Assessing the Effects of Monetary Policy Shocks on Metropolitan Housing Markets in Canada: A Local Projection Analysis

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Abstract:

This paper examines the impact of monetary policy shocks on regional housing prices across Canada during the period of March 1999 to February 2020 by employing a two-step approach: the aggregate structural monetary policy shocks are obtained by structural VAR and the effects of monetary policy shocks on regional housing markets are estimated using a local projection analysis. The results suggest that contractionary monetary policy shocks are associated with a decrease in housing prices at the national level, and this is consistent with most of the existing literature. In addition, the results also provide some evidence that the magnitude and timing of responses vary among regional housing markets. Some cities are less responsive compared to the others. However, since the magnitude of response is either small or insignificant, it implies monetary policy shocks are far from being driving forces in the regional housing markets since they can only explain a very small fraction of regional housing volatilities, if any.

Keywords: Monetary policy shocks, Housing prices, Structure VAR, Local Projection.

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I. Introduction

The housing market is a significant focus for monetary policymakers as it closely relates to economic cycles and economic fluctuations. It also plays a key role in the monetary policy transmission mechanism. Housing prices in Canada's major cities have increased substantially over the last two decades. There are many important factors influencing housing price fluctuations and a substantial amount of research has been conducted to investigate whether monetary policy shock is one of them. Canada is a geographically vast country with heterogeneous economic and demographic regions. As a result, investigating the response of the aggregate housing market at the national level is not sufficient to explain the reactions of regional housing markets. Taking both local housing market variations and segmentation into consideration can help us better understand the transmission of aggregate monetary policy shocks and the role of monetary policy shocks in explaining regional housing fluctuations.

The major metropolitan areas chosen for this study are Vancouver, Calgary, Toronto, Ottawa, Montreal, and Halifax. These represent some of the largest urban centres in Canada while geographically spanning across the country. Monetary policy generally focuses on aggregate economic conditions instead of targeting the economic performance of particular regional markets. Nevertheless, the effectiveness and transmission of monetary policy on the regional housing markets may depend on regional heterogeneity. In this regard, this paper is motivated to investigate this question by obtaining the aggregate monetary policy shocks at the national level and further examining the impact of monetary policy shocks on the city-level housing markets, in order to explore to what extent monetary policy shocks can impact the regional housing markets in Canada.

At the national level, the Structural Vector Autoregressive (SVAR) model is adopted to identify the aggregate monetary policy shocks, followed by the impulse responses employed to examine the effects of monetary policy shocks on each macroeconomic variable in the model. The forecast error variance decomposition is used to assess how much the share of house prices can be explained by each variable in the model. At the regional level, the local projection methodology is employed to estimate regional responses of each metropolitan city to aggregate monetary policy shocks.

The remainder of the paper is organized as follows: Section 2 contains the discussion of the current literature on housing markets and monetary policy shocks. Section 3 describes the data and a two-step approach, which is utilized to estimate the national and regional responses to monetary policy shocks. Section 4 presents the empirical results and their interpretation. In Section 5, I further examine the robustness of the main results with four alternative approaches, coupled by additional interpretations. Finally, Section 6 concludes.

II. Literature Review

A substantial amount of literature investigates the effects of monetary policy and monetary policy shocks on housing prices, but the empirical findings are mixed. Real housing prices are positively correlated with inflation and output gap. Ahearne et al (2005) point out that if the goal is to stabilise the economy in the long run, the monetary policy should react to housing prices, but only by a margin that is enough to slow down the potentially excessive growth, which otherwise could hinder the macroeconomic outcomes in the future. If we consider that monetary policy can dampen housing prices, it is important to examine whether monetary policy shocks have any significant impact on real estate markets.

Different approaches have been adopted in previous studies to measure responses to monetary policy shocks. Gertler and Gilchrist (1993) suggest that the real estate loans are negatively associated with a contractionary policy shock. Similarly, Paul (2017) uses a VARX model to identify structural monetary shocks in the U.S. and finds that housing prices are negatively associated with the monetary tightening. Notably, Giuliodori (2005) examines the housing market channel and measures the response of housing prices to interest rate shocks and he finds that the housing prices are lowered by 0.7% in response to a 100-basis-point monetary policy shock in an open economy. Jarociński & Smets (2008) examine the role of housing markets and monetary policy using an identified Bayesian VAR on the U.S. data and they find that monetary policy shocks explain a significant portion of housing price booms. Housing prices decline by 0.5% in response to a persistent 25-basis-point tightening after two and half years. Likewise, Assenmacher-Wesche and Gerlach (2008) examine 17 OECD countries for the period 1986-2007; they find that monetary policy shocks are negatively related to the residential property prices and their findings suggest that 25-basis-point increase in interest rates depresses housing prices by 0.4%. Similar studies have been conducted in the U.K., but the results are mixed. Aoki et al (2002) use a recursive VAR to investigate the monetary policy transmission mechanism and measure the effects of monetary policy shocks on the housing market and consumption in the U.K. Their results suggest that in response to a 50-basis-point monetary policy shock, the housing prices drop by 0.8% in five quarters. Elbourne (2008) examines UK housing market and finds housing prices declines by 0.75% to a 100 basis-point contractionary monetary policy shock. On the other hand, Bjørnland and Jacobsen (2010) explore the monetary transmission mechanism and suggest a monetary policy shock, which increase interest rates by 1%, will eventually lead to a 3% to 5% housing price drop.

Another body of literature focuses on regional responses rather than the aggregate level. Canada is a geographically vast country with economy and policies varying not only across provinces but also among cities. In general, studying aggregate housing prices alone will potentially mask the variation of the regional housing markets. There are many factors that account for the heterogeneous responses of the regional housing markets. Regional heterogeneity, such as: the growth rates of the regions, the sensitivity to the monetary policy, and the industrial and demographic features at the time of monetary tightening are key when measuring the effects of monetary policy shocks (Fratantoni and Schuh, 2003). Del Negro and Otrok (2007) employ a VAR to study the state-level housing price booms in the U.S. Their findings suggest that the housing fluctuations are mainly driven by the local factors, and that the effects of monetary policy shocks are small relative to the magnitude of fluctuations. In terms of the studies in Canada, Georgopoulos (2009) measures regional effects of monetary policy in Canada and suggests the industries of finance, insurance and real estate react positively to the monetary contraction in the first few periods, implying that the positive effect on insurance dominates negative effects on finance and real estate, showing an aggregate positive effect. However, the scope of this research did not extend to independent results of real estate. Maclean (1994) supports the idea that regional housing prices are affected by both regional and national factors. Notably, Fratantoni and Schuh (2003) point out that due to the heterogeneous economic sensitivity to monetary policy and the varied initial distribution of the economic conditions, the responses vary significantly across geographic regions. On the other hand, Allen et al (2009) suggest consideration of local market segmentation is crucial when examining the transmission mechanism of the aggregate monetary policy shocks, such as an unanticipated change in interest rates. They employ fully modified ordinary least squares to estimate the regional effects; their findings suggest that the increases in five-year mortgage rates have negative effects on Toronto and conversely the effect is positive on Vancouver and Calgary, whilst no statistically significant effect is found in Montreal or Ottawa. On the contrary, the findings from Louis et all (2009) suggest that negative links between housing markets and mortgage rate shocks are significant in Victoria, Vancouver, Toronto and Ottawa.

This paper is built upon the existing literature on assessing the relationships between monetary policy shocks and regional housing markets. Many studies have investigated the housing prices in response to monetary policy shocks in different countries; however, the amount of recent empirical research on regional responses to monetary policy shocks across Canadian cities is surprisingly low. In this regard, this paper seeks to fill this gap by exploring this research topic using both SVAR and local projection approaches.

III. Methodology

3.1 Data

For empirical examination, this paper retrieves the most recent monthly data from various sources for the period of March 1999 to February 2020 (252 observations in total). The data after February 2020 is discarded to avoid potential turbulence caused by the COVID-19 pandemic. The five variables used in the model are monthly time series data at the national level: the commodity price index (BCPI), consumer price indices (CPI), real gross domestic product (GDP), the composite housing price index (C11) and overnight rates (R). The housing price indices are collected from the Teranet-National Bank Housing Price Index Canada,[1] including the composite index C11 and the housing price index for each major city in Canada. The C11 housing price index will be used in SVAR and the city-level housing price indices will be used in the local projection model. C11 is chosen instead of Canada New Housing Price Index (NHPI), given the existing houses represent a larger proportion of the Canadian housing market whereas NHPI only measures contractors' selling prices of new homes. The indices are deflated by CPI and seasonally adjusted using

[1] This index only includes properties with at least two sales so that "sales pair" can measure the change of the house value. C11 is a national composite index of the eleven Canadian metropolitan areas: Victoria, Vancouver, Calgary, Edmonton, Winnipeg, Hamilton, Toronto, Ottawa, Montréal, Québec and Halifax. (available at www.housepriceindex.ca). All the house price indices are deflated by CPI.

ARIMA interpolation to account for the higher prices generally encountered in spring and summer. Figure A1 indicates a general upward trend of the real housing price indices of C11 and six metropolitan areas from March 1999 to February 2020 in the natural logarithm. These cover the main metropolitan areas in Canada, which span geographically across the whole country. Table A1 shows the statistics of the growth rate of housing prices.

Seasonally adjusted real gross domestic product (GDP) and seasonally adjusted core consumer price indices (CPI)[2] are collected from Statistic Canada. The commodity price index[3] and overnight rates (R)[4] are taken from the Bank of Canada. Overnight rates are used as the policy instrument in this study, given that the Bank of Canada has been using it as its monetary policy instrument since 1994. Canada implemented the inflation-targeting in 1991 and prompted a shift in the conduct of monetary policy. Champagne and Sekkel (2018) investigate the monetary policy shocks from April 1974 to October 2015 and find that there is a significant break when inflation targeting was announced in 1991. Since the data in this study starts from 1999, consideration of this structural break is not necessary.

Before proceeding, it is crucial to examine the time-series properties of the data. The summary statistics with the Augmented Dickey-Fuller test are presented in Table A2. CPI, real GDP, real housing prices and real commodity prices appear to be nonstationary in natural logarithm but stationary in first difference of the natural logarithm. Consequently, all variables are employed in log difference with the overnight rates being the only exception, which are in decimal percentages. All macroeconomic variables except overnight rate illustrated in Figure A2 are the growth rates generated by the first difference of the natural logarithm, after seasonally adjusted and multiplied by 100 for ease of interpretation.

3.2 Empirical Framework

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[2] In the benchmark model, I use the Core CPI (inflation rate for all items except food and energy) while in the robustness check, the Headline CPI (inflation rate for all items) is used. (available at https://www.statcan.gc.ca.)
[3] The Bank of Canada Commodity Price Index (BCPI) is a weighted index, which incorporates global prices for 26 commodities produced in Canada. (available at https://www.bankofcanada.ca/rates/price-indexes/bcpi/). BCPI index is seasonally adjusted and deflated by CPI in this study.
[4] The interest rates used in the study are overnight market interest rates (available at https://www.bankofcanada.ca.)

I employ and estimate Structural Vector Autoregression (SVAR) developed by Sims (1980) with restrictions on the contemporaneous interactions between the mentioned five variables for the analysis on the national level. Structural VAR analysis is one of the most popular empirical methods for the estimation of monetary policy shocks. Christiano et al. (2007) point out that SVAR with short-run restrictions is a good approach to estimate the dynamic effects of structural shocks in the economy. On the other hand, local projection estimators have been increasingly used to examine the impacts of economic shocks since Jordà (2005). The flexibility of the local projections allows for the estimation of the impact of monetary policy shocks on regional variables. With the structural shocks estimated from the SVAR model, the local projection model is employed to estimate the impact of monetary policy shocks on the regional housing markets.

Step 1: Estimation of the national monetary policy shocks.

The vector of endogenous variables chosen is given by the mentioned observed variables: BCPI, CPI, GDP, R and C11. As mentioned earlier, all data are incorporated in the form of first difference of the natural log except overnight rates. The overnight rate is the instrument variable adopted to capture monetary policy. Thus, the vector of endogenous variables is defined to be:

$$Y_t = \{\Delta \mathrm{BCPI}_t, \Delta \mathrm{CPI}_t, \Delta \mathrm{GDP}_t, \mathrm{R}_t, \Delta \mathrm{C11}_t\}'$$

Monetary policy shocks are estimated through the structural VAR, which can be expressed as:

$$B_0 Y_t = B_1 Y_{t-1} + \ldots + B_k Y_{t-k} + \varepsilon_t$$

It is important to mention that ε_t is a vector of structural shocks. We assume ε_t is mutually orthogonal with unit variance: $\mathrm{E}\{\varepsilon_t \varepsilon_t'\} = I$, $\mathrm{E}\{\varepsilon_t \varepsilon_{t-k}'\} = 0$ and B_i ($i=0,\ldots k$) are matrices of coefficients. The reduced VAR model can be written as:

$$Y_t = A_1 Y_{t-1} + \ldots + A_k Y_{t-k} + u_t$$

The reduced form innovations are a linear transformation of the underlying structural shocks ε_t:

$$\varepsilon_t = B_0\, u_t. \quad \text{and} \quad (B_0 B_0')^{-1} = \Sigma$$

Σ is the covariance matrix of innovations u_t. Since there are n^2 equations with only n(n+1)/2 restrictions, estimation of matrix B_0 and the structural innovations ε_t needs n(n-1)/2 additional restrictions. A common approach to applying the additional restrictions is employing a Choleski decomposition of the matrix Σ, where a set of "zero restrictions" are imposed on the contemporaneous structural parameters B_0. We assume the matrix B_0 to be the lower triangular, which is estimated by ordinary least squares. The relations are given by the following:

$$\begin{bmatrix} \varepsilon_{bcpi} \\ \varepsilon_{cpi} \\ \varepsilon_{gdp} \\ \varepsilon_{r} \\ \varepsilon_{c11} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \begin{bmatrix} u_{bcpi} \\ u_{cpi} \\ u_{gdp} \\ u_{r} \\ u_{c11} \end{bmatrix}$$

ε_{bcpi} defines a series of BCPI shocks, ε_{cpi}, ε_{gdp}, ε_{r} and ε_{c11} similarly define the shocks corresponding to their subscripts. u_{bcpi} u_{cpi} u_{gdp} u_r and u_{c11} are their reduced form innovations respectively. Identification can be achieved by imposing constraints on contemporaneous effects of the shocks, with the variables ordered as above. This triangular identification structure limits the response of the commodity prices, inflation and real output with a lag to monetary policy shocks. Intuitively, the identification strategy relies upon the assumption that monetary policy shocks do not affect output, inflation or the commodity prices contemporaneously but can have an immediate effect on housing prices (Assenmacher-Wesche and Gerlach 2008).

Deciding how to incorporate housing prices and monetary policy in the SVAR model presents a significant challenge. There are many identification strategies used in the existing literature and the most common being to impose the restrictions on the contemporaneous responses of the variables. One popular ordering is by placing the instrument, which captures monetary policy, as the last variable in the model, for the purpose of restricting the contemporaneous responses of the non-policy macroeconomic variables to monetary policy shocks (Aoki et al 2002). Another popular assumption is by placing the instrument variable of monetary policy before housing prices (Giuliodori, 2005; Assenmacher-Wesche and Gerlach, 2008). We will use the latter ordering in the benchmark. Whether the results are sensitive to another ordering will be further explored in the robustness check, with the assumption that the monetary policy does not have a contemporaneous effect on all the non-policy variables.

The estimating model can be sensitive to the lag length included. The number of lags is chosen by the Akaike information criterion (AIC) with the maximum lag number being fourteen, which is sufficient to capture any seasonal pattern for monthly data. The lag number of three is selected by AIC. The lag number six and twelve are used to test the sensitivity of the lag length in the model and it seems the longer lag lengths do not affect the main findings in this study.

Step 2: Estimation of the responses of regional housing prices to the aggregate monetary policy shocks

The local projection model designed by Jordà (2005) is used to estimate the impact of monetary policy shocks on regional housing markets. The model is constructed by employing the previously estimated monetary policy shocks. A key benefit of local projection is allowing us to estimate the response of a variable to an exogenous shock, which is identified by a third-party model (Jordà 2005). This approach is flexible as it does not impose a rigid theoretical structure on the data. For the purpose of estimating the regional effects of monetary policy shocks on the representative metropolitan housing markets, each city is modelled individually into the local projection model. The local projection estimators can be expressed in both difference and cumulative equations.

Difference: $$H_{t+h} - H_{t+h-1} = \beta^h MPS_t + \lambda_1^1 HG_{t-1} + \lambda_2^h HG_{t-2} + \lambda_3^h HG_{t-3} + e_{t+h}$$

Cumulative: $$H_{t+h} - H_{t-1} = \beta^h MPS_t + \lambda_1^h HG_{t-1} + \lambda_2^h HG_{t-2} + \lambda_3^h HG_{t-3} + e_{t+h}$$

H_t is the log real regional housing price at time t; MPS_t is a series of the aggregate monetary policy shocks obtained from SVAR model; HG_t is the growth rate of housing price at time t and e_{t+h} is a series of residuals. The coefficient associated with shocks (β^h) captures the change of housing price indices due to the national monetary policy shocks, and finally h is set from 0 to 50 periods.[5] Since the monthly data range from March 1999 to February 2020, there are 202 observations for each city as 50 months are lost by setting the forecast periods. The lagged values of the variable are appropriate in the local projection model (Stock & Watson, 2018). A lag number of three is included in the equations. A lag length of one, two and six are also used for sensitivity test of the

[5] A period of 20 was used in SVAR model as the majority of the impulse responses are stable after 10 months. However, in the local projection model, the cumulative responses linger for a longer period. For this reason, a period of 50 is used in the local projection estimators.

model to the lag length. The results do not show any significant difference. The local projection regressions are then estimated by OLS and the standard errors are computed by the usual Eicker-Huber-White heteroskedasticity-robust estimator, which is appropriate for lag-augmented local projections as suggested by Montiel et al (2020).

IV. Results

4.1 The aggregate monetary policy shocks

Figure 1 displays the structural shocks estimated from the structural VAR model. The shocks fluctuate around zero between positive and negative 0.5 percentage points.

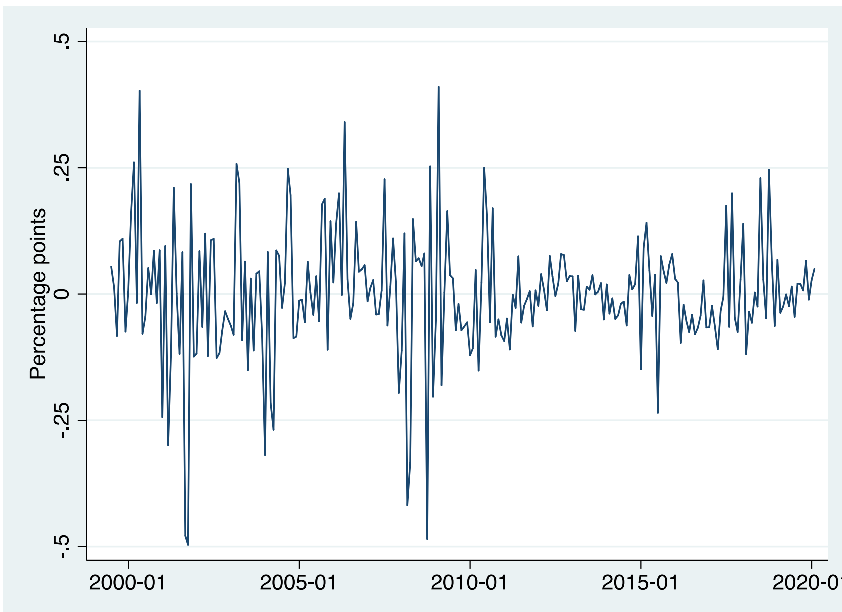


Figure 1. Benchmark monthly monetary policy shocks series in Canada (1999-2020)

Figure 2 plots the impulse responses of the growth rate of BCPI, CPI, GDP and C11 to a one standard deviation contractionary monetary policy shock, which is increasing overnight rates by 12.5-basis-point. The blue line depicts the estimate of the impulse response of the variables and the grey lines indicate the 90% error band. The standard error bands are obtained from residual-based moving block bootstrap as in Lunsford and Jentsch (2016). Monetary policy shocks result in temporary and insignificant fluctuations on the macroeconomic variables. As the results indicate, the impacts on output, inflation and commodity prices are insignificant. The overnight rate reacts positively to a one standard deviation of shock on itself, and peaks in four months at around 0.18%. Conversely, the housing price growth rate declines by 0.06% in response to a one standard deviation contractionary monetary policy shock. If the shock is normalized to 100-basis-point, the housing price growth rate will be lowered by about 0.5%.

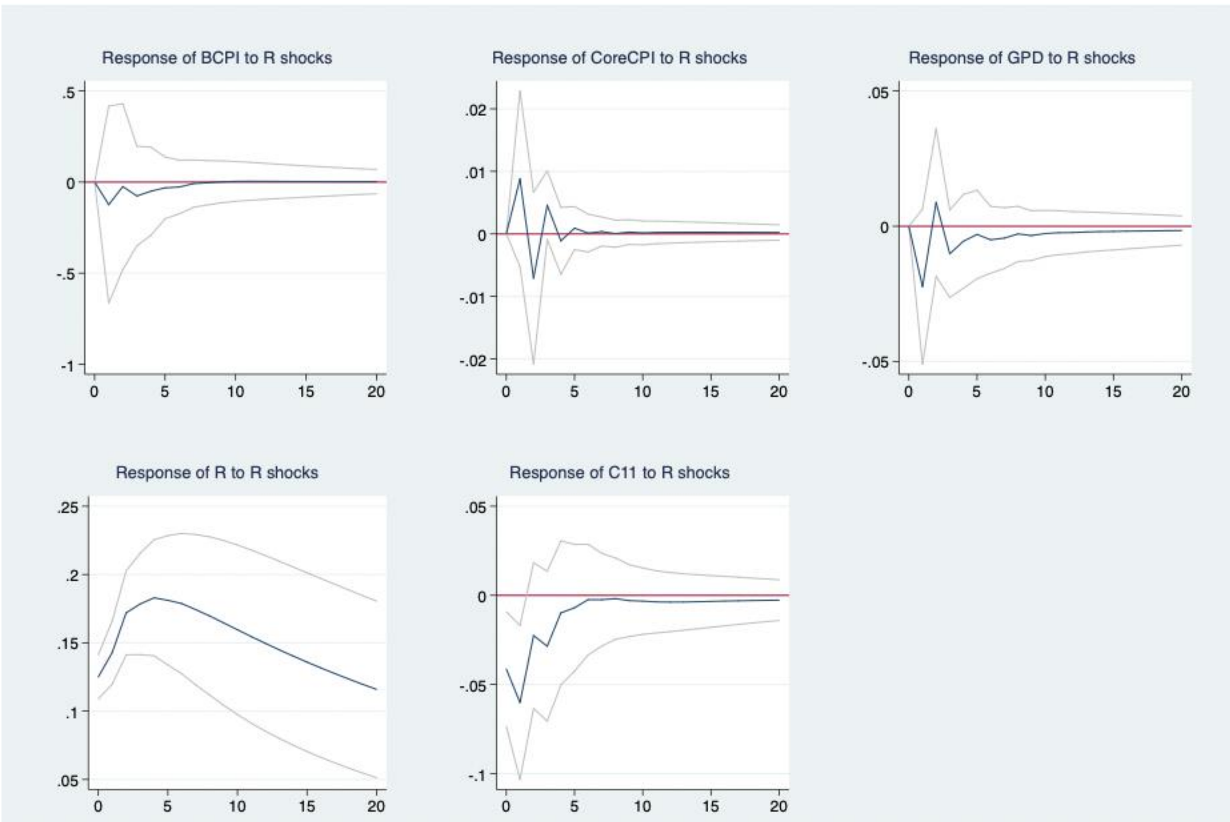


Figure 2.Impulse responses to monetary policy shocks

Note: Figure 2 depicts the impulse responses of BCPI (row 1, column 1), Core CPI (row 1, column 2), GDP (row 1, column 3), overnight rates (R) (row 2, column 1) and the composite housing price index C11 (row 2, column 2). To be noted, the responses are shown as changes of the growth rate except overnight rate (R). All the responses are percentage changes to a one standard deviation shock to R. The vertical axis shows percentage point. 90% confidence bands are displayed.

Even though the housing prices seem negatively associated with the shocks to overnight rates, the magnitude of the response is small. At this point, it is interesting to examine the variance decomposition of the national housing price index and verify how much weight can be attributed to each innovation in the system, and particularly, to monetary policy shocks. As a consequence, Factor Error Variance Decomposition analysis is used to identify the relative importance of each shock on the growth rate of housing prices. Figure 3 measures the fraction of the overall forecast variance for housing price indices that can be attributed to each of the five shocks in the model. The result shows the real housing price growth rate is mainly driven by the structural innovations in the real housing price growth rate equation, whereas overnight rate shocks only explain a trivial amount (3%) of the aggregate housing price growth.

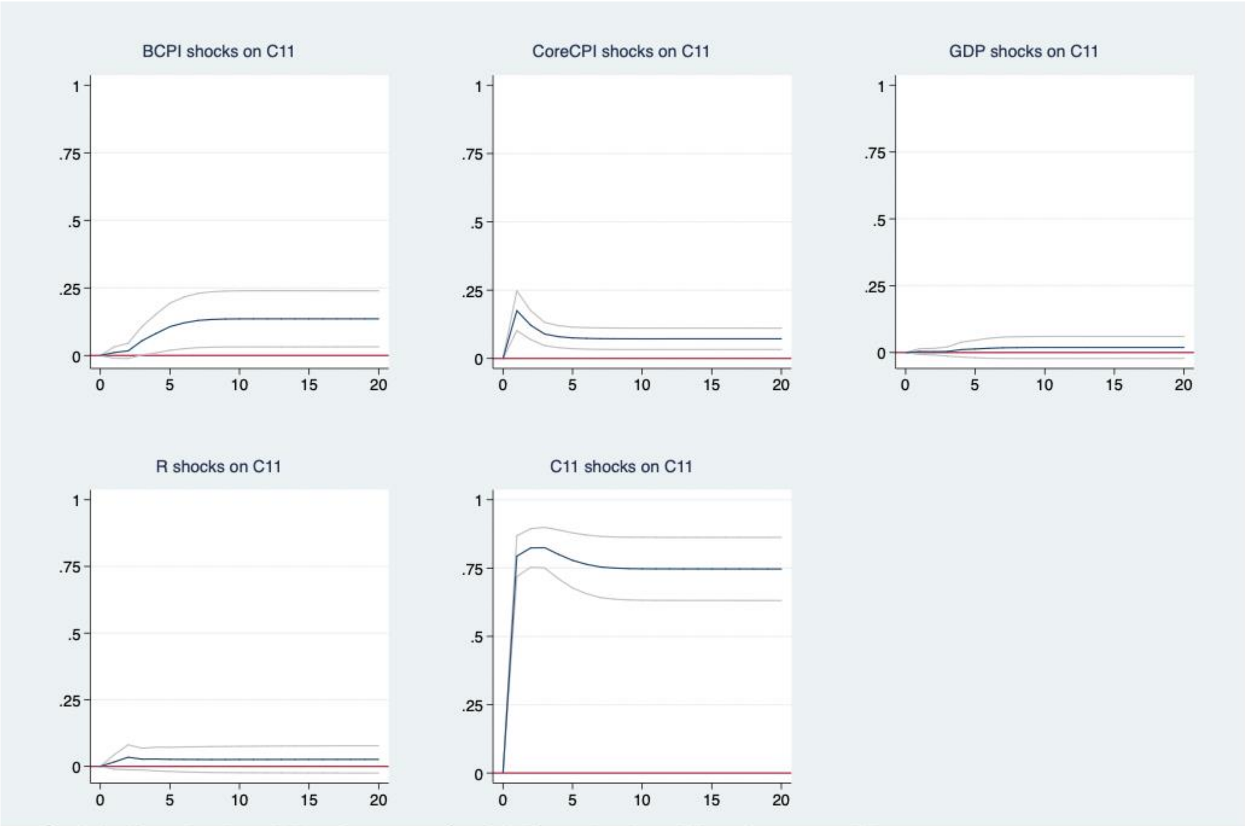


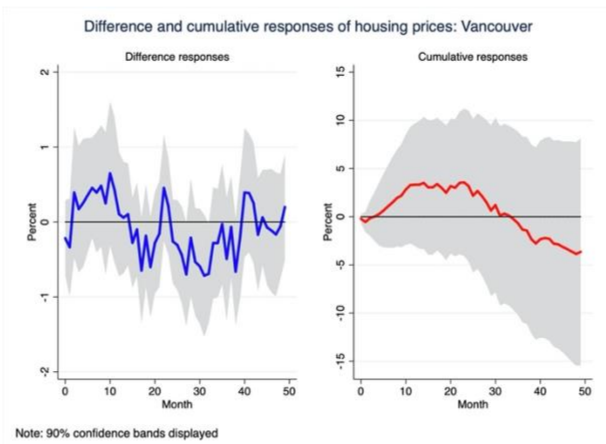
Figure 3.Forecast error variance decomposition of C11 (Benchmark Model)

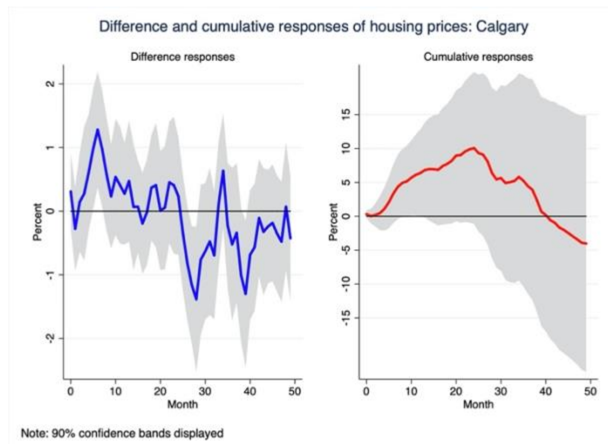
Note: Figure 3 depicts the contribution to the growth rate of housing price index C11 by BCPI shocks (row 1, column 1), Core CPI shocks (row 1, column 2), GDP shocks (row 1, column 3), overnight rate (R) shocks (row 2, column 1) and the C11 growth rate shocks (row 2, column 2). 90% confidence bands are displayed.

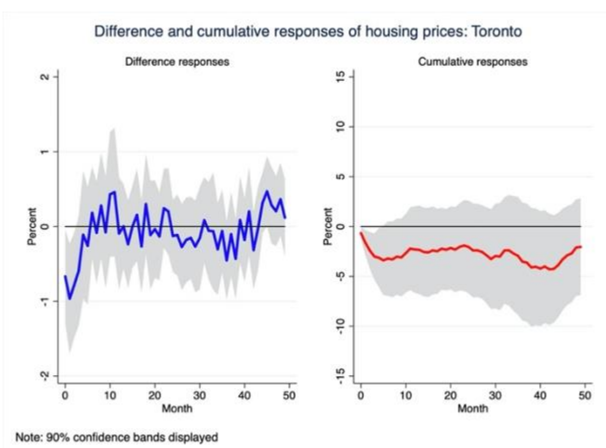
4.2 Regional housing markets in Canada

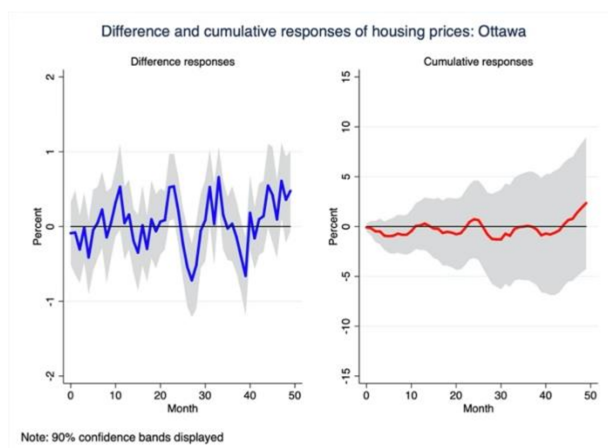
This section continues the verification of the responses of regional housing prices to the aggregate monetary policy shocks, in an effort for us to better understand housing price fluctuations across Canada. Continuing with the examination of regional variation in monetary transmission across metropolitan areas in Canada, Figure 4 measures the difference and cumulative response of housing prices in six major cities in Canada to monetary policy shocks. These findings show heterogeneity across the six metropolitan areas when facing the same aggregate monetary policy shocks. Each response depicts the percentage change in housing price in response to a series of aggregate monetary policy shocks.

Even though the national housing price index declines immediately in response to monetary policy shocks, the responses of housing prices in city-level show some heterogeneity. The only significant response is found in Toronto, where the cumulative response declines from the very beginning to monetary policy shocks. The cumulative responses of Vancouver and Calgary are positive in the first two years and turn negative afterwards, but the responses are not significant. Likewise, the cumulative responses in other cities are also insignificant.









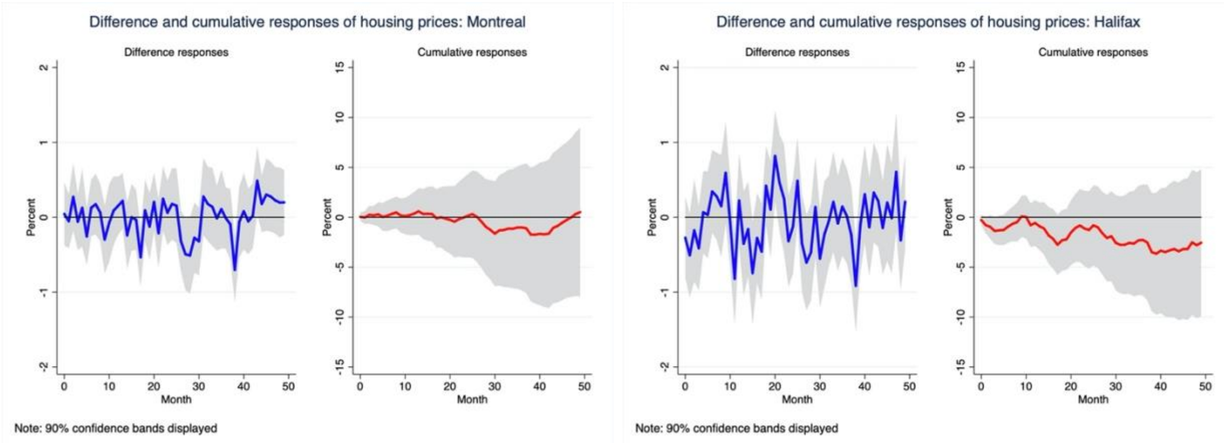


Figure 4. Difference and cumulative responses to monetary policy shocks

From a policy perspective, there is evidence that unexpected change of monetary policy would lead to different regional responses. For instance, in Toronto, monetary policies seem to have an immediate effect in cooling down the housing market as the response is immediate, whereas in other cities, the effects seem insignificant.

It should be noted that given the aggregate shocks are estimated from the SVAR model, they do not represent "true" data, thus it may result in a generated regressor issue. As the shocks are estimated from the data, using them in the local projection estimator might not have valid inferences (Pagan (1984). Hence, the results should be interpreted with caution. In addition, the Choleski identification assumption has a potential limitation as it is a special case of identification scenarios, which is identified with presumptions of simultaneous interaction among variables. Economists have different perspectives of which macroeconomic variables should be included and in which specific order. It means that the estimated monetary policy shocks are not unique and are largely dependent upon the model and the identification strategy used.

V. Robustness Analysis

5.1 Replacing variables in SVAR (Model B)

As we can see in Figure A2, the change of log Core CPI seems to be less volatile than the change of log Headline CPI (all items). To test the sensitivity of CPI in the SVAR framework, the Core CPI is replaced with Headline CPI in the five-variable VAR model and the variable ordering is kept the same. A lag number of three is chosen by AIC. Figure B1 shows the new monetary policy shocks obtained from this SVAR (Model B) against the benchmark model. The shocks estimated from this model are similar to those obtained from the benchmark model.

Figure B2 presents the impulse response for all the variables to a one standard deviation monetary policy shock in this model, which is 12.4 basis-point. The responses are shown in percentage points. The reactions of BCPI and inflation are still insignificant, except that the negative response of GDP growth rate is somewhat significant in this model. The housing price growth rate is 0.5% lower to a one standard deviation monetary policy shock. When normalized to a 100-basis-point shock, the housing price growth rate declines by 40-basis-point, which is marginally smaller than that in the benchmark model. The city-level housing price reactions to the shocks are then further examined with the new monetary policy shocks obtained from this model. Figure B3 presents the difference and cumulative responses of city-level housing prices, which have similar patterns to the benchmark model. Notwithstanding, all the cumulative responses from the regional housing markets are insignificant in this model. Thus, the results show no significant difference by replacing Core CPI with Headline CPI in this SVAR model.

5.2 Alternative ordering in the Choleski decomposition (Model C)

One might argue that the Choleski decomposition is sensitive to a different ordering of variables employed. In the benchmark model, it is assumed that with the exception of housing prices, the macroeconomic variable can only react to monetary policy shocks with a lag whereas housing prices may have an immediate response. This assumption is controversial as some economists may argue that monetary policy shocks do not have a contemporaneous effect on non-policy macroeconomic variables while interest rates can react simultaneously to all the macroeconomic variables in the model. For instance, Bjørnland and Jacobsen (2013) use federal funds rate to capture monetary policy shocks in their VAR model, where the housing price is ordered above the federal funds rate. For this reason, I further explore the alternative assumption of imposing the restriction on the simultaneous reaction from housing prices in response to overnight rates. The new SVAR model is constructed with the variables in the following order: BCPI, Core CPI, GDP, C11 and R. Lag number 3 is chosen by Akaike information criterion.

Figure C1 shows that the new monetary policy shocks obtained from this SVAR (Model C) align well with those from the benchmark model. Figure C2 depicts the impulse responses of all the variables to a standard deviation monetary policy shock, which is 12.4 basis-point in this model and is similar to that in the benchmark model. However, the response of the national housing prices to a contractionary monetary shock is no longer significant in model C. Figure C3 shows the responses of each regional housing market. The patterns in this model are also similar to those in the benchmark model. Admittedly, the positive responses in Calgary housing market in the first three years appear significant in this model. The negative responses in Toronto, which are shown in the benchmark model, become insignificant. The responses of the housing markets in other metropolitan areas still remain insignificant. Consequently, the change of Choleski ordering in the SVAR model does not contradict the results of the impulse responses of the macroeconomic variables or the responses of the regional housing markets.

5.3 Champagne and Sekkel's monetary policy shocks

Champagne and Sekkel (2018) constructed a new measure of monetary policy shocks in Canada using the data from 1974 to 2015. Their monetary policy shocks are obtained by the approach developed by Romer and Romer (2004), which uses external information such as minutes of the Federal Open Market Committee (FOMC) meetings to construct the intended changes in federal funds rate. It is free from the influence of housing prices and it is very different from our benchmark SVAR model. For this reason, it is useful to investigate whether similar results can be achieved with the monetary policy shocks estimated by Champagne and Sekkel (2018).[6] For comparison purposes, Figure D1 plots the estimated shocks obtained from the benchmark SVAR model against the Champagne and Sekkel's monetary policy shocks. In this study, only shocks in the overlapping period are used for comparison and in the local projection estimators (i.e., the period from July 1999[7] to October 2015). Both series of shocks are shown in percentage points. Champagne and Sekkel (2018) plotted zero as the shock for the month when there was no specific meeting for policy decision and summed up monetary policy shocks when there was one or more. Their monetary policy shocks are somewhat more volatile than the shocks estimated by our

[6] The Champagne and Sekkel monetary policy shocks were obtained from "Changes in Monetary Regimes and the Identification of Monetary Policy Shocks: Narrative Evidence from Canada" (Data is available at https://sites.google.com/site/julienjchampagnephd/home/research--Publications/mpshocks)

[7] The first four periods of data from benchmark model were lost due to the lags used.

benchmark SVAR model. The standard deviation of their estimated policy shocks is 0.156, marginally larger than 0.125, the standard deviation of the benchmark model.

The overlapping period of Champagne and Sekkel's monetary policy shocks are once again used for the local projection estimator to investigate the regional house reactions to their monetary policy shocks. Figure D2 depicts the difference and cumulative response of city-level housing prices to the Champagne and Sekkel's monetary policy shocks. The overall patterns of the responses are somewhat more significant when compared to our benchmark model. The positive responses in housing markets of Vancouver, Calgary and Montreal appear within approximately the first two years. However, the responses of Toronto, Ottawa and Halifax are insignificant. Again, since monetary policy shocks are estimated, some discrepancies are expected. Overall, the results imply that the positive cumulative effects in some cities may be expected up to about 2 years.

5.4 SVAR model incorporated with regional housing prices

Some studies have shown that SVAR and local projection models would achieve similar results. Hence, an SVAR model incorporated with regional housing prices is constructed, with the purpose to examine whether the similar patterns of regional price responses can be observed. In this SVAR model, the vector of endogenous variables is: $Y_t = \{\Delta BCPI_t, \Delta CPI_t, \Delta GDP_t, R_t, \Delta C_t\}'$, where ΔC_t is the log difference of regional housing price indices. Each city is incorporated into this SVAR model separately. Everything else in this model is set the same way as in benchmark model.

The impulse responses of regional housing prices to a one standard deviation contractionary monetary policy shock are shown from Figure E1 to Figure E6. The only significant impulse response of regional housing markets is observed in Toronto, whose housing prices decline immediately in response to monetary policy shocks. The impulse responses in other cities are all insignificant. The results in this SVAR support our findings from the local projection model, where we also observe significantly negative cumulative responses in Toronto housing market, but insignificant effects in the other cities. Generally speaking, the four practices employed in this section suggest the results from the benchmark model are robust.

VI. Conclusion

By constructing an SVAR model and a local projection estimator with monthly data spanning 1999:M3 to 2020:M2, this paper investigates the effectiveness of monetary policy shocks on the national housing prices, and to examine the idiosyncratic relations between regional housing market and the aggregate monetary policy shocks in six Canadian metropolitan centres.

Overall, the results support that monetary policy shocks are negatively associated with the national housing prices. This is consistent with the majority of the current literature. Second, the results also highlight the heterogeneous responses of regional housing markets in their response to monetary policy shocks. Housing markets such as Toronto show an immediate decline in the face of aggregate monetary policy shocks, while the responses of most cities seem insignificant. Additionally, the overall pattens of responses imply that the positive cumulative responses might be expected in some cities in about two years while the responses will eventually reverse and become negative in the long term. However, since the responses are insignificant, we cannot draw any strong conclusion. The results also suggest that monetary policy shocks can explain only a small amount of the volatility of the regional housing markets, if any. Thus, the effect of monetary policy shocks is certainly not a driving force in regional house fluctuations.

From a policy perspective, the relatively weak link between monetary policy shocks and regional housing prices suggests that we should interpret them with caution as the responses in most cities are either nearly negligible or insignificant. However, certain limitations previously stated in the paper may result in regional responses not being as precise as anticipated. Hence, further exploration, possibly incorporating different approaches, should be encouraged to assess the effectiveness of monetary policy shocks on regional housing markets in Canada.

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Appendix

Appendix A. Benchmark Model

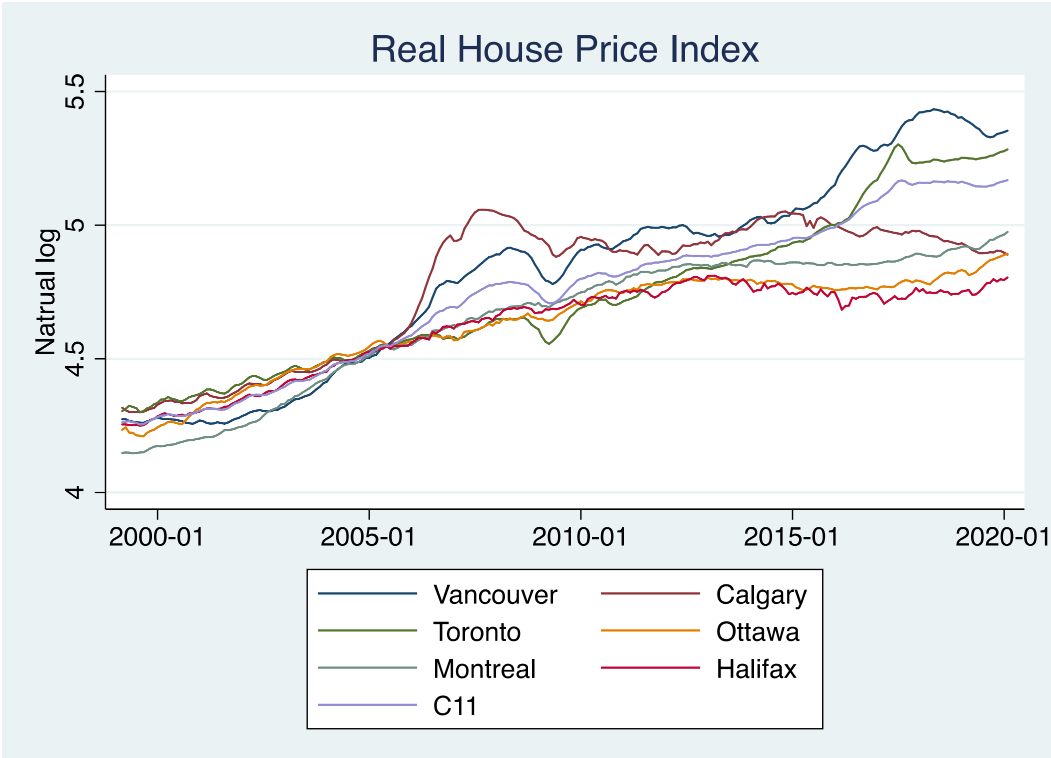
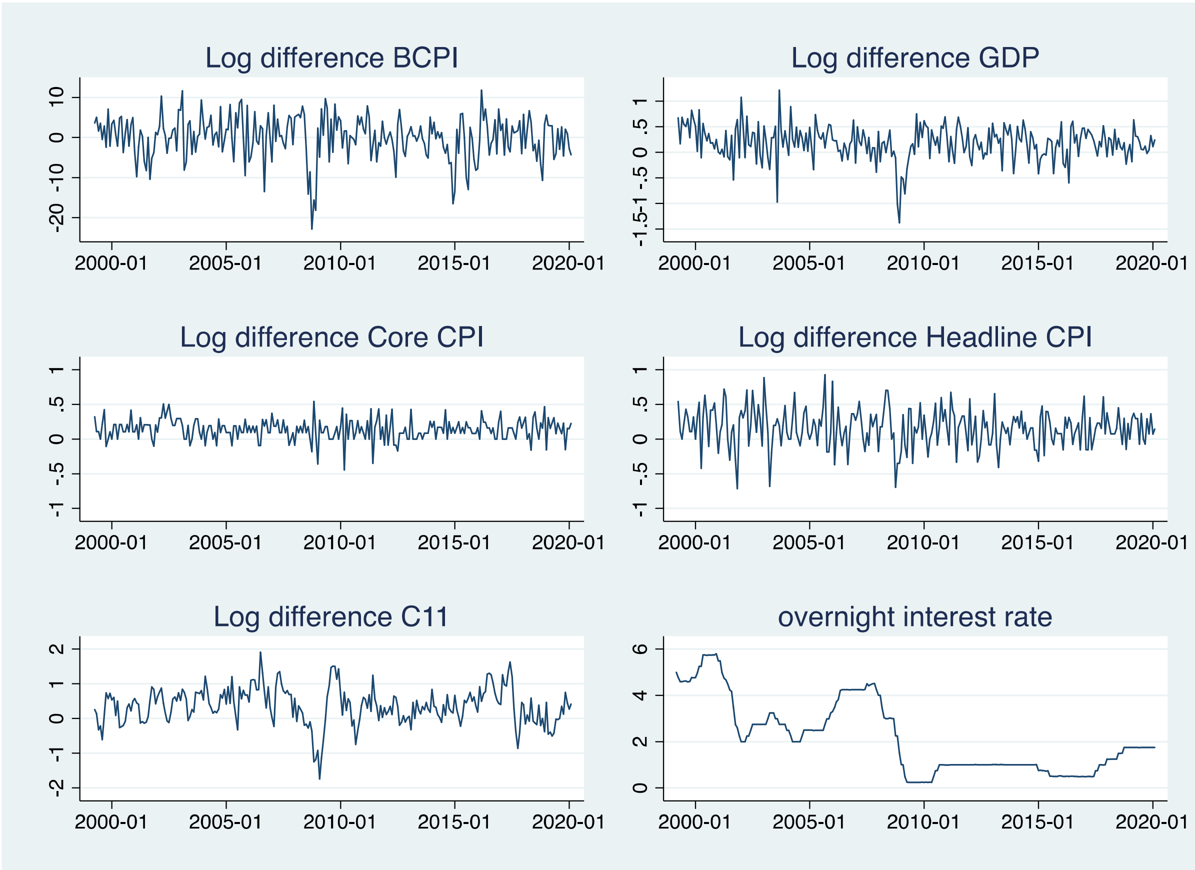


Figure A1. Seasonally adjusted real housing price index of major Canadian cities in natural log

City	*Obs*	*Mean*	*Std.Dev.*	*Min*	*Max*
Vancouver	251	.4303488	.9060724	-2.443171	3.496981
Calgary	251	.2282832	1.105652	-4.060745	4.41227
Toronto	251	.3899567	.7808612	-2.714396	2.684546
Ottawa	251	.2623777	.6195088	-1.896286	2.240419
Montreal	251	.3296966	.5034565	-1.342106	2.257299
Halifax	251	.2189294	.8894313	-3.842211	3.047228
C11 Composite	251	.3612095	.5251776	-1.73893	1.90897

Table A1. Descriptive statistics of the growth rates of housing prices



Note: all the variables are illustrated in log differences except overnight rates, which are on level. BCPI, GDP, CPI, C11 are seasonally adjusted; C11 and BCPI are deflated by CPI.

Figure A2. Monthly changes of output, inflation, housing prices and commodity prices

Augmented Dickey-Fuller test	Test Statistic	Mackinnon approximate p-value
Log BCPI	-2.185	0.2116
Δ [log BCPI]	-6.603	0.0000
Log Core-CPI	-0.612	0.8681
Δ [log Core-CPI]	-7.54	0.0000
Log Headline-CPI	-1.595	0.4862
Δ [log Headline-CPI]	-8.272	0.0000
Log GPD	-1.196	0.6755
Δ [log GPD]	-5.762	0.0000
Log C11	-1.012	0.7489
Δ [log C11]	-5.304	0.0000

Note: 1% Critical Value: -3.461; 5% Critical Value: -2.88; and 10% Critical Value: -2.57

Table A2. Augmented Dickey-Fuller test

Appendix B. Robustness check with Headline CPI in the SVAR

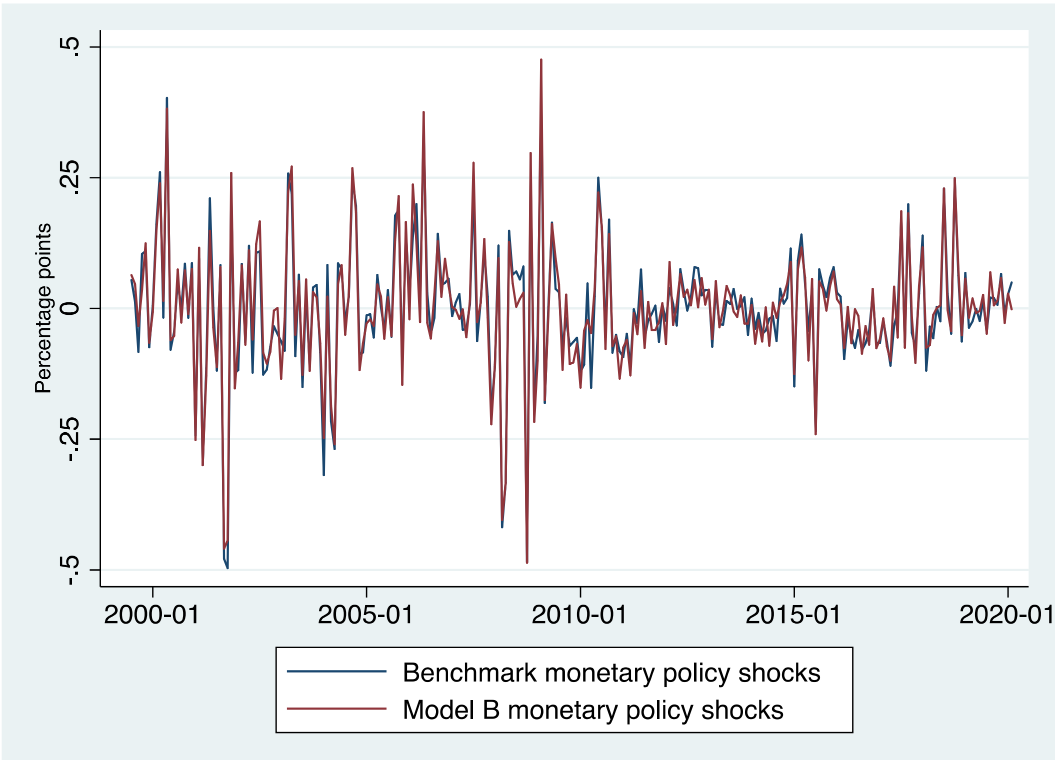
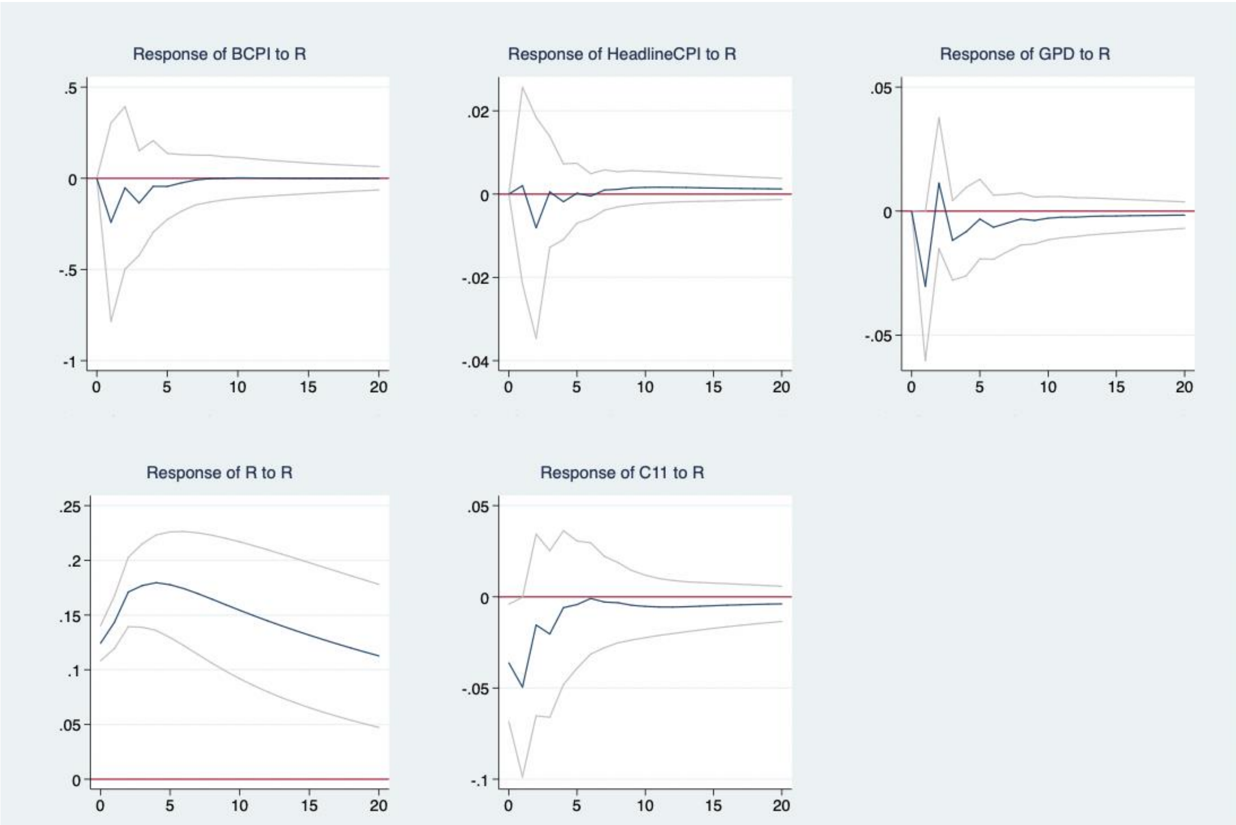


Figure B1. Monthly monetary policy shocks (Benchmark vs. Model B)



Note: Figure B2 depicts the impulse responses of BCPI (row 1, column 1), Headline CPI (row 1, column 2), GDP (row 1, column 3), overnight rates (R) (row 2, column 1) and the composite housing price index C11 (row 2, column 2). To be noted, the responses are shown as changes of the growth rate except overnight rate (R). All the responses are percentage changes to a one standard deviation shock to R. The vertical axis shows percentage point. 90% confidence bands are displayed.

Figure B2. Impulse responses to monetary policy shocks (Model B)

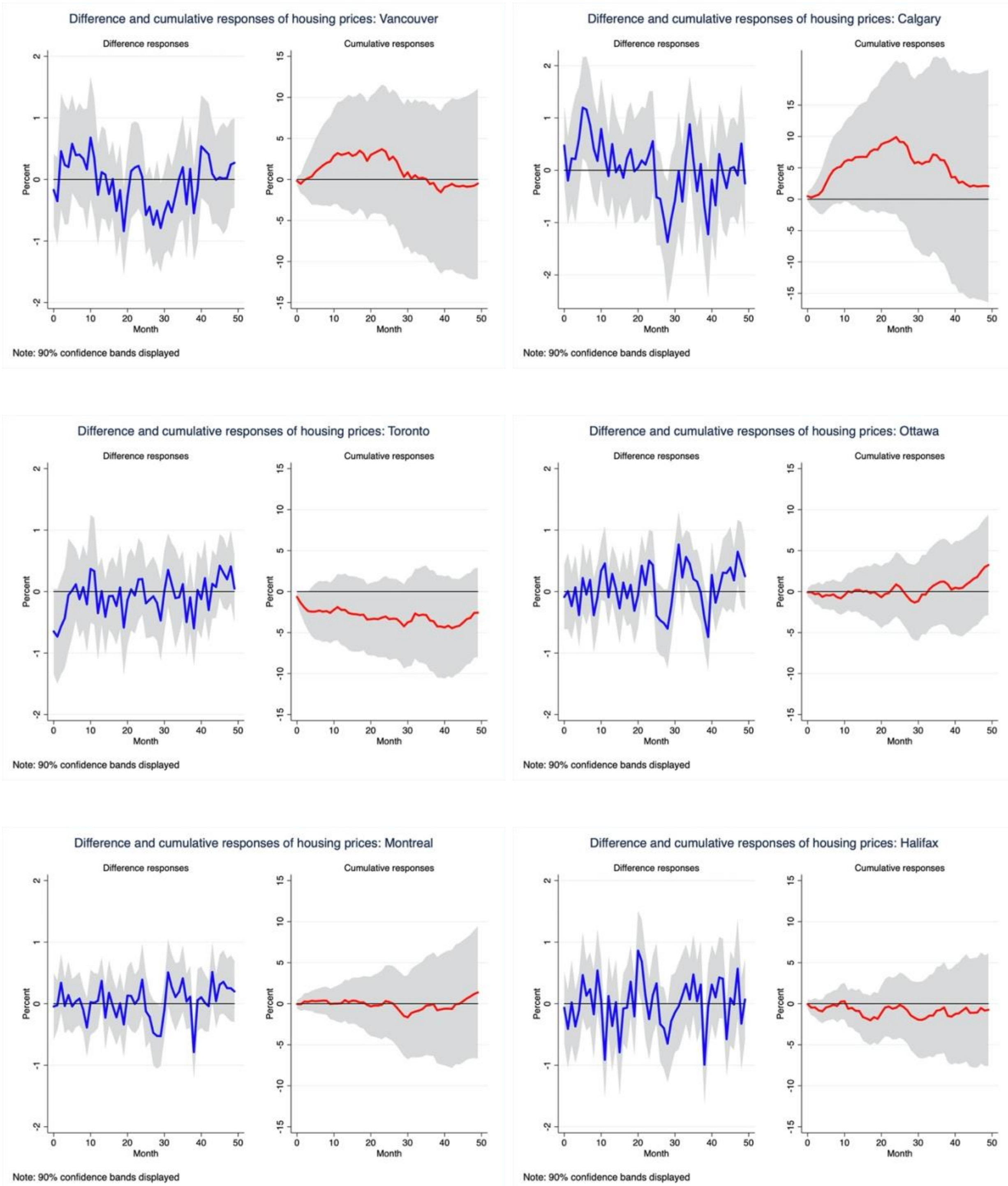


Figure B3. Difference and cumulative responses to monetary policy shocks (Model B)

Appendix C. Robustness check with a different ordering in the Choleski decomposition

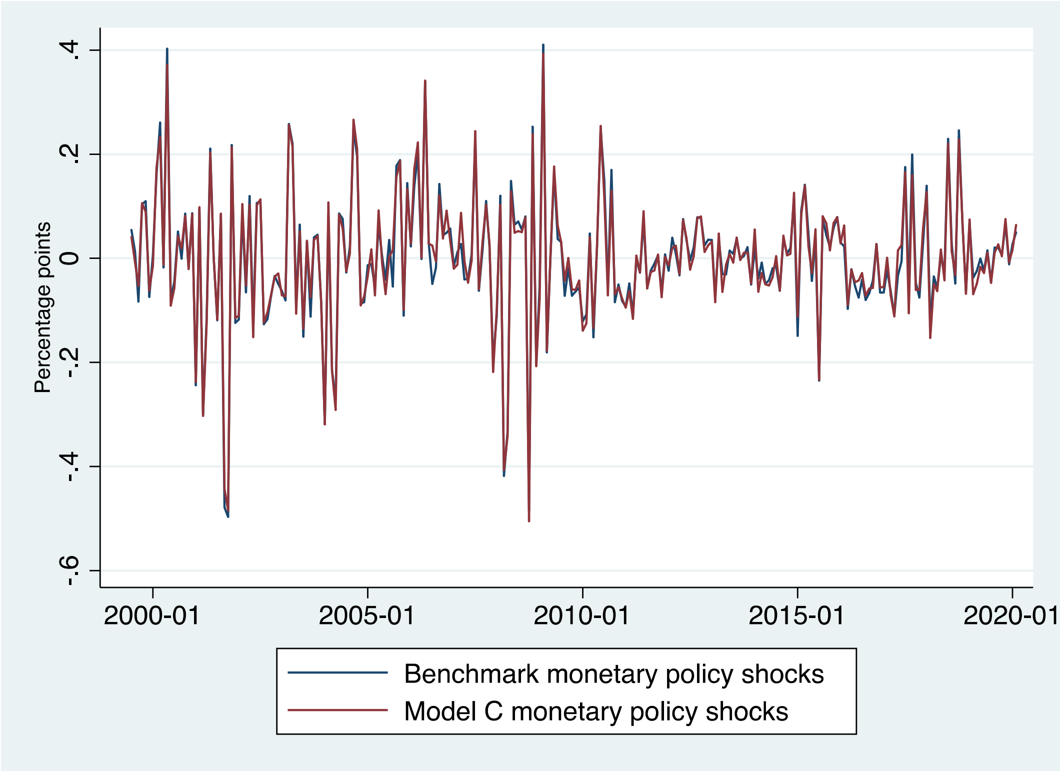
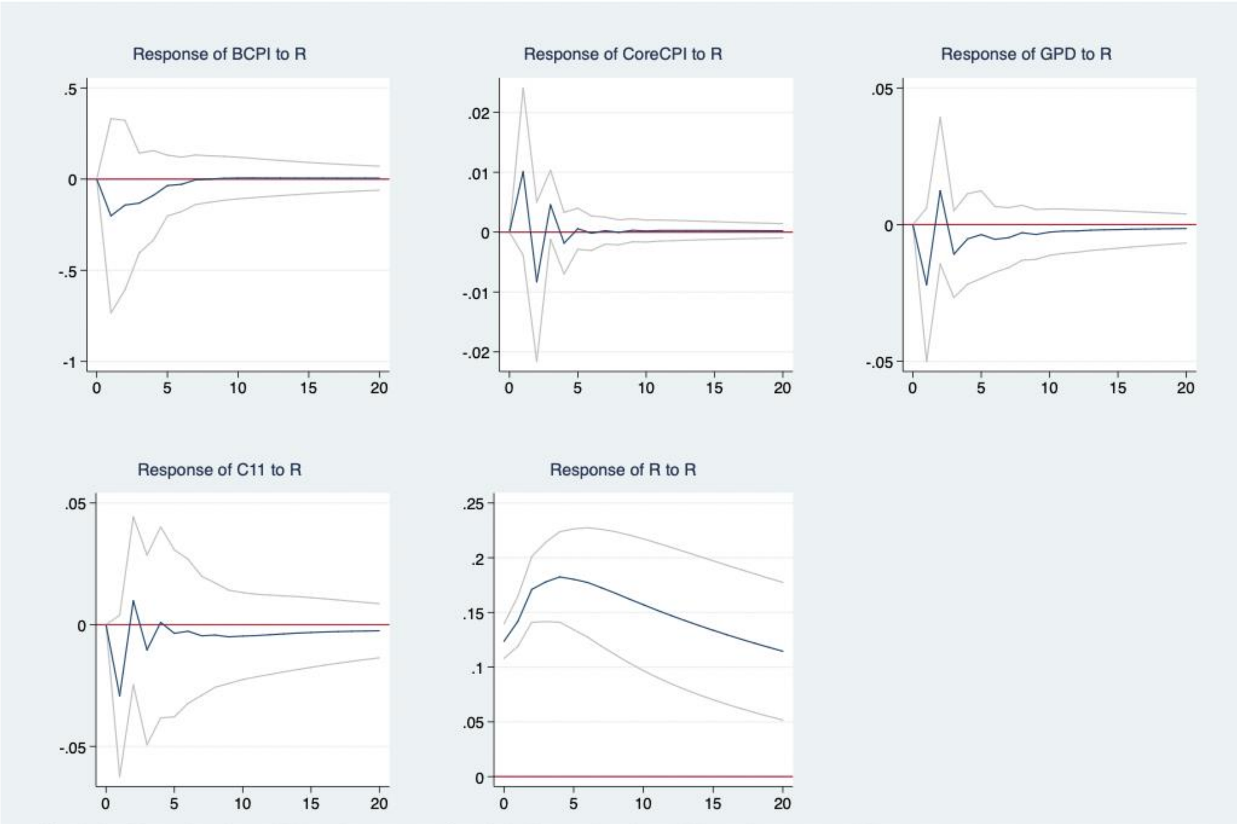


Figure C1. Monthly monetary policy shocks (Benchmark vs. Model C)



Note: Figure C2 depicts the impulse responses of BCPI (row 1, column 1), Core CPI (row 1, column 2), GDP (row 1, column 3), the composite housing price index C11 (row 2, column 1) and overnight rates (R) (row 2, column 2). To be noted, the responses are shown as changes of the growth rate except overnight rate (R). All the responses are percentage changes to a one standard deviation shock to R. The vertical axis shows percentage point. 90% confidence bands are displayed.

Figure C2. Impulse responses to monetary policy shocks (Model C)

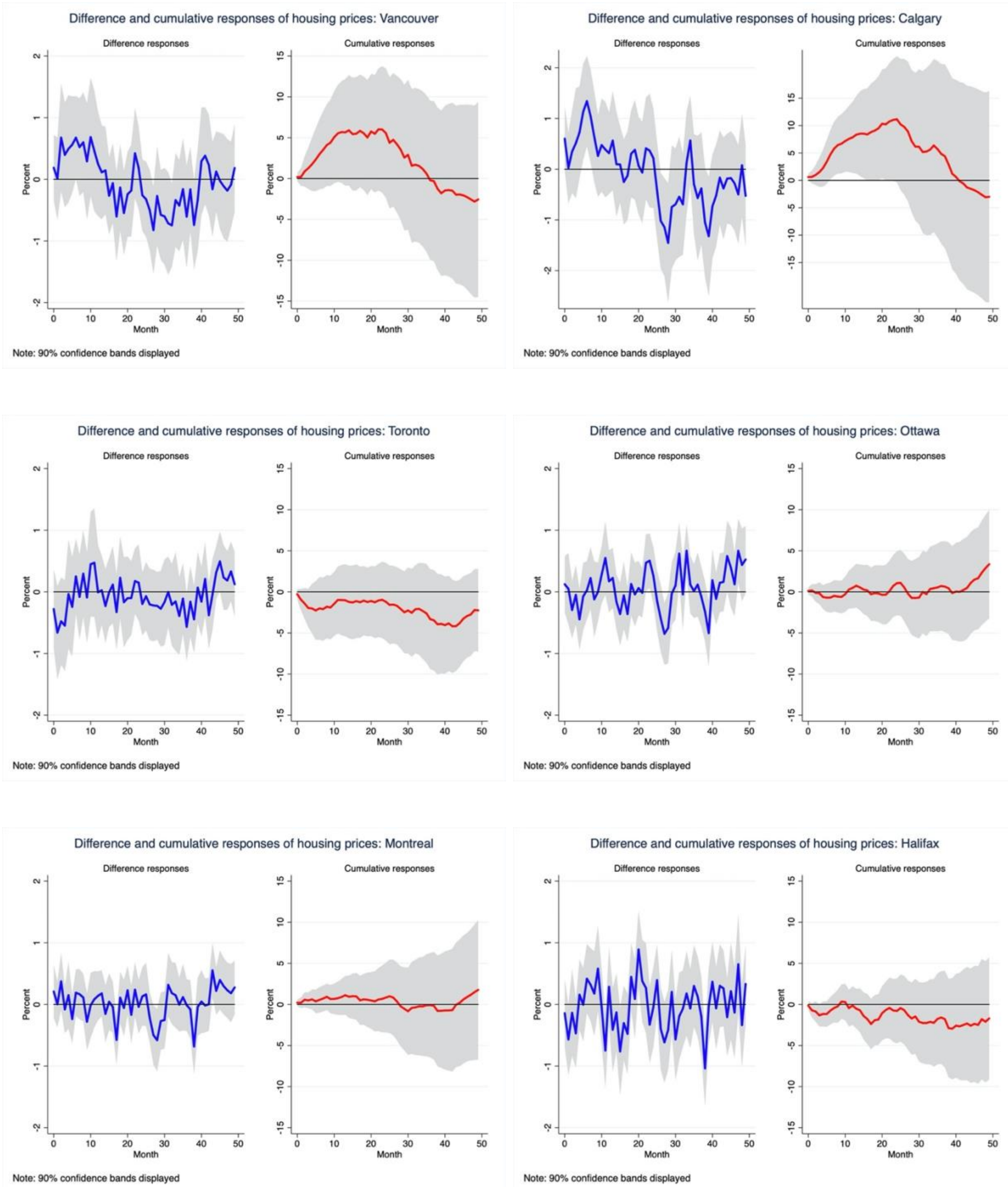
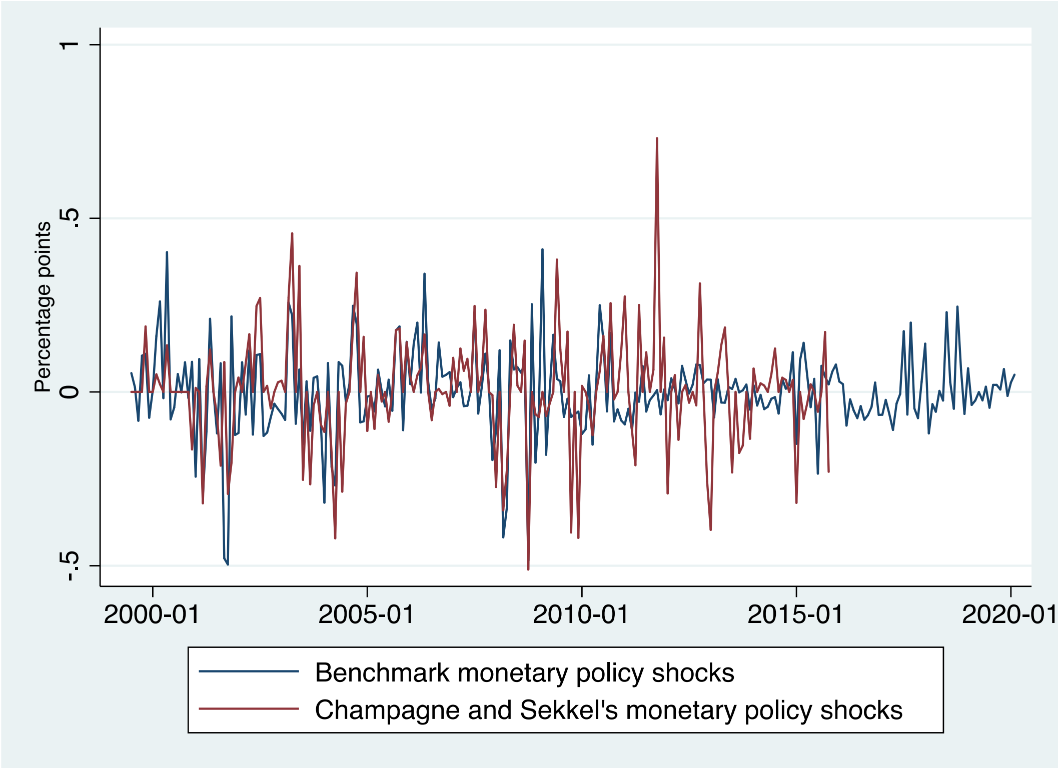


Figure C3. Difference and cumulative responses to monetary policy shocks (Model C)

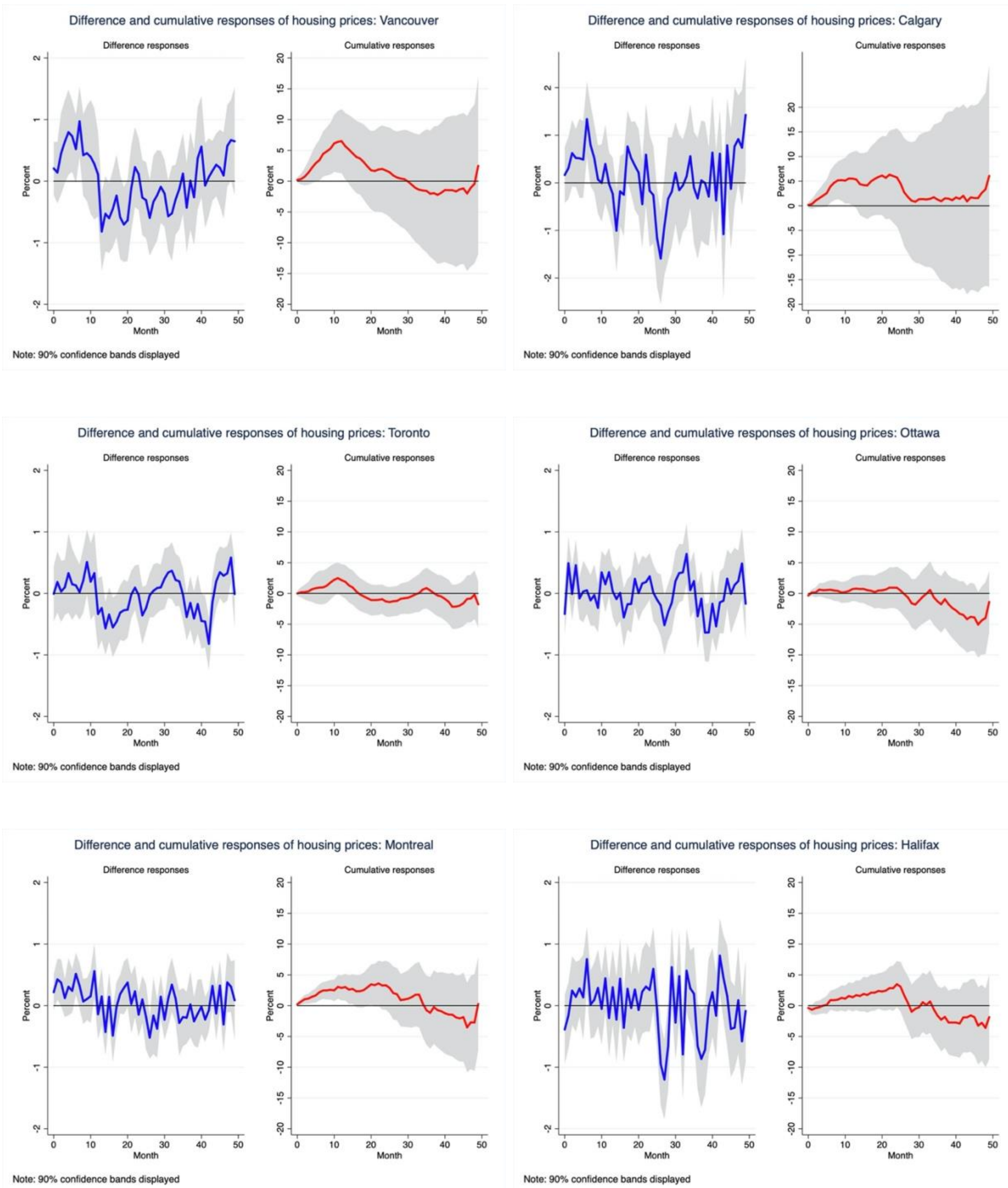
Appendix D.

Robustness check with Champagne and Sekkel's Monetary Policy shocks



Note: The Champagne and Sekkel's monetary policy shocks used in the comparison are from 1999:M7 to 2015:M10. The monetary policy shocks from the benchmark model in this figure are from 1999:M7 to 2020:M2.

Figure D1. Monthly monetary policy shocks series (Benchmark vs. Champagne and Sekkel's)



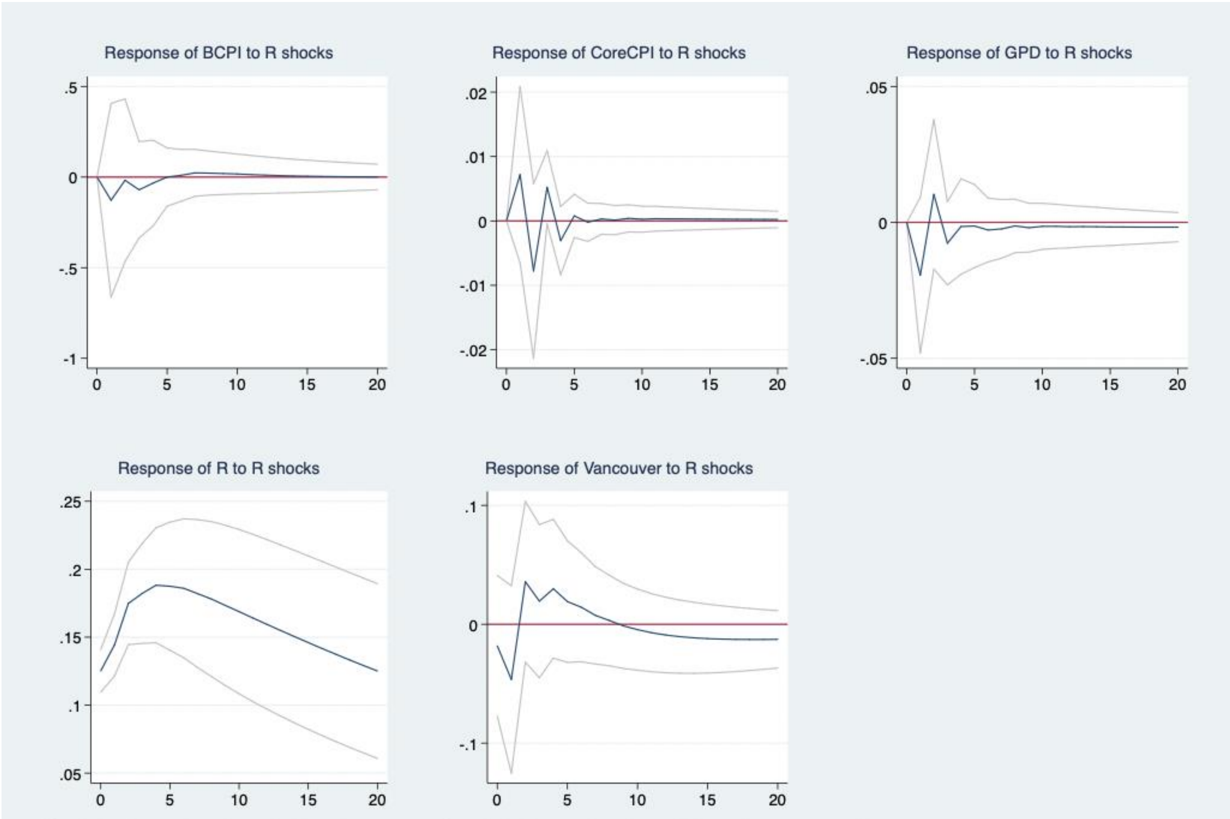
Note: Champagne and Sekkel's monetary policy shocks used in LP estimator are from 1999:M7 to 2015:M10.

Figure D2. Difference and cumulative responses to the Champagne and Sekkel's monetary policy shocks

Appendix E.

Robustness check with a SVAR model incorporated with regional housing prices

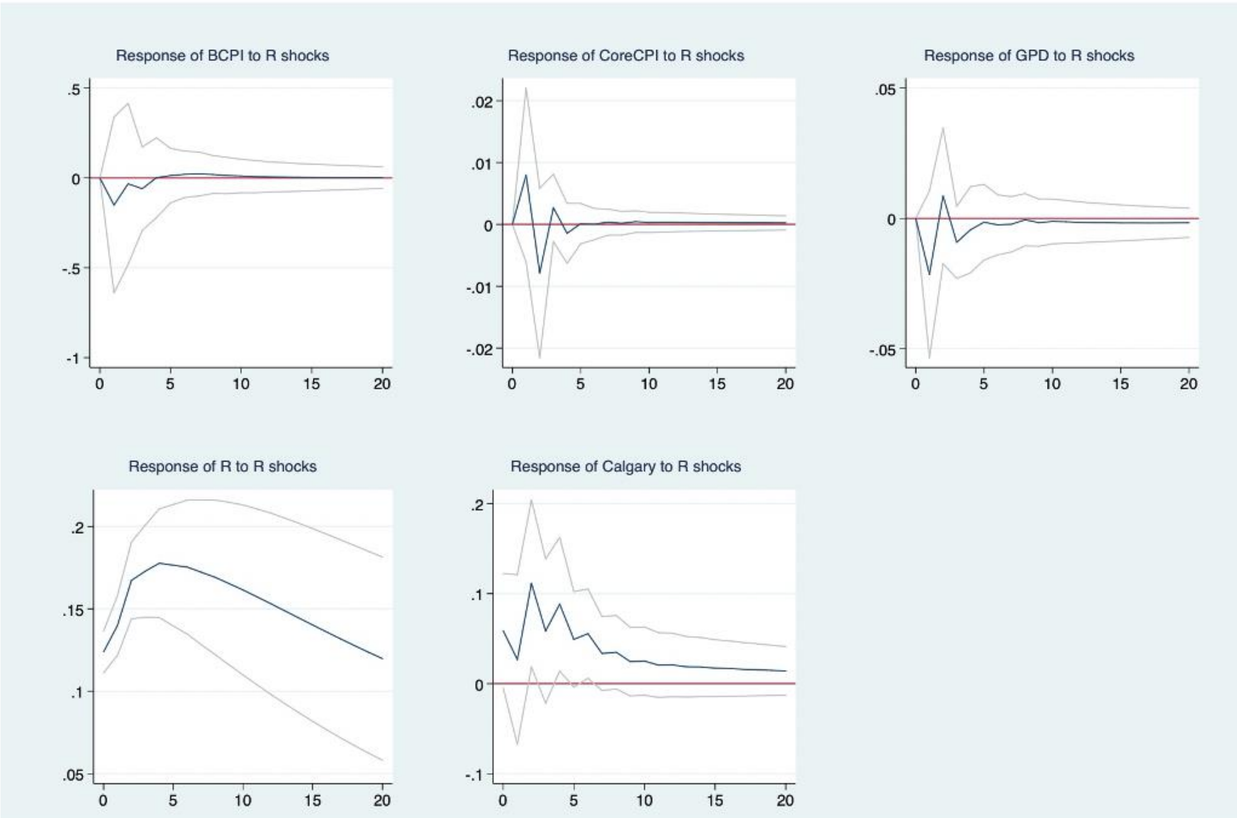
Vancouver



Note: Figure C2 depicts the impulse responses of BCPI (row 1, column 1), Core CPI (row 1, column 2), GDP (row 1, column 3), overnight rates (R) (row 2, column 1) and Vancouver housing price index (row 2, column 2). To be noted, the responses are shown as changes of the growth rate except overnight rate (R). All the responses are percentage changes to a one standard deviation shock to R. The vertical axis shows percentage point. 90% confidence bands are displayed.

Figure E1. Impulse responses to monetary policy shocks: Vancouver

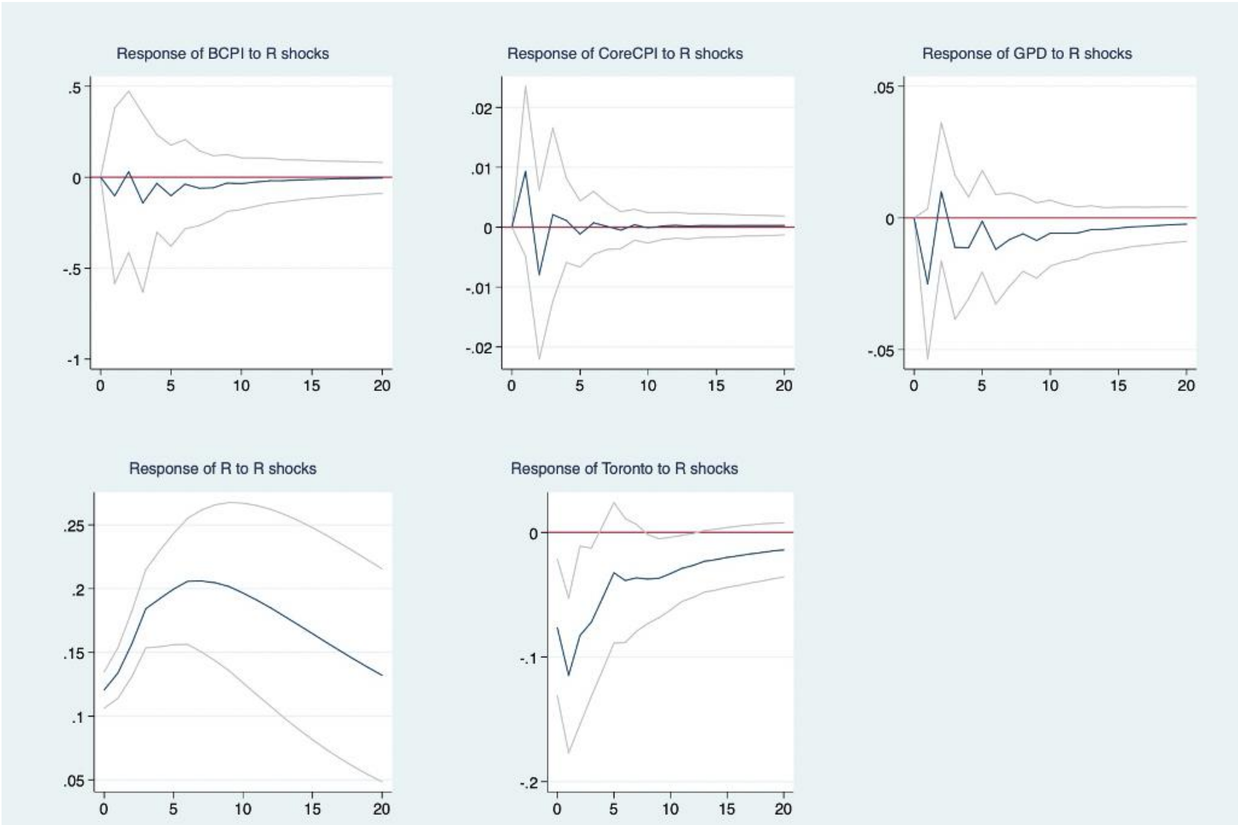
Calgary



Note: Figure C2 depicts the impulse responses of BCPI (row 1, column 1), Core CPI (row 1, column 2), GDP (row 1, column 3), overnight rates (R) (row 2, column 1) and Calgary housing price index (row 2, column 2). To be noted, the responses are shown as changes of the growth rate except overnight rate (R). All the responses are percentage changes to a one standard deviation shock to R. The vertical axis shows percentage point. 90% confidence bands are displayed.

Figure E2. Impulse responses to monetary policy shocks: Calgary

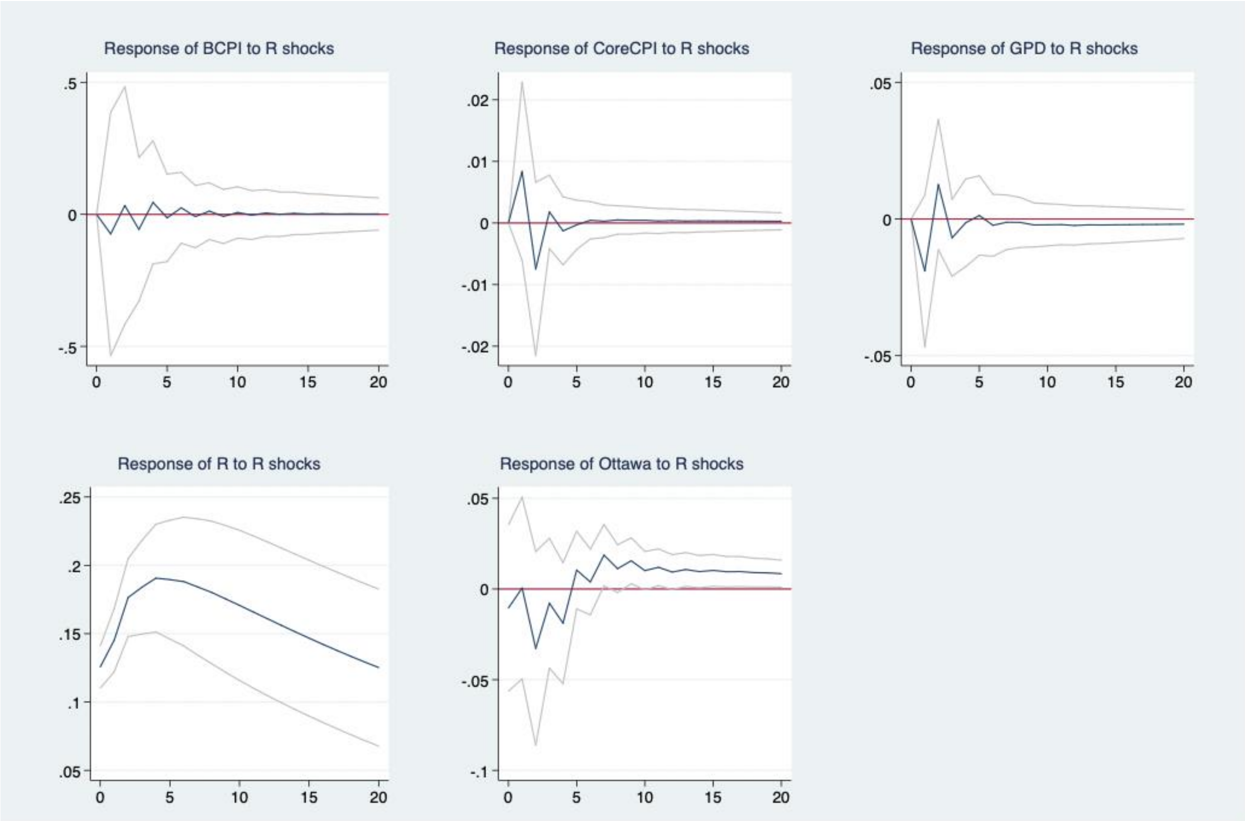
Toronto



Note: Figure C2 depicts the impulse responses of BCPI (row 1, column 1), Core CPI (row 1, column 2), GDP (row 1, column 3), overnight rates (R) (row 2, column 1) and Toronto housing price index (row 2, column 2). To be noted, the responses are shown as changes of the growth rate except overnight rate (R). All the responses are percentage changes to a one standard deviation shock to R. The vertical axis shows percentage point. 90% confidence bands are displayed.

Figure E3. Impulse responses to monetary policy shocks: Toronto

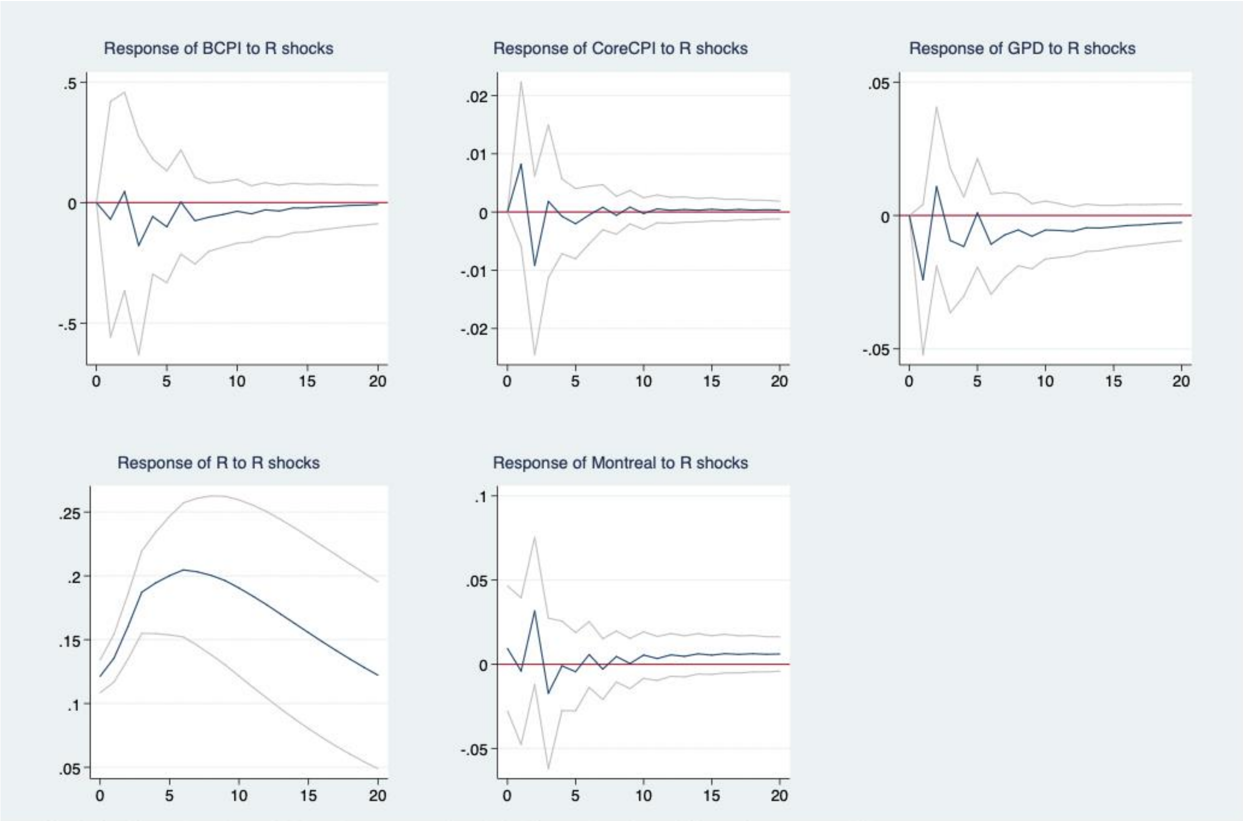
Ottawa



Note: Figure C2 depicts the impulse responses of BCPI (row 1, column 1), Core CPI (row 1, column 2), GDP (row 1, column 3), overnight rates (R) (row 2, column 1) and Ottawa housing price index (row 2, column 2). To be noted, the responses are shown as changes of the growth rate except overnight rate (R). All the responses are percentage changes to a one standard deviation shock to R. The vertical axis shows percentage point. 90% confidence bands are displayed.

Figure E4. Impulse responses to monetary policy shocks: Ottawa

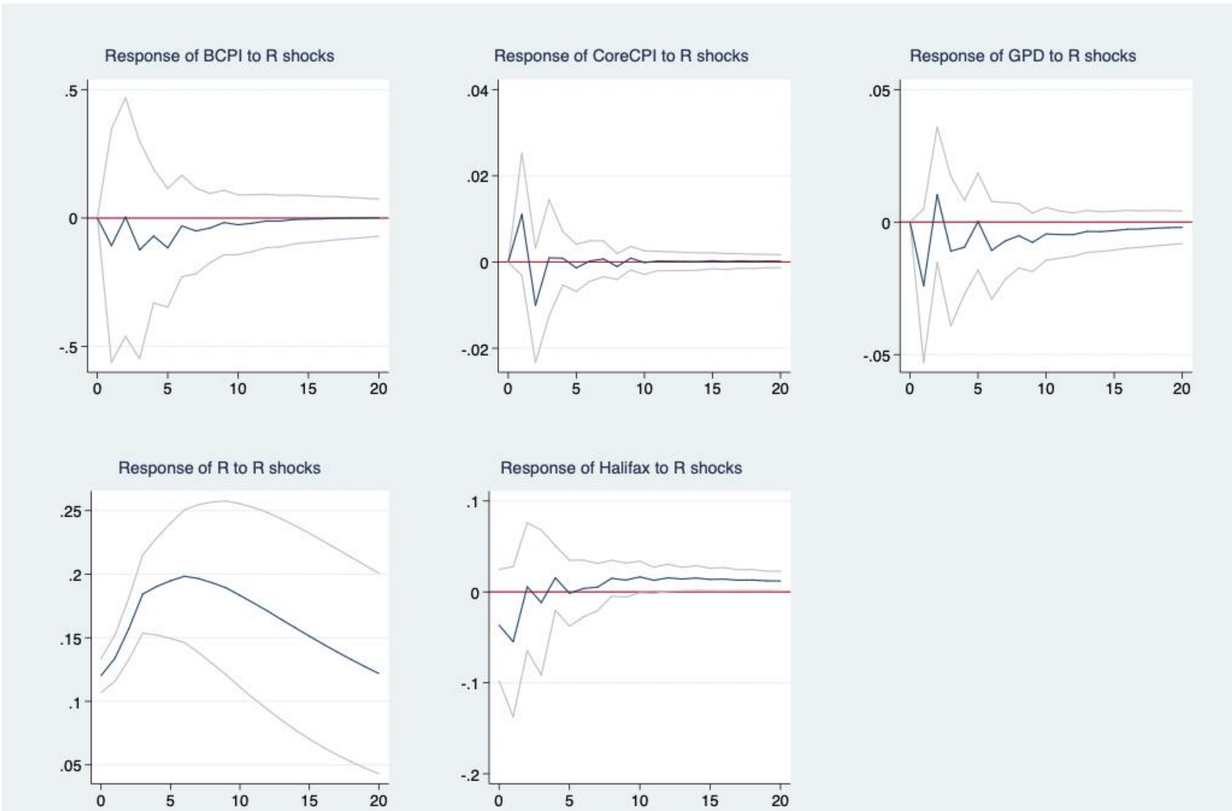
Montreal



Note: Figure C2 depicts the impulse responses of BCPI (row 1, column 1), Core CPI (row 1, column 2), GDP (row 1, column 3), overnight rates (R) (row 2, column 1) and Montreal housing price index (row 2, column 2). To be noted, the responses are shown as changes of the growth rate except overnight rate (R). All the responses are percentage changes to a one standard deviation shock to R. The vertical axis shows percentage point. 90% confidence bands are displayed.

Figure E5. Impulse responses to monetary policy shocks: Montreal

Halifax



Note: Figure C2 depicts the impulse responses of BCPI (row 1, column 1), Core CPI (row 1, column 2), GDP (row 1, column 3), overnight rates (R) (row 2, column 1) and Halifax housing price index (row 2, column 2). To be noted, the responses are shown as changes of the growth rate except overnight rate (R). All the responses are percentage changes to a one standard deviation shock to R. The vertical axis shows percentage point. 90% confidence bands are displayed.

Figure E6. Impulse responses to monetary policy shocks: Halifax