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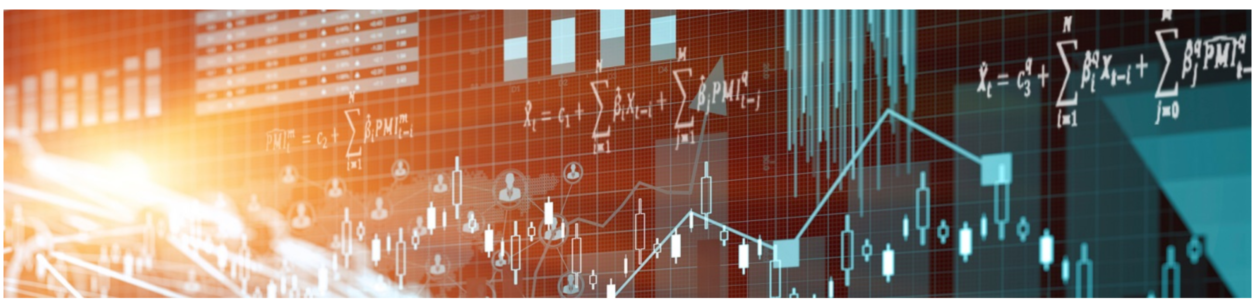

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Changes in Monetary Regimes and the Identification of Monetary Policy Shocks: Narrative Evidence from Canada

by

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Abstract

We use narrative evidence along with a novel database of real-time data and forecasts from the Bank of Canada's staff economic projections from 1974 to 2015 to construct a new measure of monetary policy shocks and estimate the effects of monetary policy in Canada. We show that it is crucial to take into account the break in the conduct of monetary policy caused by the announcement of inflation targeting in 1991 when estimating the effects of monetary policy. For instance, we find that a 100-basis-point increase in our new shock series leads to a 1.0 per cent decrease in real GDP and a 0.4 per cent fall in the price level, while not accounting for the break leads to a permanent decrease in real GDP and a price puzzle. Finally, we compare our results with updated narrative evidence for the U.S. and the U.K. and argue that taking into account changes in the conduct of monetary policy in these countries also yields significantly different effects of monetary policy.

Bank topics: Business fluctuations and cycles; Central bank research; Econometric and statistical methods; exchange rate regimes; inflation and prices; inflation targets; interest rates; monetary policy; monetary policy framework
JEL codes: E31, E32, E43, E52, E58

Résumé

Nous utilisons de l'information narrative ainsi qu'une nouvelle base de données en temps réel et des prévisions provenant des projections économiques établies par le personnel de la Banque du Canada de 1974 à 2015 pour construire une nouvelle mesure de chocs de politique monétaire et estimons les effets de la politique monétaire au Canada. Nous montrons qu'il est primordial de prendre en compte le changement structurel dans la conduite de la politique monétaire causé par l'annonce du ciblage de l'inflation en 1991 lorsque nous estimons les effets de la politique monétaire. Par exemple, nous constatons qu'une augmentation de 100 points de base de notre nouvelle série se traduit par une diminution de 1 % du PIB réel et de 0,4 % du niveau des prix, tandis que nous observons un recul permanent du PIB réel et une augmentation inattendue du niveau des prix si le changement structurel dans la conduite de la politique monétaire n'est pas pris en compte. Finalement, nous comparons nos résultats avec ceux des États-Unis et du Royaume-Uni et trouvons aussi que prendre en compte le changement de la conduite de la politique monétaire dans ces pays produit des effets différents en matière de politique monétaire.

Sujets : Cycles et fluctuations économiques; Recherches menées par les banques centrales; Méthodes économétriques et statistiques; Régimes de taux de change; Inflation et prix; Cibles en matière d'inflation; Taux d'intérêt; Politique monétaire; Cadre de la politique monétaire
Codes JEL : E31, E32, E43, E52, E58

Non-technical summary

Quantifying the effects of monetary policy is challenging and has generated a vast literature in empirical macroeconomics. Much of this literature uses vector autoregressions (VARs), identified with different approaches, and finds that the effects of monetary policy for the U.S. are relatively modest, with peak decline estimates ranging between 0.3 and 1 per cent for output following a 100-basis-point monetary innovation. However, Romer and Romer (2004; R&R henceforth) find much larger effects of U.S. monetary policy shocks using narrative methods. This strategy uses historical records to construct a series of intended interest rate changes at meetings of the Federal Open Market Committee (FOMC) and then isolate the innovations to these interest rate changes that are orthogonal to the Federal Reserve's information set. A 100-basis-point shock from the R&R shock series translates into output and price level peak declines larger than 4 per cent. The study by Cloyne and Hurtgen (2016) extends the narrative approach to the U.K. and is, to our knowledge, the only one applying narrative methods to a country other than the U.S.

Another important body of literature in monetary economics has documented important shifts in the conduct of monetary policy in the U.S. and abroad. Some prominent papers, such as Clarida et al. (2000), document that U.S. monetary policy has become more responsive to expected inflation after the Volcker disinflation. There is also evidence that monetary policy rules in small open economies have also changed significantly. For example, Alstadheim et al. (2013) show that the central banks of the U.K., Sweden and Canada shifted away from responding to exchange rate movements around the 1990s, when these countries implemented inflation-targeting (IT) regimes.

Our paper builds on these two strands of literature and applies the narrative approach to Canada, providing new evidence on the macroeconomic effects of monetary policy and highlighting the importance of changes in the conduct of systematic monetary policy. We use historical documents to construct a series of intended changes in the target policy interest rate along with a novel database of real-time data and forecasts assembled from the Bank of Canada's staff economic projections from 1974 to 2015, to isolate the innovations to the intended policy changes that are orthogonal to the policy-makers' information set. We find that following a 100-basis-point monetary policy shock, real monthly GDP has a peak decline of 1.0 per cent about 18 to 24 months after the shock and is less than 0.5 per cent lower after three years, while the price level (consumer price index) response is weaker and takes longer to materialize, falling by 0.4 per cent after three years.

We show that it is crucial for these results to depart from R&R in two important ways: (i) by controlling for U.S. interest rates as well as the USD/CAD exchange rate in the policy-makers' information set, and (ii) by accounting for the structural break in the conduct of monetary policy caused by the announcement of IT in 1991. Canada has had a continuing floating exchange rate regime since 1970 and exchange rate movements were an important factor in monetary policy decisions. Additionally, the announcement of the IT regime in 1991 prompted a sharp shift in the conduct of monetary policy. We show that while the exchange rate and U.S. interest rates were the main determinants of changes in the target policy rate in the 1970s and 1980s, gross domestic product and inflation forecasts have become the key factors since the introduction of the IT regime. Furthermore, we show that not accounting for this change leads to monetary policy shocks that imply a prize puzzle and show clear signs of endogeneity.

1 Introduction

The identification of monetary policy shocks has generated a vast literature in empirical macroeconomics. Much of this literature uses vector autoregressions (VARs), identified with different approaches, and finds that the effects of monetary policy for the U.S. are relatively modest, with peak decline estimates ranging between 0.3 and 1 per cent for output following a 100-basis-point monetary innovation. The estimates for the price level range between a positive response (coined the "price puzzle" by Eichenbaum (1992) and Sims (1992)), to slightly negative, depending on the identification strategy used (e.g., Leeper et al. (1996), Christiano et al. (1996, 1999), Bernanke and Mihov (1998), Bernanke et al. (2005), Uhlig (2005)). However, Romer and Romer (2004, R&R henceforth) find much larger effects of U.S. monetary policy shocks using narrative methods. This strategy uses historical records to construct a series of intended interest rate changes at meetings of the Federal Open Market Committee (FOMC) and then isolate the innovations to these interest rate changes that are orthogonal to the Federal Reserve's information set. A 100-basis-point innovation from the R&R measure translates into output and price level peak declines larger than 4 per cent. Coibion (2012) reconciles the differences between R&R and the previous VAR studies and suggests that the effects of monetary policy are more likely to be medium sized (i.e., about -2 per cent for output and prices). Cloyne and Hürtgen (2016) extend the narrative approach to the U.K. and find effects of monetary policy that are in line with those of Coibion (2012) for the U.S.[1]

Another body of literature in monetary economics has documented important shifts in the conduct of monetary policy in the U.S. and abroad. Clarida et al. (2000) estimate monetary policy rules for the U.S. and find substantial differences before and after Volcker's appointment, with monetary policy becoming more responsive to expected inflation in the later period. Within a time-varying VAR with stochastic volatility, Primiceri (2005) also shows that the systematic component of monetary policy has responded more aggressively to inflation and unemployment. Boivin and Giannoni (2006) estimate VARs over the pre- and post-1980 periods, and show evidence of a reduced effect of monetary policy shocks

[1] For an exhaustive integration of this long literature, see the recent survey by Ramey (2016).

in the latter period. Using a small structural model, they show that by responding more strongly to inflation expectations, monetary policy has been more effective in stabilizing the economy in the post-1980 period. Focusing on small open economies, Alstadheim et al. (2013) show that the central banks of the U.K., Sweden and Canada have shifted away from responding to exchange rate movements around the 1990s, when these countries implemented inflation-targeting (IT) regimes.

Our paper builds on these two strands of literature and applies R&R's narrative approach to Canada, providing new evidence on the macroeconomic effects of monetary policy and highlighting the importance of changes in the conduct of systematic monetary policy. As in R&R, our analysis proceeds in two stages. The first stage identifies the exogenous component of monetary policy. To do this, we use historical documents to construct a series of intended changes in the target policy interest rate along with a novel database of real-time data and forecasts assembled from the Bank of Canada's staff economic projections from 1974 to 2015. These real-time data and forecasts are used to isolate the innovations to the intended policy changes that are orthogonal to the policy-makers' information set. We then proceed to the second stage, where we estimate a monthly monetary VAR that includes our new shocks measure (ordered last) as the relevant policy rate. Following a 100-basis-point monetary policy shock, real monthly gross domestic product (GDP) has a peak decline of 1.0 per cent about 18 to 24 months after the shock and is less than 0.5 per cent lower after three years, while the consumer price index (CPI) response is weaker and takes longer to materialize, falling by 0.4 per cent after three years. We show that it is crucial for these results to depart from R&R in two important ways: (i) by controlling for U.S. interest rates as well as the USD/CAD exchange rate in the policy-makers' information set, and (ii) by accounting for the structural break in the conduct of monetary policy caused by the announcement of IT in 1991.[2] Canada has had a continuing floating exchange rate regime since 1970 and exchange rate movements were an important factor in monetary policy decisions, as documented by Fortin (1979), Courchene (1981), Lubik and Schorfheide (2007) and Alstadheim et al. (2013), among others. Additionally, the announcement of the IT regime in 1991 prompted a sharp shift in the conduct of monetary policy. We show that

[2]While the IT regime was announced in February 1991, the CPI inflation targets were initially set at 3.0 per cent by the end of 1992, 2.5 per cent by the middle of 1994, and 2.0 per cent by the end of 1995.

while the exchange rate and U.S. interest rates were the main determinants of changes in the target policy rate in the 1970s and 1980s, GDP and inflation forecasts have become the key factors since the introduction of the IT regime. Furthermore, we show that not accounting for this change leads to monetary policy shocks that imply a prize puzzle and show clear signs of endogeneity.

We find that monetary policy shocks in Canada generate output effects that are qualitatively in line with narrative evidence for other countries, as in Coibion (2012) for the U.S. and Cloyne and Hürtgen (2016) for the U.K., albeit the price level response in Canada is weaker than in those countries. However, the conduct of monetary policy in the U.S. and the U.K. has also undergone significant changes. For instance, a large number of papers argue that U.S. monetary policy has become more responsive to future expected inflation since the Volcker disinflation. Similarly, the U.K. also introduced an IT regime in 1993, and granted the Bank of England formal autonomy to pursue these targets in 1997. To what extent does accounting for the break in the conduct of monetary policy also matter for these countries? We extend the R&R monetary policy shocks for the U.S. and Cloyne and Hürtgen (2016) for the U.K. up to 2011 and account for a break in the monetary policy reaction function. We then examine the macroeconomic effects of these new measures of monetary policy shocks and find different implications for output and inflation. In line with our results for Canada, after accounting for the structural break in the systematic component of monetary policy, the shocks generate a smaller impact on industrial production and a larger (negative) impact on the price level.

We further examine the robustness of our main results to many alternative specifications and provide additional results: for instance, (i) using Jordà (2005)'s local projections method, we test the robustness of our results and also assess the response of open economy variables such as the USD/CAD exchange rate, imports and exports. We find that the Canadian dollar appreciates (relative to the U.S. dollar) by about 1.0 per cent for a year and then depreciates slowly, ending 2 per cent lower after three years, leading to a peak decline of 4.0 per cent in imports. Following the decline in economic activity, exports decrease by about 3.5 per cent despite the depreciation of the currency; (ii) we estimate a standard VAR *à la* Christiano et al. (1996, 1999) with the target policy rate instead of our shocks series and find a large price puzzle; (iii) we show the robustness of our baseline VAR results with different measures of output and price level; (iv) we restrain our sample to the period where the Bank had explicit inflation targets (1992-2015) and, finally, (v) we show that our results are robust to many alternative first-stage specifications.

The remainder of the paper is organized as follows. Section 2 details the derivation of the new measure of monetary policy shocks for Canada and provides a data description, along with some analysis of the new measure. Section 3 presents our baseline results for the effects of monetary policy and compares them with narrative evidence from the U.S. and the U.K., while Section 4 provides additional results and robustness exercises. Section 5 concludes.

2 Derivation of a new measure of monetary policy shocks for Canada

In this section, we first describe how we adapt R&R's identification strategy to the institutional details regarding the historical conduct of monetary policy in Canada, specify our first-stage regression and provide a description of our database construct of real-time data and staff forecasts. We then summarize the first-stage estimation results, present the new shocks series and finally provide some analysis.[3]

2.1 Identification

We formally represent the identification of monetary policy shocks using the following equation:

$$S_t = f(\Omega_t) + \mu_t. \tag{1}$$

The intended monetary policy variable (S_t) is a combination of a systematic component $f(\Omega_t)$, where the function (f) captures the policy-makers' reaction function to their information set (Ω_t) and an exogenous component (μ_t) that reflects unexpected changes in monetary policy. R&R's strategy to identify μ_t—the narrative approach—has become a

[3]To facilitate comparison, we will follow closely Cloyne and Hürtgen (2016)'s notation.

popular method to derive a measure of monetary policy shocks.[4] It is appealing because it goes a long way in overcoming many econometric challenges faced when estimating the effects of monetary policy, such as the simultaneous determination of interest rates and macroeconomic variables, the forward-looking behavior and real-time nature of monetary policy decisions.[5] Many studies have tackled the simultaneity problem using a timing restriction in VARs (called the "recursive assumption"), but haven't overcome the other issues, notably the forward-looking nature of policy. For example, Christiano et al. (1996, 1999)'s benchmark model assumes that a first block of variables such as output, prices, and commodity prices do not respond to monetary policy shocks within the same period, while monetary policy is allowed to react contemporaneously to the first block of variables. Other papers in the literature have used factor-augmented VARs (Bernanke et al. (2005)) to exploit a larger set of data as a better proxy for the policy-makers' information set, or used sign restrictions (Faust (1998), Uhlig (2005)) as a way to identify the shocks μ_t. However, R&R's approach implicitly assumes that the monetary policy reaction function does not change throughout the sample they study. This is at odds with some prominent papers such as Clarida et al. (2000), Primiceri (2005) and Boivin and Giannoni (2006), which show a significant change in the systematic component of U.S. monetary policy around the early 1980s, where policy began reacting more aggressively to expected future inflation.

We apply the R&R approach to identify monetary policy shocks (μ_t) for Canada.[6] Their approach has two key steps: first, they derive a series of intended changes in the federal funds rate (FFR) around FOMC meetings, and second, they control for the Federal Reserve staff real-time forecasts (Greenbooks) to create a measure of intended FFR changes that is orthogonal to information about past, current and future economic developments.

[4] Apart from monetary policy shocks, the narrative approach has also been employed to identify fiscal policy shocks; e.g. Romer and Romer (2010) and Ramey (2011) for the U.S. and Cloyne (2013) for the U.K. For a recent application to government asset purchases, see Fieldhouse and Mertens (2017) and Fieldhouse et al. (2017).

[5] Central banks devote a lot of resources monitoring the economy and forecasting in real-time the future path of macroeconomic variables (e.g., see Romer and Romer (2000) and Croushore and Stark (2001) for the Federal Reserve (U.S.); Duguay and Poloz (1994), Poloz et al. (1994) and Dorich et al. (2013) for the Bank of Canada). Moreover, there can be stark differences in using ex-post revised vs. real-time data when estimating monetary policy reaction functions (e.g., Orphanides (2001, 2003) or Molodtsova et al. (2008)).

[6] We use the term "narrative" because we use various historical documents to (i) construct the intended policy target; (ii) construct our database of real-time data and staff forecasts; and (iii) justify our estimation of equation (2).

One of the major contributions of R&R was to use the minutes of the FOMC meetings to construct the series of intended changes in the FFR, as the Federal Reserve did not always target it explicitly.[7] A handy feature of the Canadian monetary policy framework is that the Bank of Canada has always used a target interest rate explicitly (Courchene (1979), Fettig (1994)), even when it emphasized targeting the money supply.[8] Specifically, we construct our policy rate series using the *Target for the Overnight Rate* from February 1996 onward, the *operating band for the overnight rate* between April 1994 and February 1996, and the *Bank Rate* between 1973 and April 1994.[9] This framework is very similar to the U.K., where the policy rate (also called the Bank Rate) has always been the relevant policy target.[10]

The next step in the derivation of our monetary policy shock series is to purge the intended policy rate from the systematic component $f(\Omega_t)$ of monetary policy. The specific regression equation we estimate is:

$$\begin{aligned}\Delta i_m =& \alpha + \beta_1 i_{t-d14} + \sum_{h=1}^{3} \rho_h u_{t-h} + \sum_{j=-1}^{2} \gamma_j \hat{y}^f_{m,j} + \sum_{j=-1}^{2} \delta_j \pi^f_{m,j} \\ &+ \sum_{j=-1}^{2} \theta_j (\hat{y}^f_{m,j} - \hat{y}^f_{m-1,j}) + \sum_{j=-1}^{2} \phi_j (\pi^f_{m,j} - \pi^f_{m-1,j}) \\ &+ \beta_2 FFR_{t-d14} + \beta_3 ER_{t-d14} + \beta_4 \Delta FFR_{m-m_{-1}} \beta_5 \Delta ER_{m-m_{-1}} + \epsilon_m,\end{aligned} \tag{2}$$

[7]The Volcker's disinflation 1979–82 period is an example of when the Federal Reserve was not explicitly targeting the FFR.

[8]During the 1975–82 period, while the Bank publicly stated that its objective was to target the growth rate of the money stock, it achieved this by setting short-term interest rates at levels that would bring the monetary conditions consistent with the Bank's views of inflationary pressures (e.g., Fortin (1979), Sparks (1979), Racette and Raynauld (1994) and Longworth (2003)).

[9]The operating band for the overnight rate was introduced in April 1994, nearly two years before the introduction of the target rate. Even if the Bank Rate has always been the key interest rate at which the Bank lends to chartered banks, we use the operating band as our target policy rate between April 1994 and February 1996 because the introduction of the operating band was seen as a first step to provide more transparency to monetary policy (Lundrigan and Toll (1998)). Since February 1996, the Target for the Overnight Rate has been set as the mid-point of the operating band and the Bank Rate is equal to the upper limit of the band. These rates are published on the Bank of Canada website. See Appendix A.2 for more details on the construction of our intended policy rate series and a backgrounder on the key interest rates at the Bank of Canada.

[10]Also note that the Bank Rate, the operating band for the overnight rate, or the Target for the Overnight Rate are not market rates but policy rates announced by the Bank of Canada. It is similar to the intended target FFR that R&R construct from the FOMC documents, and to the U.K. Bank Rate used by Cloyne and Hürtgen (2016).

where the dependent variable (Δi_m), the change in the intended policy rate, is measured at a meeting-by-meeting frequency, as indicated by the subscript m. The subscript j denotes the quarter of the real-time data or forecast relative to the meeting date, while subscripts $t-h$ and $t-d14$ refer to information from the previous months and two weeks relative to the meeting date, respectively (and not to information from a previous meeting). Specifically, we regress the change in the intended policy target rate (Δi_m) between two meetings on the one- and two-quarter-ahead forecasts of real GDP growth ($\hat{y}^f_{m,j}$) and inflation ($\pi^f_{m,j}$), as well as the nowcast and the real-time one-quarter lag.[11] We also include the revisions to the forecasts relative to the previous round of forecasts (e.g., $\hat{y}^f_{m,j} - \hat{y}^f_{m-1,j}$), since both the level and change in the forecasts can be important determinants of the Bank's behavior. To control for economic developments between meetings, we include the intended policy rate two weeks before the meeting and the (real-time) rates of unemployment for the previous three months.[12]

The third line of equation (2) departs importantly from R&R and Cloyne and Hürtgen (2016) as we also control for the levels and changes of the U.S. FFR (FFR_{t-d14}) and the logarithm of the USD/CAD nominal exchange rate (ER_{t-d14}) two weeks before the meeting.[13] Canada is a small open economy with close ties to the U.S., and these variables are included to capture any tendency for the Bank to react to interest rate movements in the U.S. as well as the changes in the value of the Canadian dollar relative to its U.S. counterpart. For example, Fortin (1979), Courchene (1981), Kuszczak and Murray (1986) and various press releases (e.g., Bank of Canada (1992, 1993)) all point to the Bank reacting to movements in U.S. rates and/or changes in the USD/CAD exchange rate at different points in time. Racette and Raynauld (1992), Lubik and Schorfheide (2007) and Alstadheim et al. (2013) provide empirical evidence that the nominal exchange rate has been part of the Bank of Canada policy rule.

We make another important departure from R&R and Cloyne and Hürtgen (2016) and

[11]Note that we test the robustness of our results to adding a second lag ($t-2$) of real-time GDP growth and inflation (see Section 4.5) and to adding a third quarter ($t+3$) of forecasts (see Appendix D.6). We find that our results are unaffected by these alternative first-stage specifications.

[12]As mentioned by R&R, using forecasts to identify monetary policy shocks has a further advantage since they summarize a wider range of macroeconomic information as well as the anticipated movements in the economy. This approach thus allows us to identify shocks without including a large set of variables, as in the FAVAR approach of Bernanke et al. (2005).

[13]In Section 4 below, we show that our results are robust to using a seven-day lag instead of 14 days.

break the estimation of equation (2) into two sub-samples of meetings: the first sub-sample includes all those meetings preceding the inflation targets (i.e., 1974-1991) and the second sub-sample regroups all meetings afterward (1992 on).[14] The reason for doing this is three-fold: first, there is strong evidence suggesting a change in the Bank's reaction function. For example, Rowe and Yetman (2002) show that there was a major change in the Bank's objectives near the time formal inflation targets were announced. As mentioned above, Fortin (1979), Courchene (1981) and Howitt (1986), among others, provide evidence that the Bank was following U.S. interest rates and exchange rates developments very closely before the IT period.[15] More recent papers argue that since the beginning of IT, the Bank has been using economic forecasts and other current economic indicators more thoroughly to assess whether monetary conditions need to be tightened or eased (e.g., Montador (1995), Duguay and Poloz (1994), Macklem (2002), Dorich et al. (2013) and various *Monetary Policy Reports* (MPRs)). Second, we will show in the next section that our regression estimates of equation (2) strongly support this change in the reaction function, as the response of the intended policy rate (Δi_m) to changes in the USD/CAD exchange rate and U.S. FFR and to real GDP growth and inflation forecasts changes drastically in the first vs. the second sub-sample. Third, as we will show in Section 3, the effects of monetary policy are markedly different when one does not break the first-stage estimation to account for the IT period.

Lastly, we take the estimated residuals from equation (2) for each sub-sample and splice them together to create our new meeting-by-meeting series of monetary policy innovations. This new series, which can be interpreted as exogenous changes that are not taken in response to information about current and future economic developments, will then be converted into a monthly basis and used in the second stage (Section 3) to quantify the effects of monetary policy on macroeconomic variables.

[14]Because IT was announced in 1991 but the first inflation target was set for 1992, we decide to break the first-stage estimation between 1991 and 1992; consequently, our first sub-sample covers 1974-1991 and our second covers 1992 to 2015. Note that breaking the estimation right after the announcement (between February and March 1991) does not alter our results.

[15]For example, Courchene (1981) has a whole chapter titled "1980: Riding the U.S. roller coaster," arguing that Canada was simply a side passenger in the U.S. monetary policy roller coaster of the early 1980s. Also, Howitt (1986) states that the Bank's policy after 1979 consisted of resisting any long-term depreciation of the Canadian dollar and short-term fluctuations in that rate caused by temporary changes in U.S. interest rates.

2.2 Data construction

When constructing our dataset for the first-stage regression (equation 2), we need to match the variables forming the Bank's information set (Ω_t) with the intended policy rate variable. As noted above, our intended policy rate is constructed using the Bank Rate from 1973 up to March 1994, the operating band for the overnight rate between April 1994 and February 1996, and the Target for the Overnight Rate afterward. We use the changes in this series as the left-hand side variable in equation (2).

To build the information set (Ω_t), we first use a novel database of real-time data and forecasts for real GDP and inflation constructed from the Bank of Canada's staff economic projections. Bank of Canada staff produce four exhaustive projections each year, following the release of the quarterly national income and expenditure accounts, which are generally carried out around the end of March, June, September, and December.[16] These staff projections contain quarterly forecasts as well as historical (real-time) data of numerous macroeconomic aggregates. They are a material part of the analysis presented to the Governing Council every quarter in the weeks leading up to the publication of the Bank's Monetary Policy Report.[17] The quarterly staff projections are analogous to the Greenbook forecasts prepared by the Federal Reserve Board staff; they are judgmental in the sense that the forecasts are based on different sources of information and economic models. Second, we construct the (real-time) unemployment rate series from digitized Statistics Canada archives (1978-2015) and hard copies of Bank of Canada Reviews for 1973-1977. Third, our series for the USD/CAD exchange rate is taken from Statistics Canada, and the U.S. FFR is taken from the Federal Reserve Board website. Appendix A.1 presents further details on the data series used in the first-stage regression. This is a large dataset that we hope will be useful for future research.[18]

[16]Note that for many years from 2005 on, Bank of Canada staff produced eight projections per year: the four just mentioned, and four updates released before the other four monetary policy announcement dates. When available, we use these additional forecasts.

[17]See Macklem (2002) for details about the information and analysis presented by the staff to the Governing Council. We highlight the fact that these are staff estimates and thus may not be the same estimates provided in the MPR, the Bank of Canada publication containing detailed economic analysis and economic outlook and representing the view of the Governing Council, available every quarter since 2001.

[18]For example, Champagne et al. (2016) use the same projections dataset to study the real-time properties of the Bank of Canada's staff output gap estimates.

Note that the relevant inflation index varied over our sample. Up to March 1980 inclusively, we use total CPI inflation, while from April 1980 onward, we use core CPI inflation.[19] The earliest vintage of projection data where we have both GDP and inflation forecasts is 1974:Q1.

Before matching each monetary policy decision ("meetings," for short) with the relevant set of real-time data and forecasts, we need to define what exactly we mean by "meeting." Since December 2000, defining a meeting has been straightforward, as the Bank announces monetary policy decisions eight times per year on fixed, announced dates. These announcement dates consequently become our meetings from 2000:12 to 2015:10 (since the latest policy decision in our sample is October 21, 2015). Before 2000:12, the definition of meeting is less trivial as we cannot know with certainty when a meeting happened. Following Cloyne and Hürtgen (2016), we define a meeting as all dates where a change in our intended policy rate occurred; moreover, when a new set of forecasts is released but there is no change in our intended policy rate, we do not treat the forecast release as a decision itself because we cannot be sure these are genuine monetary policy decisions.[20]

Next, we need to assign the relevant projection data to each meeting since the regression in equation (2) is conducted on a meeting-by-meeting frequency. Note that we are facing the complication that we do not have a new projection for every monetary policy decision because there are more meetings than forecast releases. For all those meetings without a new projection, we assign the latest available set of forecasts.[21] Note that since the introduction of the fixed announcement dates in December 2000, this has been less of an issue because a new set of forecasts is prepared for most of the announcement dates such that matching a new projection with a meeting is straightforward.[22] Before this, we must be

[19]Since May 2001, core CPI inflation in Canada has been known as CPIX, which excludes the eight most volatile components of the CPI and adjusts the remaining components for the effects of changes in indirect taxes. Before May 2001, core inflation was defined as CPI excluding food, energy, and the effects of changes in indirect taxes.

[20]In Section 4.5, we test the robustness of the definition by adding meetings with zero policy rate change in two different ways: (i) we add all those dates where we have a new forecast but no change in the intended policy rate and (ii) we add those dates corresponding to two days after an FOMC meeting and where we do not have a meeting already defined in the week. We find that our results remain robust to adding these additional observations.

[21]Note that in equation (2) we control for developments between a given meeting and the last available projection by including monthly lags of the unemployment rate and the interest rate two weeks before the meeting.

[22]For those announcement dates without a new projection, we keep assigning the latest projection data

careful when assigning a set of forecasts to a given meeting in order to avoid endogeneity of forecasts to the policy change. Therefore, we use the projection prepared at the end of the quarter preceding the meeting date, ensuring that the forecasts do not include the effects of the subsequent policy change. Table (1) provides examples of the data assignment to meetings. The first column lists the variables of interest (i.e., regressors) from equation (2), while the other columns show the data source and the time period forecasted (or the backdata, when using lagged data) for different meeting dates (shown in the top row).

Table 1: Assigning forecasts and economic variables to Bank Rate decisions

	Meeting dates [current quarter]									
	12/22/1976 [1976:Q4]		...	4/17/1980 [1980:Q2]		5/22/1980 [1980:Q2]		...	7/17/2001 [2001:Q3]	
Variables	Source	Forecast / Data		Source	Forecast / Data	Source	Forecast / Data		Source	Forecast / Data
$\hat{y}^f_{m,t-1}$	Sep-76 proj	1976:Q3	...	March-80 proj	1980:Q1	March-80 proj	1980:Q1	...	June-01 proj	2001:Q2
$\hat{y}^f_{m,t}$	Sep-76 proj	1976:Q4	...	March-80 proj	1980:Q2	March-80 proj	1980:Q2	...	June-01 proj	2001:Q3
$\hat{y}^f_{m,t+1}$	Sep-76 proj	1977:Q1	...	March-80 proj	1980:Q3	March-80 proj	1980:Q3	...	June-01 proj	2001:Q4
$\hat{y}^f_{m,t+2}$	Sep-76 proj	1977:Q2	...	March-80 proj	1980:Q4	March-80 proj	1980:Q4	...	June-01 proj	2002:Q1
$\pi^f_{m,t-1}$	Sep-76 proj	1976:Q3	...	March-80 proj	1980:Q1	March-80 proj	1980:Q1	...	June-01 proj	2001:Q2
...	...	...	...	...	...	...	...	...	...	...
u_{t-1}	Real-time data	Nov-76	...	Real-time data	Mar-80	Real-time data	Apr-80	...	Real-time data	Jun-01
u_{t-2}	Real-time data	Oct-76	...	Real-time data	Feb-80	Real-time data	Mar-80	...	Real-time data	May-01
...	...	...	...	...	...	...	...	...	...	...
ER_{t-d14}	Real-time data	12/8/76	...	Real-time data	4/3/80	Real-time data	5/8/80	...	Real-time data	7/3/01
FFR_{t-d14}	Real-time data	12/9/76	...	Real-time data	4/3/80	Real-time data	5/8/80	...	Real-time data	7/3/01
...	...	...	...	...	...	...	...	...	...	...

Notes: Assignment of forecasts and lagged real-time data to different meeting dates. The upper row corresponds to the exact date of the meeting, with (in brackets) the corresponding year and quarter in which the given meeting is happening. The "Source" column refers to the specific staff projection database from which the real GDP growth and inflation real-time and forecasts data were prepared, while the lagged (real-time) unemployment rate, exchange rate, FFR and the policy rate are taken from Statistics Canada or Bank of Canada archives. The "Forecast/Data" column shows the year and quarter of the forecasts estimates (for real GDP growth and inflation), while it shows the specific date (month or day) for the other lagged real-time variables.

The second block of columns, corresponding to the April 17 and May 22, 1980 meetings, provides a case where we assign the same set of forecasts to two consecutive meetings. Because these two meetings happen in 1980:Q2, we use the projection data from March 1980 to get the values for real GDP growth ($\hat{y}^f_{m,t+j}$) and inflation ($\pi^f_{m,t+j}$). Moreover, we

available.

assign the relevant lags of unemployment rates, exchange rates and U.S. FFR available at the time of the meeting from our real-time data set.[23]

Lastly, we use all changes in our intended policy rate, apart from those meetings occurring within the same four weeks during the March 1980 to May 1994 period (when meetings were occurring at a high frequency).[24] Overall, our data assignment allows us to have a sample of meetings matched with projections data from 1974:M4 to 2015:M10, containing a fair number of observations (337 meetings).

2.3 First-stage estimation results

We use our dataset of changes in the intended policy rate, carefully matched (by meeting) with the staff forecasts and real-time data to estimate the regression equation (2). As mentioned earlier, our preferred strategy critically departs from R&R and Cloyne and Hürtgen (2016) as we estimate equation (2) for the pre-1992 and 1992-onward periods separately, such that our estimates account for the change in the monetary policy reaction function observed around the introduction of the IT period. To show the importance of breaking our estimation into two parts, we also estimate equation (2) using the full sample (all 337 meetings). Table (2) reports the results of these estimations.

Examining the full-sample (no-break) estimates (left column) suggests that monetary policy has been conducted in an acyclical fashion over the past 40 years. For example, coefficients on real GDP growth level sum up to 0.27, while they sum to -0.24 for the revision to the forecast. Coefficients on inflation forecast levels and revisions to inflation forecasts are very low, at 0.04 and -0.02, respectively. Thus, a 1 percentage point increase in inflation from one forecast release to the next is associated with a mild increase in the policy rate of 0.02. Finally, a 1 percentage point fall in the unemployment rate translates into a small 0.06 percentage point increase in the policy rate. Monetary policy is also

[23]Note that the *change* in the USD/CAD exchange rate and in the U.S. FFR (i.e., $\Delta ER_{m-m_{-1}}, \Delta FFR_{m-m_{-1}}$ in equation (2)) between these two consecutive meetings (May 22 and April 17, 1980) are computed as follows: $(ER_{22May1980,t-d14} - ER_{17Apr1980,t-d14})$ and $(FFR_{22May1980,t-d14} - FRR_{17Apr1980,t-d14})$, respectively.

[24]During those years the Bank Rate was changing more often than in the rest of the sample. See Appendix A for details. We test the robustness of our results in Section 4.5 to dropping changes within two weeks instead of four weeks for the specified period and find that both specifications yield similar results.

Table 2: Determinants of the change in the policy rate

	Full-sample (no-break) estimation		IT-break estimation			
	1974-2015		Pre-IT		IT period	
Variable	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Constant	0.166	(0.29)	1.954	(1.57)	-0.155	(0.30)
Initial Bank Rate	-0.029	(0.03)	0.006	(0.08)	-0.053	(0.04)
U.S. FFR:						
level	0.045	(0.03)	0.046	(0.07)	0.013	(0.03)
change	0.292***	(0.07)	0.249***	(0.08)	0.164*	(0.09)
US/CAD exchange rate:						
level	0.071	(0.27)	-1.186	(1.69)	-0.013	(0.22)
change	-3.730***	(1.35)	-14.139***	(4.00)	-1.222	(1.08)
Forecasted output growth,						
Quarters ahead:						
-1	0.223	(0.14)	0.511**	(0.21)	0.130	(0.09)
0	-0.336	(0.22)	-0.389	(0.27)	-0.156	(0.23)
1	0.341	(0.24)	0.449*	(0.25)	0.300	(0.40)
2	0.039	(0.20)	0.070	(0.30)	0.138	(0.25)
Change in forecasted output growth,						
Quarters ahead:						
-1	-0.033	(0.12)	-0.260	(0.16)	-0.046	(0.10)
0	0.225	(0.19)	-0.059	(0.25)	0.363*	(0.20)
1	-0.143	(0.20)	0.076	(0.22)	-0.498*	(0.29)
2	-0.285	(0.24)	-0.572*	(0.34)	0.062	(0.18)
Forecasted inflation,						
Quarters ahead:						
-1	0.019	(0.13)	0.074	(0.21)	-0.008	(0.20)
0	-0.198	(0.20)	-0.052	(0.25)	-1.073	(0.72)
1	0.380**	(0.17)	0.185	(0.18)	1.790	(1.29)
2	-0.160	(0.13)	-0.353**	(0.15)	-0.419	(1.09)
Change in forecasted inflation:						
Quarters ahead:						
-1	-0.084	(0.18)	-0.146	(0.26)	-0.093	(0.19)
0	-0.012	(0.24)	-0.636	(0.44)	1.123*	(0.59)
1	-0.025	(0.28)	0.207	(0.35)	-1.060	(0.95)
2	0.100	(0.33)	0.430	(0.51)	0.415	(0.82)
Unemployment rate,						
Months:						
-1	-0.333*	(0.17)	-0.390*	(0.23)	-0.240	(0.21)
-2	0.256	(0.22)	0.339	(0.34)	0.093	(0.18)
-3	0.018	(0.15)	-0.128	(0.22)	0.129	(0.12)
Observations	337		146		191	
R-squared	0.388		0.537		0.309	

Notes: Robust standard errors in parentheses; asterisks indicate statistical significance (i.e., (***: p<0.01, **: p<0.05, *: p<0.1). Dependent variable: change in the intended policy rate, constructed as described in the text. "Full-sample estimation" refers to first-stage regression estimated over the full sample (1974:M4–2015:M10). "IT-break estimation" refers to first-stage regression estimated over two sub-samples separately (i.e., Pre-IT: 1974–1991, and IT period: 1992–2015). A Chow test of parameter stability with a date break fixed to January 1992 (IT introduction) yields a F-statistic of 2.26 with an associated p-value of 0.0007.

positively related to changes in the U.S. FFR and negatively related to movements in the USD/CAD exchange rate.

This acyclical behavior of monetary policy, along with the responses to U.S. interest rates and exchange rate movements, hide considerable heterogeneity once one breaks the first-stage estimation into two sub-samples. The second and third columns (the "IT-break estimation") show the regression estimates for the 1974-1991 and the 1992-2015 sub-periods, respectively.[25] Three results stand out: first, summing coefficients on real GDP and inflation for the pre-IT period yields procyclical estimates of -0.17 and -0.29 percentage points, respectively, and a countercyclical estimate of -0.18 for the unemployment rate. A very different picture emerges for the second sub-sample: summing the same coefficients yields estimates (in percentage points) of 0.29 or real GDP, 0.68 for inflation and -0.02 for the unemployment rate, implying strong countercylical monetary policy since 1992. Second, the pre-IT behavior of monetary policy can be explained by the response with respect to the U.S. rates and USD/CAD exchange rate: a 1 per cent increase in the U.S. FFR between two meetings translates into a 0.3 percentage point increase in the policy rate, while a 1 per cent decrease in the value of the exchange rate between two meetings implies a 0.15 percentage point increase in the policy rate. Third, the response of monetary policy toward these two variables changed dramatically since 1992: the response to changes in the FFR decreased by more than a third (0.18) and fell to almost zero with respect to exchange rate movements (0.01 percentage point). Since 1992, Canadian monetary policy has been responding fiercely to economic developments related to inflation and real GDP growth and much less to exchange rate movements.[26]

Overall, our full-sample estimates for the response of the policy rate to real GDP growth and inflation forecasts are close to zero and far from the procyclical first-stage estimates

[25] A Chow test of parameter stability with a break date set to January 1992 yields an F-statistic of 2.26 with an associated p-value of 0.0007.

[26] Another way to assess the relative importance for monetary policy decisions of the "foreign variables" (i.e., U.S. FFR and the USD/CAD exchange rate) in the first sub-sample and of the forecasts in the second sub-sample is to examine the changes in the R^2 of the regressions once we take out these variables (separately) of the regression. For the pre-IT period, when we take out forecasts the R^2 falls only from 0.54 to 0.47, while it drops dramatically to 0.24 when foreign variables are taken out but forecasts are kept in. For the IT period, when we take out forecasts the R^2 drops sharply from 0.31 to 0.15, while it barely falls (0.28) when foreign variables are taken out but forecasts are kept in. In Section 4.6, we present evidence of how foreign variables and forecasts matter when estimating the effects of monetary policy.

of R&R for the U.S. and Cloyne and Hürtgen (2016) for the U.K., and are not a good representation of the Bank's behavior for more than half of our sample. Looking at our 1992-2015 estimation results, we see they are more similar than those of the U.S. and U.K., albeit not identical. For instance, our estimates for the response of the policy rate to inflation are stronger as the Bank has been targeting inflation closely over that period. As we will see below, accounting for a break in the monetary policy reaction function of the U.S. and the U.K. also leads to material differences in the macroeconomic effects of the monetary policy shocks for those countries. Finally, the residual component of equation (2) from the "IT-break" estimation (ϵ_m), i.e., the component of policy rate changes that is orthogonal to the policy-makers' information set, is our new measure of monetary policy shocks.

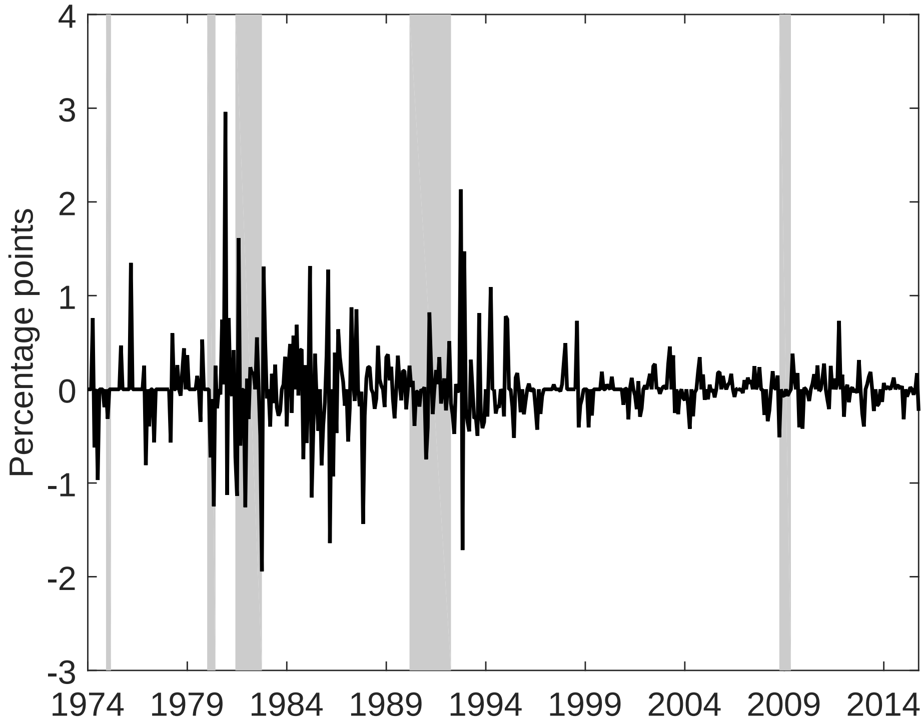
2.4 Analyzing the new shock series

This residual series corresponds to specific meeting (i.e., policy decision) dates. To use these residuals for economic analysis, they must be converted into a monthly series of monetary policy innovations. To do this, we assign each shock to the month in which the corresponding meeting occurred. If there is no meeting in a given month, we record the shock as zero for that month; if there is more than one meeting within the same month, we sum the shocks. Figure 1 presents our new monthly series of monetary policy shocks, which we denote μ_t as above.

As found by R&R for the U.S. Cloyne and Hürtgen (2016) for the U.K., our new series for Canada is more volatile in the first half of our sample, up to the end of 1992. This observation coincides nicely with the view that there was a regime change around that time (e.g., see Rowe and Yetman (2002) or Ragan (2005)), when the Bank of Canada began targeting inflation explicitly. Three other developments mentioned earlier also made the policy-making process more transparent during this sub-period: the introduction of the operating band around the overnight rate in 1994, which led to the explicit Target for the Overnight Rate in 1996, as well as the introduction of fixed announcements dates in December 2000.[27] Note that our series is substantially more volatile in the early 1990s than

[27] As noted by Cloyne and Hürtgen (2016), larger shocks in the first part of the sample could also reflect

Figure 1: New monthly monetary policy shocks series for Canada



Notes: Shaded gray bars represent recessions as determined by the C.D. Howe Institute.

the U.S. and U.K. series, likely due to the uncertain environment the Canadian economy was facing in those years.[28]

We can use our new measure of monetary policy shocks to measure the stance of monetary policy: i.e., periods with a sequence of positive innovations are ones in which the Bank raised the policy rate more than it would normally have given current and expected economic conditions. Appendix Figure B.1 plots the exogenous Bank Rate path (i.e., our new shock series, cumulated) along with the shocks series estimated over the full sample (no break) and the actual path of the Bank Rate. Interestingly, the shocks series imply a very different path for the exogenous policy rate (dotted blue vs. dashed red lines). For instance, after following a pattern similar to our new measure of shocks between 1974 and

that the level of the Bank Rate was relatively higher than in the second part.

[28]This period was marked by different developments that clouded the economy with uncertainty. For example, after five years of relative stability at around 4 per cent, inflation took off in 1988; the Bank Rate was very high, coupled with the historical high of the Canadian-U.S. 90-day treasury bill spreads; the USD/CAD exchange rate was very volatile and economic conditions started deteriorating in 1990, leading to the severe 1990–92 recession. There was also political uncertainty in the early 1990s: the aftermath of the Meech Lake Accord failure and the introduction of the new goods and services tax in January 1991.

1989, the no-break series diverged markedly afterwards: it implies that monetary policy had been very tight for 10 years up to 1999, where it loosened precipitously afterward. Since 2007, this alternative shock measure implies that given current and expected future economic conditions, monetary policy has been—by far—at its loosest stance over the last 40 years.

2.5 Predictability of the new shock series

We follow Coibion (2012) and test whether our new monthly measure monetary policy shocks is unpredictable from movements in ex-post revised data.[29] We perform a Granger causality test by regressing our innovations series μ_t on a large set of lagged macroeconomic variables (x_{t-i}) including two of the most relevant measures of inflation for Canada (CPI, CPIX), two measures of output (real GDP, industrial production), the unemployment rate, commodity price inflation, the change in the Toronto Stock Exchange Index (TSX) and the change in money supply (M2):[30]

$$\mu_t = c + \sum_{i=1}^{I} \beta_i x_{t-i} + \upsilon_t. \tag{3}$$

Under the null hypothesis that our shock series μ_t is not predictable, the β_i are jointly equal to zero. Table 3 reports the F-statistics and p-values for the null hypothesis based on estimation of equation (3) for our new measure of monetary policy innovations ("New measure of shocks," right panel) along with the alternative shock series discussed above, estimated using the full sample ("no-break," left panel).

Two things stand out: first, the shock series estimated on the full sample (no break) shows many low p-values, implying some degree of predictability. For example, this alternative shock series is significantly predictable using real GDP growth, commodity price changes and six lags of the unemployment rate; it also has low p-values when equation (3) is estimated with the CPIX and the change in the TSX. Second, a sharp contrast emerges

[29] We also look whether our new measure is uncorrelated with other structural shocks, such as the U.S. and U.K. monetary policy shocks of R&R and Cloyne and Hürtgen (2016) (correlations of 0.03 and 0.06, respectively), as well as oil supply shocks (0.00) from Kilian (2009).

[30] See Appendix A.3 for data details. Note that we have a monthly series for real GDP in Canada, which we will also use below when quantifying the macroeconomic effects of monetary policy shocks.

Table 3: Predictability of monetary policy shocks series

	Full sample (no-break) shocks				New measure of shocks			
	I = 3 lags		I = 6 lags		I = 3 lags		I = 6 lags	
Variable	F-stats	P-values	F-stats	P-values	F-stats	P-values	F-stats	P-values
CPI inflation	1.33	0.26	1.14	0.34	0.62	0.60	0.71	0.65
CPIX inflation	0.85	0.47	1.68	0.12	0.29	0.83	1.34	0.24
Change in real GDP	2.76	0.04	2.82	0.01	1.59	0.19	1.75	0.11
Change in ind. prod.	1.52	0.21	0.80	0.57	1.10	0.35	0.55	0.77
Unemployment rate	0.39	0.76	2.05	0.06	0.34	0.80	1.82	0.09
Commodity price inflation	2.96	0.03	1.65	0.13	1.66	0.17	1.09	0.37
Change in nominal USD/CAD	0.58	0.63	0.90	0.50	0.17	0.92	0.63	0.70
Change in TSX	1.89	0.13	0.94	0.46	1.37	0.25	0.54	0.77
Money growth (M2)	0.17	0.91	0.14	0.99	0.34	0.79	0.31	0.93

Notes: The table reports F-statistics and p-values for the null hypothesis that all coefficients (β_i) are equal to zero. The standard errors are corrected for the possible presence of serial correlation and heteroskedasticity using a Newey-West variance-covariance matrix. The "Full sample (no-break) shocks" specification refers to first-stage regression estimated over the full sample (1974-2015). "New measure of shocks" refers to our new series of monetary policy shocks, where the first-stage regression is estimated over two sub-samples separately (i.e., Pre-IT and IT period). Estimation sample from 1974:M1 to 2015:M10. All variables are at monthly average frequency.

when one looks at our new measure of shocks (columns 5 to 8): for example, the p-values of real GDP are almost 5 times (three lags) and 10 times (six lags) larger using our new measure and substantially larger for the change in commodity prices and the unemployment rate. Overall, most p-values are very large for the new measure; this lack of predictability and stark contrast with the alternative full-sample shock series is another argument in favor of our preferred measure and suggests that our shock series is a suitable instrument for identifying the macroeconomic effects of monetary policy in Canada.

3 Macroeconomic implications of the new measure of monetary policy shocks

3.1 Baseline results

The next stage of our analysis is to use our new measure of monetary policy shocks to estimate the macroeconomic effects of monetary policy from 1974 to 2015. To do this, we use a parsimonious VAR with the following four variables: the log monthly real GDP

(y_t), the log price level (p_t) based on the CPI,[31] the log commodity prices ($pcom_t$) based on the Bank of Canada commodity index (BCPI), converted to Canadian dollars, and our new measure of monetary policy shocks.[32] Note that our VAR includes monthly real GDP instead of industrial production; papers in the literature have used industrial production indexes because of their monthly availability and high correlation with real GDP. As industrial production is also available on a monthly basis in Canada, we use it below when we compare our results with other countries. Data definitions can be found in Appendix A.3.

Specifically, the VAR we estimate is given by:

$$X_t = B(L)X_{t-1} + \epsilon_t, \tag{4}$$

where *B(L)* is a lag polynomial with P lags. The vector of observables X_t is defined as: $[y_t, p_t, pcom_t, cum.shock_t]'$. Since VARs usually include the levels of macroeconomic variables as well as the level of interest rates, we cumulate our new monetary policy shock series ($cum.shock_t = \sum_{i=1}^{t} \mu_i$) and order it last in the VAR, and employ Christiano et al. (1996)'s recursive identification strategy, i.e., assuming that monetary policy responds to, but does not affect the non-policy variables contemporaneously.[33] Our sample has a monthly frequency t, starting in 1974:M4 and ending in 2015:M10. We use $P{=}24$ lags in the VAR estimation and include a constant and a time trend.[34]

Figure 2 presents the impulse responses of real GDP, the (CPI) price level, and the Bank Rate to a 100-basis-point monetary policy shock using our new measure of monetary policy shocks (black solid line with circles), together with 68 and 95 per cent bootstrapped confidence intervals using 2000 replications. Following this contractionary innovation to

[31] In Section 4.3, we consider two other measures of the price level: CPIX, which removes the eight most volatile components of CPI, and CPIxMIC, which excludes mortgage interest costs from the CPI.

[32] In Appendix D, we test the robustness of our results to larger VAR specifications, such as (D.1) adding the unemployment rate and the Bank Rate; (D.2) explicitly including the USD/CAD nominal exchange rate in the VAR; and (D.3) adding exports and imports to our baseline VAR specification.

[33] On the one hand, because we estimate a monthly VAR, this assumption is less restrictive than with quarterly VARs. On the other hand, if we have correctly captured the information set that the policymakers use to form their decisions in our first-stage estimation, our shock series should be contemporaneously exogenous and thus the recursive assumption should not be essential for our results. We relax this assumption in Appendix D.5 and show that our results remain robust.

[34] Appendix D.5 also shows that our results are robust to different lag structures and to removing the constant and the trend in the VAR.

the policy rate, real GDP has a peak decline of 1 per cent between months 18 and 24; the shock effects then fade as GDP ends at about -0.5 per cent after three years. The GDP response is highly significant (95 per cent) between months 6 and 24. The price level (CPI) is less responsive to the contractionary shock: it stays roughly flat for the first 24 months, where it starts falling and ends 0.4 per cent lower after three years. It is only in the last 4 months that the response is significant. The last panel of Figure 2 shows that the increase in the Bank Rate is short-lived:[35] the Bank Rate increases on impact, starts falling in month four and turns negative after 12 months, ending at zero after three years.[36]

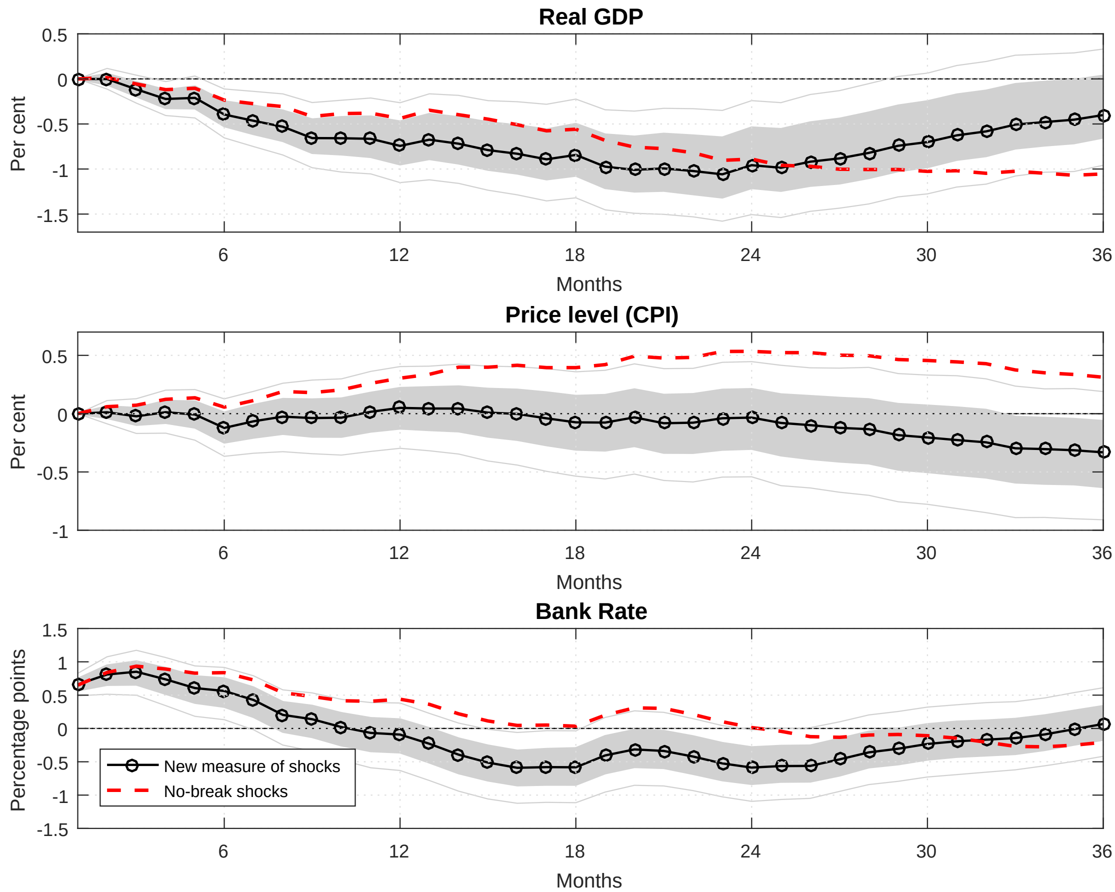
Figure 2 further shows the importance of accounting for the break due to the introduction of IT in Canada; the red dashed lines represent the impulse responses from the estimation of the same VAR as in equation (4), but where we substitute our new measure of shocks for the shock series estimated without any break in the first-stage regression ("no-break" shocks). Two things stand out: first, the response of real GDP is smaller for the full-sample shocks during the first two years but keeps declining persistently afterward while the response to our new shocks measure is stronger but more temporary, as it retreats during the last 12 months. Consequently, there is a substantial difference (0.7 percentage points) between the real GDP responses after three years. Second, the response of the price level (CPI) is also quite different using the no-break shock series. While our new shock series implies a flat response of the CPI for 24 months before falling, the response following the no-break shocks exhibits a price puzzle: it is positive throughout with a peak above 0.5 per cent after two years. This alternative response of CPI lies largely outside the 68 per cent confidence bands of our main estimates, and for the last 18 months lies close to the 95 per cent upper band.

Overall, these results show how accounting for the break in the monetary policy reaction function matters for our estimates of the effects of monetary policy. When one does not consider the IT break, the real GDP response experiences a slow but persistent decline

[35]For this third panel, we add the Bank Rate ordered last in the VAR.

[36]While the wider literature on the effects of monetary policy tends to employ VARs, R&R use single regressions. Coibion (2012) finds that an important part of R&R's large effects of monetary policy is due to the contractionary impetus implied by the single regression approach and to the non-reserve borrowing period (1979–82); when R&R shock series is used in a VAR instead, the effects become smaller and more robust to individual shocks episodes. For sake of completeness, in Section 4.1 we present single regression results and show that they are in line with our VAR results. In Appendix F, we perform a similar sensitivity exercise and find that our results are robust to any three-year period in our sample.

Figure 2: Macroeconomic effects of monetary policy shocks



Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock along with the corresponding 68 and 95 per cent confidence bands. "New measure of shocks" refers to our new measure of monetary policy shocks (black line with circles) while "No-break shocks" refers to the shock series estimated over the full 1974–2015 sample (dashed red line) in the first-stage regression. The VAR includes log real GDP, log CPI, log BCPI and the measure of monetary policy shocks. For the Bank Rate response, the VAR includes the same set of variables, adding the Bank Rate (ordered last). P=24. Sample: 1974:M4 to 2015:M10.

following the monetary policy shock, and a price puzzle emerges.

3.2 Comparison with other countries

An important contribution of the previous section is to highlight the importance of accounting for a break in the central bank's reaction function when deriving our measure of monetary policy shocks for Canada. Here we compare our results with updated results from R&R (U.S.) and from Cloyne and Hürtgen (2016) (U.K.) and show that accounting for a break in the conduct of systematic monetary policy is also important for these countries.[37] We first gather real-time and forecast data up to 2011 for the U.S. from the Federal Reserve Board's Greenbooks and for the U.K. from the Bank of England's Inflation Reports.[38] We then identify the (extended) monetary policy shocks series for both countries in two different ways: (1) we estimate the first-stage regression over the full sample as in R&R and Cloyne and Hürtgen (2016), and (2) we break the first-stage estimation into two parts to account for a change in the monetary policy reaction function, as we did for our shocks series above.[39] Finally, we use these extended shock series in VARs for the U.S. and the U.K. separately, and estimate the effects of a 100-basis-point monetary policy shock.[40] Figure 3 presents the impulse response for the U.S. (left) and the U.K. (right).

The red (diamond) lines show the impulse responses for the shocks estimated without break, as in R&R, and the shaded area represents the 68 per cent confidence bands. For the U.S., the responses are somewhat weaker than in the original R&R paper. The peak decline for industrial production is about 1 per cent between 12 and 18 months, while the price level exhibits a small price puzzle in the first year but then falls steadily to reach -1.4 per cent after three years. Now, when one accounts for a break due to a change in the monetary policy reaction function (dashed blue line), the implications of a monetary policy shock differ markedly, as we found for Canada. For instance, industrial production has a similar response for the first two years, but then retreats faster following the shocks estimated with a break. The difference for the price level is even more important: using the break-shock series, there is no price puzzle and the decline is more pronounced, with the price level ending more than 2 per cent lower after three years, close to the findings in

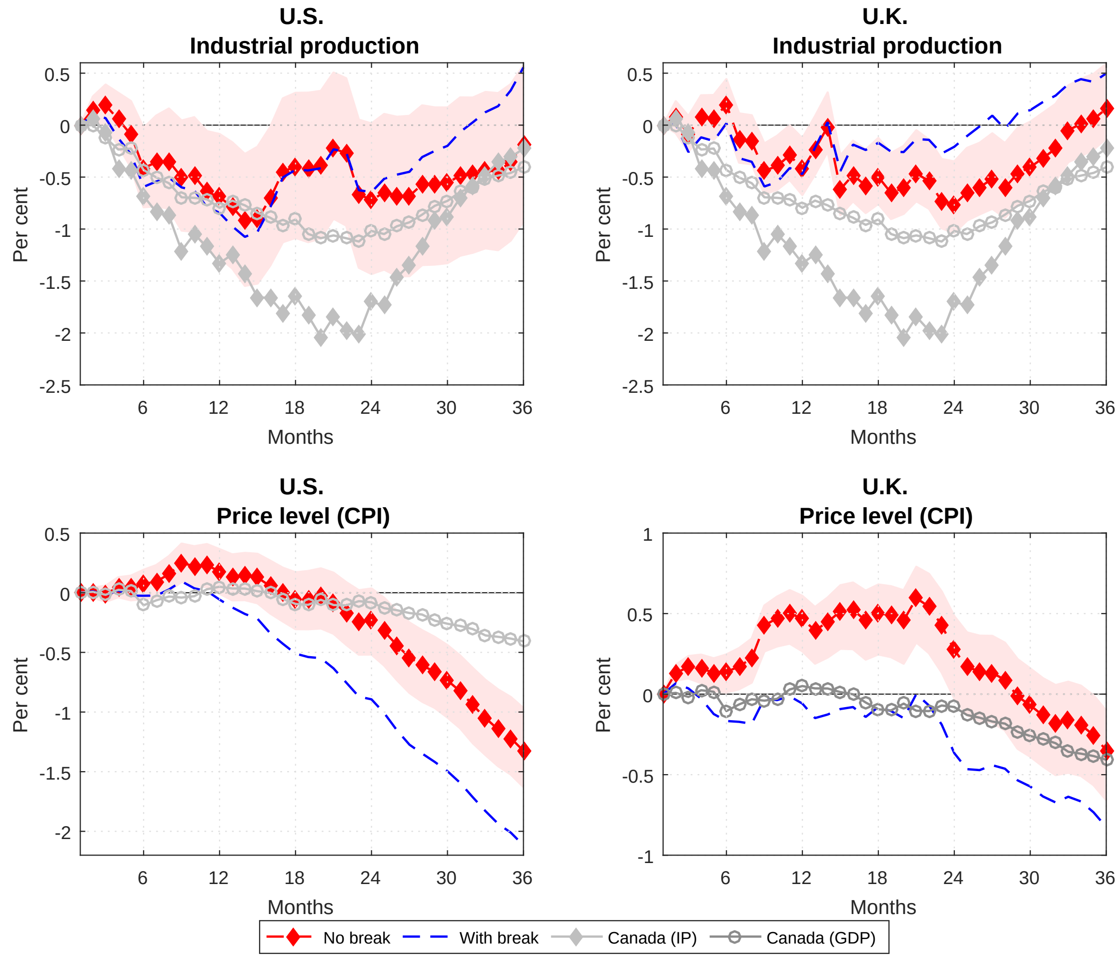
[37]For a broader comparison with the literature on the effects of monetary policy, notably for Canada, see Appendix C.5.

[38]Because the Federal Reserve Board imposes a five-year ban on the Greenbooks' forecast data, they are available only up to 2011. The U.K. forecasts were taken from the Inflation Reports' Fan Chart data. See Appendix A.4 and A.5 for more details.

[39]For the U.S., we break the estimation between 1983 and 1984, coinciding with the beginning of the "Great Moderation" period (e.g., McConnell and Perez-Quiros (2000)). For the U.K., we impose a break with the introduction of IT (i.e., between 1992 and 1993). Note that if we use other break dates such as 1979 (Volcker period) for the U.S. and 1997 (Bank of England independence) for the U.K., we also get substantially different results between the break and the no-break shocks.

[40]As above, we use a standard VAR with output, the price level, a commodity price index and the measure of monetary policy shocks. Note that for data availability at a monthly frequency, we use industrial production instead of real GDP. Also note that using R&R's original VAR (industrial production, the producer price index and the measure of shocks) does not alter the U.S. results.

Figure 3: Macroeconomic effects of monetary policy: Evidence from the U.S. and U.K.



Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock from a VAR including log industrial production, log CPI, log commodity price index and the measure of monetary policy shocks, along with the corresponding 68 and 95 per cent confidence bands. "Canada (GDP)" refers to the baseline VAR above with log real GDP as the measure of output in the VAR. P=24. Monthly data. Sample for the U.S. is 1969:M1-2011:M12. For the U.K.: 1975:M1-2011:M12. For Canada is: 1974:M4-2011:M12.

Coibion (2012).[41]

A similar pattern also occurs for the U.K. when one breaks the first-stage estimation to account for a change in the conduct of systematic monetary policy. As seen on the right-hand side of Figure 3, both shocks series imply an industrial production response that is

[41]Focusing on the 1988–2008 sample, Barakchian and Crowe (2013) show that R&R shocks (in a recursive VAR with industrial production and the producer price index (PPI) imply a mild positive response of industrial production and a weaker decline in the price level relative to R&R for 1969–96. These responses are consistent with industrial production retreating more rapidly following the shock estimated with a break.

similar over the first 18 months, but diverge afterward as the response to the break-shocks series retreats faster and gets out of the confidence bands between months 23 and 33. As for the U.S., the difference in the price level responses are more important: while the no-break shock series imply a price puzzle for about two years, the shock series estimated with a break imply a flat price level which then declines steadily to -0.8 per cent after three years, a peak effect twice as big as with the no-break shocks. Note that these differences implied by the two shocks series are broadly consistent with those for Canada. Overall, the impulse responses for the U.S. and the U.K. indicate that accounting for a structural break in the monetary policy reaction function matters importantly for the estimation of the effects of monetary policy.[42]

Figure 3 also shows the responses for Canada with a shorter sample (ending in 2011). The light-gray lines (circles) represent the baseline results shown above while the gray lines (diamond) present the analogous results using industrial production instead of real GDP. Two things stand out: first, the response of industrial production for Canada has a shape similar to real GDP, but its peak effect is twice as large. Second, the CPI response is substantially weaker in Canada than in the U.S. and the U.K.; at a peak effect of -0.4 per cent, it is about one-fourth of that in the U.S. and half that of the U.K.[43] These results suggest that the slope of the Phillips curve is steeper in the U.S. (and the U.K.) than in Canada.[44] This is in line with the New Keynesian small open economy model of Gali and Monacelli (2005), who show that the slope of the Phillips curve is decreasing on the degree of openness of the economy.

[42]As the FFR and the Bank Rate hit the zero lower bound (ZLB) during and following the crisis, many have argued that it is not appropriate to use the policy rate for the stance of monetary policy during the ZLB episode. To address this concern, we proceed with two robustness exercises: one where we substitute the FFR (U.S.) and the Bank Rate (U.K.) with Wu and Xia (2016, 2017) shadow rates, and another exercise where we simply stop our sample in 2007, excluding the Great Recession period and its aftermath. All in all, we find that our results are robust to these different specifications. See Appendix C.2 and C.3 for details.

[43]In Appendix C.1, we estimate VAR at a quarterly frequency using real GDP for all three countries. The GDP responses are similar between the three countries and the CPI response in Canada is much weaker, as in Figure 3.

[44]For example, a regression of the inflation on the output gap and its own four lags yields coefficients on the gap of 0.14 for Canada and 0.28 for the U.S.

4 Additional Results and Robustness Exercises

In the sub-sections below, we provide additional results and assess the robustness of our main results to different specifications. First, we estimate the effects of monetary policy shocks with Jordà (2005)'s local projections method instead of a VAR specification; second, we use local projections to estimate the effects of monetary policy on other macroeconomic and trade variables; third, we assess whether the standard VAR with the policy rate instead of our shocks series yields the well-known price puzzle (Sims (1992), Eichenbaum (1992)); fourth, we use different measures of the price level in the VAR and test the robustness of our results; fifth, we restrain our sample to the IT period (1992-2015); sixth, we test the robustness of our results to alternative first-stage specifications; and finally, we evaluate the importance of forecasts and controls for the foreign variables (i.e., USD/CAD exchange rate and the FFR) when identifying monetary policy shocks by excluding them separately from the first-stage regression.

4.1 Single equation results and the effects on other macro variables

In order to make our results as comparable as possible to previous literature, we have opted to use our shocks series within a standard VAR model. Nonetheless, single regression approaches such as Jordà (2005)'s local projections have increasingly been used to investigate the effects of economic shocks in general, and monetary policy shocks in particular.[45] The flexibility of the local projections setup allows for the assessment of the effects of monetary policy shocks on other macroeconomic variables that are more difficult to cast within a VAR. For instance, given that Canada is a small open economy, quantifying the effects on trade variables and the exchange rate is of particular interest as monetary policy shocks also affect GDP and inflation through the exchange rate channel. Consequently, in this section we first examine the responses of GDP and the price level within this single equation model and see if they are in line with those from the baseline VAR. Then, we assess

[45] For recent examples, see Owyang et al. (2013), Auerbach and Gorodnichenko (2013) and Ramey (2016) among others.

the effects on the unemployment rate and trade variables. Specifically, the local projection model we estimate is the following:

$$x_{t+h} - x_t = c + \Phi_h(L)z_{t-1} + \beta_h \mu_t + \varepsilon_t, \tag{5}$$

for $h = 0,1,2,...,36$. The variable of interest is x, $\Phi_h(L)$ is a polynomial lag operator, z_{t-1} is a vector of controls, and μ_t is our measure of monetary policy shocks.

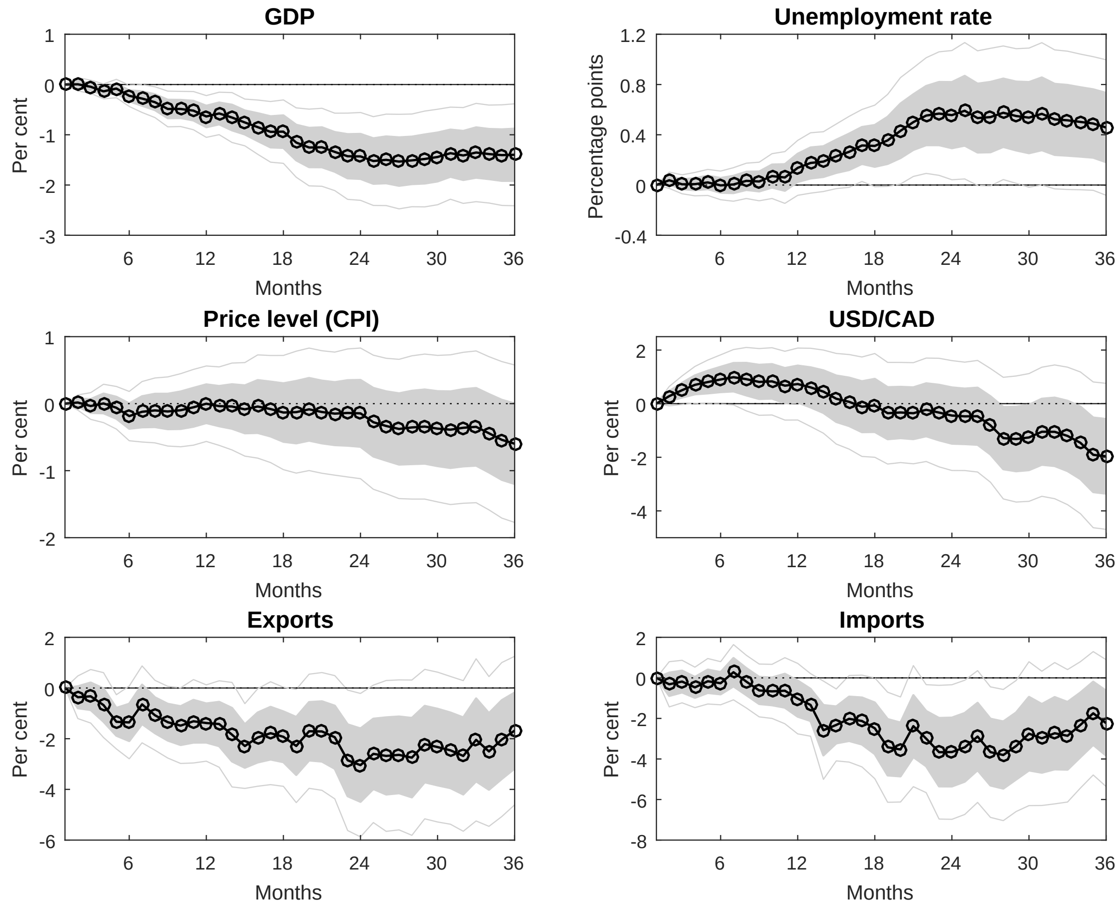
Figure 4 shows the impulse responses to a 100-basis-point contractionary monetary policy shock. The results for real GDP and the CPI are very similar to the ones obtained from the baseline VAR. A distinctive quantitative feature is that the responses of monthly GDP and the CPI are somewhat stronger than the ones from the VAR model. Following the monetary policy shock, the price level falls by over 0.6 per cent after 36 months, whereas real GDP falls by 1.3 per cent and the decline is more persistent.[46] These results are consistent with the more persistent response of the policy rate in the local projections model relative to the VAR. Note that the divergence in monetary policy effects from the shocks estimated with and without a break discussed in Section 3 above is also very apparent when using local projections (see Appendix D.7 for details).

The response of the unemployment rate is flat for 12 months and then rises by about 0.5 percentage points throughout the next two years, as shown in the upper right panel of Figure 4.[47] Trade variables also respond strongly to monetary policy shocks: the nominal USD/CAD exchange rate does not react on impact, then rises for about 15 months and then slowly declines, ending almost 2 per cent lower after three years. This response of the USD/CAD exhibits a slow initial overshoot but then declines in accordance with the uncovered interest parity condition. This depreciation of the Canadian dollar leads to a peak imports decline of 4.0 per cent while the decline in economic activity drags exports down by 3.7 per cent after 24 months despite the currency depreciation. Overall, the trade balance closely follows the path of the USD/CAD exchange rate: it worsens in the first 15 months as the Canadian dollar appreciates following the policy rate increase, and then

[46] These larger responses with single regressions are also found by Coibion (2012) for the U.S. and by Cloyne and Hürtgen (2016) for the U.K.

[47] This response is similar to the one from a large VAR including the unemployment rate, as shown in Appendix D.1.

Figure 4: Single equation approach



Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation using local projections model with corresponding 68 and 95 per cent confidence intervals. The local projections model includes (monthly) log real GDP, log CPI, log BCPI, log nominal USD/CAD exchange rate, log exports, log imports and our new measure of shocks. Sample: 1974:M4 to 2015:M10.

improves afterward as the currency depreciates.

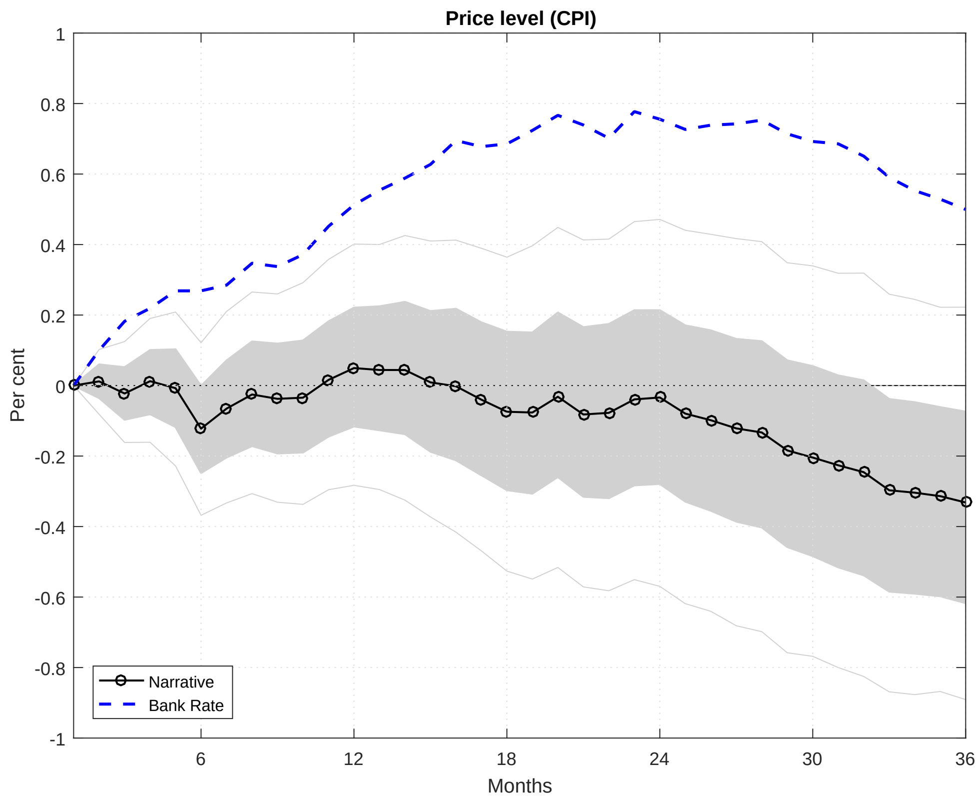
4.2 The price puzzle

Sims (1992) first documented the observation that a monetary policy tightening is followed by an increase in the price level when measured in conventional VARs employing observed interest rates and the recursive identification strategy. Dubbed the "price puzzle," this observation has raised doubts about the validity of the recursive identification assumption and paved the way to a large literature that proposed various methods to resolve this puzzle, such as expanding the VAR with oil or commodity prices or using factor-augmented VARs.

R&R show that including the Greenbook forecasts in the central bank's information set removes the price puzzle for the U.S.

For Canada, we also find a large price puzzle when we replace our exogenous shock series with the Bank Rate as the policy instrument in the VAR specification and use the standard recursive identification strategy. Figure 5 shows the price level response to a 1 percentage point increase in the Bank Rate in our VAR (dashed line) along with the analogous price response to our shock series. The response is large and positive through the first three years, and lies largely outside the 95 confidence bands of our main estimate.[48]

Figure 5: VAR with the new narrative exogenous shocks vs. conventional, recursive VAR with Bank Rate



Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock from VAR with our new measure of monetary policy shocks (solid black line with circles) along with the corresponding 68 and 95 per cent confidence bands. The chart also shows a conventional VAR with the Bank Rate instead of our shocks measure as the policy variable (dashed blue line). Both VARs contain log real GDP, log CPI, log BCPI and the monetary policy variable ordered last. P=24. Sample: 1974:M4 to 2015:M10.

[48] In Appendix C.4, we plot the impulse price response along with the corresponding 68 and 95 confidence bands and show that the price puzzle is significant at 95 per cent for almost three years. Note that if we add other variables in this VAR (such as the unemployment rate), we also find a price puzzle.

R&R and Cloyne and Hürtgen (2016) document that the narrative identification strategy solves the price puzzle obtained using conventional recursive VAR methodology for the U.S. and U.K., respectively. However, we showed above that the identification strategy must also critically account for breaks in the central bank's reaction function, such as the introduction of IT regimes in Canada and the U.K., to ensure that monetary policy shocks are correctly identified.

4.3 Different price measures

Our baseline VAR results in Section 3 pertain to using total CPI as the price measure. In Canada, two other important indicators of inflation in Canada are computed from (i) the core CPI (CPIX), which excludes the eight most volatile components of CPI, and (ii) CPI excluding mortgage interest costs (CPIxMIC). Panel A of Figure 6 presents robustness exercises to using these alternative measures of the price level: the CPIX (dashed blue line) and the CPIxMIC (dotted red line). As is clear from the impulse responses of real GDP and the price level, our baseline results are robust to using either of these three measures of prices.

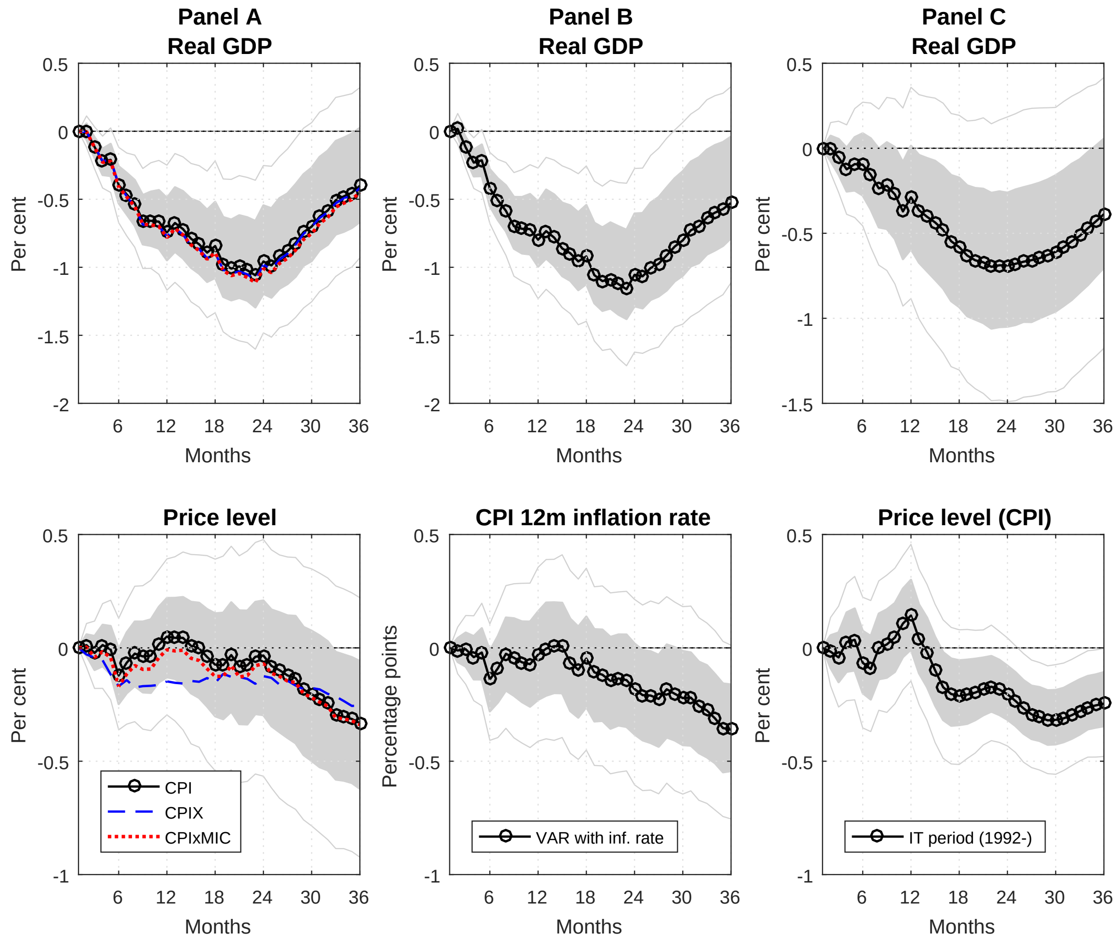
In Panel B, we further test the robustness of our results to estimating a VAR with the 12-month CPI inflation rate instead of the CPI price level. The upper chart shows that the real GDP response is similar to our baseline results, whereas the 12-month inflation rate stays flat for 18 months and declines by 0.4 percentage points afterward. This peak impact is consistent with the decline in the price level found in Figure 2, although the inflation response declines sooner than the price level response.[49]

4.4 Inflation-targeting period

The Bank of Canada announced in 1991 a new IT framework for monetary policy with a first inflation target set for 1992. By then, inflation quickly converged to 2 per cent and has remained low and stable since. Likewise, between the early 1990s and the Great

[49]This is due to the same lag structure (24 months) in the VAR as for the baseline VAR with the price level. If we incorporate more lags (e.g., 36 months) in our baseline VAR (because the 12-month inflation rate implicitly incorporates more lags), we also get a faster decline of the price level. See Panel B of Appendix Figure D.5.

Figure 6: Robustness to different price measures and sub-samples



Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock from our baseline VAR (solid black line with circles) with corresponding 68 and 95 per cent confidence bands. All VARs include log real GDP, a price measure, log BCPI, and the new measure of shocks. Panel A: alternative price measures. Log CPIX (dashed blue line) and log CPIxMIC (dotted red line). Panel B: 12-month CPI inflation rate in the VAR instead of the price level. P=24. Sample: 1974:M4 to 2015:M10. Panel C: Baseline VAR estimated only for the IT period. P=12. Sample: 1992:M1-2015:M10.

Recession following the financial crisis, the volatility of GDP growth has been significantly lower relative to the previous two decades. The lower volatility of output and inflation during this period is also reflected in the estimated monetary policy shocks. As seen in Figure 1, our estimates of monetary policy shocks are less variable after the introduction of IT. Given this remarkable shift in the conduct of monetary policy, we now examine if the effects of monetary policy have remained stable throughout this period.

To estimate the effects of monetary policy for the IT period, we estimate our first-stage regression using only data from 1992 to 2015. We then use our baseline VAR to estimate the responses of real GDP and CPI during this period.[50] Panel C of Figure 6 shows the results. Following a 100-basis-point monetary policy shock, real GDP falls to a peak effect of -0.7 per cent, weaker but qualitatively in line with our baseline estimates. The confidence bands are also larger for the shorter period. For the price level, it stays relatively flat for 15 months following the monetary policy shock, where it then falls by 25 basis points after three years, slightly lower than our main estimates. Note that although the CPI response is weaker than our baseline estimates, it is significant for the last 20 months. Overall, our estimates suggest that monetary policy effects on GDP and inflation are quite similar before and after the introduction of IT.

4.5 Alternative first-stage specifications

In this section, we examine the robustness of our baseline results to different first-stage specifications. First, as mentioned in Section 2, we consider meetings that are at least four weeks apart during the 1980s up to May 1994, where Bank Rate changes occurred frequently. In Panel A of Figure 7, we test the robustness of our results by considering all meetings that are at least two weeks apart for that period (dashed blue line), as done in Cloyne and Hürtgen (2016).[51] The responses of real monthly GDP and CPI inflation are both qualitatively similar to our main results, although the CPI response is slightly stronger, ending 0.5 per cent lower after three years.

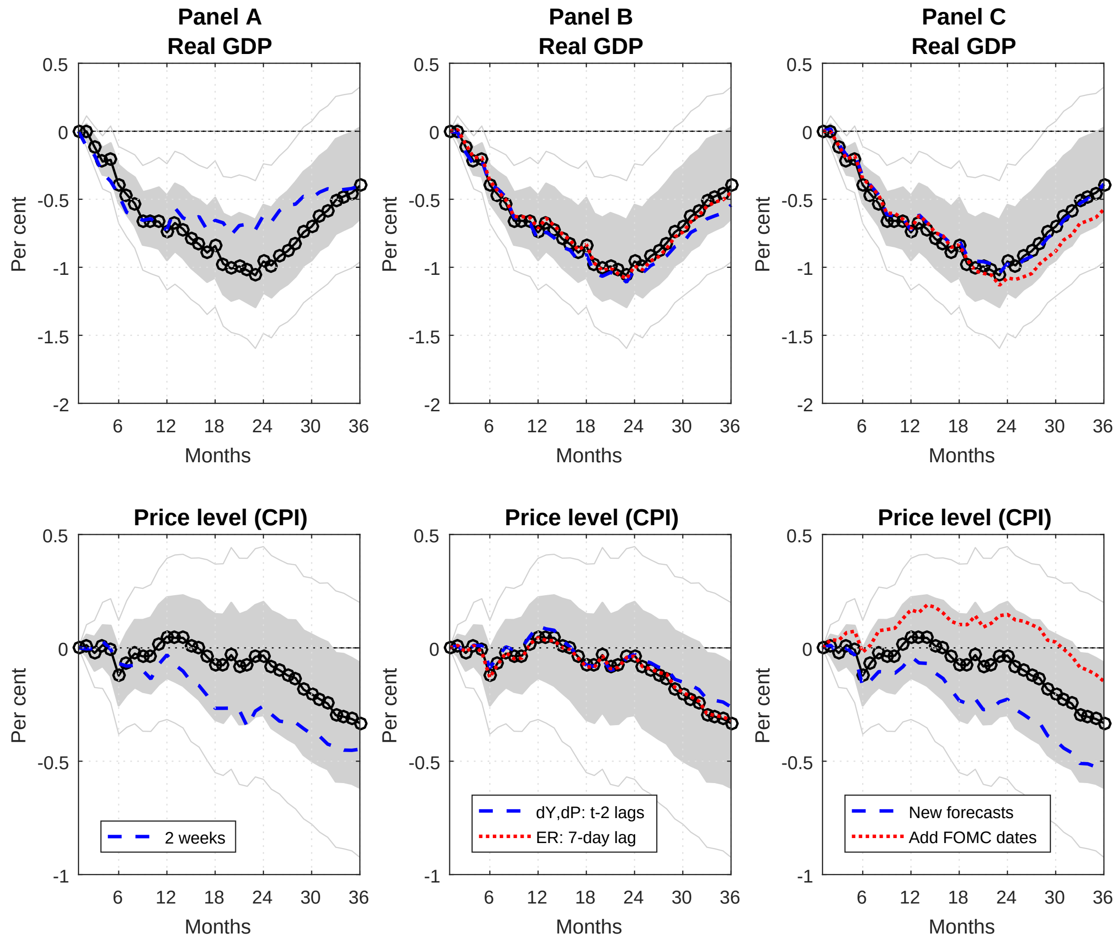
Second, in Panel B we modify the set of first-stage regressors in two ways: (i) we add second lags of real-time GDP growth and inflation (dashed blue line), and (ii) we use a one-week lag (instead of two-week) for the USD/CAD nominal exchange rate in the first-stage regression (dotted red line). For both cases, impulse responses are similar to our baseline results.

Finally, in Panel C we test the robustness of our results to including additional observations (i.e., meetings) to our first-stage regression. Recall that before the beginning of the fixed announcement dates in December 2000, monetary policy decisions were not announced and thus we cannot identify meetings that happened without changes in the

[50] We estimate our baseline VAR with only 12 lags given the smaller sample.

[51] This increases the number of meetings (i.e., observations in our first-stage regression) from 337 to 549.

Figure 7: Robustness to different first-stage specifications



Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock using our new measure of shocks (solid black line with circles) with corresponding 68 and 95 per cent confidence bands compared with shock series of different first-stage specifications. VARs include (monthly) log real GDP, log CPI, log commodity prices, and the alternate shock series. The alternative shocks series are estimated from different specifications of equation (2): Panel A—meetings are at least two weeks apart between 1980 and 1994 (dashed blue line); Panel B—adding second lags of real-time inflation and GDP growth (dashed blue line) and including 7-day lag of the USD/CAD exchange rate (dotted red line) instead of 14-day lag; Panel C—all new forecast dates included as meetings, even if the intended policy rate did not change (dashed blue line); add meeting date defined as 2 days after FOMC, if no meeting in that week. P=24. Sample: 1974:M4 to 2015:M10.

policy rate. We test two different approaches: (i) we treat as meetings the instances when the intended policy rate was unchanged but a new set of forecasts was released;[52] and (ii) we define as meetings when an FOMC announcement occurred in the U.S. and there was no

[52]This adds 18 meetings to our first-stage regressions.

change in our intended policy rate during that week.[53] In both cases, the responses of real monthly GDP are virtually unchanged while the CPI exhibits a stronger response when we add new forecasts and a weaker response when we add the FOMC dates. Although these responses differ slightly from our baseline estimates, they are within the 68 per cent confidence bands.

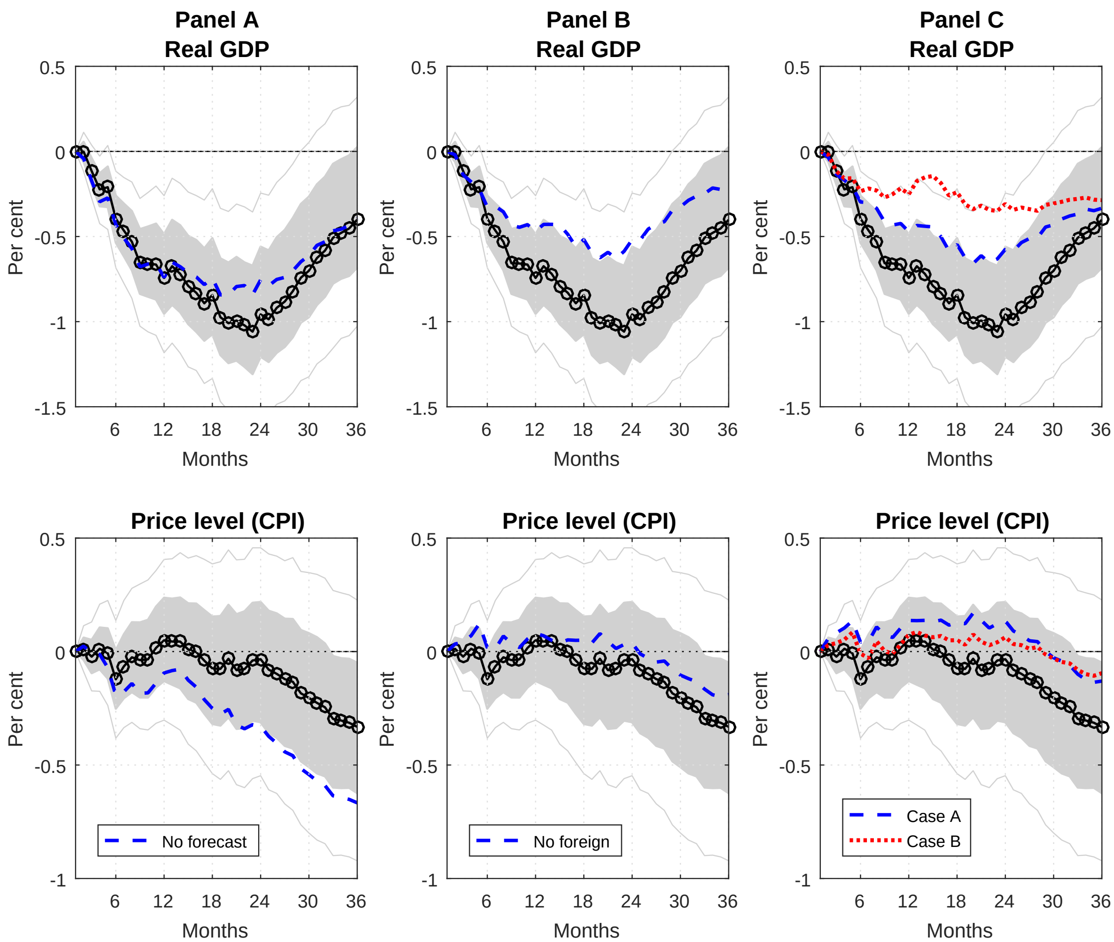
4.6 The importance of controlling for forecasts and foreign variables

In this section, we explore the importance of adding forecasts and the foreign variables to our first-stage specification. As we discussed earlier, in our first-stage regression we critically depart from the narrative literature by (i) breaking the estimation into two subsamples and (ii) including U.S. short-term interest rates and the USD/CAD exchange rate ("foreign variables"). In this section, we examine the importance of controlling for those foreign predictors as well as the real GDP growth and inflation forecasts when identifying our monetary policy shocks. Panel A of Figure 8 shows the responses of real monthly GDP and the CPI to monetary policy shocks when the first-stage regression does not include forecasts of either GDP growth or inflation. This omission decreases the GDP response slightly and leads to a much stronger inflation response. This is contrary to the evidence from the U.S. (R&R) and U.K. (Cloyne and Hürtgen (2016)) where the exclusion of forecasts leads to the well-known price puzzle. As discussed in Section 2.1, there is extensive narrative evidence, in addition to our own estimates, that the role played by the forecasts was very different before and after 1992, when IT began. In this sense, it is no surprise that the exclusion of the forecasts does not lead to a price puzzle.

In Panel B, we show the responses of real GDP growth and the CPI to monetary policy shocks estimated with first-stage regressions that omit the foreign predictors. In this case, we find a much weaker response of real GDP, highlighting the importance of controlling for the foreign predictors in the policy-makers' information set.

[53] Many commentators have argued that the Bank of Canada often acted right after the FOMC; we thus define a meeting as the date two days after an FOMC meeting occurred and when we did not already have a meeting defined in that week. This adds 108 observations to our set of meetings. Note that we do not view this second approach as a precise way of identifying meetings, but more as a robustness check for our results.

Figure 8: Impact of excluding forecasts and foreign variables



Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock using our new measure of shocks (solid black line with circles) with corresponding 68 and 95 per cent confidence bands compared with different specifications of equation (2). VARs include log (monthly) real GDP, log CPI, log commodity prices, and the shocks measure. Panel A: first-stage regression without nowcasts and forecasts (dashed blue line). Panel B: first-stage regression without foreign variables (dashed blue line). Panel C (Case A, dashed blue line): first-stage regression estimated without foreign variables for 1973-91 and without nowcasts and forecasts for 1992-2015. Panel C (Case B, dotted red line): first-stage regression estimated without foreign variables and forecasts for both sub-samples. P=24. Sample: 1974:M4 to 2015:M10.

Finally, in Panel C we perform two different exercises. First (Case A, dashed blue line), we exclude the foreign variables of the first-stage regression for the pre-IT sample (1974-91) and the forecasts for the IT sample (1992-2015). This leads to a very weak response of real GDP while a small price puzzle emerges in the first two years. Finally, we exclude both foreign variables and forecasts, from both sub-samples (Case B, dotted red line). We find a weak, flat response of real GDP of barely 0.3 per cent, while the price level stays roughly around zero throughout. These results highlight the importance of controlling for foreign predictors during our first sub-sample (1974 to 1991) and economic forecasts from the staff projections in the latter part of our sample (1992 to 2015). Both are key to explaining our response of real GDP and removing part of the price puzzle.

5 Conclusion

Quantifying the effects of monetary policy is one of the most enduring questions in macroeconomics. The estimates vary markedly across the literature: on the one hand, many papers identifying the exogenous component of monetary policy using different VAR models obtain modest responses of output and inflation to monetary policy shocks. On the other hand, papers relying on R&R's narrative identification strategy find larger effects of monetary policy. The identification of monetary shocks is complicated by the fact that important shifts in the conduct of monetary policy have occurred in the U.S. and other countries.

This paper tackles these issues for Canada by applying the narrative identification strategy of R&R. We construct a new, rich dataset of real-time data and forecasts from the Bank of Canada's staff projections going back to the early 1970s, as well as a series of intended changes in the target policy rate to identify a new measure of monetary policy shocks for Canada. Canada is an interesting case study as it is a textbook small open economy, closely linked with the U.S. It also experienced a clear change in the conduct of monetary policy, as the Bank of Canada has been operating within an IT framework since 1991.

We show that our new measure of monetary policy shocks crucially departs from R&R on two aspects: first, the monetary policy reaction function includes U.S. interest rates and the USD/CAD exchange rate; second, it accounts for the change in the Canadian monetary regime following the adoption of IT. Before the introduction of IT, changes in the target policy rate were explained mostly by changes in the USD/CAD exchange rate and U.S. interest rates, while they have been more significantly centered around the staff forecasts for output and inflation since. We find that a 100-basis-point monetary policy shock from our new measure generates a peak decline in real GDP and the (CPI) price level of 1.0 and 0.4 per cent, respectively. Furthermore, we show that not accounting for the change in monetary regime leads to monetary policy shocks that generate a price puzzle and show clear signs of endogeneity.

We compare our estimates for the effects of monetary policy in Canada with those of the U.S. and the U.K. from the narrative literature. Whereas our response for output is of a magnitude similar to that of the U.S. and the U.K., the peak decline of CPI in Canada is much smaller. One implication of this result is a flatter Phillips curve in Canada relative to the U.S. and the U.K., consistent with New Keynesian small open economy models, which find that the slope of the Phillips curve is decreasing with the degree of openness of the economy. Furthermore, we show that accounting for changes in monetary policy regimes in these countries also leads to monetary shocks that have a smaller impact on output and stronger (negative) impact on the price level, in line with our evidence for Canada.

Our results offer new evidence on the effects of monetary policy and highlights the importance of acknowledging the institutional changes in the conduct of monetary policy when identifying monetary shocks. In doing so, we provide a new data set and a new measure of monetary policy shocks for Canada, a textbook small open economy, and hope that these data will provide interesting avenues for future research.

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Appendix A Data

This section describes the various data series along with relevant sources used in the paper. We first start with the data used in the first-stage regression, then we detail the intended policy rate series used as the dependent variable in the first-stage regression and provide a backgrounder on the Bank Rate. Lastly, we describe the ex-post data used in the predictability tests and second-stage analysis (Sections 2.5, 3 and 4).

A.1 First stage-data details

The Bank of Canada staff produce four exhaustive projections each year, following the release of the quarterly national income and expenditure accounts, which are generally carried out around the end of March, June, September, and December. These staff projections contain quarterly forecasts as well as historical real-time data of different macroeconomic aggregates. Since the introduction of eight (fixed) monetary policy announcements dates per year in 2000, for some years Bank staff have produced eight projections per year, i.e., one before each monetary policy announcement. In those instances, we use these additional projections when we assign real-time data and forecasts to meetings.

We follow Romer and Romer (2004) and use real-time data and forecasts for real GDP growth and inflation from the Bank of Canada's staff projections database: ow

- **Real GDP growth**: Annualized quarterly real GDP growth rates, seasonally adjusted. 1973:Q1 to 2015:Q3.
- **Inflation rate**: Annualized quarterly inflation rate. Computed as total CPI inflation (1974:Q1 to 1979:Q4), core inflation (1980:Q1 to 2000:Q1) and CPIX inflation (2000:Q2 to 2015:Q3). Core inflation from 1980:Q1 to 2000:Q1 is defined as CPI excluding food, energy, and the effects of changes in indirect taxes. CPIX excludes the eight most volatile components of CPI and adjusts the remaining components for the effects of changes in indirect taxes.

Other real-time variables in the first-stage regression:

- **Unemployment rate**: Real-time monthly unemployment rate, seasonally adjusted. Source: Archives of Statistics Canada Labour Force Survey Monthly Releases. Covers period from 1977:M1 to 2015:10. For the 1973:M1 to 1976:M12 period, we manually recorded the real-time monthly unemployment rate from hard copies of Bank of Canada Reviews between 1973 and 1976.

- **U.S. federal funds rate**: U.S. federal funds effective rate. Source: Federal Reserve Board. H15, Selected Interest rates. Identifier: `RIFSPFF_N.M`.

- **U.S./CAD exchange rate**: Nominal exchange rate, U.S. dollars per Canadian dollar. Source: Bank of Canada.

A.2 Constructing the intended changes in the target policy rate

Since February 1996, the key policy instrument of the Bank of Canada has been the Target for the Overnight Rate. Set by the Bank, the Target for the Overnight Rate lies in the middle of a 50-basis-point operating band. For example, if the operating band is 2.25 to 2.75 per cent, the Target for the Overnight Rate would be 2.50 per cent. The top of that band (2.75 per cent) is the Bank Rate—the interest rate at which the Bank of Canada charges Canadian charter banks and other participants on one-day loans. Consequently, since February 1996, any change in the Target for the Overnight Rate is equal to an analogous change in the Bank Rate. We use these changes as our intended policy rate changes from February 1996 onward. Before 1996, although the Bank Rate has always been the key monetary policy tool of the Bank, we use changes in the 50-basis-point operating band from the April 1994 to February 1996 period. The objective of the introduction of the 50-basis-point operating band was to provide more transparency to monetary policy (e.g., Lundrigan and Toll (1998)), which became clearer in February 1996 when the Bank Rate was set as the top of the band. Before March 1994, we use changes in the Bank Rate as our intended policy rate series.

Note that between March 1980 and February 1996, the Bank Rate was floating and set at 25 basis points above the average yield on the 3-month treasury bills at the federal government's weekly auction. However, the Bank was still implementing monetary policy by setting the Bank Rate: since the Bank of Canada observed all the bids at each weekly auction, it could place a reserve bid for these bills, setting the minimum price or maximum yield it wished to tolerate on treasury bills, and thus on the Bank Rate (e.g., Bank of Canada (1980), Courchene (1981), Fettig (1994), or Montador (1995)).

To sum up, our intended series of policy rate changes is constructed as:

- **January 1973 to March 1994**: Changes in the Bank Rate. CANSIM v39078.
- **April 1994 to February 1996**: Changes in the 50-basis-point operating band. CANSIM v39076 and v39077.
- **February 1996 onward**: Changes in the Target for the Overnight Rate. CANSIM v39079.

All these series can be found on the Bank of Canada website.

A.3 Ex-post (revised) data

In this sub-section, we describe the variables used once we have identified our new shock series in the first-stage analysis. These series are used in the predictability tests (Section 2.5), in Section 3 (macroeconomic effects of monetary policy), and in Section 4 (robustness exercises and extensions). All these data series were downloaded in February 2016.

- **Real GDP**: Gross domestic product at basic prices. Monthly, seasonally adjusted. CANSIM v65201210s for 1982:M1 to 2015:M12; v329529 from 1973:M1 to 1981:M12. Source: Statistics Canada.
- **CPI**: Consumer Price Index (CPI). Monthly. CANSIM v41690973. Source: Statistics Canada.
- **CPIX**: CPI excluding its eight most volatile components and adjusted for the effects of changes in indirect taxes. Monthly. CANSIM v41692942. Source: Statistics Canada.
- **CPIxMIC**: CPI excluding mortgage interest costs. Monthly. Constructed from CPI (v41690973) and MIC (v41691056). Source: Statistics Canada.

- **Unemployment rate**: Monthly unemployment rate (aged 15 years and older, all persons), seasonally adjusted. Downloaded from FRED database, with identifier: LRUNTTTTCAM156S. Source: OECD.

- **Industrial production**: Index of industrial production. Monthly, seasonally adjusted. CANSIM Table 379-0031 for data from 1997:M1 to 2016:M12. Backcasted to 1974 with series downloaded from St-Louis FRED database, with identifier: CANPROINDMISMEI. Source: OECD.

- **BCPI**: Bank of Canada Commodity Price Index (BCPI) converted to Canadian dollars. Monthly. CANSIM v52673496. Source: Statistics Canada.

- **USD/CAD**: Nominal exchange rate, U.S. dollars per Canadian dollar. Source: Bank of Canada.

- **TSX**: Toronto Stock Exchange Composite Index. End-of-the-month value. CANSIM v122620. Source: Statistics Canada.

- **M2**: Monetary supply aggregate M2. Monthly. CANSIM v122620. Source: Statistics Canada.

A.4 Romer and Romer (2004) extended U.S. monetary policy shocks series

In Sub-section 3.2 of the paper (and in the robustness exercises below), we extend the measure of monetary policy shocks of Romer and Romer (2004) (R&R henceforth) up to 2011, the last year the Greenbook forecasts are available. We downloaded the Greenbook data from Yuriy Gorodnichenko's website (http://eml.berkeley.edu/~ygorodni/). To generate the shock series, we perform the exact same regression as in R&R's equation (1), using the Greenbook data from 1969 up to 2011. Note that the shocks used in Section C.3 below (1969-2007) are estimated using only Greenbook data from 1969 to 2007, thus excluding the Great Recession period in the first-stage estimation.

A.5 Cloyne and Hürtgen (2016) extended U.K. monetary policy shocks series

As for the U.S. shocks, we extend the Cloyne and Hürtgen (2016) shocks up to 2011 using forecasts from the Inflation Reports' fan chart data from 2008 to 2011. The data are available on the Bank of England website.[54] To generate the shock series, we take the residuals from the exact same regression as in Cloyne and Hürtgen (2016), using the real-time and forecast data up to 2011. For the sample ending in 2007, we directly use the shocks series from Cloyne and Hürtgen (2016).

A.6 Ex-post (revised) data for the U.S. and the U.K.

The ex-post data for the U.S. are:

- **Industrial production**: Industrial Production Index (INDPRO), downloaded from the FRED database on 2017/06/02.
- **CPI**: Consumer Price Index (CPALTT01USM661S), downloaded from the FRED database 2017/06/02.
- **Commodity Price Index**: Commodities Research Bureau (CRB) index downloaded on 2017/06/02.
- All these series are the same as those used in Coibion (2012).

The ex-post data for the U.K. are:

- **Industrial production**: Industrial Production Index. Office for National Statistics (ONS) series CVMSA.[55]
- **CPI**: Consumer Price Index. We use Cloyne and Hürtgen (2016) series up to 2007, and the ONS series D7BT for 2008 onward.[56]

[54] For example, *http://www.bankofengland.co.uk/publications/Pages/inflationreport/irprobab.aspx*.

[55] Downloaded here: *https://www.ons.gov.uk/economy/economicoutputandproductivity/output/timeseries/k222/diop*

[56] Downloaded here: *https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/d7bt/mm23*

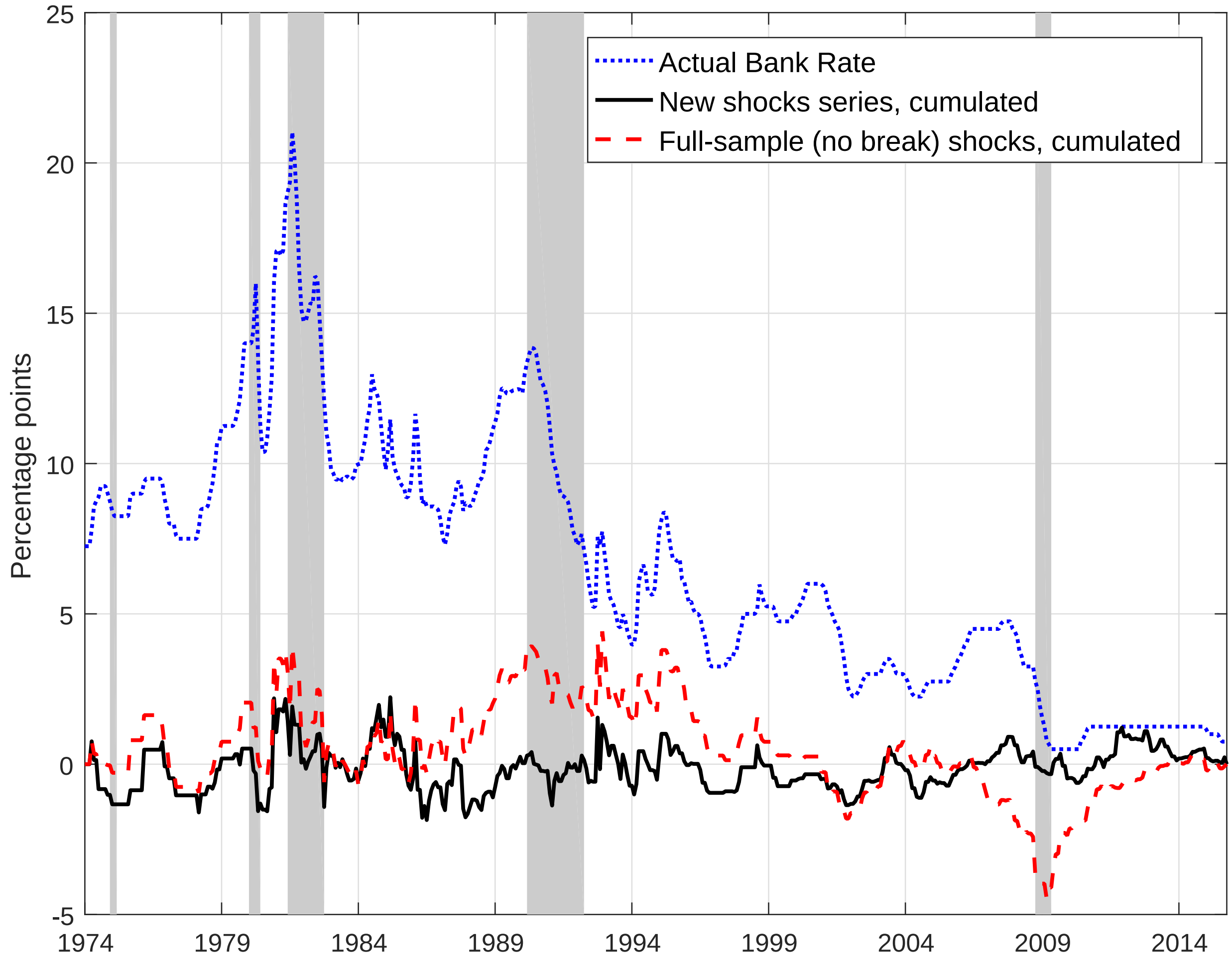
- **Commodity Price Index**: International Monetary Fund (IMF) commodity price index for 1992 onward.[57] Backcasted before 1992 using Barakchian and Crowe (2013) data. Converted to Sterling.

[57] Downloaded here $http://www.imf.org/external/np/res/commod/index.aspx$.

Appendix B First-stage analysis

Figure B.1 shows the actual path of the Bank Rate (dotted blue line), along with two exogenous paths constructed by cumulating our monthly shock series: (1) our new measure of shocks, which accounts for structural break due to inflation targeting (IT) (solid black line), (2) shocks estimated in the first stage with the full, not accounting for the break (dashed red line).

Figure B.1: Cumulated shock series and actual Bank Rate



Notes: This figure shows the path of the Bank Rate (dashed blue line) from 1974 to 2015 together with our new shock series cumulated (solid black line) and the cumulated shock series estimated with the full sample (dashed red line). Shaded gray bars represent recessions determined by the C.D. Howe Institute.

Appendix C Comparison with the literature: More results

C.1 Comparison with U.S. and U.K.: Quarterly VAR with real GDP

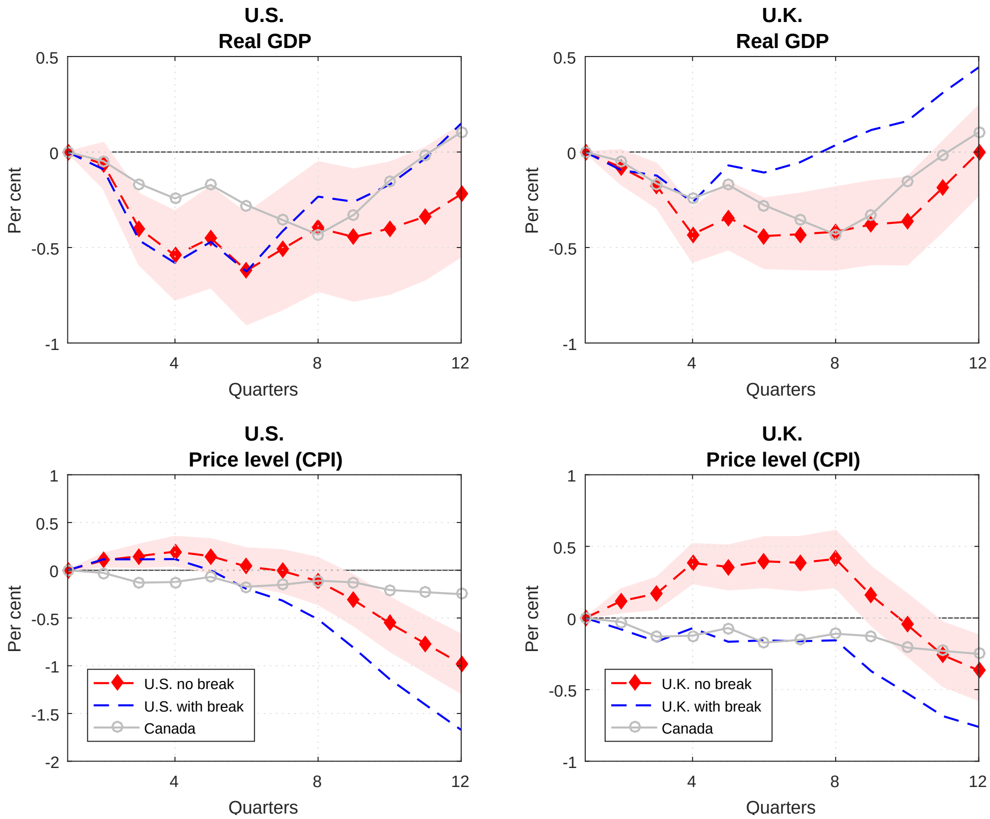
A nice feature of the Canadian data is that real GDP is available monthly, allowing us to estimate the effects of monetary policy on real GDP at the monthly frequency. However, for the U.S. and the U.K. (and many other countries), studies have to rely on industrial production to estimate the effects of monetary policy on output at the monthly frequency. To get a square comparison for real GDP, here we estimate a quarterly VAR for Canada, the U.S. and the U.K. over the same time period as in the paper (i.e., up to 2011, inclusively). To get a quarterly measure of shocks, we sum the monthly series at the quarterly level. Figure C.1 presents the results.

The impulse responses are generally similar as in the paper, albeit real GDP reacts slightly less than industrial production for both the U.S. and the U.K. More importantly, we notice that the divergences of the responses to the shocks estimated with and without a break in the first stage remain robust to using GDP data. The responses to the break-shock series exhibit a more rapid recovery than to the no-break shocks for both countries, and the CPI responses are stronger and do not exhibit a price puzzle.

C.2 Comparison with U.S. and U.K.: Robustness to using Wu and Xia (2016, 2017) shadow rates

In many developed economies such as the U.S. and the U.K., the target overnight policy rate hit the zero lower bound following the financial crisis. Some argue that using the federal funds rate (FFR) (U.S.) or the Bank Rate (U.K.) in the first-stage regression to estimate the monetary policy shocks is not appropriate as the target policy rate as it is stuck at the zero lower bound; central banks might well have been responding to the forecasts but were simply using other tools. Consequently, when estimating the monetary

Figure C.1: Quarterly VAR with real GDP



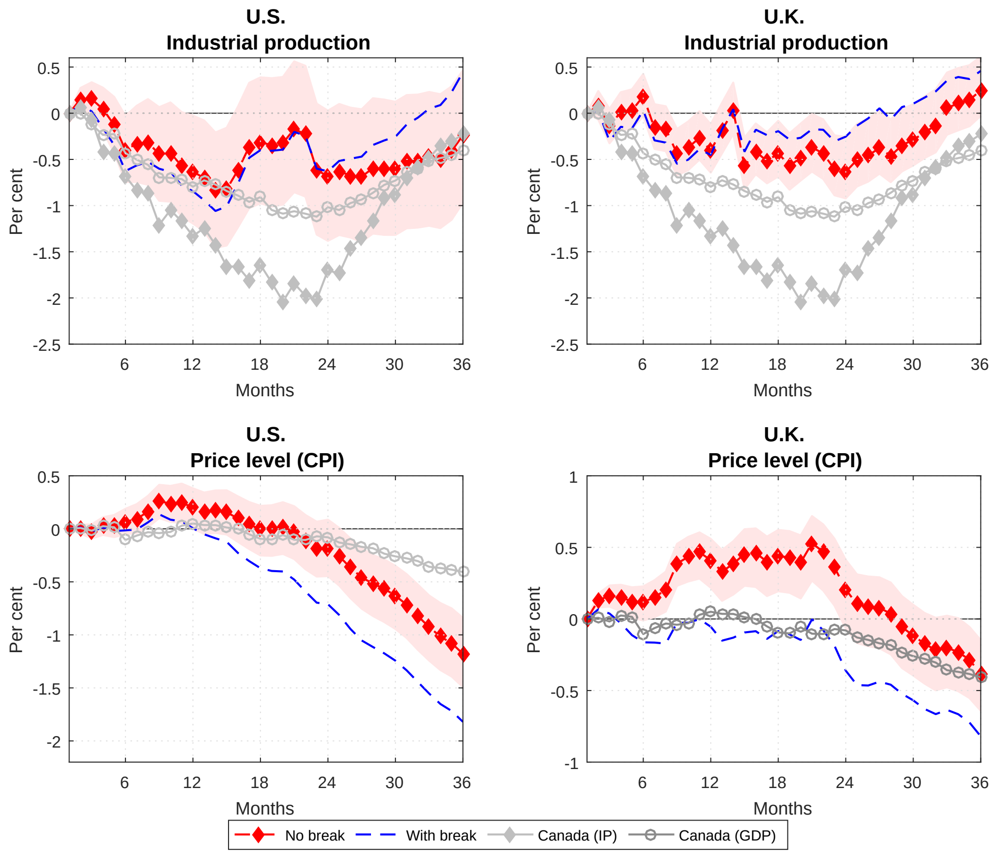
Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock from a VAR including log real GDP, log CPI, log commodity price index and the measure of monetary policy shocks, along with the corresponding 68 and 95 per cent confidence bands. Quarterly data. P=8. Sample for Canada is: 1974:Q2 to 2011:Q4. For the U.S.: 1969:Q1 to 2011:Q4. For the U.K.: 1975:Q1 to 2011:Q4.

policy shocks for the U.S. and the U.K. from 2009 onward, we use changes in Wu and Xia (2016, 2017) shadow rates instead of using the (zero) changes in the target policy rates for both countries.[58] We then use the resulting shock series in the baseline VAR. Figure C.2 replicates Figure 3 of the paper using these alternative shock series estimated with the shadow rates for the U.S. and the U.K., and includes the same Canadian impulse responses from the paper for comparison.

We can see that the responses of industrial production and the (CPI) price level are

[58] Wu and Xia (2016, 2017) use a term structure model with shadow rates to analyze monetary policy when the FFR is close to the zero lower bound. They show that their model produces a shadow rate that effectively summarizes the stance of monetary policy during this period. As the shadow rates are computed at the end of the month, we use the end-of-the-month value for a given meeting minus the end-of-month value of the previous month to get the change in the policy rate.

Figure C.2: Macroeconomic effects of monetary policy shocks: Robustness to using shadow rates



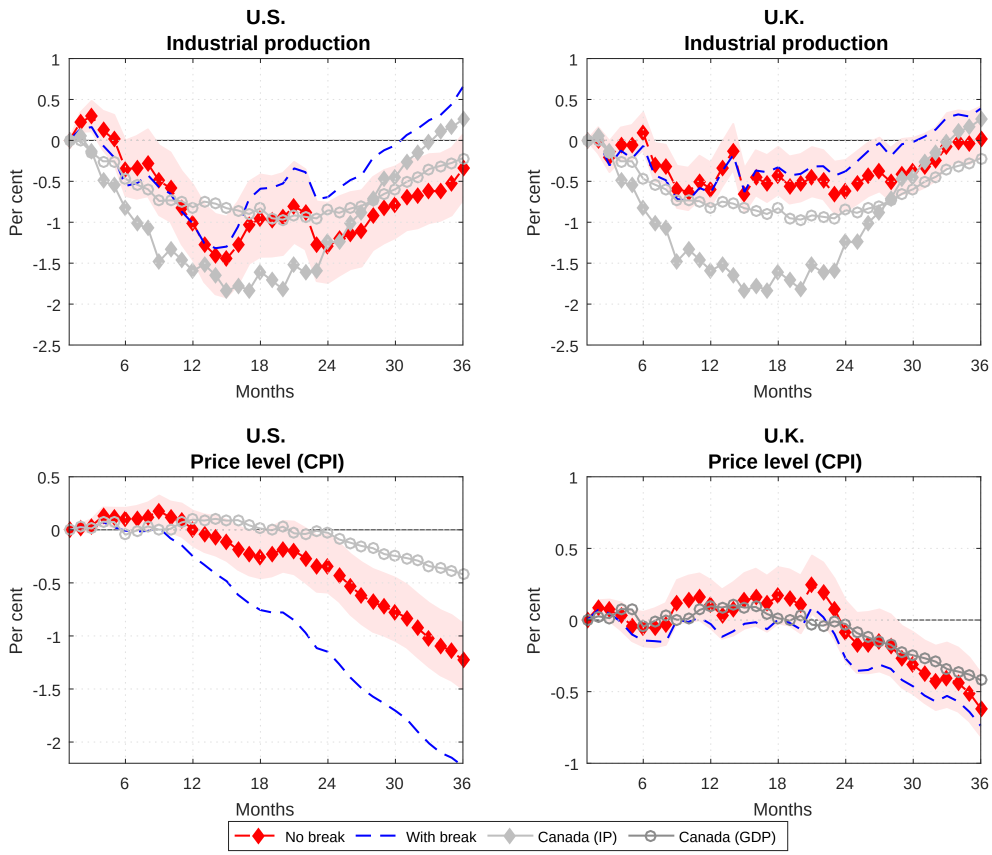
Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock from a VAR including log industrial production, log CPI, log commodity price index and the measure of monetary policy, along with the corresponding 68 and 95 per cent confidence bands. P=24. Monthly data; Sample for Canada is: 1974:M4-2011:M12. For the U.S.: 1969:M1-2011:M12. For the U.K.: 1975:M1-2011:M12.

virtually unchanged from those in Figure 3 of the paper. Notably, the differences in the impulse responses between the shocks estimated with and without a break in the first-stage regression are as important as in the paper.

C.3 Comparison with U.S. and U.K.: Robustness to excluding the Great Recession

We just showed above that our results for the international comparison are robust to using Wu and Xia (2016) shadow rates from 2009 to 2011 instead of the overnight policy rate. Here we test the robustness of the international comparison one step further as we completely take out the Great Recession period. We show that the main results of the Section 3.2 in the paper remained unchanged for the U.S. and become somewhat weaker for the U.K. As seen in Figure C.3, breaking the first sub-sample estimation to account for the introduction of IT in the U.K. matters less than with the extended (to 2011) sample. After peaking at -0.6 per cent (12-15 months), industrial production increases more rapidly when the shock series is estimated with a break, but this increase is within the 68 per cent confidence band. The price level responses exhibit a similar pattern to that shown in the paper, where the response of CPI to the full-sample (no break) shocks display a mild price puzzle while the shocks estimated with a break do not. Again, this difference is within the 68 per cent confidence bands. For the U.S., the results in the paper for the R&R extended sample remain very robust to stopping in 2007. Industrial production reacts similarly to both shock series during the first 18 months, but then the response to the break-shock series increases markedly and ends about 1 per cent higher than the no-break shocks. The difference for the price level is more drastic, as in the paper. The response to the break-shocks declines more rapidly and ends more than 1 per cent below the response to the no-break shocks.

Figure C.3: Macroeconomic effects of monetary policy shocks: Robustness to pre-2008 sample

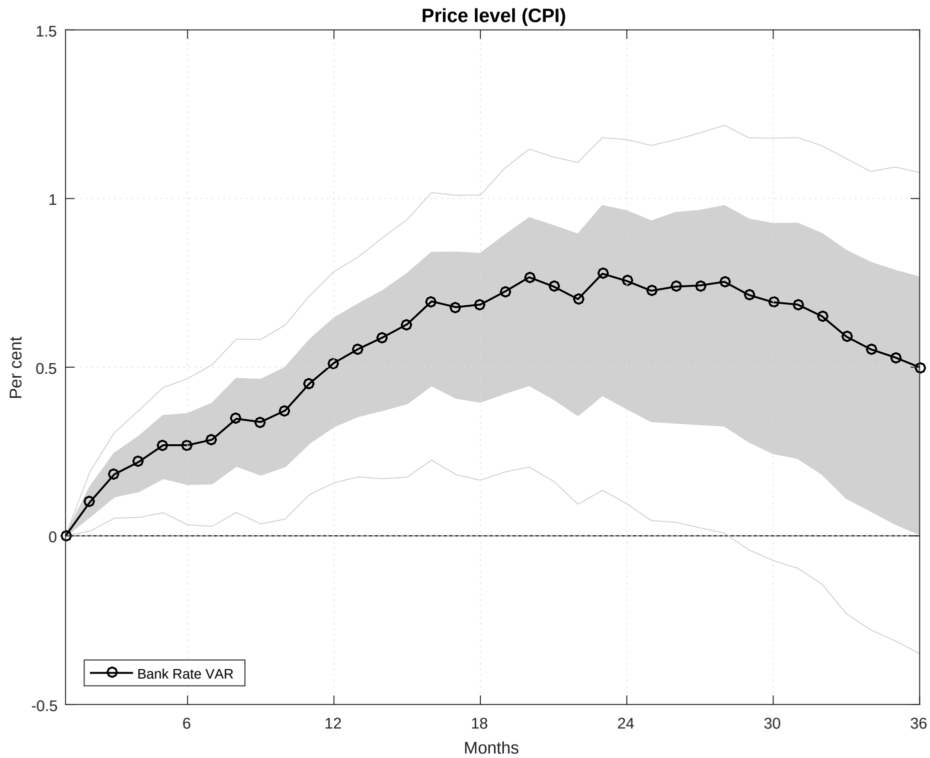


Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock from a VAR including log industrial production, log CPI, log commodity price index and the measure of monetary policy, along with the corresponding 68 and 95 per cent confidence bands. P=24. Monthly data. Sample for Canada is: 1974:M4-2007:M12. For the U.S.: 1969:M1-2007:M12. For the U.K.: 1975:M1-2007:M12.

C.4 The price puzzle

Figure C.4 presents the same CPI impulse response as Figure 4 in the paper, adding the corresponding 68 and 95 bootstrapped confidence intervals using 2,000 replications. Following a 100-basis-point contractionary monetary policy shock identified in the standard recursive way *à la* Christiano et al. (1996, 1999) (instead of our new narrative measure of monetary policy shocks), the price level increases significantly with a peak impact of 0.8 after two years. It ends after three years just below 0.6 per cent. For the first 32 months, both confidence bands lie above the zero line, undeniably showing a positive response of the price level following a contractionary monetary policy shock identified in a standard recursive VAR.

Figure C.4: Conventional recursive VARs with Bank Rate as measure of monetary policy shocks



Notes: Impulse responses to a 100-basis-point contractionary monetary policy shock from a conventional recursive VAR with the Bank Rate as the monetary policy instrument (not including our new measure of shocks), along with the impulse response we show the corresponding 68 and 95 per cent confidence bands. VAR includes log real GDP, log CPI, log BCPI and the Bank Rate. P=24. Sample: 1974:M4 to 2015:M10.

C.5 Comparison with wider literature

Our paper is related to various areas of the empirical monetary policy literature. A first comparison of interest is the extent to which our results are in line with the evidence of Coibion (2012) for the U.S., as it provides a good benchmark for the effects of monetary policy shocks. Coibion (2012) reconciles the strong effects from R&R to the weak effects of the earlier literature (e.g., Christiano et al. (1996, 1999), Bernanke and Mihov (1998), among others) and finds that the effects of monetary policy are more modest than R&R but substantially stronger than those of the earlier literature. Using a VAR similar to ours with the original cumulative R&R shock series (1969-96), he finds that the R&R shocks lead to a peak fall in U.S. industrial production of close to 2 per cent and a peak decrease of the price level also of about 2 per cent. Our peak real monthly GDP response at 1.0 per cent lies in between those estimates, while the peak decline of the price level in Canada is much smaller than in the U.S., at about 0.4 per cent. As we show in Section 3.2 of the paper (and in Appendix D.4 below), the response of industrial production is much larger (about -1.8 per cent peak impact), more in line with the evidence in Coibion (2012). All in all, the U.S. evidence presented in the paper and above suggests that the Coibion (2012) results for the extended sample have become smaller for industrial production and similar for the price level. Moreover, the evidence we present in the paper suggests that accounting for the break in the monetary policy reaction function matters significantly for identifying monetary policy shocks.

There are a few papers for Canada on identifying the effects of monetary policy with VARs. Armour et al. (1996) use a standard VAR with the recursive assumption à la Christiano et al. (1996, 1999) and find small effects on output and prices (peak of -0.1 per cent). Other papers argue that since Canada is a small open economy, VARs identified with the recursive assumption imply very strong assumptions on the contemporaneous relationship between exchange rates and monetary policy. In order to circumvent this problem, Cushman and Zha (1997) estimate a VAR with home and foreign parts, block exogeneity and non-recursive restrictions using data from 1973 to 1993, corresponding roughly to our pre-IT sub-period. They find that following a contractionary monetary policy, there is little movement in interest rates, but a strong reaction of the exchange rate. While there is a small price puzzle following the shock, the price level slowly decreases, reaching a peak impact after two years, where the price level flattens afterward. Quantitative comparisons with our paper are complicated by the fact that Cushman and Zha (1997) identify monetary policy shocks through changes in the money supply, and not interest rates. All in all, they find very small effects of monetary policy on output, prices and the trade balance. Applying a similar model, but to a more recent period following the introduction of IT, Bhuiyan (2012) finds that a 1 per cent increase in interest rates has peak impacts on output of about 0.2 per cent after six months and 0.5 per cent on the price level between one and two years after the shock. While the peak impact on prices is very similar to the one we obtain, the output response to our narrative shocks is substantially larger. Overall, our estimates of the effects of monetary policy shocks on output and inflation are higher than have been found in previous studies for Canada.

Appendix D More robustness exercises

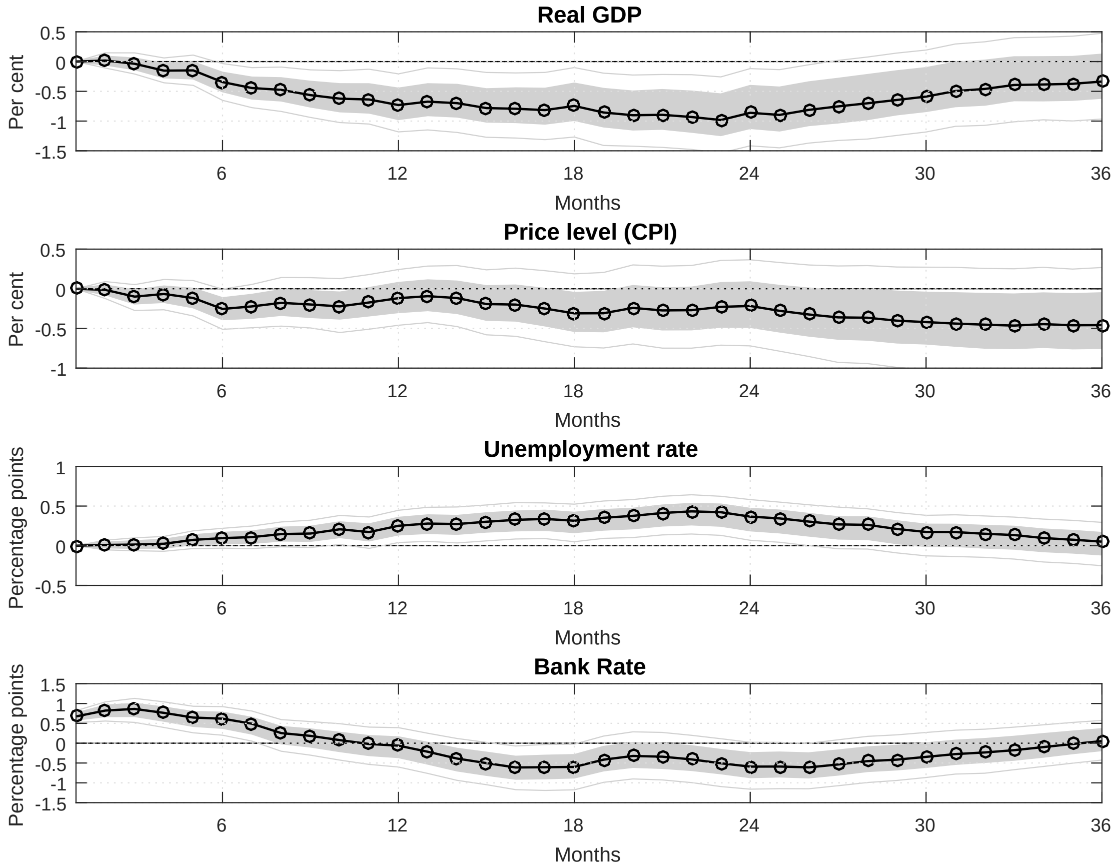
D.1 Large VAR with unemployment rate and Bank Rate

In this section, we verify the robustness of our main VAR results to a larger VAR specification that adds the unemployment rate and the Bank Rate to our baseline VAR containing real GDP, CPI, commodity prices and our shock series. As shown in Figure D.1, the impulse responses of real monthly GDP and CPI are very similar to our baseline responses. The unemployment rate also accords well with the expected sign based on empirical studies and theoretical macroeconomic models: following the contractionary monetary policy shocks, the unemployment rate increases, with the peak impact happening between 18 and 24 months after the shock.

D.2 Large VAR with the exchange rate

We mention in the paper that our baseline VAR includes an index of commodity prices (i.e., the BCPI) in Canadian dollars, thus accounting for the movements in the USD/CAD exchange rate. Here we slightly modify this baseline VAR from the paper by using the

Figure D.1: Large-scale VAR with the unemployment rate

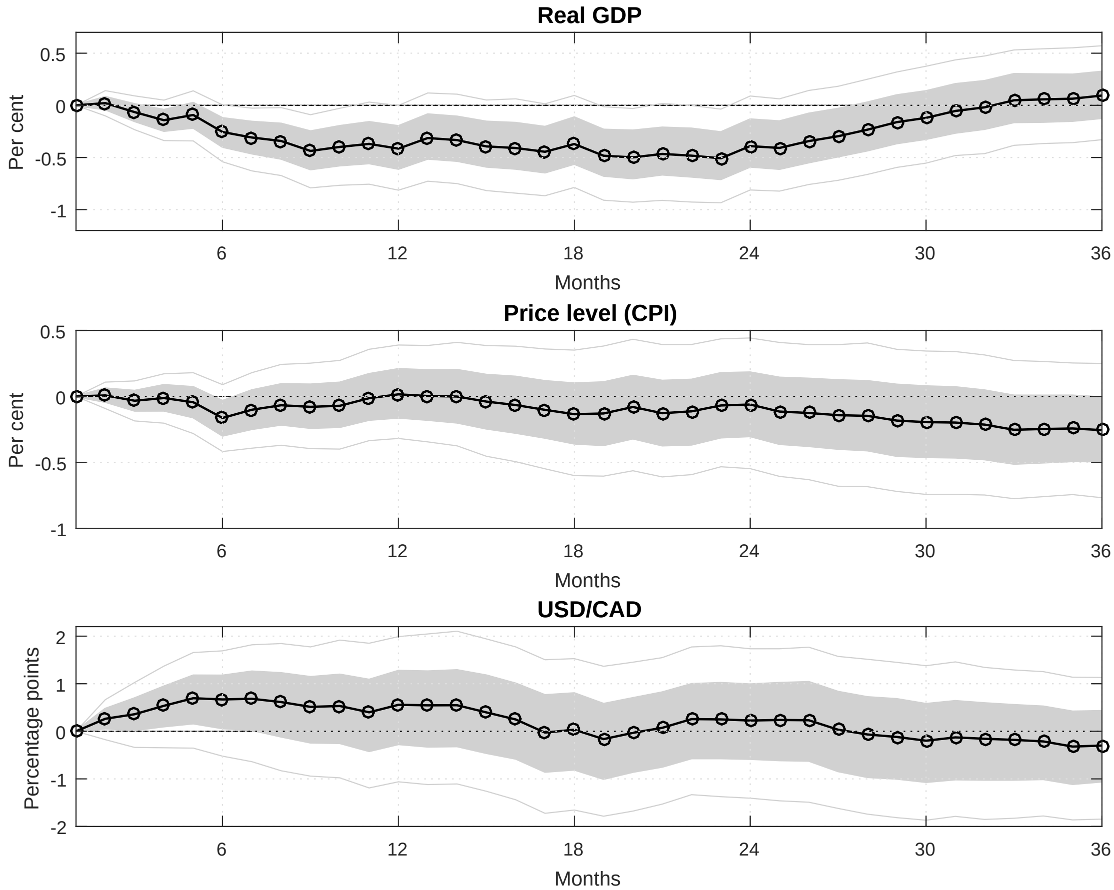


Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation along with the corresponding 68 and 95 per cent confidence bands. The VAR includes log real GDP, unemployment rate, log CPI, log BCPI, our new cumulated shock measure and the Bank Rate.

commodity price index (BCPI) in U.S. dollars and explicitly adding the USD/CAD exchange rate as a separate variable. We order the exchange rate after the commodity price index and before the shock, assuming that exchange rate shocks do not contemporaneously affect the other macroeconomic variables but itself reacts on impact to shocks to the macro variables. This specification also implies that monetary policy reacts contemporaneously to exchange rate movements. Figure D.2 presents the impulse responses to a 100-basis-point monetary policy shock.

First, we see that the exchange rate appreciates slowly for about 15 months before declining and remaining around zero for the next two years. This response is qualitatively similar to the one found from the local projections in Section 4 of the paper, although the

Figure D.2: Large-scale VAR with the exchange rate



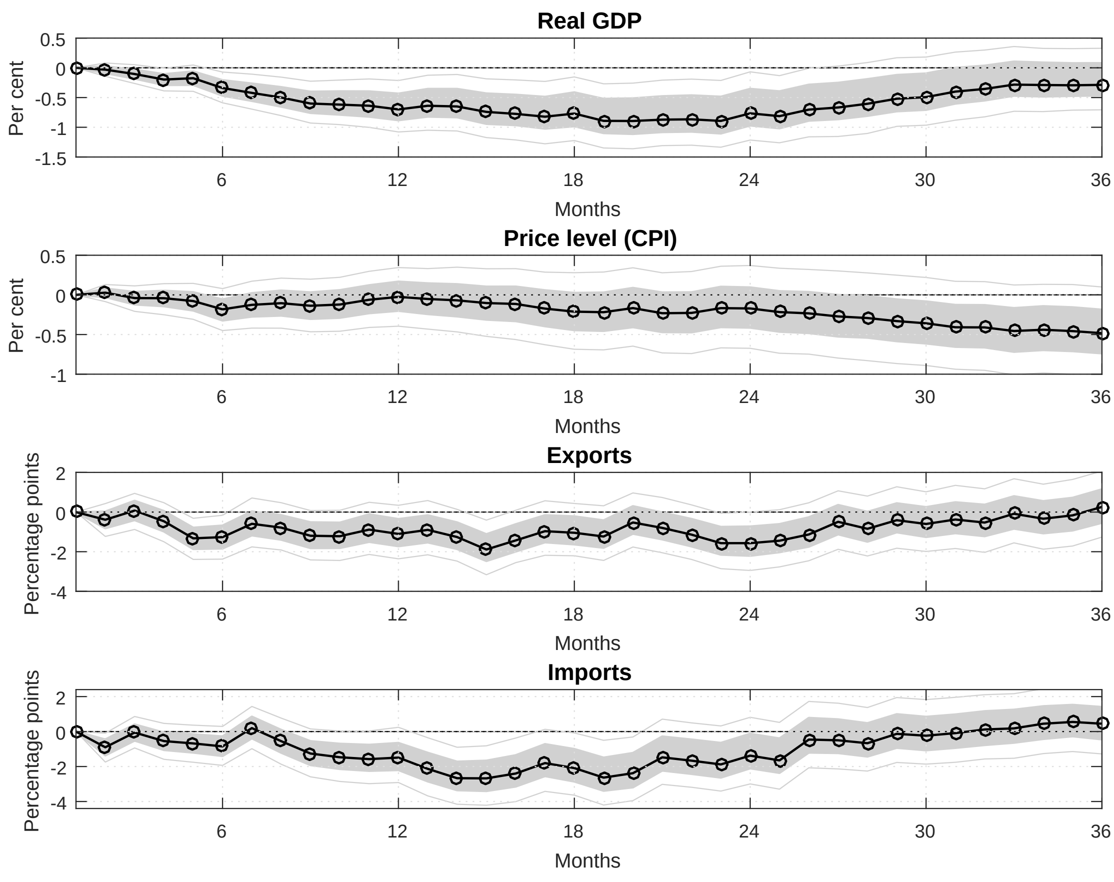
Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation along with the corresponding 68 and 95 per cent confidence bands. The VAR includes log real GDP, log CPI, log BCPI (in USD), log USD/CAD nominal exchange rate and our new cumulated shock measure.

local projections impulse response decline turns negative during the last 12 months. Even if the appreciation of the USD/CAD is slow to materialize, its subsequent depreciation is in accordance with the uncovered interest parity condition and does not exhibit a "delayed overshooting." The CPI price level stays roughly flat for two years before declining to about -0.35 per cent, again roughly in line with our baseline specification. However, we notice that although the response of real GDP is qualitatively similar to our baseline results, it is smaller in this VAR specification. Because this VAR specification simply includes the dynamics of the commodity price index and the exchange rate explicitly (instead of having both variables in the commodity price index in Canadian dollars), this weaker response of GDP relative to our baseline result is somewhat puzzling. Finally, we note that if we use shocks estimated without a break in the first-stage estimation instead of our new measure of shocks, we recover our results that the response of real GDP declines steadily throughout the three-year horizon, and we find a large price puzzle.

D.3 Large VAR with trade variables

We test another VAR specification where we add to our baseline VAR trade variables such as exports and imports. The VAR thus includes, in order, log real GDP, log CPI, log BCPI (in Canadian dollars), log exports, log imports and the new measure of shocks. Figure D.3 presents the impulse responses to a 100-basis-point monetary policy shock.

Figure D.3: Large-scale VAR with trade variables



Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation along with the corresponding 68 and 95 per cent confidence bands. The VAR includes log real GDP, log CPI, log BCPI (in CAD$), log exports, log imports, and our new cumulated shock measure.

Again, we note that the responses of real GDP and the price level are in line with our baseline results, although the response of CPI is slightly stronger here and somewhat weaker for real GDP. Exports and imports decline throughout following the shock: during the first year, in line with the appreciation of the Canadian dollar observed in Figure D.2, the trade balance is negative as exports decline more than imports, but it becomes positive for the next 18 months as the CAD depreciates.[59]

D.4 Extension: Industrial production in VAR instead of real GDP

In Section 3.2 of the paper, we compare the industrial production response for Canada with those of the U.S. and the U.K. Here we present the full impulse responses with confidence bands for our 1974:M4-2015:M10 sample. Figure D.4 presents the impulse responses of output and the price level. As it was the case for the sample ending in 2011, we note that the CPI response is practically the same when real GDP is substituted for industrial production (IP) in the VAR, even if the peak response of IP (-1.8 per cent) is much larger than real GDP (-1.8 per cent).

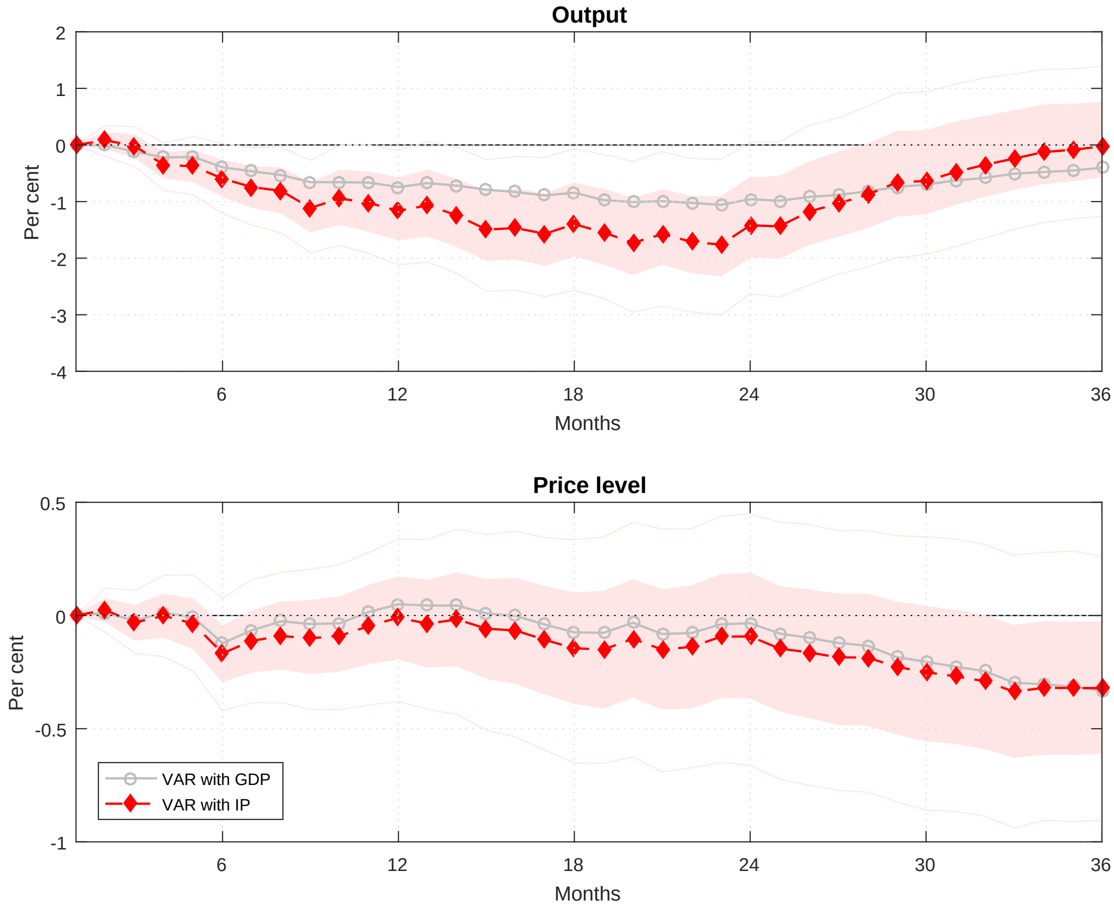
D.5 Robustness to different VAR assumptions

A large number of VAR studies use the recursive assumption of Christiano et al. (1996, 1999), ordering the monetary policy's instrument last in the system. In our baseline VAR, we proceed accordingly and also order our cumulative shock series last. Nonetheless, if our shock series effectively captures the information set of policy-makers, our measure of shocks should be exogenous to contemporaneous real GDP and CPI. Hence, here we order our measure of monetary policy shocks first, letting GDP and CPI be free to react upon impact to our monetary policy shocks. Panel A of Figure D.5 shows the results. The responses of real GDP and inflation are very similar to our baseline results.

Next, Panel B shows how different lag structures of the VAR impact our results. A VAR with 12 lags yields essentially the same response for real GDP as our baseline 24-lags specification, while the response of CPI is a bit weaker. On the other hand, the 36-lags

[59] Note that ordering the exports and imports variables first in the VAR (before real GDP) does not alter the results.

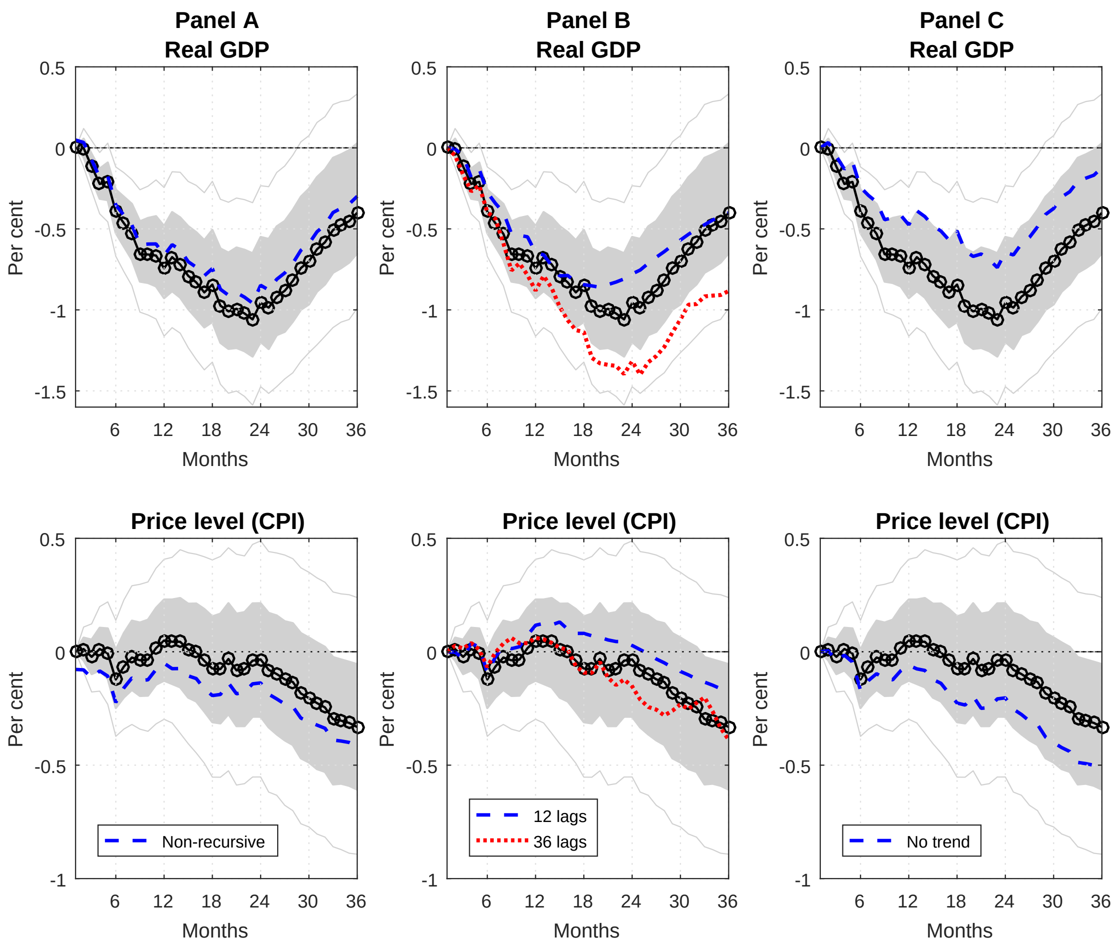
Figure D.4: Industrial production vs. real GDP as output measure in VAR



Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation along with the corresponding 68 and 95 per cent confidence bands. The VAR includes log IP, log CPI, log BCPI and our new cumulated shock measure (solid line with circles). P=24. Sample 1974:M4 to 2015:M10.

VAR yields somewhat stronger responses from real GDP, but very similar results for CPI. Cloyne and Hürtgen (2016) also find a stronger response for their output measure (IP) when they use 36 lags in the VAR. Finally, a VAR specification without trend produces similar responses, although the real GDP responses are slightly weaker and stronger, respectively.

Figure D.5: Robustness to different timing, lags structures and trend assumptions in VAR

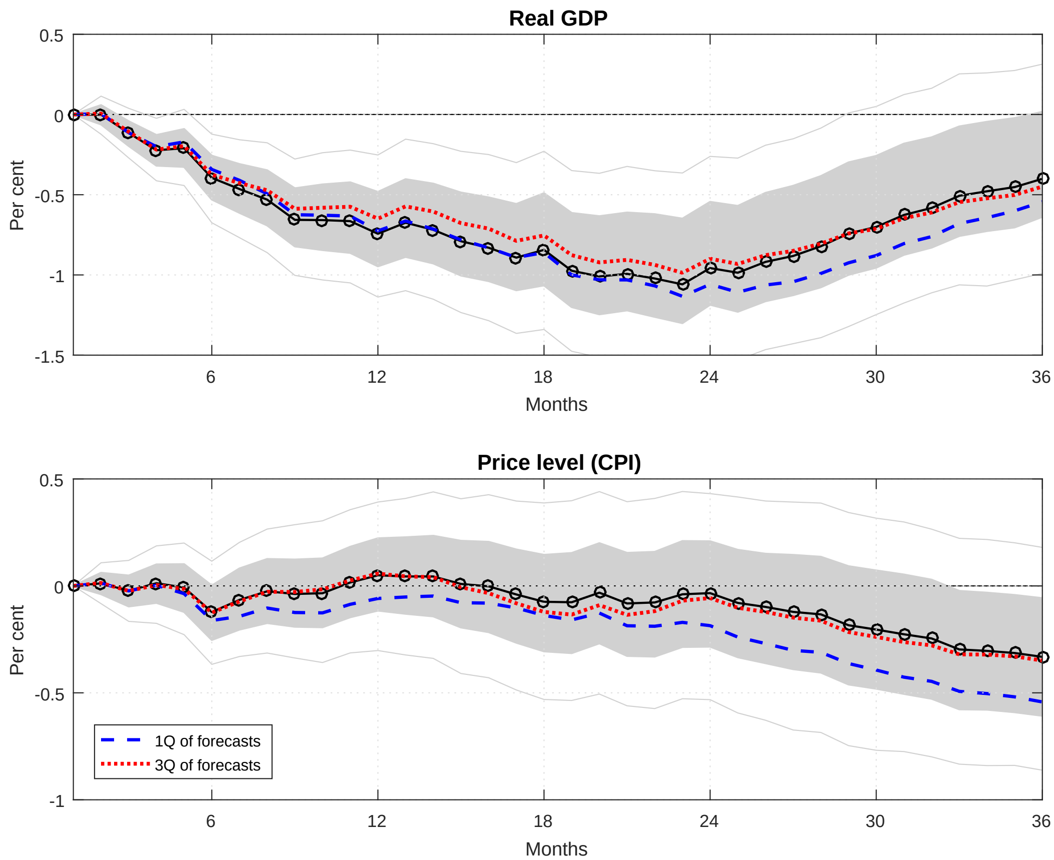


Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation along with the corresponding 68 and 95 per cent confidence bands. The VAR includes log real GDP, log CPI, log BCPI and our new cumulated shock measure (solid line with circles). Panel A: VAR with our shock series ordered first (dashed blue line). Panel B: VAR with alternative lag structures, 12 (dashed blue line) and 36 lags (dotted red line), respectively. Panel C: VAR without a trend (dashed blue line).

D.6 First-stage regression: Robustness to using one- or three-quarter-ahead forecasts

Here we test the robustness of our main results to alternative first-stage specifications where we: (i) use only one quarter of real GDP and inflation forecasts, and (ii) use three quarters ahead of real GDP and inflation forecasts. The results are shown below in Figure D.6. On the one hand, we can notice that using a third quarter ahead of forecasts does not affect our results at all; we take from this that the third quarter does not matter in determining changes in the target policy rate. On the other hand, removing the second quarter of forecasts does matter quantitatively for our results, although the patterns of the impulse responses remain similar. This suggests that the second quarter of forecasts do matter in the first-stage regression when identifying monetary policy shocks.

Figure D.6: Robustness to different forecast horizons

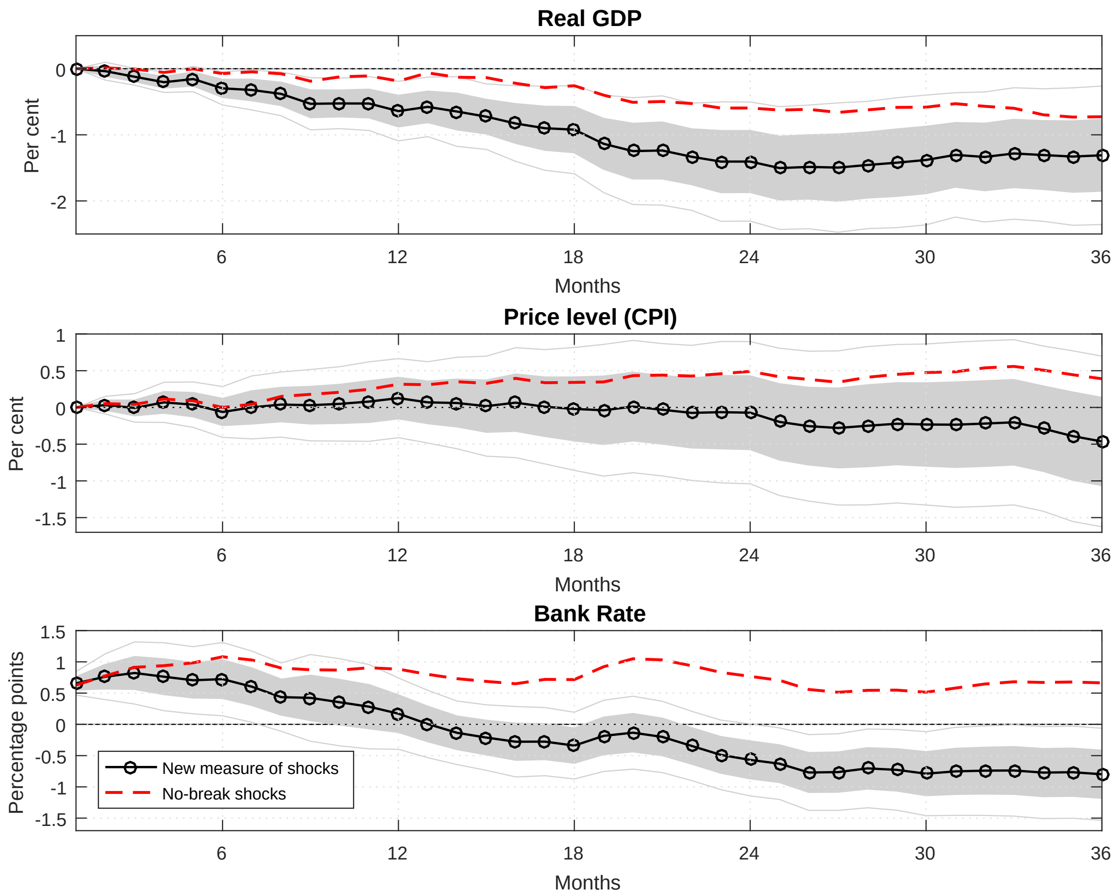


Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation along with the corresponding 68 and 95 per cent confidence bands. The VAR includes real GDP, CPI, BCPI and our new cumulated shock measure (solid line with circles). Same VAR replacing our shock series with a shock series estimated in first stage using only one-quarter-ahead forecasts (dashed blue line) and same VAR replacing our shock series with a shock series estimated in first stage using three-quarters-ahead forecasts (dotted red line).

D.7 Robustness of VAR results to single regressions

In the main text, we show that not accounting for the structural break in the conduct of monetary policy caused by the introduction of IT in 1991 leads to substantially different effects of monetary policy on output and the price level. For instance, our VAR results showed that following a contractionary monetary policy shock estimated from the full sample (no break) instead of our preferred measure of shocks, we obtain two very different results. First, a price puzzle emerges: the price level increases after six months and stays positive throughout the next 30 months. Second, the real GDP response is smaller in the next 18 months, but keeps declining persistently afterward while the response following our new shock measure is stronger but more temporary. Here we show that these findings also pertain to using single regressions instead of VARs. Figure D.7 presents the impulse responses following a 100-basis-point contractionary monetary policy shock in the local projections model of Section 4.1 using our new measure of monetary policy shocks (solid line with circles) along with responses using the alternative shock series that does not account for the structural break ("No-break shocks," dashed red line). As in the VAR case, both the real GDP and the CPI responses show marked differences from the main results: notably, the price level experiences a price puzzle following the shock estimated over the full sample, just as in the VAR.

Figure D.7: Single equation approach: New measure of monetary policy shocks vs. full-sample shocks



Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation using local projections model with corresponding 68 and 95 per cent confidence intervals. The local projections model includes (monthly) log real GDP, log CPI, log commodity prices and our new cumulated shock series (solid line with circles). The alternative model uses the shock series identified over the full sample in the first stage instead of our new measure of shocks (dashed red line).

Appendix E Quarterly single equation results for other macroeconomic variables

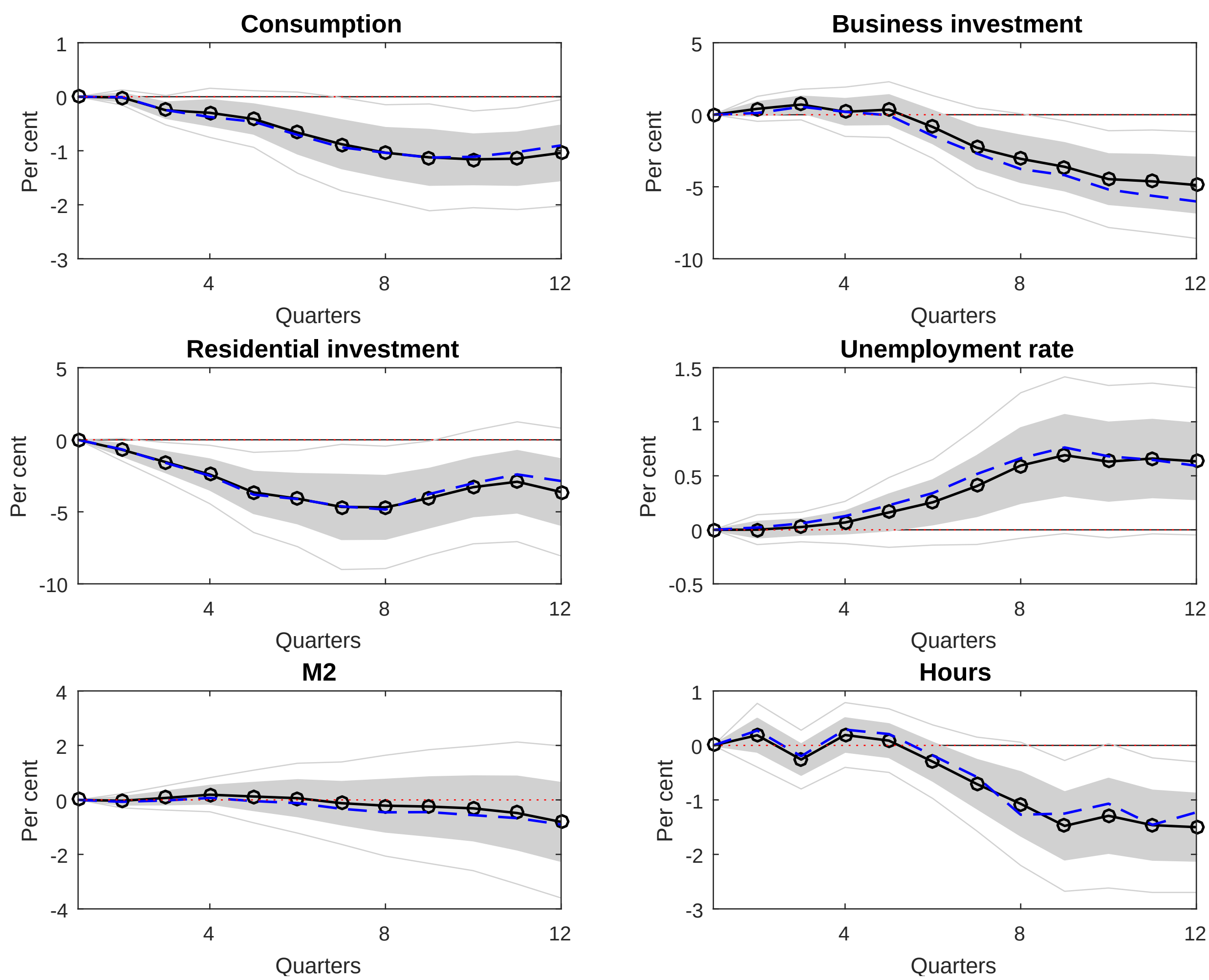
The flexibility of the single regression approach allows for consideration of the effects of monetary policy shocks on a range of different macroeconomic aggregates. In this section, we show the impulse responses (to a 100-basis-point contractionary monetary policy shock) of various Canadian variables of interest estimated using the local projections method discussed in Section 4.1 of the main text.

Figure E.1 presents the impulse responses (solid line with circles) for some components of real GDP (i.e., consumption, business investment, and residential investment), as well as for the unemployment rate, the money supply (M2), and total hours worked. It also shows the responses when controlling for the dynamics of the other variables in the model (dashed blue line). In general, these responses are broadly in line with what one would expect from theoretical macroeconomic models. For instance, the response of consumption is very similar to GDP; business and residential investment take a heavy hit following a monetary contraction, as the policy rate increase raises borrowing costs, with peak effect at about 5 per cent. The responses of consumption, investment, the unemployment rate, M2 and the unemployment rate are qualitatively in line with the estimates found by Cloyne and Hürtgen (2016).[60] The quarterly response of the unemployment rate also fits well with the monthly response found in the large VAR sub-section D.1 above.

Figure E.2 shows analogous impulse responses for international trade variables of interest. First, we note an appreciation of the Canadian dollar relative to the U.S. dollar (in nominal terms) and a drop in exports of about 4.5 per cent after three years. This fall in exports is mainly due to non-commodity exports, which fall by about 5 per cent, while commodity exports fall by 2.5 per cent. On the imports side, although the Canadian dollar appreciates and import prices stay relatively stable following the shock, we observe a drop in imports of almost 5 per cent.

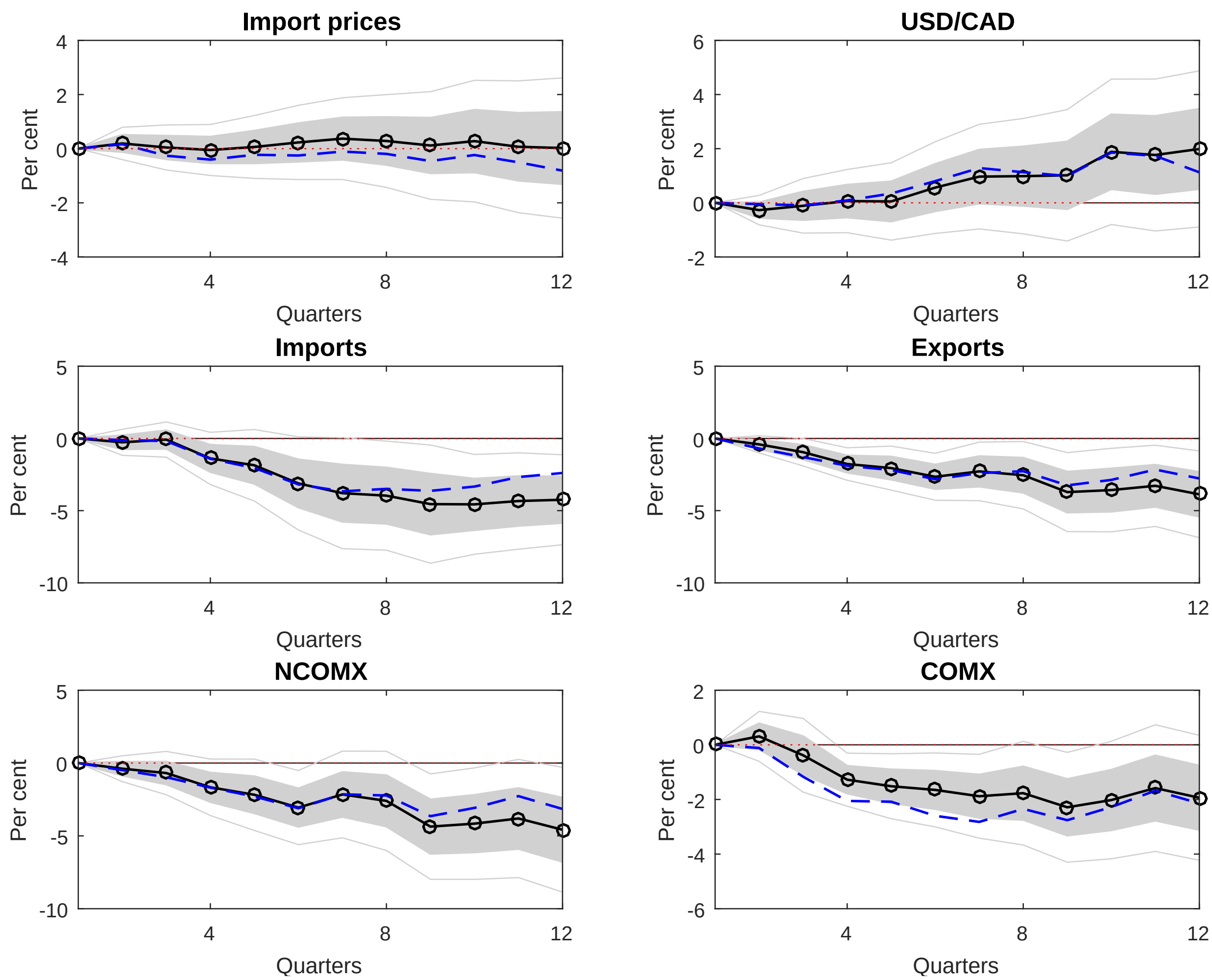
[60]See their local projections results in Appendix D.2.

Figure E.1: Quarterly single regression results



Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation (solid line with circles) using local projections model with corresponding 68 and 95 per cent confidence intervals. Quarterly data, 1974:Q2 to 2015:Q3. Dashed blue line shows same impulse responses, but controls for the other variables in the model. We include four quarters of lags of the variable of interest (and controls, if applicable), and eight quarters of lags for the shock measure.

Figure E.2: Quarterly single regression results



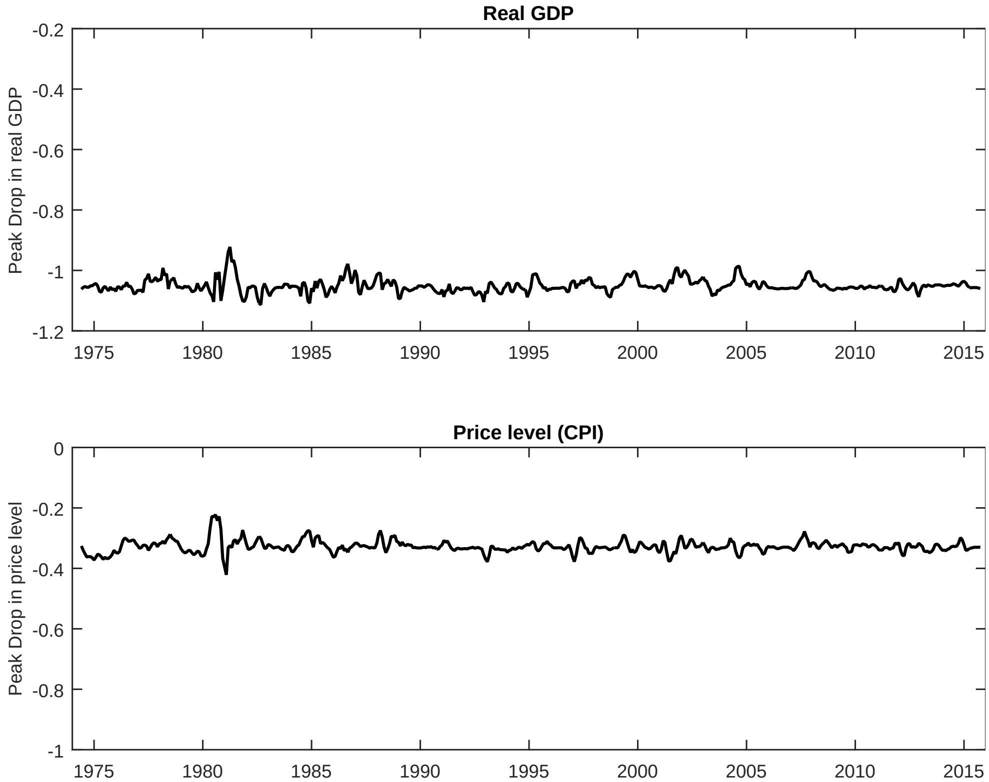
Notes: Impulse responses to a 100-basis-point contractionary monetary policy innovation (solid line with circles) using local projections model with corresponding 68 and 95 per cent confidence intervals. Quarterly data, 1974:Q2 to 2015:Q3. Dashed blue line shows same impulse responses, but controls for the other variables in the model. We include four quarters of lags of the variable of interest (and controls, if applicable), and eight quarters of lags for the shock measure.

Appendix F Sensitivity of baseline results to specific episodes

Coibion (2012) shows that the implications of the R&R shocks are very different once one takes out the Volcker period; are our main VAR results also very sensitive to specific episodes / outliers? To assess this sensitivity, we follow Coibion (2012) and set rolling three-month intervals of our shocks series to zero. By doing this, we obtain *n-2* different shock series, each of which has a different three-month interval of zeroes between 1974:M4 and 2015:M10. For each of these series, we estimate the VAR equation (4) in the paper and extract the implied peak effect of monetary policy shocks on real GDP and the (CPI) price level.[61] The results are presented in Figure F.1. What is striking here is how stable our results are to outliers relative to R&R's U.S. shocks: for example, Coibion (2012) shows that the peak response of industrial production decreases from about 4.5 per cent to about 2 per cent when outliers from the early 1980s are taken out. The same picture emerges for the price level. In our case, Figure F.1 shows that the real GDP and price responses are not very sensitive to any particular episode in the sample.

[61]This exercise is based on Figure 5 in Coibion (2012). However, it differs slightly as he uses single regressions instead of VARs to estimate the peaks effects, because his aim is to reconcile R&R's single regression results with other papers in the literature.

Figure F.1: Sensitivity of peak effects of monetary policy shocks to individual episodes



Notes: Each line presents the peak effect of our new measure of monetary policy shocks on macroeconomic variables estimated from the VAR. For each time period, the monetary policy shock for that month and the previous two months are set equal to zero, so the lines show the sensitivity of estimated peak effects to three-month time intervals. The VAR includes log real GDP, log CPI, log BCPI, and our new measure of monetary policy shocks.