing.

These issues have important implications for monetary policy. Policy statements or speeches may move long-run interest rates even when the policy rate is unchanged. Unconventional monetary policy, which is more likely to be necessary in an environment with low real interest rates, is not captured by changes to the policy rate at all. Consequently, in this paper we take a more comprehensive view of monetary policy in Canada. We develop a new series of monetary policy shocks that includes information across the entire yield curve, and estimate the effects of these shocks on inflation and real GDP from 1996–2020.

There are three main elements to our analysis. We start by deriving a new series of monetary policy shocks, which is unique in that we include not only scheduled and unscheduled policy changes but also speeches by senior officials in our sample of monetary policy dates.[1] Speeches by the Governor and other senior officials are now much more common than in the early 1990s and often communicate monetary policy intentions over the short- and medium-term. As these communications are closely monitored by media and financial markets, they may have effects on interest rates both in the short and medium to long run

[1] We also control for possible contamination through releases of statisical information in Canada as well as major policy announcements by the Federal Reserve.

as financial markets use this information to update their expectations of future policy rates.

We thus require a broader measure of the monetary policy stance. Our approach is to estimate changes in the yield curve for government bonds on dates related to monetary policy events. More specifically, we construct a series of functional monetary policy shocks as changes in the Nelson-Siegel yield curve factors using the approach developed by Inoue and Rossi (2021). The model summarizes the yield curve using only three latent factors—level, slope, and curvature—so that changes to these factors indicate how the entire yield curve is influenced by monetary policy actions.

We then use local projections to estimate the effect of changes to these factors on inflation and real GDP at a monthly frequency. One issue here is that real interest rates have trended downwards over the last 25 years and frequently been negative, which may have influenced the effectiveness of monetary policy. It is therefore important to see whether the responsiveness of the economy to monetary policy depends on the level of the real interest rate. We thus augment the standard local projection framework to include interaction terms between the real interest rate and other model variables, so that the impact of monetary policy can vary with the level of the real interest rate. Our approach is similar in spirit to the state-dependent local projections used by Auerbach and Gorodnichenko (2012), Tenreyro and Thwaites (2016), and Ramey and Zubairy (2018) to account for the state of the economy when estimating the effects of fiscal and monetary policy.

Our main results are as follows. Movements in all three factors between January 1996 and February 2020 have significant and large effects on inflation and real GDP. A 100 basis point increase in the level factor decreases inflation by 6.88% at its peak impact and real GDP by 7.81%. The effects of the same increase in the slope factor are smaller and the effects of changes to the curvature factor are smaller still. One needs to put these numbers, however, into perspective. Monetary policy events cause movements in all three factors, and these movements often offset each other. For example, increases in the slope factor are often accompanied with decreases in the level factor leading to a twisting of the yield curve. This tends to make monetary policy less effective, as the effects of lower yields as some maturities are offset by the effects of higher yields at others.

We also find strong evidence that the level of the real interest rate matters for the impact of monetary policy actions. When interest rates are lower, the effects of monetary policy actions through the yield curve are muted. As real interest rates have been negative for much of the last decade, this casts some doubt on the effectiveness of monetary policy. It also suggests that policymakers will require larger interest rate adjustments to achieve a given effect on the economy when operating in a low interest rate environment.

A particular advantage of our approach is that we can directly evaluate specific monetary policy episodes. Indeed, every event has a unique impact on the yield curve as summarized by changes to the three Nelson-Siegel factors. We use our estimates to study nine distinct policy events of interest. Three results stand out.

First, at the start of the Global Financial Crisis, the Bank of Canada cut interest rates aggressively in October 2008, bringing the policy rate to the effective lower bound. Surprisingly, our estimates show that these emergency cuts were not effective. Indeed, we find a tightening at the short end of the yield curve indicating that markets were expecting more decisive actions by the Bank.

We can also directly study the impact of forward guidance. The Bank of Canada employed this tool prominently for the first time in April 2009 when it indicated it would hold the policy rate at the effective lower bound until July 2010. We present evidence that this commitment had little to no effect on inflation and real GDP. One particular explanation is that the responses were muted due to the low interest rate environment monetary policy operated in.

The third episode concerns the emergency cuts combined with the announcement of quantitative easing during the CoVid period. We show that these policy actions had a very large effect especially bringing down short-term yields. Hence, one can argue that the Bank of Canada maximized the impact of its rate cuts by averting a twisting of the yield curve that could have tempered the effects of policy actions. Notwithstanding, the response of inflation and real GDP is estimated to be small and short-lived, possibly due to negative real interest rates.

The literature on identifying the effects of monetary policy is large and many recent papers have focused specifically on identifying the impacts of unconventional policy (see Rossi (2021) for an extensive overview). We combine several elements from this literature. First, we use high frequency (daily) financial data to identify monetary policy shocks around policy announcements and other Bank of Canada communications in the spirit of Kuttner (2001) and Gürkaynak et al. (2005). This leads to a new series of Canadian monetary policy shocks, complementing the main alternative developed by Champagne and Sekkel (2018), who use a narrative approach based on real-time data and forecasts available to Bank of Canada staff. An important distinction is that the Champagne and Sekkel (2018) shocks are designed to reflect conventional monetary policy shocks—unanticipated changes to the short-run policy rate—whereas our shocks include both conventional and unconventional policy actions.

Second, we use movements in the entire yield curve of government bonds rather than a particular interest rate to measure the impact of policy announcements. This is in line with the recent finding of Ravenna and Ingholt (2021) that the success of monetary policy mainly relies in managing inflation expectations, which are reflected in the government yield curve. Our approach is then in contrast with other contributions that either generate a shadow interest rate[2] or use the interest rate on bonds of a longer maturity to account for the effective lower bound.[3] A particular advantage of our approach is that it views each monetary policy action as distinct, so we do not need to take a stand on the appropriate policy instrument. Our policy shocks will thus include the effects of both conventional and unconventional policy, without any special treatment.

[2]For example, MacDonald and Popiel (2020) study policy at the zero lower bound in Canada during the financial crisis.

[3]See Gertler and Karadi (2015), who use one-year Treasuries as their main monetary policy instrument.

Third, we use a local projection approach to estimate the impact of the shocks on inflation and real GDP. This is a slight departure from Inoue and Rossi (2021), who use a VAR as their benchmark model for the US. In our case, the local projection framework is preferable because it allows us to more easily account for the changing level of the real interest rate over our sample period. Interestingly, our estimated results for Canada are in the same range as for the US being roughly at 1-2% maximum impact on GDP for unconventional monetary policy.

Many studies estimate the effectiveness of unconventional monetary policy in the US.[4] **?** provide a comprehensive summary of international experience with unconventional monetary policy, including the effects of these policies on financial and macroeconomic variables. For Canada, MacDonald and Popiel (2020) study the effects of unconventional monetary policy when the policy rate was at the zero lower bound during the financial crisis. Similar to our study of this episode, they find only small impacts on inflation and output. Gambacorta et al. (2014) estimate the impact of unconventional policy in the US on other countries including Canada. We are the first paper, however, to provide a systematic evaluation of such episodes in Canada across central bank communication, explicit forward guidance, and large-scale asset purchases.

Finally, we incorporate into the functional approach to monetary policy shocks a direct influence of the level of interest rates, adding to the recent discussion of whether the level of interest rates is important for the effectiveness of monetary policy. While we find evidence that a low level of interest rates weakens the impact of monetary policy, we do not study in detail how changes in the yield curve influence the transmission mechanism of monetary policy. There is both theoretical and empirical evidence that interest rate pass-through is lower when interest rates are low. Some papers point to the banking sector or the credit channel as the main explanation (see for example Borio and Gambacorta (2017), Ulate (2021) or Gertler and Karadi (2015)). We leave the evaluation of this question for future research.

[4]See Weale and Wieladek (2016), Bernanke (2020), Karadi and Nakov (2021), Zhang (2021) among many others.

2 A New Series of Canadian Monetary Policy Shocks

2.1 Background and Monetary Policy Events

We construct a new series of Canadian monetary policy shocks as daily changes of the yield curve on dates that are related to monetary policy events. Our list of dates includes scheduled and unscheduled monetary policy decisions, releases of the *Monetary Policy Report* (MPR), and speeches by the Governor or a Deputy Governor that relate either to the current monetary policy stance or the current state of the economy. We use the time period of inflation targeting from the beginning of 1990 to the end of 2022 to construct the shocks.

For most of this time period, the Bank of Canada conducted monetary policy mainly using a corridor system where it announces the Bank Rate (the rate financial institutions pay to borrow from the Bank of Canada) and the deposit Rate (the rate these financial institutions earn on settlement balances held at the Bank of Canada). The Bank then managed liquidity in the overnight market so that the overnight rate stayed close to the target which is the midpoint of the corridor.

During the Global Financial Crisis and the recent pandemic the implementation of monetary policy changed as the policy rate reached its lower bound which is considered 0.25% by the Bank of Canada. Unlike the US, the Bank of Canada did not engage in quantitative easing during 2008 and 2009. It did, however, turn to unconventional monetary policy when Governor Mark Carney used forward guidance in April 2009, committing to maintain the overnight rate target at 25 basis points until the second quarter of 2010. As Canada recovered from the crisis, forward guidance was toned down, and in 2014, under Governor Stephen Poloz, policymakers "stopped providing routine forward guidance altogether."(Poloz (2018)).

During the recent pandemic, the Bank of Canada turned to quantitative easing, purchasing government securities to affect interest rates further out on the yield curve. Purchases of these assets were paid for by increasing the settlement balances of financial institutions at the Bank of Canada. As a consequence, the overnight market largely disappeared with settlement balances far above the small amount necessary to ensure the proper market functioning in normal times. With the overnight rate driven down to the deposit rate, the Bank was forced to operate within a floor system of monetary policy.

To take into account these circumstances, our series of monetary policy events includes all formal announcements of interest rate decisions and unconventional policy. Up until 2000, the Bank of Canada "maintained a relatively flexible approach to announcing changes to the Bank Rate."(Bank of Canada (2000)). The policy rate could be adjusted on any business day as deemed appropriate. This changed in September 2000 when the Bank introduced a new system of eight fixed policy dates each year where the Bank would announce any changes to the overnight rate. With the exception of a few unscheduled meetings in 2008 and March 2020, the Bank of Canada has followed this schedule.

We also include the release of the MPR as events into our series of dates. Until recently, the release of the MPR did not coincide with these policy announcements. Often the report was released a few days after the formal decision and combined with a press conference providing an opportunity to engage in forward guidance. Similarly, we regard any speeches by a member of the governing council mentioning the state of the economy or monetary policy decisions as relevant events. Dates for these speeches are taken from the Bank of Canada's webpage, but are available only from the beginning of 1995.

2.2 Methodology and Data

We follow the methodology of *functional monetary policy shocks* introduced by Inoue and Rossi (2021) to construct a new series of monetary policy shocks for Canada. Monetary policy shocks are identified as a change in the entire yield curve on the date of a monetary policy action. We use the Nelson and Siegel (1987) framework to summarize the information in the yield curve by only three latent factors—labeled β_1, β_2, and β_3—that represent the level, the slope and the curvature of the curve respectively.

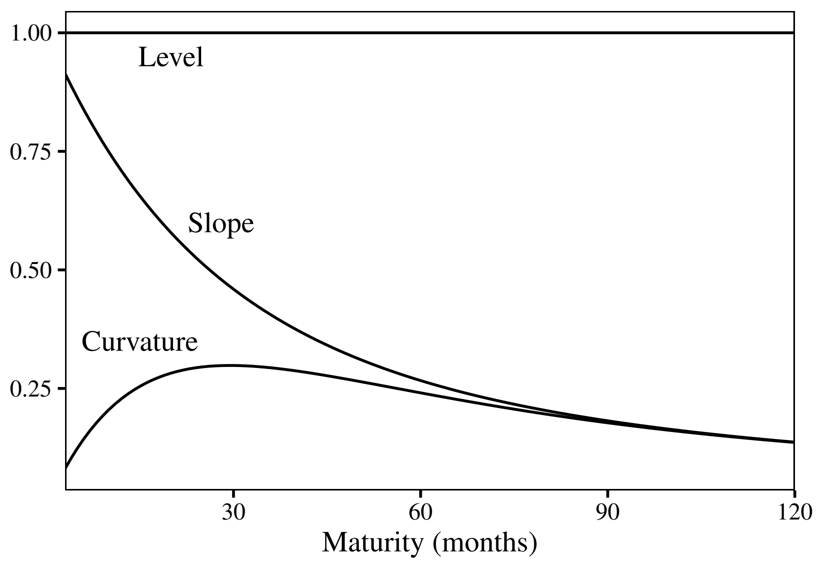
Define $y_t(\tau)$ as the yield on a government bond with maturity τ. These yields are related to the Nelson-Siegel factors according to

$$y_t(\tau) = \beta_{1,t} + \beta_{2,t}\left(\frac{1-e^{-\lambda\tau}}{\tau\lambda}\right) + \beta_{3,t}\left(\frac{1-e^{-\lambda\tau}}{\tau\lambda} - e^{-\lambda\tau}\right) + \epsilon_t(\tau), \tag{1}$$

where λ is a parameter and $\epsilon_t(\tau)$ is an error term.

Figure 1 shows the three Nelson-Siegel factor loadings for maturities between 3 and 120 months. A change to the level factor has the same effect on yields at all maturities, akin to a permanent increase in interest rates. The slope instead has the largest impact on short-run bond yields, while the curvature factor peaks in the medium term. Using these factor loadings, the Nelson-Siegel model provides substantial dimensionality reduction, summarizing fluctuations in the entire yield curve with only three factors.

Figure 1: Nelson-Siegel factor loadings



Note: The Nelson-Siegel factors are β_1 (level), β_2 (slope), and β_3 (curvature) from equation (1) with a parameter value of $\lambda = 0.0609$.

To construct the shocks we use the daily zero-coupon yields on Government of Canada Securities developed by Bolder et al. (2004) and maintained by the Bank of Canada. Following Inoue and Rossi (2021), we use yields on bonds maturing in 3, 6, 12, 24, 36, 48, 60, 72, 84, 96, and 120 months and fix $\lambda = 0.0609$.[5] We then estimate the three factors on each date by OLS, as shown by Diebold and Li (2006). Finally, we calculate the daily change in these factors on dates that we have identified as monetary policy events. The functional shock is then identified as the changes in the three factors.

One potential issue with using daily changes in the Nelson-Siegel factors as monetary policy shocks is that they may be contaminated with other sources of information released on the same day. A likely source of contamination is releases of relevant economic data series by Statistics Canada. For example, Gürkaynak et al. (2005) show that the largest deviations between US monetary policy shocks using daily and intraday windows occur on days coinciding with the release of the employment report. To account for this we exclude any days coinciding with the release of the Consumer Price Index, the Labour Force Survey, or Gross Domestic Product. These dates are taken from Statistics Canada's *The Daily Bulletin*, but are only available online beginning in 1996. For the same reason, we also remove any dates corresponding with a meeting of the Federal Open Market Committee of the Federal Reserve, using an updated set of the meeting dates from Gürkaynak et al. (2005).

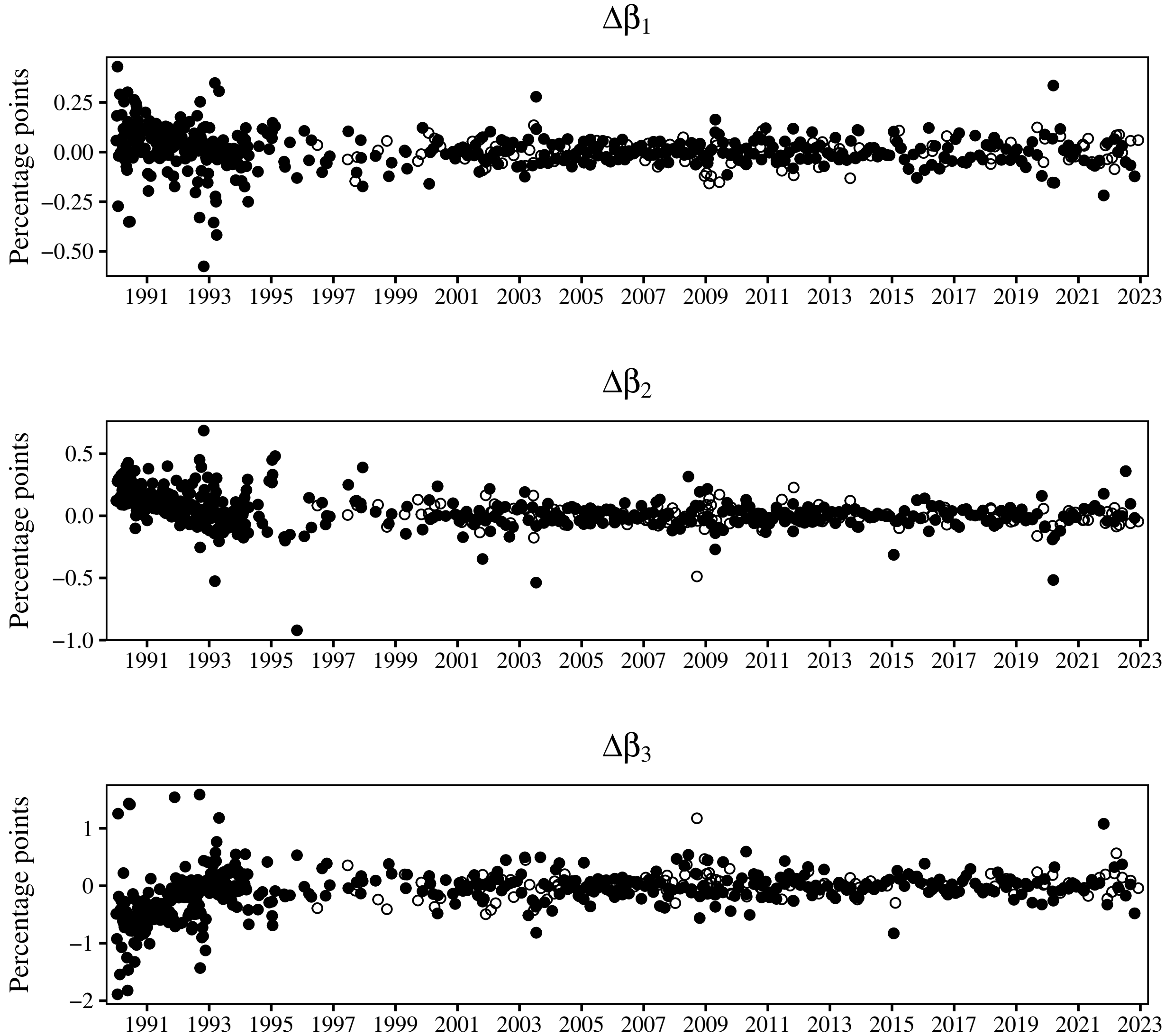
2.3 Time Series of Shocks

Figure 2 shows a time series of our monetary policy shocks, calculated as the change in the three Nelson-Siegel factors on days corresponding to monetary policy events. The solid black circles show differences in the estimated factors $\Delta\beta_i$ on monetary policy meeting days or releases of the *Monetary Policy Report*, while the hollow circles show these differences after a speech.

Summary statistics for changes to the three estimated factors β_i are shown in Table 1 for three different time periods. Panel A shows statistics for shocks based only on monetary policy announcements and releases of the MPR. Panel B also includes speeches by the Governor or a Deputy Governor. Both Figure 2 and Table 1 show that changes in all three

[5]This calibration is common in the empirical literature and uses the value that maximuzes the impact of the curvature factor at exactly 30 months maturity (see Diebold and Li (2006)).

Figure 2: Functional monetary policy shocks



Note: The solid black circles are the daily change in the Nelson-Siegel factor $\Delta\beta_i$ on scheduled or unscheduled monetary policy meeting days and releases of the MPR. The hollow circles are the daily change in these factors after a speech by a member of the governing council related to current economic conditions or current monetary policy.

factors β_i were much larger between 1990 and 1995.[6] The frequency of shocks is much higher in this period as the policy rate was set weekly and tied to weekly Treasury bill auctions. The shocks also do not appear to be mean zero over this period and are persistently positive

[6] Since there are no speeches in our dataset over this time, panels A and B are identical.

or negative, indicating they could be serially correlated.

These facts could reflect the inflation target not coming fully into effect until 1996, even though the Bank of Canada officially adopted inflation targeting in the early 1990s. Hence, the period between 1990 and 1995 is often seen as a transition to a new monetary policy regime. Markets may have struggled to understand the Bank of Canada's intentions or the Bank of Canada may have lacked credibility given the high inflation rates of the 1980s. Consequently, it may be difficult to interpret the changes in the Nelson-Siegel factors as monetary policy shocks in the sense of unanticipated policy actions in a well-established monetary policy framework.

For this reason—and recognizing the unusual circumstances of the pandemic—we will restrict our data to the period from 1996 to February 2020 for the analysis estimating the impact of our shocks on inflation and real GDP. Over this period the changes in all factors β_i are mean zero and decline in scale by approximately one half relative to the other periods. The distribution of changes in the factors are similar whether or not speeches are included in the sample, indicating that monetary policy shocks arising from speeches do not look fundamentally different than those arising from explicit monetary policy announcements. With one exception, the most extreme changes are associated with announcements rather than speeches. For completeness, we also include the shock series for the CoVid period in Table 1.

Table 1: Summary statistics

Panel A: Announcement dates and MPR releases only									
	1990–1995			1996–2019			2020–2022		
	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$
Mean	0.02	0.09	-0.24	0.00	0.00	-0.01	-0.01	-0.01	0.03
Std. Dev.	0.13	0.17	0.51	0.06	0.10	0.21	0.11	0.17	0.32
Min	-0.58	-0.92	-1.89	-0.17	-0.54	-0.83	-0.22	-0.52	-0.48
Max	0.43	0.69	1.59	0.28	0.39	0.59	0.33	0.36	1.08
Range	1.01	1.61	3.48	0.45	0.93	1.42	0.55	0.88	1.56
Obs.	207	207	207	219	219	219	20	20	20
Panel B: Announcement dates, MPR releases, and speeches									
	1990–1995			1996–2019			2020–2022		
	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$
Mean	0.02	0.09	-0.24	0.00	0.00	0.00	0.00	-0.01	0.04
Std. Dev.	0.13	0.17	0.51	0.06	0.09	0.21	0.09	0.12	0.26
Min	-0.58	-0.92	-1.89	-0.17	-0.54	-0.83	-0.22	-0.52	-0.48
Max	0.43	0.69	1.59	0.28	0.39	1.17	0.33	0.36	1.08
Range	1.01	1.61	3.48	0.45	0.93	2.00	0.55	0.88	1.56
Obs.	207	207	207	345	345	345	39	39	39

Note: Summary statistics for the changes in β_i over different sample periods.

Table 1 shows that changes to the curvature factor are much more variable than changes in the other two factors, which may appear to indicate that monetary policy shocks have a disproportionate effect on bonds maturing over the medium term. However, from the structure of the Nelson-Siegel model, for a value of $\lambda = 0.0609$, the curvature factor peaks at around 0.3 compared with 0.9 for the slope factor (see Figure 1). The total effect of a monetary policy shock on the yield curve at any given maturity is the sum of the changes in the three β_i scaled by the relevant factor loading. Since loadings on the slope and level factor are much larger at most horizons, smaller changes to these factors may still have a larger impact.

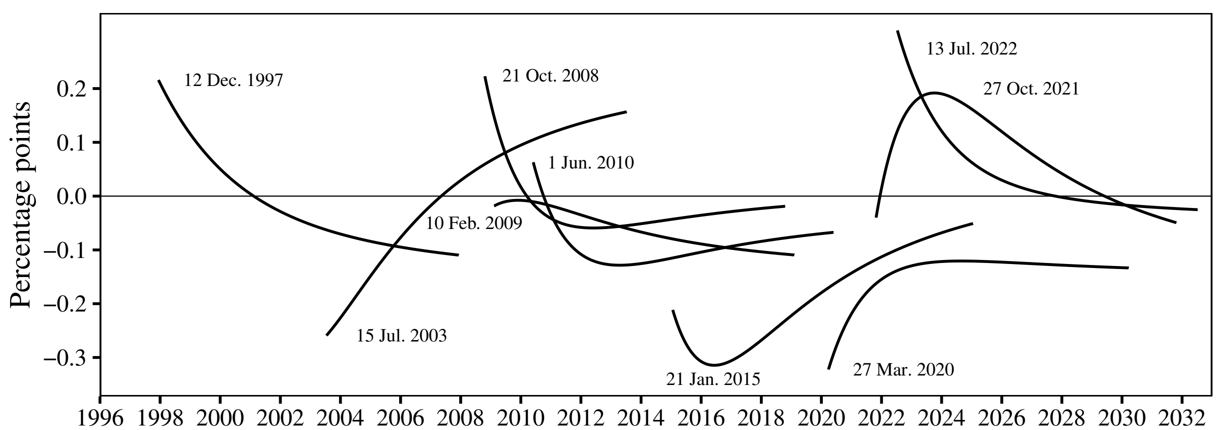
Table 2 shows the functional shocks for a collection of dates of interest as expressed by changes in the three factors. Here, we include some important dates in the CoVid period as well. Notice that on any given date, the shocks to the factors are typically not all of the same sign. This illustrates that the effects of monetary policy on the yield curve can be complex, increasing yields at some maturities while lowering yields at others. The benefit of the functional shock approach is that it provides a more complete picture of the effects of monetary policy, which would be missed if only shocks to the policy rate were taken into account.

Table 2: Monetary policy shocks on select dates

Date	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$	Event
1997-12-12	-0.17	0.39	0.08	Policy rate increased by 50 bps in response to volatile financial markets.
2003-07-15	0.28	-0.54	-0.36	Policy rate lowered by 25 bps in response to the SARS virus.
2003-07-17	0.12	-0.08	-0.82	Release of the *Monetary Policy Report*, including downward revisions for economic activity.
2008-10-21	0.03	0.19	-0.56	Policy rate lowered by 25 bps in response to the Global Financial Crisis.
2008-10-23	0.04	0.08	-0.18	Release of the *Monetary Policy Report*.
2009-04-21	0.10	-0.27	-0.16	Policy rate reaches the lower bound (25 bps). Statement includes explicit forward guidance.
2009-04-23	0.16	-0.14	-0.37	Release of the *Monetary Policy Report*, including general principles for quantitative easing programs.
2010-06-01	-0.01	0.07	-0.51	Policy rate raised by 25 bps, moving the interest rate off the effective lower bound and return to standard operating framework.
2015-01-21	0.10	-0.31	-0.83	Policy rate lowered by 25 bps in response to a decline in the price of oil.
2020-03-04	0.07	-0.19	-0.10	Policy rate lowered by 50 bps at a scheduled meeting in response to the COVID crisis.
2020-03-13	0.33	-0.52	-0.26	Policy rate lowered by 50 bps at an unscheduled meeting.
2020-03-27	-0.15	-0.17	0.33	Policy rate lowered by 50 bps to the lower bound (25 bps) at an unscheduled meeting. Announcement of two new quantitative easing programs.
2021-10-27	-0.22	0.18	1.08	Termination of remaining asset purchase programs. Change to forward guidance suggesting interest rates could begin to rise sooner than previously thought.
2022-07-13	-0.05	0.36	-0.17	Policy rate increased by 100 bps in response to high inflation.

Figure 3 shows the impact of the monetary policy shocks on the dates from Table 2 on the entire yield curve.[7] We use the change in the three Nelson-Siegel factors reported in Table 2 to trace out the effect on the entire yield curve up to a maturity of ten years using equation (1). The figure illustrates the complex effects that monetary policy can have on the yield curve. On 12 December 1997, for example, there is a clear twisting of the yield curve. Monetary policy raised the short end of the yield curve by 22 basis points while lowering the long end of the yield curve by 11 basis points. The same effect occurs in reverse on 15 July 2003. We examine these shocks, and the effects on inflation and real GDP, in more detail in Section 4.

Figure 3: Shocks to the yield curve on select dates



Note: Shocks to the Nelson-Siegel yield curve at six dates from Table 2.

If our proposed series of functional shocks is to represent exogenous monetary policy fluctuations, they should be unpredictable. We examine predictability of our series with Granger causality tests. After aggregating our shocks to a monthly frequency by averaging all shocks in a given month, we regress the change in each of the Nelson-Siegel factors on lags of macroeconomic variables or the changes themselves over the three different sample periods. Table 3 shows p-values for the resulting Granger causality tests. Each regression includes three lags of the independent variable, shown in the first column and we adjust the

[7] For dates that follow each other within a month, we have plotted only the initial sshock. Later on, when we analyze these episodes, we aggregate shocks that occur within the same month.

p-values using the Benjamini and Hochberg (1995) procedure to account for the multiple testing issue. Between 1990 and 1995 there is strong evidence of predictability for all three shocks confirming our decision to exclude this period for the later analysis. For the 1996 to 2019 period, the series of each of the three factors becomes much less predictable. The smallest p-values are well above conventional thresholds for statistical significance. The results are essentially unchanged when we add the data for the CoVid period.

Table 3: Granger causality tests

	1990–1995			1996–2019			1996–2022		
	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$	$\Delta\beta_1$	$\Delta\beta_2$	$\Delta\beta_3$
$\Delta\beta_1$	0.10	0.04	<0.01	0.72	0.76	0.82	0.86	0.90	0.72
$\Delta\beta_2$	0.20	0.04	0.01	0.89	0.84	0.82	0.86	0.90	0.72
$\Delta\beta_3$	0.09	0.04	<0.01	0.72	0.48	0.82	0.91	0.21	0.72
Bank rate	0.06	0.04	<0.01	0.72	0.76	0.41	0.91	0.73	0.72
Inflation	0.27	0.35	<0.01	0.72	0.84	0.82	0.92	0.90	0.94
Comm. inflation	0.69	0.08	<0.01	0.72	0.48	0.82	0.86	0.53	0.72
M2 growth	0.10	0.08	<0.01	0.77	0.76	0.97	0.91	0.90	0.94
Real GDP growth	0.69	0.29	0.01	0.72	0.61	0.41	0.86	0.47	0.72
Unemployment rate	0.03	0.27	<0.01	0.72	0.76	0.41	0.91	0.68	0.96
TSX growth	0.03	0.08	<0.01	0.72	0.48	0.41	0.86	0.25	0.72

Note: p-values for Granger causality tests for three different sample periods at monthly frequency. Each regression includes a constant and three lags of the variable in the first column. Growth rates are calculated as year-over-year percentage changes. We aggregate changes in the factors $\Delta\beta_1$, $\Delta\beta_2$, and $\Delta\beta_3$ to a monthly frequency by summing all the changes in a given month. To account for the issue of multiple testing, p-values are adjusted using the Benjamini and Hochberg (1995) procedure.

3 Effects of Monetary Policy on GDP and Inflation

We next use our series of functional shocks to estimate the effects of monetary policy on inflation and real GDP between January 1996 and February 2020. In particular, we estimate the set of local projections:

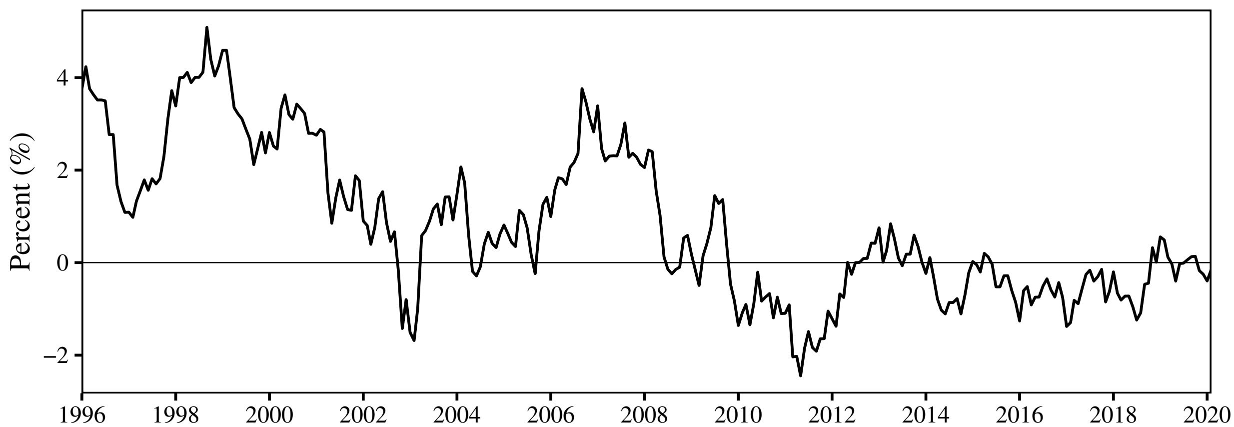
$$
\begin{aligned}
y_{t+h} - y_{t-1} &= \alpha_{1,h}\Delta\beta_{1,t} + \alpha_{2,h}\Delta\beta_{2,t} + \alpha_{3,h}\Delta\beta_{3,t} + b_h X_{t-1} \\
&\quad + (r_{t-1} - \bar{r})(\gamma_{1,h}\Delta\beta_{1,t} + \gamma_{2,h}\Delta\beta_{2,t} + \gamma_{3,h}\Delta\beta_{3,t} + d_h X_{t-1}) + u_{t+h,h},
\end{aligned} \tag{2}
$$

where y_t is the response variable (the log of real GDP or the CPI, multiplied by 100), r_{t-1} is the real interest rate, calculated as the difference between the bank rate and actual year-over-year inflation, X_{t-1} is a vector of control variables, and $\Delta\beta_{1,t}$, $\Delta\beta_{2,t}$, and $\Delta\beta_{3,t}$ are the components of the functional shocks from the previous section. By using the difference $y_{t+h} - y_{t-1}$ as the dependent variable, the coefficients $\alpha_{1,h}$, $\alpha_{2,h}$, and $\alpha_{3,h}$ indicate the cumulative impact of a monetary policy shock on variable y, h periods after the shock occurs. We aggregate the monetary policy shocks to a monthly frequency by summing all shocks in a given month. The controls include a constant, three lags each of inflation and real GDP growth, the Bank Rate, commodity price inflation, the unemployment rate and lags of the functional shocks. Inflation, commodity inflation, and real GDP growth are all calculated as year-over-year growth rates. We exclude the CoVid period from the sample because of the large effects on inflation and GDP, but will return to this issue in Section 4.

Equation (2) extends the standard local projections approach by Jordà (2005) since it allows for an interaction between the demeaned real interest rate, $r_{t-1} - \bar{r}$ and shocks to the three Nelson-Siegel factors. Figure 4 shows the real interest rate over our sample period. The average real interest rate is 0.82%, but it has drifted downwards over the sample period and is typically negative in the second part of the sample. Monetary policy thus operated in very different interest rate environments over our sample, with the second half corresponding to a situation where the policy rate was consistently at or near the zero lower bound.

With our approach, the interaction terms $\Delta\beta_{i,t}(r_{t-1} - \bar{r})$ for $i = 1, 2, 3$ capture how the effects of monetary policy vary with the real interest rate. Since we demean the real interest rate, the coefficients $\alpha_{1,h}$, $\alpha_{2,h}$ and $\alpha_{3,h}$ are to be interpreted as the impact of the functional shocks when the real interest rate is at its average level over the sample period. Note that we lag the real interest rate in the interaction term so that there are no issues of endogeneity. The coefficient $\gamma_{1,h}$ indicates the additional effect of a change in the level factor when the real interest rate is one percentage point above its mean, and likewise for $\gamma_{2,h}$ and $\gamma_{3,h}$. Statistical significance of the γ parameters can then be taken as evidence that the effect of monetary policy depends on the level of the real interest rate.

Figure 4: Real interest rate

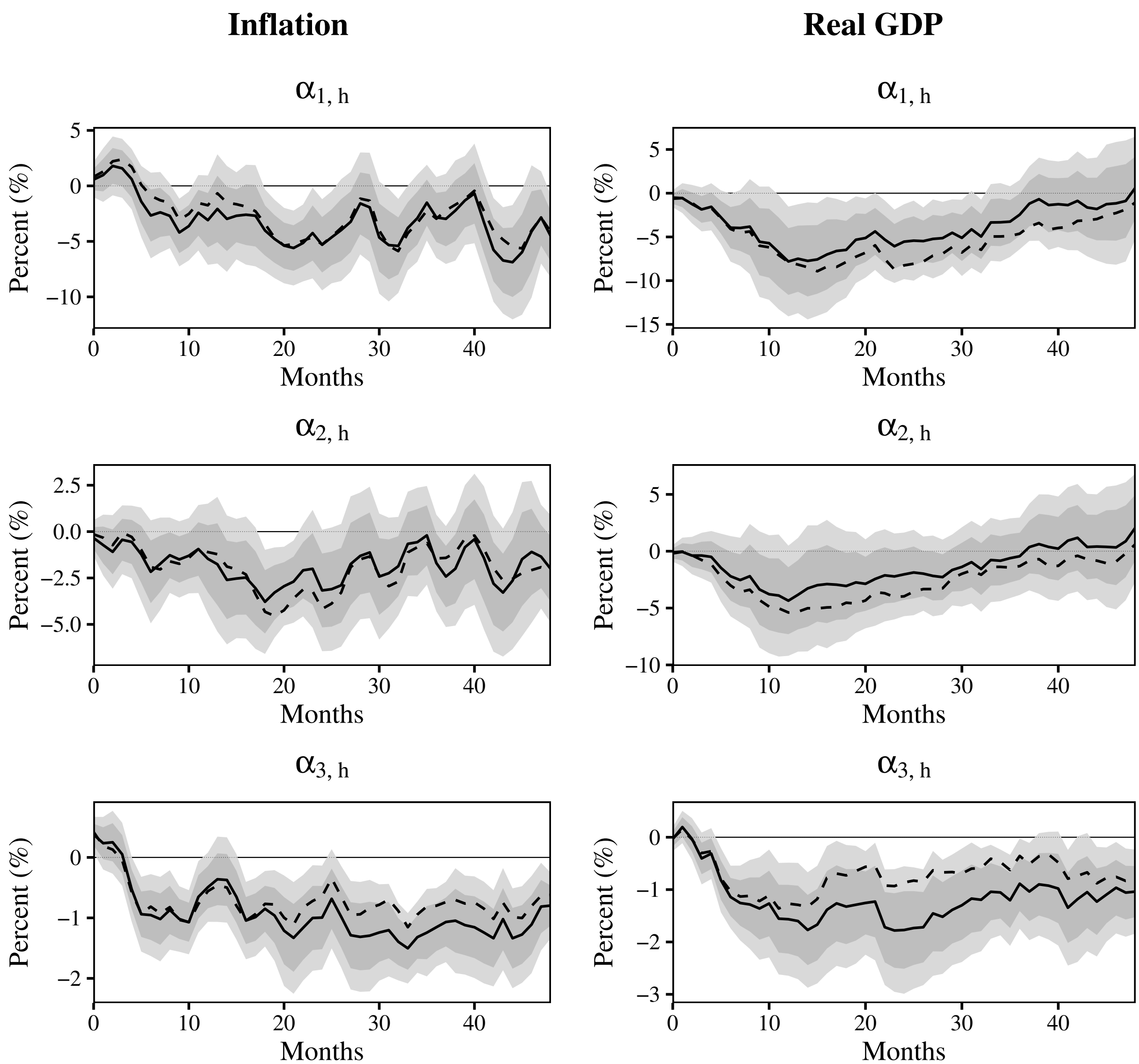


Note: Ex-post real interest rate, defined as the difference between the bank rate and actual year-over-year inflation.

Figure 5 shows the responses of inflation and real GDP to a 100 basis point increase in each of the three factors when the real interest rate is at its mean, which are simply the coefficients $\alpha_{1,h}$, $\alpha_{2,h}$ and $\alpha_{3,h}$ from our specification (2), all else constant. Changes to the individual factors will of course have different effects on the yield curve, with only the level factor β_1 increasing yields by 100 basis points across all maturities. An increase to the slope or curvature factors of the same magnitude will impact yields at some maturities more than others, as illustrated in Figure 1. The dark and light shaded areas are 68% and 90% confidence intervals, calculated using a Newey-West HAC with $h + 1$ lags, where h is the impulse response horizon (see Stock and Watson (2018)).

The responses of inflation indicate that tighter monetary policy causes inflation to fall, after a lag of several months. The shocks to all three factors have statistically significant effects at the 90% confidence level. The effects are also economically very large. A unit

Figure 5: Responses of inflation and real GDP to the monetary policy shocks



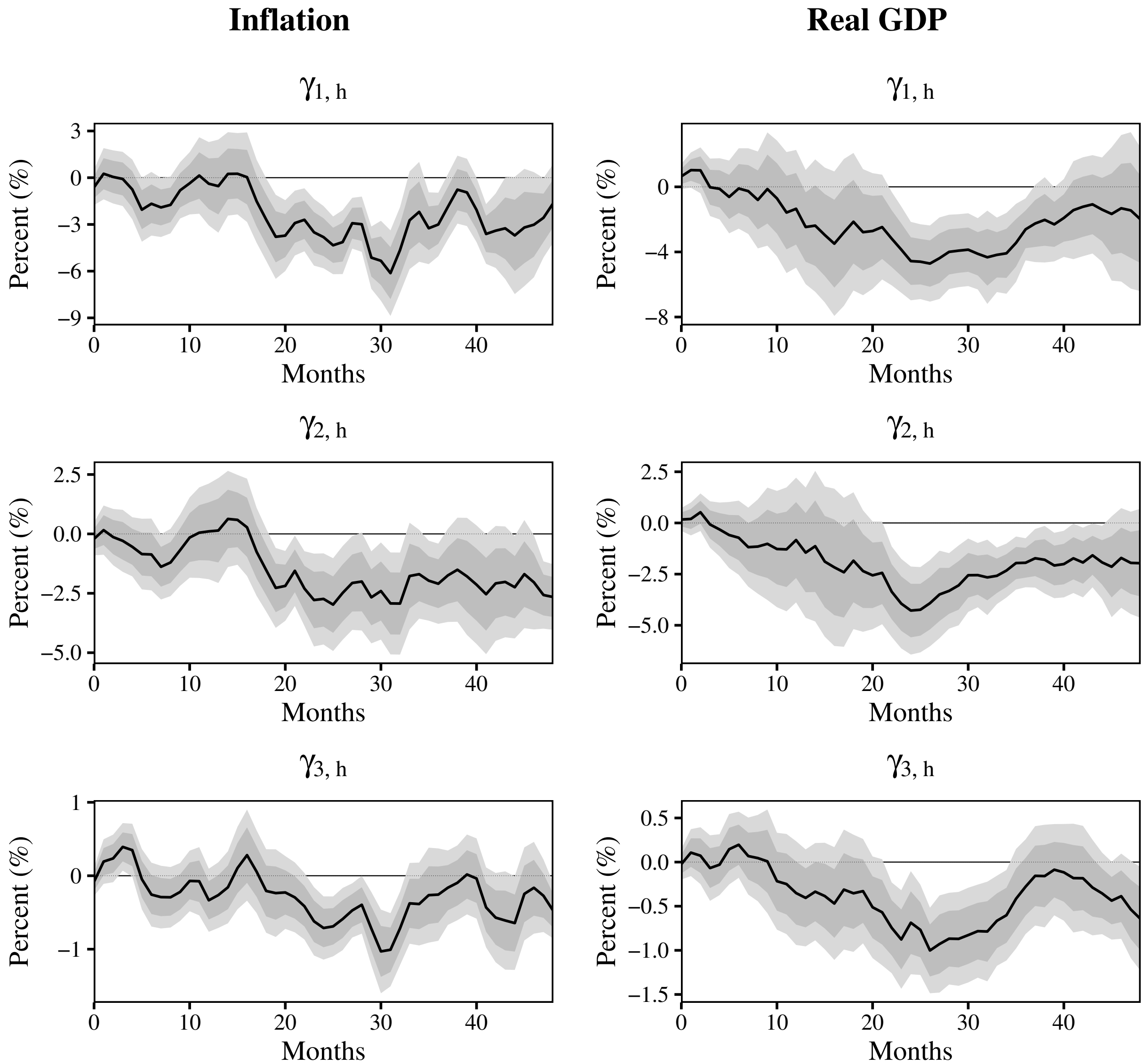
Note: Responses of inflation (left) and real GDP (right) to the functional monetary policy shocks. Solid lines show the responses to one unit increase in β_1 (top row), β_2 (middle row), and β_3 (bottom row) estimated from the local projections (2) when the real interest rate is at its average level ($r_{t-1} = \bar{r}$). Standard errors are calculated using a Newey-West HAC with $h+1$ lags. For comparison, the dashed lines show the estimates of $\alpha_{1,h}$, $\alpha_{2,h}$ and $\alpha_{3,h}$ from a restricted model where $\gamma_{1,h} = \gamma_{2,h} = \gamma_{3,h} = 0 \; \forall \; h$.

increase in the level factor (β_1) has a cumulative effect on the price level of -6.88%, 45 months after the shock occurs, since it corresponds to an upward shift of the entire yield curve. The slope effect (β_2) is smaller, since the unit increase in the factor primarily affects the short end of the yield curve. The curvature factor has an even smaller effect. Likewise, real GDP declines after a tightening of monetary policy with the effects being both statistically and economically significant. Again, the effects are very large. The maximum impact of a unit increase in the level factor is -7.81%, 13 months after the shock occurs.

For comparison, we also show the estimates of the coefficients from the restricted model with no interaction effect between monetary policy and the level of the real interest rate (ie. $\gamma_{1,h} = \gamma_{2,h} = \gamma_{3,h} = 0$) as dashed lines in the figure. The estimates from the restricted model tend to be within the narrower 68% confidence intervals of the unrestricted estimates. The largest differences occur for the response of GDP to a shock to the level or curvature factors, but overall the restricted model matches the response from the unrestricted model very well.

We turn next to the question of whether the responses of inflation and real GDP depend on the level of the real interest rate. Figure 6 plots the estimates of $\gamma_{i,h}$ from equation (2) for all the horizons $h = 0, ..., 48$. There are several important observations. First, rejections of the null hypothesis $\gamma_{i,h} = 0$ are quite common. For example, evidence for an interaction effect is smallest for the curvature shock in the projections of inflation, but the effect is still significant in 13 of the 49 tests. Second, statistical significance is much more common at horizons greater than 20 months. These facts indicate that for the long-run effects of monetary policy the level of interest rates matters. Third, the null hypothesis that the effects of monetary policy do not depend on the level of the real interest rate is rejected more frequently for real GDP than for inflation. Fourth, the estimates of $\gamma_{i,h}$ are typically negative. Recall from Figure 5 that the signs of $\alpha_{i,h}$ are typically negative too. This implies that monetary policy tends to be more effective at higher levels of the real interest rate and less effective at lower levels of the real interest rate.

Figure 6: Interaction effect of monetary policy shocks and the real interest rate



Note: Estimates of the interaction effect between monetary policy shocks and the real interest rate, $\gamma_{1,h}, \gamma_{2,h},$ and $\gamma_{3,h}$ from (2), for inflation (left) and real GDP (right). Standard errors are calculated using a Newey-West HAC with $h + 1$ lags.

4 Analyzing Specific Monetary Policy Actions

The traditional approach to studying the effects of monetary policy interprets a shock as the exogenous fluctuations in a single, short-term policy rate. These shocks are almost always assumed to be uncorrelated with other shocks in the economy, since otherwise they could not be associated with primitive exogenous variation in monetary policy. In our approach, however, a shock is represented by the change to the entire yield curve after a specific monetary policy event, and we represent this functional shock using changes to the three Nelson-Siegel factors. Our three shocks should then be thought of as jointly representing exogenous variation arising from monetary policy decisions. In particular, the three shocks may be correlated with each other, and in our sample they are, as long as they remain uncorrelated with all other macroeconomic shocks. And each date in our sample will be associated with different movements in the three factors of the Nelson-Siegel model.

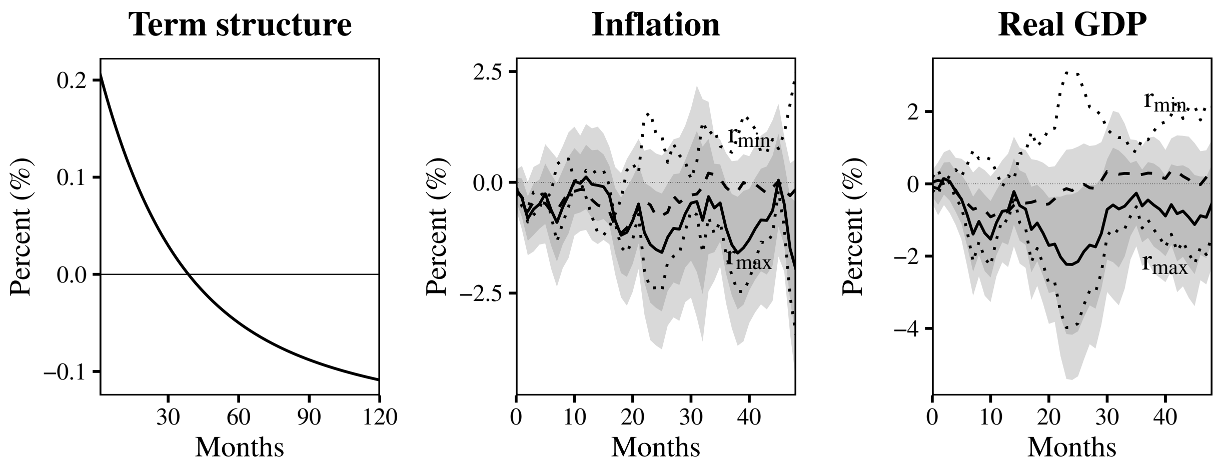
We can thus study the effect of any particular monetary policy decision directly. To do so, we use the estimated changes in β_i on specific dates of interest as well as the estimates from our local projections to evaluate the impact on inflation and real GDP. Table 2 outlines nine distinct episodes of interest. Since our estimation is at a monthly frequency, for some events we add the shocks to the factors across multiple single events that follow closely after each other. We group these episodes further into three distinct categories which are conventional policy, forward guidance and events associated with the CoVid period.

For all of these episodes, we look at the changes in the yield curve when estimated with the Nelson-Siegel model and plot impulse response functions for inflation and real GDP. The impulse response functions show the responses taking into account the level of the real interest rate during these episodes. For certain events, we also compare these responses with different assumptions regarding interest rates, using maximum and minimum interest rate levels across the sample period and the naive specification where there are no interaction terms.

4.1 Conventional monetary policy shocks

Asian Fiancial Crisis (12 December 1997) In response to volatility in financial markets arising from the Asian financial crisis, the Bank of Canada raised its policy rate by 50 basis points. Our estimates of the functional shock show a big increase in the slope factor ($\Delta\beta_2 = 0.38$) combined with a decline in the level factor ($\Delta\beta_1 = -0.17$). Because the slope and level factors moved in opposite directions, the effect was a twisting of the yield curve, raising short-run interest rates while lowering long-run interest rates, as shown in the left panel of Figure 7.

Figure 7: Monetary Policy and the Asian Financial Crisis



Note: The left panel shows the estimated change in the yield curve. Solid lines show the response of inflation and real GDP using the actual real interest rate $r_{t-1} = 3.11\%$. For comparison, the dotted lines show hypothetical responses for the same shock but with the real interest rate at the maximum ($r_{max} = 5.09$) or minimum ($r_{min} = -2.45$) sample value and the dashed lines shows the response using naive estimates from a restricted model where $\gamma_{i,h} = 0$ for $i = 1, 2, 3$ and $h = 0, ..., 48$.

Even though the movements in the yield curve were large and the real interest rate was at a fairly high level (3.11%), the estimated responses of inflation and GDP are not conclusive. Tighter monetary policy at the short-end of the yield curve is running against looser monetary policy at the long-end of the yield curve. The point estimates are negative, indicating that the short-run effect had a larger impact, but the response is significant only at the 68% level, because of the partially offsetting long-run effect. We know this is the case because Figure 5 showed that changes to the level or slope individually have significant effects on inflation and, for the level shock, real GDP as well. Hence, the twisting of the yield curve, with longer maturities actually falling appears to have muted the effects of the Bank of Canada's tightening.

Still there is some evidence that the relatively high level of interest rates during this period helped the policy to have its intended effect on inflation and real GDP. To illustrate this, the dotted lines in the center and right panels of Figure 7 show hypothetical responses to the same shocks if the real interest rate were instead at its highest or lowest sample value. Had real interest rates been very negative, as they have been over the past decade, the policy would have instead put upward pressure on both inflation and real GDP.

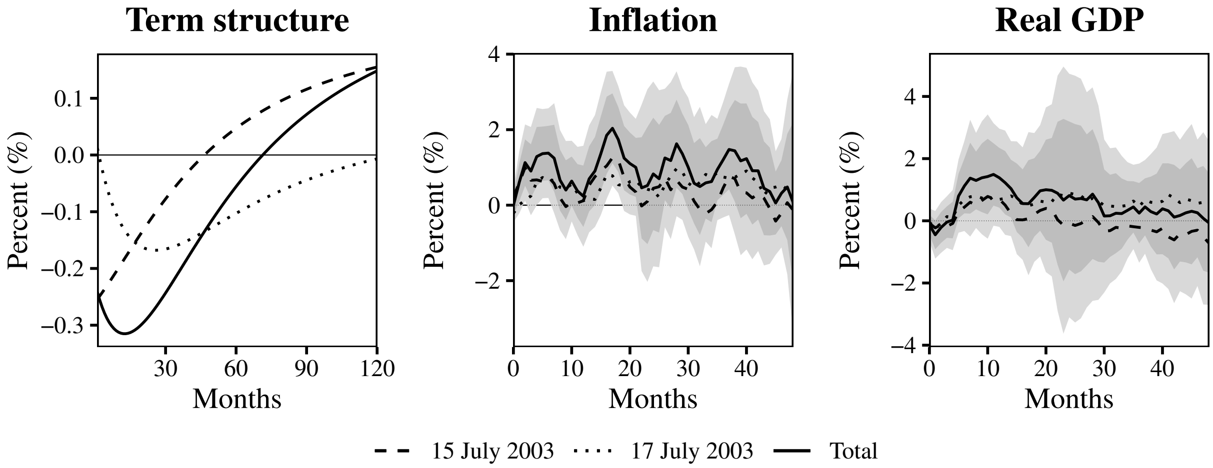
SARS Virus (15–17 July 2003) The Bank of Canada cut the overnight target rate by 25 basis points to 3 percent on 15 July. Two days later, on 17 July, the MPR was released, and the Bank acknowledged that their outlook for inflation and output had been affected by a series of unanticipated developments since the April MPR. One of those developments was the outbreak of the Severe Acute Respiratory Syndrome (SARS) virus.

Figure 8 shows the effects of the two associated monetary policy events as well as the total effect through the episode. The response of the term structure shows that the interest rate announcement was unanticipated. Once again the term structure twists, this time falling at short maturities while rising at long maturities. In this case the short-run expansionary effect dominates with significant positive responses of inflation, but somewhat weaker significance for increasing real GDP. Notice that the release of the MPR added significantly to the policy shock, causing short-term yields to fall even further. Hence, communication, rather than the policy announcement itself, contributed to the effectiveness of the policy action.

Global Financial Crisis (21–23 October 2008) On 8 October, the Bank of Canada lowered its policy rate by 50 basis points after an unscheduled meeting following the collapse of Lehman Brothers and the rapidly deteriorating economy. Because this decrease was a coordinated response with the Fed, however, we exclude this shock from our sample. On 21 October, the Bank of Canada then lowered its policy rate again at its scheduled meeting by 25 basis points. Two days later, the October MPR was released adding further information on the monetary policy stance. This episode includes these last two events.

Figure 9 shows the impact of the monetary policy shocks on 21 and 23 October. Both

Figure 8: Monetary Policy and the SARS Virus



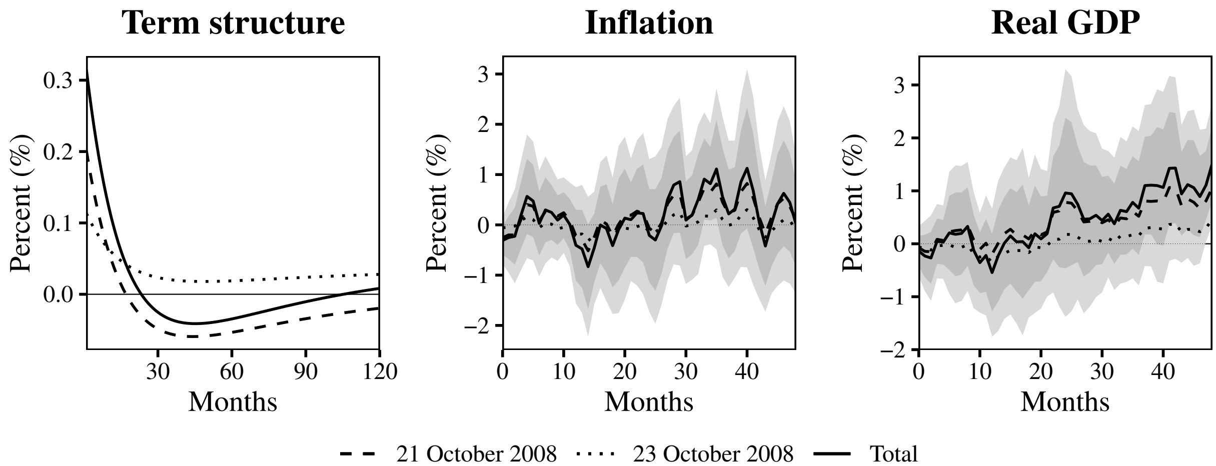
Note: The left panel shows the estimated change in the yield curve, while the right-hand panels show the responses of inflation and GDP. Solid lines show the combined effects of the two monetary policy events in July 2003. Dashed lines correspond to the effect of the 15 July event and dotted lines to the effect of the 17 July event. All responses of inflation and output use the actual real interest rate $r_{t-1} = 0.90$.

shocks are contractionary over the short run, raising yields on maturities of less than 30 months, which indicates that markets were anticipating a larger cut of the policy rate than the 25 basis points. The tightening effect is driven by a total increase in the slope factor of 27 basis points on those two dates. But there is also a cumulative decline in the curvature factor of 75 basis points, which is why yields decline for maturities between 30 and 100 months. This explains why, although there is a slight decline in real GDP after about one year (not statistically significant), the expansionary effects eventually dominate as the response of real GDP turns positive approximately two years after the shock.[8]

Oil Price Shock (21 January 2015) The Bank of Canada dropped its policy rate by 25 basis points to 0.75 percent in response to a sharp decline in oil prices. It was the first interest rate cut since the Global Financial Crisis. The cut was largely unanticipated which is reflected in big downward movements of the slope and curvature factors, $\Delta\beta_{2,t} = -0.31$

[8]If we had also included the October 8th shock as part of the aggregate shock, the tightening at the short end of the yield curve would have been smaller. Interestingly, however, adding this additional shock does not change the general results for the effects on inflation and real GDP.

Figure 9: Monetary Policy and the Global Financial Crisis



Note: The left panel shows estimated changes in the yield curve, with the other two showing the effects on inflation and real GDP. Solid lines correspond to the cumulative effect of the two events. The dashed line shows the effect of the shock on 21 October while the dotted line shows the effect of the shock on 23 October. All responses of inflation and output use the actual real interest rate $r_{t-1} = -0.15$.

and $\Delta\beta_{3,t} = -0.83$ respectively. The left panel of Figure 10 shows that the policy change shifted the entire yield curve down.

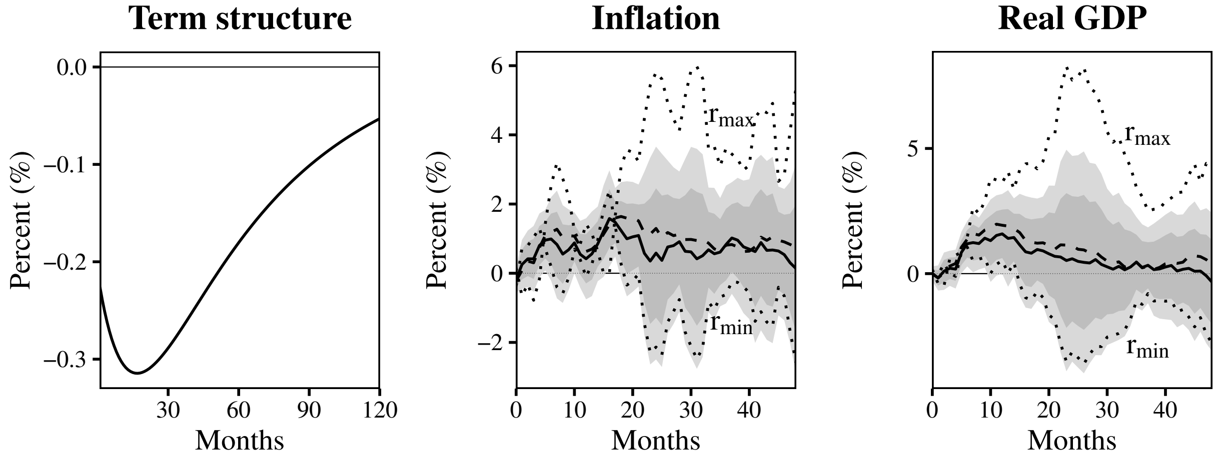
The solid lines from the middle and left panels of Figure 10 show the responses of inflation and real GDP to this policy shock. Not surprisingly, the policy change had a significant and strong expansionary effect on both variables over the first two years. Still, the negative real interest rate at the time somewhat muted the response of inflation and real GDP. The policy would have been considerably more expansionary at a higher value of the real interest rate, and particularly so at horizons between 24 and 48 months.

4.2 Forward guidance

Conditional Commitment (21 April 2009) On 21 April, the Bank of Canada reduced its policy rate to its effective lower bound of 0.25 percent for the first time. The policy announcement also contained the first true forward guidance statement.[9] At the same time,

[9] "Conditional on the outlook for inflation, the target overnight rate can be expected to remain at its current level until the end of the second quarter of 2010 in order to achieve the inflation target. The Bank will continue to provide such guidance in its scheduled interest rate announcements as long as the overnight

Figure 10: Monetary Policy and the Oil Price Decline



Note: The left panel shows estimated changes in the yield curve, while the other panels show response of inflation and real GDP. Solid lines show the response of inflation and real GDP using the actual real interest rate $r_{t-1} = -0.22$. For comparison, the dotted lines show hypothetical responses for the same shock, but with the real interest rate at the maximum ($r_{max} = 5.09$) or minimum ($r_{min} = -2.45$) sample value and the dashed lines shows the response using naive estimates from a restricted model where $\gamma_{i,h} = 0$ for $i = 1, 2, 3$ and $h = 0, ..., 48$.

there was widespread speculation that the Bank of Canada would follow other central banks by implementing quantitative easing programs. We include the release of the MPR in the policy shock since the Bank announced in its statement that it would provide further clarifications in its report.[10]

An advantage of our methodology is that we can directly evaluate the impact of unconventional policy measures. Figure 11 shows that the initial forward guidance provided in the 21 April policy statement had a substantial effect on yields, especially at shorter maturities. The release of the MPR on 23 April provided only a small extra short-run effect to the policy announcement, but has a large contractionary effect in the long-run. A potential explanation is that markets had anticipated specific details of a bond-buying program to be announced, perhaps even including actual purchases. Instead, the policy laid out general

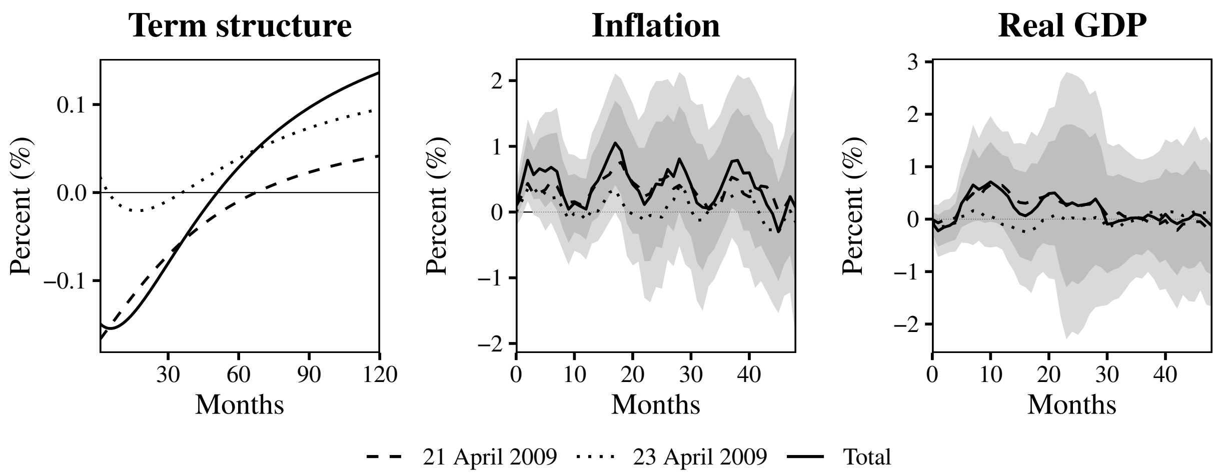
rate is at the effective lower bound." Bank of Canada 2009, `https://www.bankofcanada.ca/2009/04/fad-press-release-2009-04-21/`

[10]The 21 April policy statement points out that, "The Bank retains considerable flexibility in the conduct of monetary policy at low interest rates, consistent with the framework to be outlined in the Bank's *Monetary Policy Report* on 23 April."

terms and principles that future policies might follow. The total effect resulted again in a twisting of the yield curve, with short-run yields falling and long-run yields rising.

As a consequence, our estimates show a mixed set of results. While inflation responded somewhat positively initially, there was neither a significant effect on inflation nor on real GDP in the long run. These results are not surprising as the expansionary effects of a decline in the slope and curvature factors are largely offset by the contractionary effect from the increase of yields at higher maturities. Hence, we conclude that forward guidance was largely unsuccessful.

Figure 11: Monetary policy and the Conditional Commiment

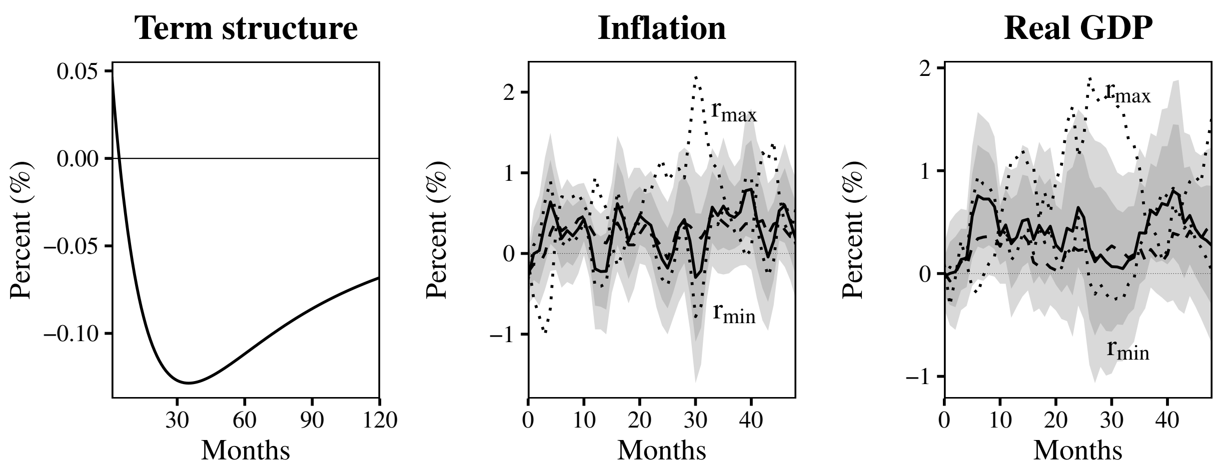


Note: The left panel shows the estimated change in the yield curve, while the right-hand panels show the responses of inflation and GDP. Solid lines show the combined effects of the two monetary policy events in April 2009. Dashed lines correspond to the effect of the April 21st event and dotted lines to the effect of the 23 April event. All responses of inflation and output use the actual real interest rate $r_{t-1} = -0.49$.

Exiting the Zero Lower Bound (1 June 2010) It is interesting to then also look at the impact of monetary policy when the conditional commitment ran out. The Bank of Canada moved away from the effective lower bound, raising the policy interest rate by 25 basis points on 1 June 2010. The increase in the policy rate was largely expected, but the policy statement included language that could be interpreted as dovish on future interest rates, stating that "Given the considerable uncertainty surrounding the outlook, any further reduction of monetary stimulus would have to be weighed carefully against domestic and global economic developments." Hence, one can interpret the announcement as providing further, albeit less direct forward guidance.

The effect on the yield curve was basically a downwards shift across all yields except at very short maturities as shown in Figure 12. This was largely due to the curvature factor, which declined by about 50 basis points. However, the impact on inflation and real GDP is not significant. This could be again attributed to the fact that real interest rates were negative at this time, muting the effects of monetary policy. Indeed, a counterfactual with larger real interest rates shows a much larger and significant response of both inflation and GDP.

Figure 12: Monetary policy and Exit from the Zero Lower Bound



Note: The left panel shows estimated changes in the yield curve, while the other panels show response of inflation and real GDP. Solid lines show the response of inflation and real GDP using the actual real interest rate $r_{t-1} = -0.89$. For comparison, the dotted lines show hypothetical responses for the same shock but with the real interest rate at the maximum ($r_{max} = 5.09$) or minimum ($r_{min} = -2.45$) sample value and the dashed lines shows the response using naive estimates from a restricted model where $\gamma_{i,h} = 0$ for $i = 1, 2, 3$ and $h = 0, ..., 48$.

4.3 The CoVid period

Next we study the effects of monetary policy undertaken during the CoVid period. We did not include this time period for our estimation of equation (2) because the change in real GDP is so large during this period that it would have skewed our point estimates and inflated their standard errors. Instead, we use our estimates from the pre-CoVid period, combined with the monetary policy shocks from the CoVid period in this section. This relies on the assumption that there have been no changes to our parameter estimates in the local projections since March 2020. While this is clearly a strong assumption, it allows us to the look at the Bank of Canada's first foray into large scale asset purchases.

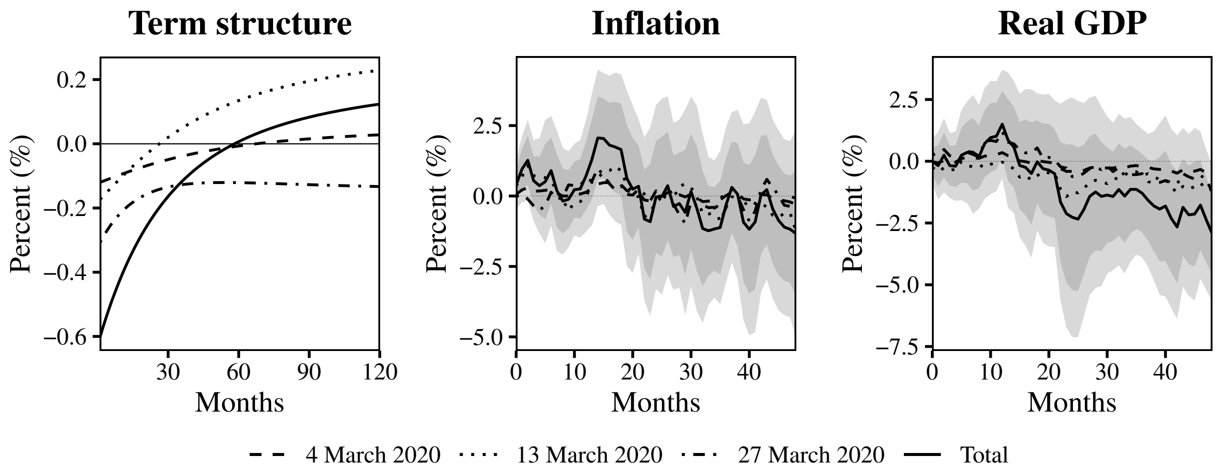
Emergency Cuts & Quantitative Easing (13–27 March 2020) In March 2020, the Bank of Canada undertook four distinct policy changes in response to the pandemic. First, the policy rate was lowered by 50 basis points to 1.25 percent at a scheduled meeting on 4 March. Following that, the policy rate was again reduced by a further 50 basis points at an unscheduled meeting on 13 March. Only two days later, on 15 March, the Bank of Canada announced a coordinated liquidity provision program, jointly with the Bank of England, the Bank of Japan, the European Central Bank, and the Federal Reserve. Finally, at an unscheduled meeting on 27 March, the policy rate was further lowered by a final 50 basis points to the effective lower bound. At the same time, the Bank of Canada announced that it would begin large scale asset purchases of both Government of Canada bonds and Commercial paper.[11]

Figure 13 shows the impact of these policy measures on the yield curve, excluding the 15 March event since it fell on a weekend and was a coordinated response involving several other central banks. The shock on 4 March has an impact primarily on the short end of the yield curve, but at a smaller size than the cut in the policy rate, indicating that a cut in interest

[11] The stated goal of these purchases was to both, provide liquidity to strained financial markets and as to "enhance the effectiveness of all other actions taken so far." Bank of Canada 2020, `https://www.bankofcanada.ca/2020/03/press-release-2020-03-27/`

rates was anticipated, but markets were surprised by the size of the change. The 13 March shock has an interesting effect on the yield curve, lowering short-run yields while raising long-run yields. Finally, the 27 March statement has an unambiguously expansionary effect, lowering yields across all horizons. Hence, the mere announcement of quantitative easing caused a distinct downward shift in the level of the yield curve.

Figure 13: Monetary policy and the Pandemic Response



Note: The left panel shows estimated changes in the yield curve, while the other panels show response of inflation and real GDP. Solid lines show the response of inflation and real GDP using the actual real interest rate $r_{t-1} = -0.16$. The solid line is the cumulative effect of all three shocks, while the dashed, dotted, and dashed-dotted lines show the individual effects of the shocks on 4, 13, and 27 March, respectively.

The policies had the intended stimulative effect on economic activity over the first 24 months, raising both inflation and output, although the estimates are typically not statistically significant at even the 68% level. In economic terms, the magnitude of the responses are quite large: The cumulative impact on both variables is about 2 percentage points at its peak. However, the effects die out pretty quickly.

These results provide some weak evidence that monetary policy actions undertaken over the COVID crisis can explain some of the elevated inflation rates observed during the recovery period. However, because real interest rates were very low at the time, the contribution of monetary policy to inflation (and real GDP) was lower than it would have otherwise been at a normalized level of the real interest rate.

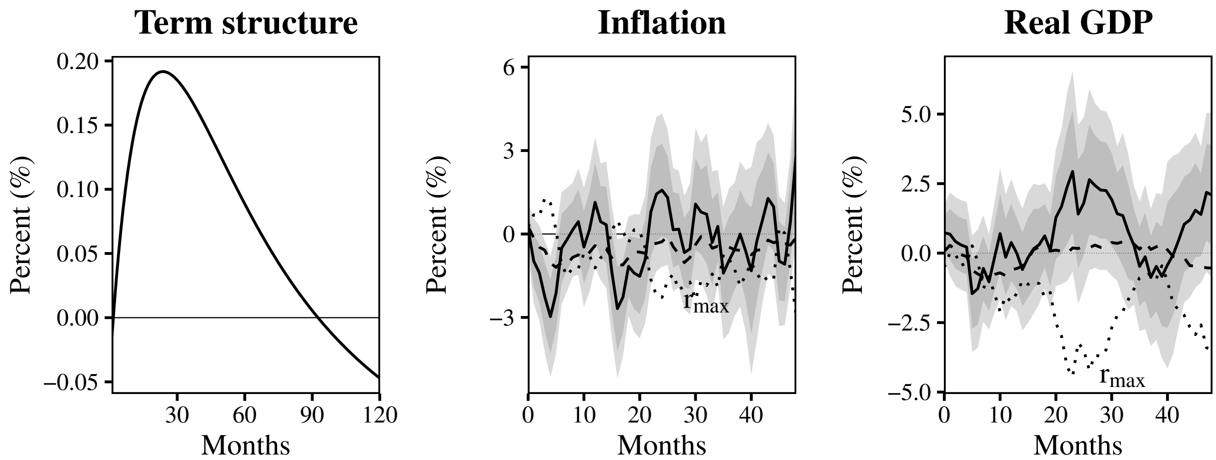
Termination of QE (27 October 2021) The announcement following the scheduled meeting on 27 October 2021 included two interesting components. First, the Bank of Canada announced the end of the quantitative easing programs. It would continue to purchase assets only to replace maturing bonds so as to maintain the existing size of the balance sheet, which it referred to as the "reinvestment phase". Second, there was a change in forward guidance with the policy announcement indicating that interest rates would be rising at a faster than expected pace.

This is reflected in the responses of the yield curve in Figure 14, which shows an increase in yields across almost all maturities with the strongest effect on maturities of medium term. The response of inflation is very volatile, but is typically negative over the first two years and occasionally statistically significant. The response of real GDP, however, is somewhat counterintuitive. There is essentially no response until 20 months after the shock, at which point GDP actually increases, and the effect is statistically significant at the 68% level. Overall, the policy did not cause a contraction in real GDP because of the very low level of the real interest rate of -3.88% which is close to the minimum across our sample. At higher interest rates the response would have been much stronger, in the anticipated direction, and statistically significant. Hence, our results indicate that the policy change is unlikely to have generated a meaningful reduction in inflation and GDP which is consistent with current observation about the recovery from the pandemic.

Catching Up to High Inflation (13 July 2022) Starting in March 2022, the Bank of Canada started to raise interest rates in response to the emergence of inflation after the pandemic. On 13 July 2022, the Bank increased the policy rate by 100 basis points, the largest increase during the tightening cycle in the second half of 2022. Figure 15 shows that markets were surprised by the extraordinary size of the rate increase with the yield curve sharply increasing for shorter maturities.

The impulse response functions, however, show a counterintuitive response to the tight-

Figure 14: Monetary policy and Termination of QE



Note: The left panel shows estimated changes in the yield curve, while the other panels show response of inflation and real GDP. Solid lines show the response of inflation and real GDP using the actual real interest rate $r_{t-1} = -3.88$. For comparison, the dotted lines show hypothetical responses for the same shock but with the real interest rate at the maximum ($r_{max} = 5.09$) sample value while the dashed lines shows the response using naive estimates from a restricted model where $\gamma_{i,h} = 0$ for $i = 1, 2, 3$ and $h = 0, ..., 48$. The response at the minimum real interest rate is not shown as it is very close to the solid line.

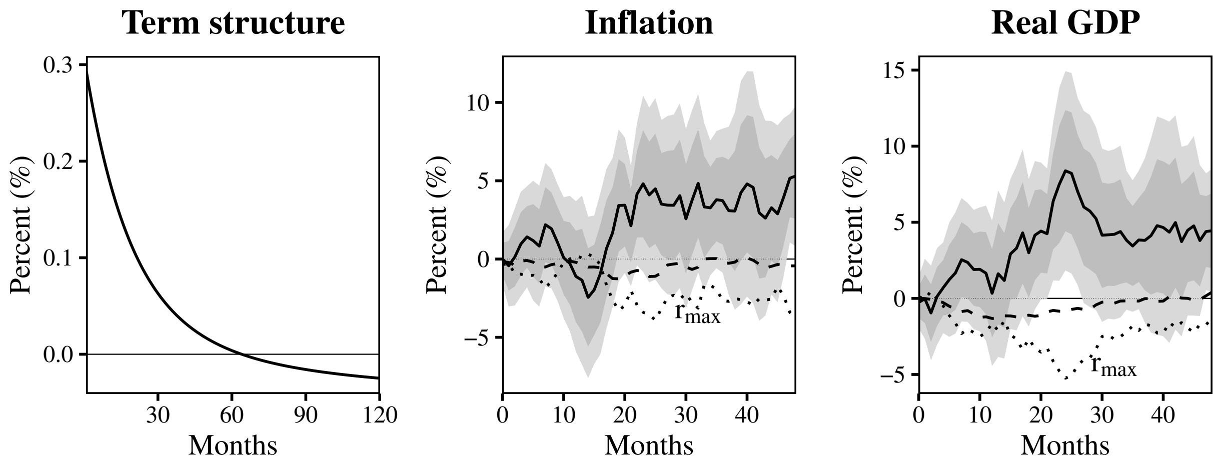
ening of monetary policy with both, inflation and GDP sharply increasing in the medium and long run. Once again, our specification attributes this fact to the extremely low level of real interest rates at this time, $r_{t-1} = -4.57$. Given that the shock caused yields to increase at most maturities, if the real interest rate had been at a more typical sample value, we would expect this shock to be contractionary, and statistically significant, consistent with Figure 5. Again, we can cautiously interpret this finding as indicating that the effects of monetary policy are muted at low levels of real interest rates.[12]

5 Conclusion: Four Lessons from the Yield Curve

We develop a new series of Canadian monetary policy shocks and study their effects on inflation and real GDP. Following Inoue and Rossi (2021), we define a functional monetary

[12]One could argue, however, that our linear specification may not be appropriate when capturing time periods where real interest rate deviate largely from their long-run mean.

Figure 15: Monetary policy and high inflation



Note: The left panel shows estimated changes in the yield curve, while the other panels show responses of inflation and real GDP. Solid lines show the response of inflation and real GDP using the actual real interest rate $r_{t-1} = -4.57$ which is at the minimum for our sample period. For comparison, the dotted lines show hypothetical responses for the same shock but with the real interest rate at the maximum ($r_{max} = 5.09$) sample value while the dashed lines shows the response using naive estimates from a restricted model where $\gamma_{i,h} = 0$ for $i = 1, 2, 3$ and $h = 0, ..., 48$.

policy shock as a shift in the entire yield curve after a monetary policy action, which we measure using changes in the three Nelson-Siegel factors. Using local projections, we show that an increase in any of these three factors lowers inflation and real GDP, and in most cases those effects are statistically significant at the 90% level. We further show that these responses are state dependent: monetary policy tends to be more effective when the real interest rate is higher. Finally, we study the responses of inflation and real GDP to specific monetary policy events of interest over our sample period.

Looking at monetary policy through the lens of changes in the yield curve is a powerful tool for two main reasons. First, monetary policy is not seen narrowly as decisions about short-term interest rates, but includes communication and unconventional policy actions that are designed to influence the entire yield curve. Second, each policy event has a unique impact on the entire term structure and, hence, a unique impact on inflation and GDP. We have looked at Canadian monetary policy through the lens of the yield curve and found four main lessons from looking at the most prominent policy events over the last 25 years.

1. Monetary policy influences inflation and real GDP primarily by moving the entire yield curve rather than moving only the policy rate. The biggest effects tend to be associated with shifting interest rates across the entire term structure, whether or not this was the intended policy effect.

2. Major monetary policy actions tend to twist the yield curve with interest rates at the short and the long maturities moving in opposite directions. Hence, only looking at changes of the policy rate is too narrow and risks overestimating the effects on inflation and real GDP.

3. The level of interest rates is crucial for how big the impact of monetary policy will be. When real interest rates are low, the effects of monetary policy tend to be muted, possibly even reversed.

4. Unconventional policy such as communication, forward guidance and quantitative easing are effective in the sense that they can have large effects on the yield curve. The effects of these policies on inflation and GDP are muted, however, since they tend to coincide prominently with periods of low interest rates.

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