

Housing Market Responses to Monetary Policy Shocks in Canada:
Evidence from National and City Level Data

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ABSTRACT

This paper investigates the impact monetary policy shocks have on housing markets in Canada using both national and city level data. The data which includes spans the period of 1999-2016 includes house prices, housing starts and residential investment as housing market variables. This study uses a structural VAR model and a Bayesian process to generate impulse response functions for the national economy. National level monetary policy shocks identified through this process are used in projection method estimate the impact on regional housing markets of Vancouver, Calgary, Winnipeg, Toronto, Ottawa, Montreal and Halifax. The results suggest that house prices in Calgary may respond to monetary policy shocks but beyond this finding, the results fail to identify any prominent national or regional responses to monetary policy shocks.

Section 1 | Introduction

Housing markets in recent years have gained sizeable attention due to the fact that it was the housing market in the United States that prompted the financial crisis of 2008-2009. As Figure 1 shows, house prices in Canada have grown enormously since 1999: real house prices have more than doubled, and nominal house prices are now more than three times their value in 1999. This rise has exceeded the increase of household income in recent years (IMF, 2016). In this situation, concerns have grown about the extent to which developments in the housing markets could affect other sectors of the economy.

[Fig 1]

There is a strong link between monetary policy, interest rates and housing markets. Empirical results have shown a negative relationship between monetary policy and housing prices through the channel of interest rates (Allen et al. 2009). This link also has sound theoretical backing (Mourouzi-Sivitanidou, 2011). However, the impact of monetary policy on the housing market can go beyond the effects of interest rates. Monetary policy may also improve consumer confidence and expectations, thus increasing aggregate demand, and stimulating economic growth (Bachmann and Sims, 2012).

Consumer confidence is typically thought to impact aggregate demand through the household spending channels of precautionary saving and expected future income (Ludvigson, 2004). If consumer confidence is high, then expected future incomes increase and household spending should do the same in order to smooth consumption. On the other hand, if consumer confidence is low then precautionary saving will increase again to smooth consumption. This will in turn decrease household spending, a large portion of which goes towards housing. Monetary policy has been shown to significantly impact investor sentiment (Kurov, 2010) which is highly related to consumer confidence (Fisher and Statman, 2003). Changes in monetary policy may therefore have effects on household consumption and demand for housing through this channel that are not identified in analyzing the effects of interest rate shocks.

In order to examine the relationship between monetary policy and housing markets, a national level analysis alone might not suffice. Variations in consumer preferences and a different economic structure may cause housing prices to inflate at different rates across cities (Reichert 1990). As a consequence, the response of regional housing variables to the same, centralized, monetary policy, could be very different. Further, monetary policy shocks could contribute to the formation of regional housing bubbles, that have been shown to have the potential to spread to other regions (Nneji, Brooks and Ward, 2015). Thus, to fully understand the implications of the national level monetary policy on the housing market of a country, regional responses need also to be studied.

This paper aims to analyze the impact of monetary policy shocks on housing markets in Canada from a broad perspective. First, it examines the overall response of a number of national housing market variables to a monetary policy shock. By focusing on monetary policy shocks rather than changes in the interest rates, the analysis is able to capture a larger variety of effects that could operate through other channels, for instance changes in consumer confidence or expectations. Second, the paper provides an analysis of the impact of the national monetary policy shock on local housing markets in a number of Canadian cities.

The current body of research in this area seems to suggest that national housing markets in the United States and Europe respond negatively to monetary policy shocks (Vargas-Silva, 2008; Bjornland and Jacobsen, 2010; Jarocinski and Smets, 2008). Using a panel VAR, Goodhart and Hoffman (2008) find that these results are consistent across OECD countries at the aggregate level. These results suggest that Canada's national housing markets should be expected to respond negatively to monetary policy shocks, but clear evidence is still lacking. Some works have focused on the relationship between interest rates and the Canadian regional housing market, with mixed results. Allen et al. (2009) find that house prices in Toronto are negatively related to mortgage rates, while in Edmonton and Vancouver the same relationship is positive. On the other hand, Louis, Brown and Balli (2009) find that house prices in Vancouver, Victoria,

Toronto, and Ottawa exhibit negative responses to mortgage rate shocks. The same study also finds that housing starts in Edmonton and Vancouver respond negatively to the same mortgage rate shocks.

A gap exists in the current literature as the national housing market responses to monetary policy shocks in Canada have not been studied in depth. In addition, although a larger body of work has focused on the regional housing markets, a consensus on the effects of monetary policy shocks on regional housing variables has not been reached yet. Thus, the contribution of this paper to the literature is twofold. First, it examines the national level housing market responses to monetary policy shocks in Canada, using a very recent data sample going from 1999 to the end of 2016. Second, it examines the responses of regional housing markets to the national level monetary policy shocks, using a different approach and more recent data compared to previous studies.

The national level analysis performed in the paper uses a structural VAR model identified using sign restrictions. The responses obtained for the baseline model show that monetary policy shocks do not have a significant impact on house prices, residential investment, and housing starts in Canada. These results are unchanged if different measures of interest rates are employed, and if oil prices are included as an additional variable in the VAR. On the other hand, when adding lags beyond the number suggested by the Akaike information criterion, the housing market variables display a significant positive rebound after an initial negative response; however, the patterns are quite unstable and the responses are still insignificant in most periods. Further, when the restrictions on GDP, the exchange rate, and inflation are extended to 1 year, the housing market variables of housing starts and residential investment display negative responses but this robustness test may not accurately represent the responses to monetary policy shocks demonstrated by real variables. Overall, this alternative specification of the model seems to confirm that the impact of monetary policy shocks on national housing variables in Canada is not clearly identified in our data.

The regional level analysis of housing market responses is conducted using a projection method estimated with OLS. A time series of monetary policy shocks is identified from the structural VAR employed for the national analysis. These national level shocks are then regressed on the growth rates of

housing prices and housing starts in the cities of Vancouver, Calgary, Winnipeg, Toronto, Ottawa, Montreal, and Halifax. Thus, the shocks are the same for all cities, but the effects may differ based on regional changes in housing markets. The results show that, over a horizon of one year, all cities show no significant responses to monetary policy shocks. However, when the horizon is extended to two years, the impact of the shocks becomes significant for house prices in Vancouver and Calgary, although only the result for Calgary is robust to alternative specifications of the model.

The paper will follow with a review of the literature on the response of the housing markets to monetary policy shocks in section 2. Section 3 will describe the methodology employed, and Section 4 will provide an overview of the data and procedure used in the estimation of the model. The results at the national level, and their robustness, will be discussed in section 5. Section 6 will report the results of the analysis at the city level. Section 7 will conclude.

Section 2 | Literature Review

The relationship between monetary policy shocks and housing markets has been previously examined in the literature for large economies, like the United States or Europe, or across OECD countries. As discussed, the impact of monetary policy shocks on the Canadian housing market at the national level have not received significant attention, while the studies focusing on their regional effects have produced inconsistent results. The following literature review will discuss the current body of knowledge on national level housing markets in 2.1, and the existing studies on the regional responses to monetary policy shocks in 2.2.

2.1 National Level Research

Goodhart and Hoffman (2008) employ a panel VAR model to study the overall impact of monetary policy shocks on house prices across OECD countries. Using data for the period 1970 - 2006, this impact is estimated to be negative. While the results focus on OECD countries as a group and do not isolate the specific response of Canada as the present paper aims to do, they do establish a general relationship that holds in average across a set of countries that includes Canada.

With respect to country specific analyses, a negative relationship between housing markets and monetary policy shocks has been estimated for the United States. In a paper that serves as a foundation for the analysis in the following sections, Vargas-Silva (2008) uses sign restrictions in a VAR model to identify the responses of key housing market variables to monetary policy shocks. The paper finds that housing starts and residential investment respond negatively to a contractionary shock, i.e. a shock that increases the nominal interest rate. However, in this study the response of house prices is restricted to be negative. This implies that if residential investment and housing starts react to monetary policy shocks through their impact on house prices, then the results may be determined, at least to some extent, by the assumptions of the model. A similar argument could be made for the ordering restrictions that are used as a robustness check.

Jarocinski and Smets (2008) perform a similar analysis on the U.S. economy but without placing any sign restrictions on housing market variables. Monetary policy shocks are found to have negative effects on both real housing prices and residential investment in a Bayesian VAR model. This model includes inflation, the federal funds rate, and the long-term interest rate spread, among other variables and uses zero restrictions to identify monetary policy shocks. Focusing on the period from 1987 to 2007, the analysis shows that residential investment experiences a negative response for up to 4 years after the initial shock. This negative response is spread over a much longer period of time compared to the findings of Vargas-Silva (2008). In addition, Jarocinski and Smets (2008) are able to identify a negative impact of monetary policy shocks on house prices without imposing any sign restrictions. While this impact is not as large as for residential investment, it is still significant 6 years after the initial shock. Overall, the findings

by Jarocinski and Smets (2008) and Vargas-Silva (2008) for the United States are in line with those obtained by Goodhart and Hoffman (2008) for the OECD countries as a group.

In their empirical results, Jarocinski and Smets (2008) do not find evidence of a 'home price puzzle', a result that instead was imposed in the work of Vargas-Silva (2008). A home price puzzle occurs when monetary policy shocks are associated with increasing house prices. This type of response is unexpected, because economic theory predicts a response of the opposite sign. Housing supply in the short run is typically fixed due to construction costs and other market frictions (Mourouzi-Sivitanidou, 2011). A contractionary monetary policy shock increases interest rates in the economy, including mortgage rates. As this represents a direct increase in the cost of home ownership, the demand for housing should decrease. Consequently, housing prices should decrease following the monetary policy shock. However, this decrease does not always emerge in empirical analyses, and this is the reason why it needed to be imposed in the VAR model of Vargas-Silva (2008). The Canadian analysis performed in section 5 of this paper aims at studying the responses of a number of housing market variables, including house prices, to monetary policy shocks. For this reason, it would not be appropriate to restrict the response of this variable, which will therefore be left unrestricted.

Given that Jarocinski and Smets (2008) and Vargas-Silva (2008) identify a negative relationship between housing markets and monetary policy shocks in the United States, it is tempting to make inferences on the Canadian economy based on this result. It is even more tempting to do so because housing price cycles in Canada have been shown to closely mirror those in the United States (Cunningham and Kolet, 2007). However, this connection cannot be made because the Canadian economy must be modelled differently than the United States. Lit et al. (2012) note that the United States is a large country with the potential to impact the global economy, while they suggest that Canada should be treated as a small open economy. In a VAR framework, this characteristic can be accounted for by including exchange rates in the model, as suggested by Cushman and Zha (1997). Thus, the research in this paper will differ from the U.S. analyses by Jarocinski and Smets (2008) and Vargas-Silva (2008) primarily by focusing on Canada but also

by including exchange rates in the VAR model. In doing this, the analysis should be able to account for the features of a small open economy that differentiate Canada from the United States.

An area of research that is related to the question of interest in this paper includes a number of contributions that focus on the analysis of the relationship between house prices and interest rates. For Canada, Muellbauer, St-Amant, and Williams (2015) find that a percentage increase in the nominal interest rate will decrease house prices by 7% over 5 years. If monetary policy shocks increase interest rates, then housing markets should respond negatively to these shocks. Monetary policy shocks however, may also be able to impact housing markets through different channels. If monetary policy shocks increase economic uncertainty or impact consumers long term expectations, then effects will be captured in an analysis of monetary policy shocks on housing markets that are not identified by analyzing the relationship between housing markets and interest rates. Thus, the research in section 5 will build upon, and extend the scope of, the analysis performed in Muellbauer, St-Amant, and Williams (2015).

2.2 Regional Response Research

The relationship between regional housing markets and mortgage rates in Canada has been studied by Allen et al. (2009). The study finds mixed results across cities when accounting for regional characteristics such as municipal labour force, net migration, and provincial GDP. The analysis finds that Toronto house prices respond negatively to mortgage rates, while a home price puzzle (i.e. a positive response) is found in the results for Edmonton and Vancouver. Although the focus of this paper is on the relationship between housing prices and mortgage rates, and not monetary policy shocks, these findings provide insights about possible regional differences across Canadian housing markets. As previously mentioned, changes in mortgage rates will likely follow monetary policy shocks but monetary policy shocks may have additional effects (i.e. consumer confidence or expectations) that are not transmitted directly through interest rates. Thus, the focus of this paper departs from the analysis of by Allen et al. (2009).

Nonetheless, the work by Allen et al. (2009) does suggest that national level results may not be representative of cross-city differences, and the authors recommend performing regional analyses to capture heterogeneity in housing markets.

A regional analysis on Canada has also been performed on the topic of housing market responses to mortgage rate shocks, which are defined as unexpected non-systematic increases in mortgage interest rates. Louis, Brown, and Balli (2009) study the responses of housing market variables in various census metropolitan areas (CMAs) in Canada. In this paper, housing starts in Calgary, Edmonton and Victoria are found to have the strongest responses to the mortgage shocks, while house prices respond the most in Vancouver, Victoria, Toronto and Ottawa. While the focus of Louis, Brown, and Balli (2009) is on the impact of mortgage rate shocks, rather than monetary policy shocks, the results of this paper further motivates the importance of a regional analysis of the Canadian housing markets. Overall, the framework employed here extends the contributions of both Allen et al. (2009) and Louis, Brown and Balli (2009) in terms of the type of relationships studied, but also with respect to the much more recent data set used in the empirical estimations.

Outside Canada, the impact of monetary policy shocks on regional housing markets has been extensively studied for the United States. In the same paper previously mentioned, Vargas-Silva (2008) also examines the regional responses to monetary policy shocks, and finds that only the North-East and Mid-West regions share the national level findings. Differences between regional and national level responses to monetary policy shocks seem to be a generally consistent finding in the literature (Arnold, 2001; Arnold and Vrugt, 2002; Carlino and Defina, 1998). Section 6 aims at performing for Canada a similar analysis of regional effects as done by Vargas-Silva (2008), but this paper will be able to study “regions” on a much more local level.

In another study on the United States, Del Negro and Otrok (2007) employ a dynamic factor model to decompose state-level house price movements into national and state-level components. This study finds that state-level differences have historically explained a sizable fraction of the house price movements, but

since 2001 the national component has become a larger. The authors then generate impulse responses on the national level and find that house prices respond negatively to monetary policy shocks. The estimated national component of state-level house prices are then shown to determine the impact of national level monetary policy shocks on house prices at the state level. In this analysis, Del Negro and Otrok (2007) identify two effects that cause regional house prices to fluctuate differently. One is that regions respond differently to the same monetary policy shocks and the second is that national monetary policy shocks can be transferred to regions differently. The framework adopted by Del Negro and Otrok (2007) is interesting; however, this paper will employ a simpler approach and only focus on the overall impact of monetary policy shocks on regional housing markets.

Section 3 | Methodology

3.1 National Identification Procedure

This paper uses a structural VAR model for the analysis, identified using sign restrictions. The reduced-form VAR model takes the form:

$$Y_t = b + B_1 Y_{t-1} + \dots + B_q Y_{t-q} + u_t \quad (1)$$

The covariance matrix of the reduced-form shocks is $E(u_t u_t') = \Omega$, and Y_t is defined as follows:

$$Y_t = \begin{bmatrix} i_t \\ n_t \\ \pi_t \\ y_t \\ x_t \\ p_t \\ s_t \\ h_t \end{bmatrix} \quad (2)$$

The variable i_t is the short-run interest rate, n_t is the long-term interest rate, π_t is inflation, y_t is real GDP, and the exchange rate is represented by x_t . In terms of housing market variables, p_t is a nominal house price index, s_t is housing starts in Canada, and h_t is national residential investment. Except for the

nominal interest rate, all other variables are expressed in log differences, as common in the literature on housing markets (Allen et al. 2009, Jarocinski and Smets 2008). The set of variables included in the VAR follows Vargas-Silva (2008), except for the long-term interest rate that is added to capture effects at longer horizons. This choice follows the research by Muellbauer, St-Amant, and Williams (2015) who show that national house price fluctuations in Canada can be largely explained by movements in long-term variables.

As in Vargas-Silva (2008), the structural monetary policy shocks are identified using a sign restriction approach. This method was originally introduced by Uhlig (2005), and involves placing restrictions on the sign of the responses of selected variables in the VAR based on empirically documented relationships or consistently with economic theory. This method is useful as it allows to identify the shocks of interest, in this case monetary policy shocks, without making any assumptions about the other structural shocks of the economy and their impact on the variables of the model.

As common in the literature, I consider the responses to a contractionary monetary policy shock, i.e. a shock that increases the short-term interest rate. The same restriction is applied to the long-term interest rate. This implies that the analysis performed in this paper focuses on the impact of monetary policy shocks that increase interest rates at different horizons. The restrictions on inflation and real GDP are derived from macroeconomic theory, which postulates that both variables should be negatively related to the nominal interest rate (Williamson, 2010). The response of the exchange rate is restricted to be negative, as this is consistent with the assumption that Canada operates as a small open economy (Cushman and Zha, 1995). The sign restrictions are summarized below:

$$\begin{bmatrix} i_t \\ n_t \\ \pi_t \\ y_t \\ x_t \\ p_t \\ s_t \\ h_t \end{bmatrix} = \begin{bmatrix} \geq 0 \\ \geq 0 \\ \leq 0 \\ \leq 0 \\ \leq 0 \\ None \\ None \\ None \end{bmatrix} \quad (3)$$

Residential investment and housing starts are two of the housing market variables of interest, so their responses are left unrestricted. The impact of monetary policy shocks on house prices is also left

unrestricted, as in Jarocinski and Smets (2008). Thus, this paper does not make any a priori assumptions on the house price puzzle, so its presence in the data will be evaluated based on the results of the analysis.

In the baseline estimation, the sign restrictions are imposed at impact and for one additional period after the impact (so for a total of 2 quarters). The reasoning behind this choice is that housing is a long-term investment, so households are more likely to react to changes in the economy that linger for longer than just a quarter. This assumption is relaxed as a robustness test, the results of which are discussed in section 5.2.

3.2 Regional shock responses

The second part of the empirical analysis aims at identifying the impact of the shocks obtained through the procedure outlined in section 3.1. on local housing markets. This impact is estimated using an OLS regression in which the local housing variables are included as dependent variables, and the shocks are employed as regressors. This approach is a version of the projection method introduced by Jorda (2005), and has previously been adopted by Kilian (2009).

The structural shocks can be obtained from equation (1) as:

$$u_t = C \varepsilon_t \quad (4)$$

$$\varepsilon_t = C^{-1}Y_t - C^{-1}\hat{Y}_t \quad (5)$$

where the predicted \hat{Y}_t is:

$$\hat{Y}_t = \hat{b} + \hat{B}_1 Y_{t-1} + \dots + \hat{B}_q Y_{t-q}$$

The coefficients contained in \hat{b} and \hat{B} are estimated from the reduced-form VAR in the national analysis, and C is the matrix measuring the impact of the structural shocks on the variables included in Y_t . The time series of the structural monetary policy shocks obtained from (5) can then be included in a linear regression in which either the regional house price indices or the regional housing starts are employed as dependent variables. This methodology is in the spirit of the “local projections” analysis originally

introduced by Jorda (2005). A projection typically only includes time trends or constants as controls (Ramey, 2016), so a constant term will be added. Given that the distribution of the shocks is assumed to be time invariant, omitting a time trend should not be problematic.¹ In equations (6) and (7) regional controls are not included as may be expected. This is because the inclusion of any variables such as the regional labour force or household incomes would control for the effects that monetary policy shocks have on the housing market variables through these regressors. In this case, the total effect that monetary policy shocks have on the housing market is of interest so omitting these controls will not result in an omitted variable bias.

The regressions take the following form:

$$\Delta \ln(p_t) = \alpha + \sum_{i=0}^q \alpha_i \varepsilon_{t+i} + \omega_t \quad (6)$$

$$\Delta \ln(h_t) = \beta + \sum_{i=0}^q \beta_i \varepsilon_{t+i} + \eta_t \quad (7)$$

In equations (6) and (7), p_t is the house price index at time t , h_t is housing starts at time t , and ε_t is the national level shock obtained from (5). The residuals in these equations are denoted by ω_t and η_t . The variable q is the horizon, i.e. the number of lagged shocks included in the regression. The regressions are repeated for the CMAs of Vancouver, Calgary, Winnipeg, Toronto, Ottawa, Montreal, and Halifax. The analysis of the results focuses on the sum of the values of α_i and β_i , and on the joint significance of these coefficients, for q equal to 4 and 8 quarters (1 and 2 years).

An issue that arises in this approach is that the independent variables are estimated variables. This implies that the standard errors of the estimated parameters of (6) and (7) should be calculated by a bootstrap procedure that accounts for the uncertainty in the estimation of the monetary policy shocks used as regressors. Since the sign restriction approach used to identify these shocks is already computationally intense, adding a bootstrap procedure would make the estimation very long. For this reason, the standard

¹ This claim is supported by the results of a regression of the shocks used in section 6.1 and 6.2 on a time trend, which show no relationships between these variables. The results of this exercise are reported in Appendix A.

errors in (6) and (7) will be computed as if the independent variables were observed data, and consequently they will be smaller than they would be if a bootstrap approach was used. This should be taken into account when interpreting the results.

A second issue that needs addressing is the possibility of reverse causality in the regression models defined by (6) and (7). Reverse causality in these equations would occur if changes in house prices or housing starts impacted monetary policy shocks within the same period. This could happen if the identified monetary policy shocks actually included other structural shocks originating in the housing markets. Given the specific sign restrictions imposed to identify the monetary policy shocks of interest, this is quite unlikely to be the case in our model. In addition, the housing market variables used in (6) and (7) are measured at the regional level, while monetary policy shocks are identified at the national level. Thus, for the issue of reverse causality to affect the results, the identified national monetary policy shocks would need to incorporate local housing markets shocks. This makes it even more unlikely that the issue of reverse causality is present in our estimations.

Section 4 | Data and Implementation

4.1 Data

The analysis is performed using variables defined at the quarterly frequency. The data goes from the fourth quarter of 1999 to the fourth quarter of 2016, resulting in 69 observations for each variable². Prior data is not available for the national house price index offered by Teranet, and the analysis needs to be performed at the quarterly frequency because residential investment is not available at the monthly level. It should be noted that, given that this is a relatively small sample, the results of the empirical analysis may not be overly precise.

² House price data for some CMAs have fewer observations depending on when collection began.

The data on housing starts and residential investment is measured by the Canadian Mortgage and Housing Corporation and made available through CANSIM tables. A housing start is defined as the beginning of construction work on a building (“CMHC”, 2017), while residential investment refers to the value of spending by individuals, enterprises, and governments on the construction of residential properties (“Statistics Canada”, 2017). Residential investment data is already available at the quarterly level, but quarterly housing starts data must be computed by aggregating the monthly figures.

The house price indices are composite indices of house prices in Canada from Teranet, and they are available for each of the different CMAs and at the national level. Regional house price indices measure the average change in house prices for properties that have been sold at least twice. These indices are aggregated through a weighted average to obtain the national house price index (“Teranet”, 2017). This method of calculation is effective in capturing the growth in house prices, but may not capture the full volatility of house prices. Another caveat is that this price index does not include the sale of new homes, and these features should be taken into consideration when interpreting the results in sections 5 and 6.

Summary statistics about the national level housing variables employed in the analysis can be found in table 1. The regional analysis focuses only on housing starts and house prices, because residential investment data are not available for CMAs in Canada. Notice that the national house price index and the regional indices are based on the same data and methodology, allowing the results to be comparable across CMAs, and at the regional and national level.

[Table 1]

The short run interest rate is the 3-month interest rate on T-bills. This variable is interpreted as a proxy for the policy instrument, and is used for the identification of the monetary policy shocks. The 10-year government bond rate is the long-term interest rate. As previously mentioned, this variable is included to capture the changes in the cost of housing that are due to the long-term effects of monetary policy shocks. The data for the T-bills and bond rates are the averages of the monthly rates for the months included in each

quarter. The exchange rate is CAD to USD measured in cents; inflation is measured from the core-CPI, and national GDP is measured in constant dollars.

Two additional variables are employed in the robustness analysis. As discussed by Li and Zanetti (2016) the business prime rate (prime rate) is more volatile than the 3-month T-bills rate and may be able to capture more realizations of the monetary policy shock.³ Thus, the prime rate is used as a proxy for the policy instrument instead of the 3-month interest rate on T-bills as a robustness check. A second robustness test includes oil prices in the VAR model as oil shocks have been found to strongly influence the Canadian economy (Jimenez-Rodriguez and Sanchez, 2005). The oil variable used in this exercise is the monthly price of WTI crude oil, averaged to obtain quarterly data.

As previously noted, all the variables are measured in percentage changes (log differences), except for the interest rates. Further information about each variable and the data sources can be found in appendix B.

4.2 Implementation

In the baseline analysis, the number of lags of the variables included in the VAR model (1) was set equal to one, as suggested by the Akaike information criterion. The framework described in section 3.1 is estimated using Bayesian methods following those outlined by Koop and Korobilis (2010). Let γ denote a vector that incorporates all the coefficients included in the vector and matrices: b, B_1, \dots, B_q . The joint posterior distribution is defined as:

$$P(\gamma, \Omega | X) = P(\gamma | \Omega, X) \cdot P(\Omega | X) \quad (8)(9)$$

$$P(\Omega | X) \sim IW(\hat{\Omega}, n) \quad (9)$$

$$P(\gamma | \Omega, X) \sim N(\hat{\gamma}, V_{\Omega}) \quad (10)$$

³ The prime rate is a representative price of those offered by the largest 5 banks in Canada taken from the last Wednesday of each month (“Bank of Canada”, 2017) and then averaged on the quarterly level.

In all distributions, X denotes the data set. In (9), $IW(\hat{\Omega}, n)$ is an inverse Wishart distribution, with scale parameter $\hat{\Omega}$ set equal to the estimated covariance matrix obtained using OLS, and the degrees of freedom n is the number of observations. In (10), $N(\hat{\gamma}, V_{\Omega})$ is a normal distribution with mean $\hat{\gamma}$, which is obtained from the OLS estimates of the VAR coefficients reshaped into vectorial form. In addition, V_{Ω} is the covariance matrix of the vector γ , which is function of the matrix Ω (Koop and Korobilis, 2010). The form of the prior and posterior distributions, and the values of their parameters, follow standard assumptions in the Bayesian VAR literature (Giannone, Lenza and Primiceri, 2015).

In order to estimate the national level responses discussed in section 5, the posterior distribution defined by (9) and (10) are used to draw values of γ and Ω , which are then used to compute impulse-response functions for all the variables included in the VAR model. Each function that satisfies the sign restrictions discussed in section 3.1 is saved until 3,000 responses are retained. The median impulse responses are plotted, with error bands that represent the 16th and 84th percentiles. For a more technical description of this procedure, please refer to appendix C.

Finally, the 3000 impulse response functions that satisfy the imposed sign restrictions can be used to obtain the series of monetary policy shocks to be employed in the regional analysis. An impact matrix C can be computed from each one of these responses, and a corresponding series of shocks can be generated using equation (5). Given that 3000 draws are retained, 3000 series of monetary policy shocks are generated. The median shock for each period is then taken to produce a single series of monetary policy shocks.

Section 5 | National Analysis

Section 5.1 reports the results obtained from the implementation of the methodology outlined in section 3, followed by a discussion of the robustness of these results in section 5.2. The use of the business prime rate as the policy rate, the inclusion of oil prices in the VAR model, an increase in the number of lags included in the model, and prolonging the restrictions on variable responses are all used as robustness

checks. The baseline results fail to identify any responses in Canada's national housing market variables to monetary policy shocks: the responses of house prices, housing starts, and residential investment are all insignificant. These findings are robust to all checks with the exception of when variable responses are restricted for 1 year. In this case house prices are not found to respond, but both residential investment and housing starts react negatively to monetary policy shocks. A caveat of these results is that the sample employed for the analysis is relatively small and contains the financial crisis. This feature of the data may have an impact on the findings discussed in this section.

5.1 Results

Figure 2 reports the responses of the variables to a contractionary monetary policy shock normalized to increase the 3-month T-bill rate by 25 basis points. The figure also shows the responses corresponding to the 16th and 84th percentiles. As imposed by the estimation procedure, the 10-year bonds rate increases, while inflation, GDP growth, and the exchange rate decrease. The impact of the monetary policy shock on the housing variables, however, is not clearly identified. In terms of median responses, house prices show a tendency to increase at impact, indicating the possible presence of a house price puzzle in the data. On the other hand, both housing starts and residential investment show a tendency to decline after the shock.⁴ However, the responses of all the housing market variables are insignificant at all horizons and any effects of the monetary policy shock seem to disappear very quickly.

[Figure 2]

Overall, these findings do not provide a clear picture of the impact of monetary policy shocks on the Canadian housing market at the national level. This being the case, it is important to point out that this claim does not mean that housing market variables are unimpacted by interest rates; it only suggests that changes in interest rates due to unexpected shocks to monetary policy appear to have no significant impact on these variables. Consequently, the results reported in Figure 2 do not imply that a change in the

⁴ The magnitudes of the median responses at the time of impact as seen in Figure 2 are presented in appendix D.

systematic component of monetary policy would have no impact on housing prices, or other housing markets variables. However, they do indicate that the relationships between interest rates and housing markets estimated in some previous contributions (for instance Muellbauer, St-Amant, and Williams, 2015) might actually be very different in size depending on the source of variations in the interest rates.

It should also be noted that the results found here may be impacted by the sample used. The data employed in the analysis goes from 1999 to 2016, and includes the financial crisis. Given that the financial crisis was a unique period of time for monetary policy, it might be advisable to split up the sample into two periods around this event. However, this is unfortunately not a possibility in this paper because the sample is already composed of a relatively small number of observations, so reducing its size further would make it too small for any significant analysis. And as previously noted, not all the variables of interest (residential investment) are available at the monthly level, so the data used in the empirical estimations needs to be defined at the quarterly frequency.

5.2 Robustness Check

In order to test the robustness of these results, three exercises were performed. In the first, the business prime rate (prime rate) was used as a proxy for the policy rate, instead of the 3-month T-bill rate. As previously discussed, the prime rate is more volatile than other short-term rates, so it might be able to capture a larger set of unexpected interest rate changes. In the second robustness exercise, oil prices were included in the VAR model. This extension of the model is supported by the work of Jimenez-Rodriguez and Sanchez (2005) who find that oil prices can have a substantial impact on the Canadian economy. Thus, this variable is included in the VAR to ensure that the relationships that the model aims at capturing are not affected by oil price fluctuations. The final robustness check entails increasing the number of lags included in the model. Given that the Akaike information criterion selected only one lag for the baseline analysis, and this number seems uncharacteristically low when compared to other models on national housing

markets (Vargas-Silva, 2008; Bjornland and Jacobsen 2010), a robustness check in which the VAR is estimated with more lags of the variables is also performed.

Figure 3 reports the results obtained using the prime rate as the short-term interest rate. As in the baseline framework, a monetary policy shock is normalized to increase the short-term interest rate by 25 basis points, and all the same sign restrictions are imposed. From Figure 3, it is clear that the results do not change if the prime rate is used in the analysis. Thus, despite the ability of this variable to capture more unexpected interest rate fluctuations, the impact of monetary policy shocks on the Canadian national housing market is still not clearly identified in the data employed in this study.

[Figure 3]

The results for the VAR model that includes oil prices are reported in Figure 4. The impact of monetary policy shocks on oil prices was left unrestricted, while everything else is the same as in the baseline model. Again, the results are very similar to those reported in Figure 2. In addition, Figure 4 also shows that the response of oil prices to the monetary policy shock is not well identified.

[Figure 4]

In another robustness check for the national level analysis, the VAR model was extended to include additional lags of the variables. Figure 5 reports the responses for the case in which 2 lags are used. In this case, the results are slightly different compared to the baseline results. The responses of house prices, housing starts, and residential investment are negative (but insignificant) at impact, but then briefly become positive and significant after about one year. Nonetheless, the patterns display a somehow unstable behavior and are insignificant in most periods so, overall, the impact of monetary policy shocks on the housing variables of interest still seems to be unclear.

[Figure 5]

[Figure 6]

Monetary policy may take as long as 6-18 months to impact real variables, so the procedure is also repeated while imposing restrictions for 4 quarters to account for this. These results can be found in figure 6 and indicate that house prices still do not respond to monetary policy shocks but show a negative response to monetary policy shocks for housing starts and residential investment. Although these findings do not replicate the previous results, they are not sufficient to challenge the overall findings of section 5.1.

A few additional robustness checks were performed: the sign restrictions were implemented for 1 and 3 quarters; the model was estimated excluding the long run interest rate, or excluding housing starts, or excluding residential investment; and finally, the monetary policy shocks were identified without imposing sign restrictions on GDP and exchange rates. All these exercises were delivering very similar results to those obtained from the baseline framework.

Section 6 | Regional Analysis

The regional analysis studies the impact of the identified national monetary policy shocks on house prices and housing starts for the CMAs of Vancouver, Calgary, Winnipeg, Toronto, Ottawa, Montreal, and Halifax. The results for the baseline framework do not provide evidence of a significant effect of monetary policy shocks on housing starts in any of the cities. This finding is robust to alternative series of the monetary policy shocks, obtained from different specification of the VAR model described in section 3. The impact on housing prices is also insignificant for all cities when 4 quarters of monetary policy shocks are considered. However, when accounting for 2 years of monetary policy shocks, the model does estimate a joint significant effect on house prices in Vancouver and Calgary, although this result is not very robust to alternative monetary policy shocks series and may not be significant when employing a more appropriate bootstrap method of estimating standard errors for generated variables.

6.1 Results

The results obtained from the estimation of equations (6) and (7) with the inclusion of 4 lags ($q = 4$) can be found in table 2. The table reports the sum of the coefficients attached to the different lags of the monetary policy shock, and the F-statistic for the test of joint significance of these coefficients. In terms of point estimates, the shock seems to have an unclear overall effect on both house prices and house starts. The table also shows that monetary policy shocks are jointly insignificant in explaining movements in these variables for all cities. This suggests that neither regional house prices nor housing starts respond to monetary policy shocks for the past year in a clear direction. This result is consistent with the national analysis discussed in section 5 that does not identify a significant impact of monetary policy shocks on housing market variables at the national level.

[Table 2]

Table 2 also presents the results emerging from the estimations that use a horizon of 8 quarters ($q = 8$). In this case, the hypothesis of joint insignificance of the coefficients is rejected for house prices in Vancouver and Calgary. In terms of point estimates, the sum of the coefficients is negative for both cities, but the magnitude of this sum is much larger for Calgary than for Vancouver. However, the significance of these sums cannot be commented on without additional testing. For all the other cities, an F-test cannot reject the null that all coefficients in (6) are equal to zero, and for all cities, the null that all the coefficients are zero in (7) cannot be rejected. For the case in which 8 quarters are used in the estimations though, the sum of the point estimates of the coefficients in both (6) and (7) seem to be leaning more on the negative side compared to the case in which $q = 4$. This finding suggests that the largest effects of monetary policy shocks on housing variables might actually be delayed, and appear only in later periods. It is important to again mention that the independent variables used are estimated variables but the standard errors are estimated following the standard procedure instead of a bootstrap method. For this reason, the significance of the findings for Calgary and Vancouver may not hold when employing a more appropriate methodology.

6.2 Robustness Check

To examine the robustness of the results reported in Table 2, the linear regression described in (6) and (7) are estimated again using alternative series for the monetary policy shock. These series are obtained from two of the alternative specifications of the VAR that were employed for the robustness analysis in section 5.2: the model in which oil prices are included, and the model in which two lags of the variables are used instead of only one.

Table 3 reports the results for equations (6) and (7) estimated using shocks identified from the VAR that includes oil prices. The results are very similar to those obtained for the baseline framework. The only relevant difference is that now the F-test of the joint significance of the parameters can only be rejected for Calgary in the case in which 8 quarters of the monetary policy shocks are included in the regression. As before, the sum of the point estimates of the coefficients in (6) and (7) seem to be negative for most cities when $q = 8$, while this is not the case when $q = 4$.

[Table 3]

The results from the second robustness check are included in table 4. These results are largely consistent with the previous findings. However, for the case in which $q = 8$, the null hypothesis that the coefficients in equation (6) are all zero can be rejected for several cities: Calgary and Vancouver, as in the baseline analysis, but also Winnipeg, Montreal, and Halifax. Thus, using the shock series identified from a VAR that includes two lags of the variables, monetary policy shocks seem to have a more evident negative effect on house prices in a number of Canadian cities.

[Table 4]

Overall, the analysis suggests that for all cities, housing starts do not exhibit a significant response to monetary policy shocks. This result holds when including monetary policy shocks over 1 and 2-year periods. Similarly, monetary policy shocks do not affect house prices significantly in any of the cities when 4 quarters of the shocks are included in the analysis, but a more clear negative impact emerges for some

cities if 8 quarters are used instead. This result might indicate that the largest effects of monetary policy shocks on local house prices only appear with a delay of more than one year but the same issue arises as in section 6.1 in that the standard errors are smaller than if they had been estimated using a bootstrap method. This suggests that the significance of these findings may not hold when using a more appropriate method of estimation.

Section 7 | Conclusion

The previous research generally finds that monetary policy shocks have a negative impact on a number of housing market variables. This relationship has not been studied for Canada at the national level, and some related regional analysis has provided mixed results. Broken into two sections, this paper analyzes the impact of monetary policy shocks on Canada's national housing markets using a structural VAR model identified through sign restrictions, followed by a city level analysis which employs a projection method to estimate the effects of national monetary policy shocks on house prices and housing starts.

The results for Canada departs from the findings of the literature on the United States and other OECD countries, which predict that housing markets respond negatively to monetary policy shocks. At the national level, this study does not identify any clear and significant housing market responses to monetary policy shocks. This result is robust to many alternative specifications, including the use of a prime business rate, oil prices, and additional lags but not to extending the length of the restrictions imposed on GDP, inflation and the exchange rate to 1 year following the shock. A possible reason for this finding could be the small sample used for the analysis, which might not contain enough observation for the VAR framework to be able to identify a clear effect. In addition, the sample period includes the recent financial crisis, during which the relationships between variables might have been altered compared to more normal times.

In the regional analysis, city level house prices and housing starts are regressed on monetary policy shocks for 4-quarter and 8-quarter horizons. The results show that these shocks do not have a significant

impact on housing starts in any of the cities, confirming the findings obtained at the national level. Similarly, the monetary policy shocks do not have a significant impact on house prices when including lags for up to one year. However, when 8 quarters of the shocks are used, the null hypothesis that the effect of these shocks on house prices is zero is rejected for Calgary and Vancouver in the baseline framework, and for some other cities as well in one of the robustness exercises.

Overall, this research finds that housing markets in most Canadian cities respond in a fashion that is consistent with the national level responses. Except maybe for house prices in Vancouver and Calgary, this analysis fails to identify any evident and significant housing market responses to monetary policy shocks in Canada on the national or regional levels. The empirical results of this study could substantially improve if a longer sample period, or monthly data, was available. On the other hand, some extensions that could be pursued include making use of different house prices or house price indices, performing the same analysis at the provincial level, or attempting to break down the impact that monetary policy shocks have on regional residential investment should the data become available.

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APPENDIX A

Independent Variable	Coefficient
Shocks (Section 6.1)	0.003 (0.007)
Shocks with Oil price included in VAR model (Section 6.2)	0.003 (0.006)
Shocks with 2 lags included in VAR model (Section 6.2)	0.004 (0.006)

Coefficient on a time variable to test for the inclusion of a trend variable in the projection equations (6) and (7).

APPENDIX B

Variable	Vector Identifier	Explanation
House Prices	N/A	Composite of City housing price indices, available from Teranet website.
Housing Starts	v729949	Number of units started over monthly period collected by CMHC and available monthly from CANSIM 027-0001. This source also provides the housing starts by CMA.
Residential Investment	v62143961	Gross Fixed Capital Formation on Residential construction. Seasonally adjusted and chained 2007 dollars on CANSIM 380-0068.
Business Prime	v122495	Representative of those offered by big 6 banks available monthly (last Wednesday of Month) on CANSIM 176-0043.
T-Bill Rate	v122531	3 month and 1 year T-bill rate average over the quarter available on CANSIM 176-0043.
Government Bond Rate	v122543	10-year Government bond rate averaged over the quarter available on CANSIM 176-0043.
CPI	v41690973	All-items CPI, Nationwide available monthly from CANSIM 326-0020.
GDP	v65201483	2007 Constant Dollars, seasonally adjusted, available monthly from CANSIM 379-0031.
Exchange Rate	v37694	Cents/USD: Monthly data, available from CANSIM 176-0049.
WTI Crude	N/A	Available from the Federal Reserve St. Louis website. Average of quarter WTI oil prices.

APPENDIX C

In order to generate the impulse response functions, the following loop is performed until the specified number of draws (3,000 for this paper) is reached:

1. Values for Ω and γ are drawn from the posterior distributions discussed in section 4.
2. An orthogonal (rotation) matrix P is drawn.
3. The Cholesky decomposition of Ω is multiplied by the randomly drawn rotation matrix P to get the impact matrix.
4. The impact matrix is normalized so that the increase in the short-term interest rate is 0.25 at impact.
5. The normalized impact matrix and the draw of γ are used to compute the responses of all variables to the shock of interest.
6. The responses are checked to see if they satisfy the restrictions imposed.
 - 6.1. If they do not, the draws of Ω and γ and the computed impact matrix are discarded, and the procedure starts again from step 1.
 - 6.2. If the restrictions are satisfied, the draws of Ω and γ and the computed impact matrix are kept, and the procedure starts again from step 1.

APPENDIX D

Variable	Size of median impact
3-month T-Bill Rate	0.250
10 Year Government Bond Rate	0.269
Inflation	-0.005
Real GDP	-0.008
Exchange Rate	-0.030
House Price Index	0.005
Housing Starts	-0.045
Residential Investment	-0.007

Value of the median impulse response functions at the time of impact as displayed in Figure 2.

TABLES

Variable	Observations	Mean	Std. Dev.	Min	Max
House Prices	69	120.38	35.52	67.61	195.22
Housing Starts	69	521.91	76.46	328.35	653.74
Residential Investment	69	101561	15570.65	67113	125427

Table 1. Summary Statistics (residential investment is in thousands, and housing starts are tens of thousands)

	Horizon	Vancouver	Calgary	Winnipeg	Toronto	Ottawa	Montreal	Halifax
House Prices	4	0.0074	-0.0089	0.0028	0.0047	0.0006	0.0009	-0.0045
F-Test		<i>1.15</i>	<i>0.97</i>	<i>0.29</i>	<i>0.63</i>	<i>0.01</i>	<i>0.04</i>	<i>1.08</i>
Housing Starts	4	-0.0385	-0.0677	-0.0015	0.0570	0.0182	-0.0927	-0.0018
F-Test		<i>0.55</i>	<i>0.65</i>	<i>0.00</i>	<i>0.57</i>	<i>0.02</i>	<i>2.24</i>	<i>0.00</i>
House Prices	8	-0.0217	-0.0700	-0.016	0.0008	-0.0050	0.0037	-0.0091
F-Test		<i>4.36**</i>	<i>26.50***</i>	<i>1.26</i>	<i>0.01</i>	<i>0.21</i>	<i>2.03</i>	<i>1.76</i>
Housing Starts	8	-0.0692	0.0645	-0.1272	-0.0041	0.0128	-0.0740	-0.0962
F-Test		<i>0.58</i>	<i>0.19</i>	<i>0.52</i>	<i>0.00</i>	<i>0.00</i>	<i>0.46</i>	<i>0.11</i>

*Table 2. F-test of results from equations (6) and (7) where the monetary policy shocks are the independent variables. Shock value is sum of all shock coefficients. *, **, and *** are 90%, 95%, and 99% significance levels respectively.*

	Horizon	Vancouver	Calgary	Winnipeg	Toronto	Ottawa	Montreal	Halifax
House Prices	4	0.0109	-0.0055	0.0005	0.0064	0.0008	0.0009	-0.0049
F-Test		2.28	0.43	0.01	0.98	0.02	0.04	1.00
Housing Starts	4	-0.0108	-0.0736	0.0009	0.0783	0.0232	-0.0957	0.0304
F-Test		0.05	0.86	0.00	1.08	0.03	1.79	0.04
House Prices	8	-0.0083	-0.0559	-0.0102	0.0079	-0.0016	-0.0063	-0.0068
F-Test		0.50	12.20***	1.24	0.48	0.02	0.56	0.86
Housing Starts	8	-0.0666	-0.0119	-0.1447	0.0181	0.0523	-0.0804	-0.0716
F-Test		0.48	0.01	0.79	0.02	0.04	0.52	0.06

*Table 3. F-test of results from equations (6) and (7) where the monetary policy shocks are the independent variables. Shocks are identified from a VAR model that includes oil prices. Shock value is sum of all shock coefficients. *, **, and *** are 90%, 95%, and 99% significance levels respectively.*

	Horizon	Vancouver	Calgary	Winnipeg	Toronto	Ottawa	Montreal	Halifax
House Prices	4	0.0025	-0.0039	-0.0049	-0.0019	-0.0047	-0.0054	-0.0086*
F-Test		0.15	0.26	0.87	0.09	0.75	1.46	3.59
Housing Starts	4	0.0002	-0.0752	0.0023	0.0640	0.0209	-0.0919	0.0500
F-Test		0.00	0.76	0.00	0.65	0.02	1.59	0.12
House Prices	8	-0.0225	-0.0584	-0.0190	-0.0021	0.0012	-0.0185	-0.0133
F-Test		3.82***	13.54***	3.72*	0.08	1.09	5.64**	3.80*
Housing Starts	8	-0.0024	-0.0186	-0.1058	0.0188	0.0627	-0.0394	-0.0094
F-Test		0.00	0.02	0.44	0.02	0.04	0.09	0.00

*Table 4. F-test of results from equations (6) and (7) where the monetary policy shocks are the independent variables. Shocks are identified from a VAR model that has 2 lags. Shock value is sum of all shock coefficients. *, **, and *** are 90%, 95%, and 99% significance levels respectively.*

FIGURES

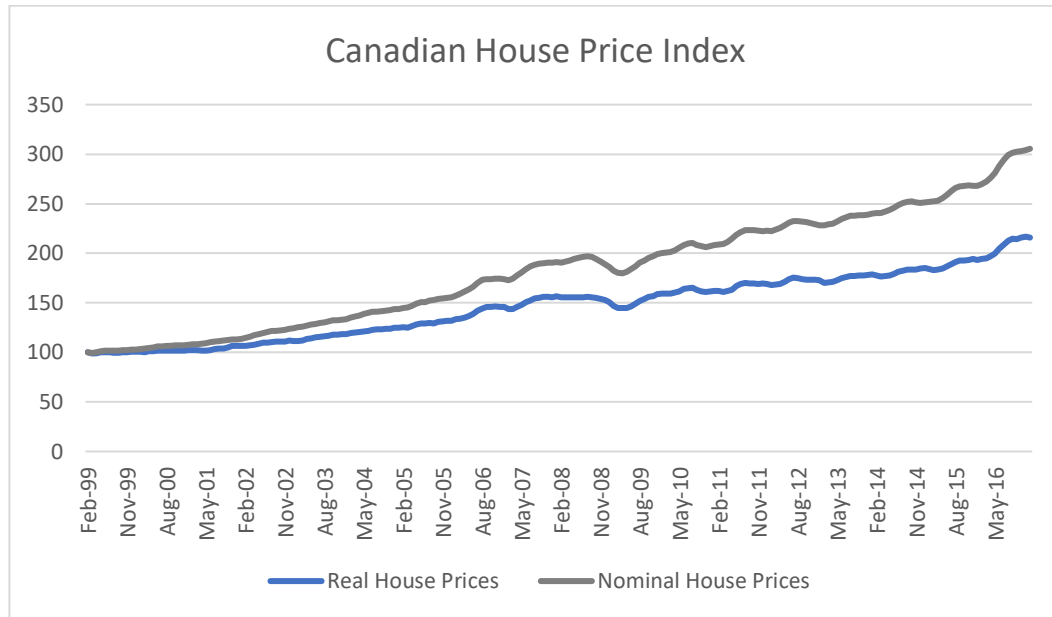


Figure 1. House Prices and Real House Prices in Canada from 1999-2016.
 Source: Teranet Composite House Price Index and CANSIM Consumer Price Index.

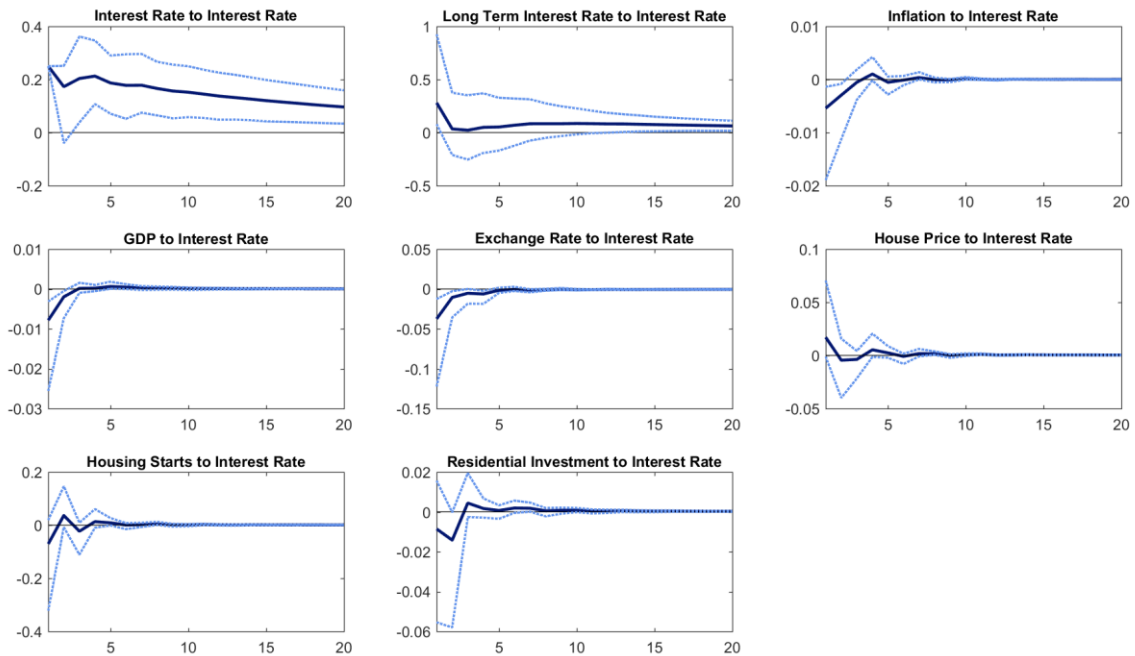


Figure 2. Impulse response function of a positive interest rate shock. Error bands represent 16th and 84th percentile responses.

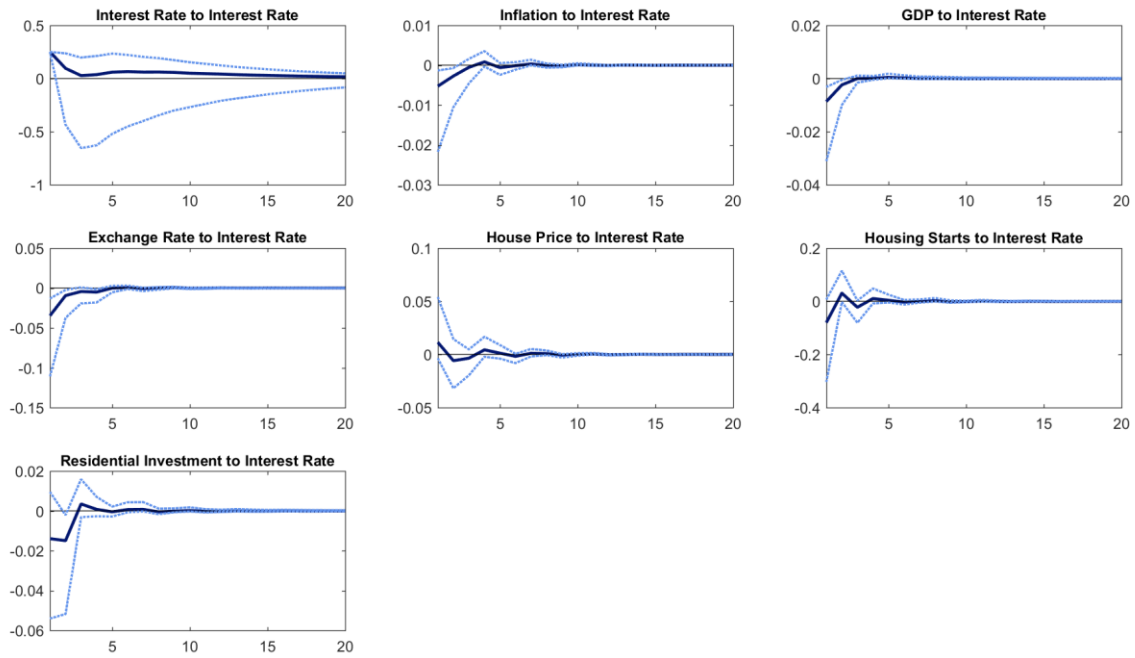


Figure 3. Impulse response function of a positive interest rate shock. Interest rate variable is the prime business rate. Error bands represent 16th and 84th percentile responses.

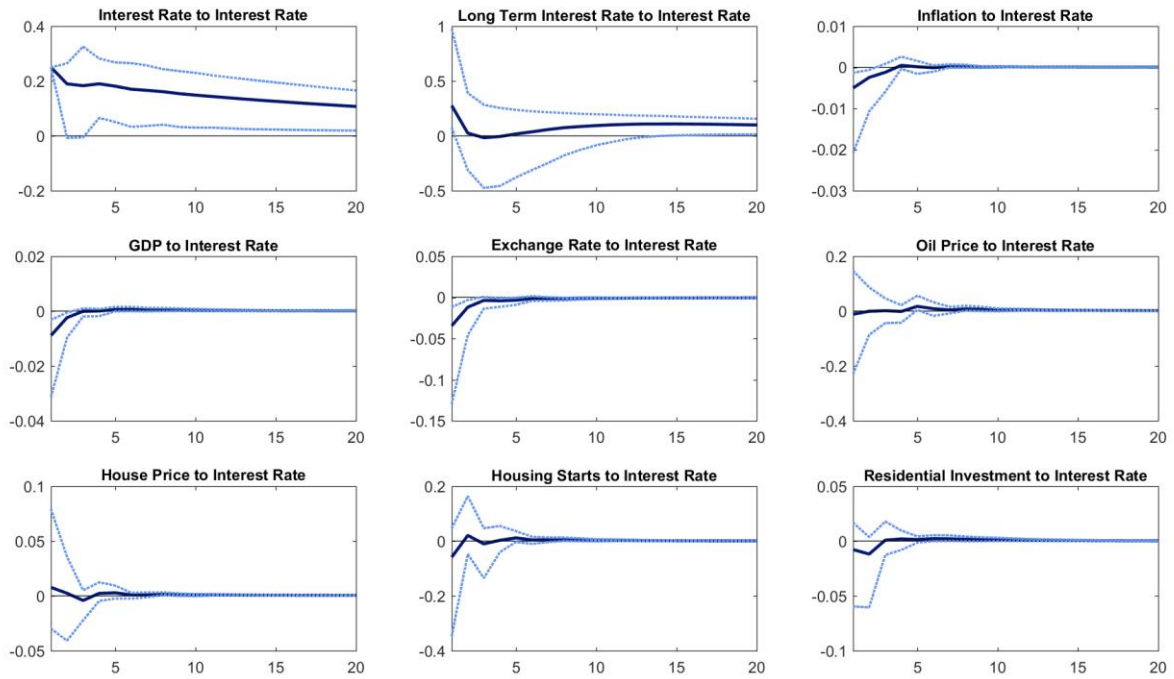


Figure 4 Impulse response function of a positive interest rate shock with oil prices included in the VAR. Error bands represent 16th and 84th percentile responses.

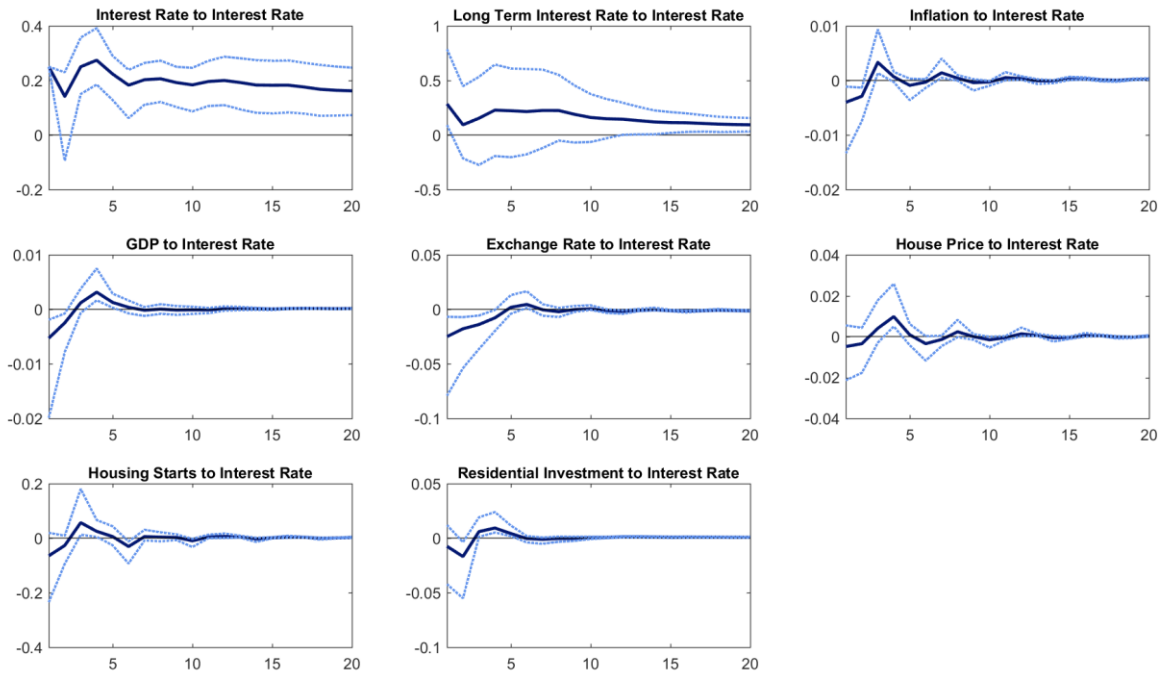


Figure 5 Impulse response function of a positive interest rate shock with the inclusion of 2 lags instead of 1. Error bands represent 16th and 84th percentile responses.

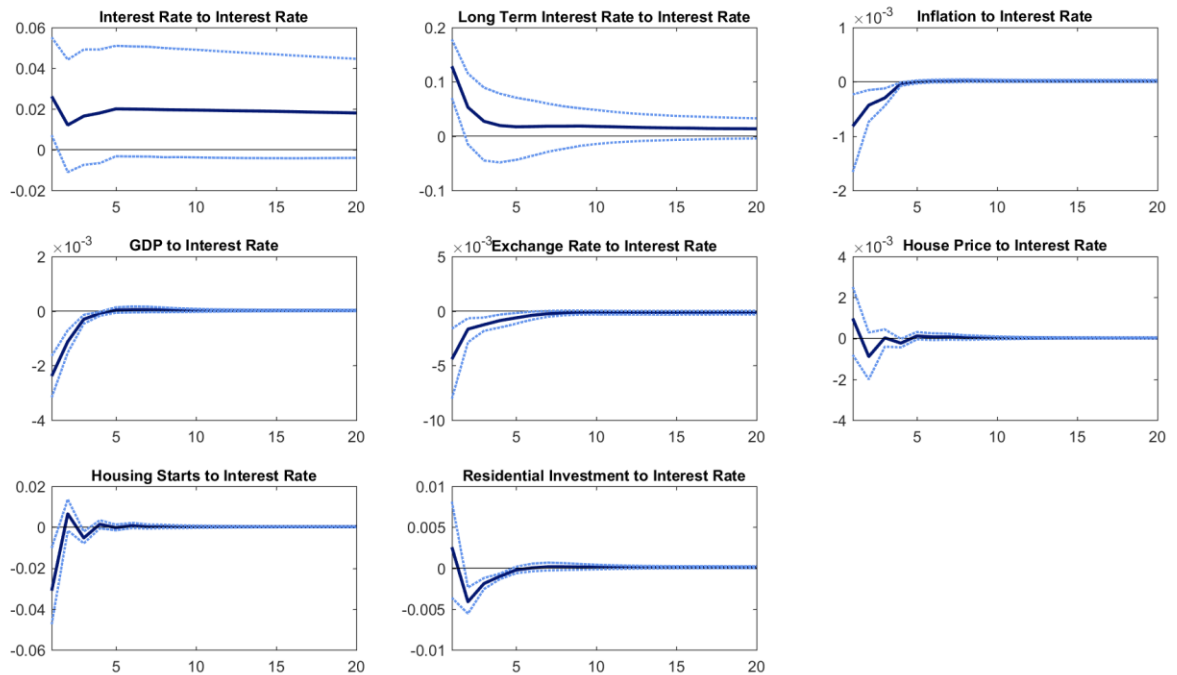


Figure 6 Impulse response function of a positive interest rate shock with sign restrictions imposed for 4 quarters. Error bands represent 16th and 84th percentile responses.