The House Rules: Housing Market Responses to Oil Price Shocks in Canada

By Thoby Cameron
8739706

Major Paper presented to the Department of Economics of the University of Ottawa in partial fulfillment of the requirements of the M.A. Degree

Supervisor: Professor Francesca Rondina
ECO 6999

Ottawa, Ontario
April 2018

Abstract
This paper estimates the response of house price indices in metropolitan areas across Canada to international oil price shocks. This is done to provide insight into differences in the relative responses of housing markets in Canada — particularly between those in oil-producing regions and those in regions less economically dependent on oil production. International oil price shocks are estimated at the international level as per Kilian (2009), and the respective housing market responses are computed with Jordà (2005)'s local projection method. Results support the notion that regions respond heterogeneously to oil price shocks. There is also some indication that responses vary based on whether the oil price shock is induced by a shock to the global supply of oil, global demand for commodities, or the precautionary demand for oil.

I sincerely thank my supervisor, Professor Francesca Rondina, who was incredibly patient, thorough, supportive, responsive, and insightful throughout the process of writing this paper; in addition, I am extremely grateful to my colleagues and Director, Nick Macaluso, at Environment and Climate Change Canada who have been exceedingly patient, flexible, and supportive.

I. Introduction

Canada is the second largest country in the world by area, and possesses significant geographical heterogeneity in its distribution of energy resources. I hypothesize that local economies respond to changes in international energy markets depending on the size of their energy sector. Accordingly, I investigate the differences in housing market responses to international oil shocks in metropolitan regions across Canada. First, international structural oil shocks are identified using a recursive Structural Vector Autoregressive (SVAR) model, as per Kilian (2009). Second, responses to these shocks are estimated at the national level using a local projection method outlined in Jordà (2005). Finally, this framework is extended to metropolitan-level house price data across Canada. This analysis departs from existing literature concerning national macroeconomic impacts in response to international oil market shocks by focusing on regional house-price data in Canada, one of the world's largest exporters of energy products. Additionally, it employs the local projection method of estimating impulse response functions, allowing for more flexibility in responses across horizons.

Much of Canada's occidental economic history was driven by the exploitation of its natural resources. Early traders took advantage of its stock of wildlife for exportation of furs back to Europe (Innis, 1999). Since, Canada has remained dependent on natural resources as a pillar of its economy; in 2017, natural resource sectors accounted for about 16 percent of its GDP, a statistic uncommon in many developed, advanced economies. Of this sixteen percent, six and a half alone come from energy (Natural Resources Canada, 2017*b*), making Canada, in 2017, the fifth largest producer of crude oil in the world (Natural Resources Canada, 2017*a*). Meanwhile in 2016, Canada had the tenth largest GDP in the world (World Bank, 2016). The prominent role of energy products in Canada's economy has even lead some researchers to question whether Canada suffers from Dutch Disease (Beine, Bos and Coulombe, 2012).[2]

This does not paint an accurate picture, however, of the heterogenous nature of the economic significance of the energy sector region-by-region in Canada: it is the second largest country by area in the world, but many areas have no direct participation in the production of oil or energy products. In 2016, 79.6 percent of all of Canada's oil was produced in Alberta (Natural Resources Canada, 2016), where about 12 percent of the population lives (Statistics Canada, 2017*a*). It is highly likely, then, that changes in the price of oil at the international level would likely produce effects across many sectors of Canada's economy; additionally, it is likely that these effects vary by region. My analysis focuses on the regional, and potentially different, effects of oil price shocks on housing markets in Canada.

II. Literature Review

A. On the role of oil price shocks on macroeconomies

Oil plays a prominent role in public discussion surrounding the macroeconomy, which has led to a great deal of research on the effect that oil price increases and decreases have on economic indicators. Hamilton (1983) remarks that nearly every recession in the post-war period in America has been preceded by a dramatic surge in oil prices. After establishing that the relationship between these events is more than a purely statistical coincidence, Hamilton addresses the possibility that

[2] The phenomenon in which a country's currency value moves in tandem with the price of one or more commodities.

both recessions and oil prices increases could be dually caused by other explanatory variables. In a series of Granger causality tests, he concludes that no salient macroeconomic variables[3] could be responsible for both an increase in oil prices and a U.S. recession three to four years later. Hooker (1996) points to this study, along with a number of others (see Burbidge and Harrison, 1984, Hamilton, 1985, and Gisser and Goodwin, 1986) that support the notion that oil prices were exogenous to the U.S. economy. He goes on to state that this led to a body of research that treated oil price variations as exogenous (or, more specifically, predetermined) to the macroeconomy, or to be used as instrumental variables in an attempt to peel out endogeneity issues in other macroeconomic relationships (see Hall, 1991 or Ramey, 1991, for example).

Hooker (1996) finds that oil prices no longer Granger cause variation in macroeconomic variables, and that accounting for structural breaks in the 1970s reduces the predictive power of oil prices on macroeconomic variables. Hamilton (2003) explains that this is largely due to the fact that before 1973, the Texas Railroad Commission (TRC) regulated supply of domestic oil production in the U.S. such that it would meet demand. Thus, oil price price variation came almost exclusively from foreign supply disruptions. After 1973, however, when Middle East oil producers began to dominate the international oil market, the TRC was no longer able to effectively control domestic supply, and as a consequence the strictly exogenous nature of oil price movements no longer held (ibid.). Instead of using oil price movements as an instrument to identify exogenous variation in U.S. macroeconomic variables, Hamilton (2003) identifies exogenous oil price shocks (as opposed to simply analyzing the movement in oil prices) through foreign military conflicts that led to supply short falls. This kind of oil price shock, as Kilian (2009) points out, only captures the exogenous movement in oil prices when it is caused by changes in the supply of oil.

This point motivates my method of first estimating oil price shocks based on what is driving them. The reasoning is as follows: since global supply and demand of oil drive variations in its price, any research pertaining to the effects of oil price shocks first requires the source of the shock to be cleanly identified. Generally, increased economic activity (and as a consequence, demand for oil) drives up oil prices, while discoveries and innovations related to supply dampen them. To establish how house prices respond to oil price changes first requires identifying what is driving them. Oil price changes caused by different macroeconomic developments — such as the increased supply, increased demand, or as will be discussed briefly, increased precautionary demand — could foreseeably elicit different responses over time in Canadian house prices.

In 2009, Lutz Kilian proposed a method to resolve the issue of endogeneity, separating oil price shocks from the movement in the demand and supply of oil (Kilian, 2009). His method decomposes the real price of oil into three components: the global supply of crude oil shocks, world aggregate demand shocks, and precautionary oil-specific demand shocks. Each shock is found to evoke a different response in the price of oil. In practice, three variables are included in a recursively identified SVAR model: world oil production, aggregate economic activity (a measure for the global demand for commodities),[4] and crude oil acquisition costs (a proxy for the price of oil faced by the American economy) Such a structure implies that, in any given period, oil price can be affected by oil production and economic activity, but not the converse. Oil supply is entirely inelastic to all other variables contemporaneously, as it cannot adjust to changes in demand. This approach is able to isolate the shocks in oil price that are distinct from the global demand for commodities and oil supply disruptions, which can be interpreted as the precautionary demand for oil. Kilian's

[3]These are a series of macroeconomic variables outlined in Sims (1980)'s seminal paper: real GNP, unemployment, price level, wages, money, and import price.

[4]This paper, Kilian (2009), also introduces a measure for real economic activity (REA) derived from dry cargo single voyage ocean freight rates, which continues to be updated and is publicly available on Kilian's website (Kilian, 2000-2017).

results suggest that, between 1975 and 2007, oil prices changes have been driven primarily by aggregate demand and the precautionary demand of oil. Orthogonalized shocks are then imported to a national-level analysis on the economy of the U.S. Results suggest that differentiating between oil price shocks is important for the U.S. economy. While oil price shocks stemming from the demand for commodities and those stemming from oil-specific precautionary demand shocks both elicit negative responses in GDP, the former initially raises output before falling. Kilian's work departs from that of Hamilton (1983), Hooker (1996), and Hamilton (2003) as it not only addresses the issue of the endogeneity of oil prices, but captures the behavioural component in oil demand and compares it with shocks stemming from supply of oil and demand for commodities.

This method has since become ubiquitous in the discussion surrounding the identification or estimation of oil price shocks (see Apergis and Miller (2009), Bodenstein, Erceg and Guerrieri (2011), Hamilton (2011), or Baumeister and Peersman (2013), for example). My estimation process orthogonalizes oil price movements internationally in a similar manner in an attempt to identify how Canadian house prices are affected by oil price shocks.

As a final note, it is worthwhile mentioning that much of the research that studies the effects of oil price shocks on macroeconomic variables focuses on countries that are net oil importers. However, unlike oil importers, Canada could exhibit expansionary reactions to oil price shocks. Canada and Norway share a peculiar position among advanced economies, which normally are largely dependent on foreign oil production, and thus oil price shocks represent, almost exclusively, increased production and transportation costs. Norway and Canada, however, are both net oil exporters. Bjørnland (2009), for example, finds that increased transportation and production costs brought on by higher oil prices are likely accompanied by positive income shocks, demonstrating that stock returns in oil rich Norway respond positively to price shocks.

B. On the impacts of shocks on Canadian housing markets

There has been significant public attention devoted to Canada's rising real-estate prices, especially in large urban centres like Vancouver and Toronto, and especially because — unlike most similarly developed countries — Canada's housing market has not experienced any substantial downturn since the financial crisis of 2009.

There is not a large literature detailing the response of house prices in Canada in the wake of macroeconomic shocks. Most relevant to the present analysis, Allen et al. (2009) point out that national-level responses to macroeconomic shocks are not necessarily indicative of regional-level development in Canada; house prices of cities across Canada are only weakly related to each other in the long run. This suggests that housing markets in Canada develop heterogeneously over time. It is possible, then, that aggregated country-level analysis of the response of Canadian house prices in the wake of innovations to explanatory variables does not depict accurately underlying relationships. This notion motivates the regional aspect of my analysis. Some regional economies in Canada, such as Alberta or Newfoundland, rely heavily on oil extraction and production, but their unique responses would likely be drowned out by much larger markets such as Toronto, Montréal, or Vancouver. Conversely, it is possible that areas with little to no oil activity and relatively lower wages that neighbour oil producing regions (Winnipeg, for example) could exhibit negative responses if there is sufficient employment-induced emigration to reduce housing demand.

More recently, Killins, Egly and Escobari (2017), develop a similar recursive model structure to

Kilian (2009) and extend it to include (separately) both Canadian and U.S. house price indices. They also control for other macroeconomic channels through which oil price could affect housing prices, dynamic feedback effects, and the housing cycle. They find that oil-specific demand shocks (orthogonalized oil price shocks[5]) are the only shocks that elicit statistically significant impacts in either country. The response in housing price growth in both countries is positive, but larger in Canada. My analysis departs from this analysis in two ways: first my sample period is more recent; I use the local projection method to compute impulse response functions instead of including all variables in a single SVAR structure; and finally, I analyze the individual responses of metropolitan housing markets in Canada, consistent with Allen et al. (2009)'s finding that city-level housing markets in Canada do not necessarily evolve in tandem with one another.

In a recent contribution, Kilian and Zhou (2018) use oil price shocks as a means to identify heterogenous income shocks across urban areas in Canada, taking advantage of the fact that regions with large oil production sectors will be disproportionately affected. Through a SVAR model including six variables;[6] using recursive identification, it is shown that at the national level, Canada's house price index responds positively to oil price shocks. Analysis relies exclusively on Canadian data, treating Canada as a small open economy and oil price changes in Canada as predetermined. While their paper's subject matter is closely related to mine, their main goal is to identify the channels through which positive income shocks in one region of Canada might spread to another; mine is to explicitly analyze the effects of internationally identified oil shocks on local housing markets. Their results and analysis, however, do underline some key avenues through which the effect of oil price shocks might spread from one region to another: the empirical panel estimation suggests that inter-provincial trade and redistribution payments across provinces increase the demand for housing even where oil production is not present.

C. My research focus

Kilian (2009) has presented a method to orthogonalize oil price shocks, separating components that are due to global oil production, global demand, and oil-specific precautionary demand. As we have seen, this has been applied to multiple macroeconomic contexts, including the Canadian real estate market at a national level (Killins, Egly and Escobari (2017)). On the other hand, Kilian and Zhou (2018) recently analyze the effects of oil price shocks across regions in Canada, but employ a different estimation strategy which does not differentiate between the source of oil price shocks. To the best of my knowledge, there is no analysis of oil price shocks stemming from global oil production, global demand, and oil-specific precautionary demand on Canadian housing markets at a regional or metropolitan level.

III. Data

I make use of data at both the international level and the Canadian level. International data consists of Kilian's measure of real economic activity (a measure of global economic activity), available on his personal website (Kilian, 2000-2017),[7] and global oil production data as reported by the U.S. Energy Information Administration (2000-2017).[8] At the Canadian level, I collect house price

[5]Their measure for oil price is the West Texas Intermediate.

[6]$y_t = (\Delta rpoil_t, \Delta emp_t, \Delta p_t, \Delta rph_t, int_t)$ the Western Canada Select oil price, employment, CPI inflation, real housing price index, and the 5-year fixed rate mortgage rate respectively.

[7]Please see: http://www-personal.umich.edu/ lkilian/paperlinks.html.

[8]Please see series 3a of the standard tables: https://www.eia.gov/outlooks/steo/.

index data from Teranet and National Bank of Canada (2000-2017) and oil price data (Western Canada Seleect) from the Canadian Association of Petroleum Producers (2000-2017). All Canadian data is deflated with seasonally adjusted CPI's from Statistics Canada CANSIM table 326-0022 (Statistics Canada, 2000-2017*b*). Additionally, all data has been seasonally adjusted.

The timeframe of analysis spans from January 2000 to December 2017, resulting in 216 data points. The availability of data is limited by the house price index, which is available beginning in 1999 (Teranet and National Bank of Canada, 2000-2017). This house price index tracks the growth in sales of individual properties; newly sold properties do not enter the index as at least two transactions need to occur. For periods in which a particular property was not sold, contemporary growth is imputed from growth in that period of other properties. In order to ensure the index represents growing house prices and not improvements in a particular home, exclusions are made when a property undergoes extensive retrofitting and upgrading. House price indices are available across eleven metropolitan areas in Canada (Victoria, Vancouver, Calgary, Edmonton, Winnipeg, Hamilton, Toronto, Ottawa, Montréal, Québec City, and Halifax). In addition to the house price index, Teranet also provides the count of properties that went into producing the index in any given period. Finally, two aggregate measures of house price are included: C11, a composite of all metropolitan areas; and C6, a composite of the aforementioned eleven metropolitan areas with the exception of Victoria, Edmonton, Winnipeg, Hamilton, and Québec City. Figure A1 in the Appendix outlines the evolution of a hand-full of these markets over the selected time period.
Inspection of Figure A1 reveals that heterogeneity exists in the development of these markets: not only are some chronically stronger than others, there are also movements which reflect international events that appear to have affected Canadian housing markets differently. First, the effect of the financial crisis is clearly visible just before 2010. Nearly all markets contract with the exception of Québec City. More recently, we can see the fork in the initially bullish trend of Calgary from Vancouver in Toronto in about 2016 and continuing thereafter.

Data used to estimate the international oil shocks is largely the same as outlined in Kilian (2009); instead of using West Texas Intermediate as a measure of oil price, I use the Canadian-specific measure, the Western Canada Select (WCS). WCS is an oil blend (technically a Dilbit stream) and a benchmark crude produced exclusively in Western Canada. It is a heavier and more sour crude than the American standard, the West Texas Intermediate (WTI) (Oil Sands Magazine, 2017). This price is more representative of the price faced by Canadian producers, and thus the Canadian economy, than the WTI. Figure A documents the path of the price of Western Canada Select oil prices; the data reflects some of the international phenomena related to oil price. Most recently (late 2015 and on), the substantial drop in the price per barrel to its lowest point since the beginning of the millennium is immediately visible. Even more drastic than this decline, however, is the immense drop in the price of oil in at the time of the financial crisis of 2009.

I use oil production in millions of barrels per day collected from the U.S. Energy Information Administration (2000-2017). Data is expressed in annualized percentage change in millions of barrels produced per day. As a measure for real economic activity world-wide, I use Kilian's indicator available directly from his website (Kilian, 2000-2017). The series is derived from single-voyage freight rates published from Drewry Shipping Ltd., which in turn is based on bulk, dry cargo. While there is some discussion about what constitutes the best stand-in for industrial production, especially on a global scale (see Ravazzolo and Vespignani, 2015, for example), I choose to use the aforementioned for continuity with Kilian (2009).

IV. Framework

A. International Shocks

I estimate international oil shocks as per Kilian (2009): an international VAR model (see Equation 1) is estimated and identified recursively to produce structural oil shocks ϵ_t, where $\epsilon_t = C^{-1}u_t$ and $C^{'}C = \Omega = CE(\epsilon_t\epsilon_t^{'})C^{'}$. The recursive nature of identification of structural shocks assumes that WCS oil price can be affected contemporaneously by real economic activity and global oil production, while WCS oil price can have a contemporaneous effect on neither of these variables. This is reasonable first because we anticipate neither oil production nor aggregate global economic activity to be able to respond meaningfully to oil price movements within the same month. Second, we want the Canadian measure of oil price to be represented as exogenously as possible in this model. By explicitly including international variables such as economic activity and oil production in the model, we are effectively allowing for the possibility that either of these variables could also be affecting house prices through a channel that is not oil price. For example, if oil prices rise with increased international demand (and as a result, demand for commodities), then simply analyzing the effect of oil price movements on Canadian house prices might result in biased estimates of the effect of oil prices on house prices, which could be increasing partially due to higher global demand and partially due to higher oil prices.

The use of Western Canada Select as an oil price measure implies that its respective identified shocks measure the change in oil prices faced by Canadians that is unexplained by oil production and economic activity at the global level.[9] WCS is preferable to a foreign measure of oil price because, while the price of Canadian oil moves in tandem with global prices, subtle timing differences are more representative of what Canadian producers and households would face in a given month.

$$\begin{bmatrix} OilProd_t \\ REA_t \\ WCS_t \end{bmatrix} = y_t = \gamma + B_1 y_{t-1} + B_2 y_{t-2} + \ldots + B_p y_{t-p} + u_t \tag{1}$$

B. Applying shocks to Canadian house prices

To evaluate the effects of international oil shocks on the Canadian economy, I import the ϵ_t values implied from Equation 1 into a local projection frame work, as per Jordà (2005). This allows me to obtain the impulse responses of house prices in various Canadian regions given a shock in international oil variabes. Jordà (2005) points out that local projections should be more robust to misspecification given that each impulse response is estimated separately, allowing for flexibility across horizons. This is because impulse responses are traditionally computed by pushing forward a given shock across time through estimated coefficients; a moving average representation of this process suggests that any biases that are a result of misspecification will be magnified as the horizon increases due to non-linearities in the data generating process (Ronayne et al., 2011).[10] Local projections instead estimate new coefficients for every step forward, and thus, while not circumventing a potential bias present in estimated coefficients altogether, mitigate compounding it by increasing orders as the horizon extends.

[9]Kilian (2009) refers to these shocks as oil-specific precautionary demand shocks.

[10]Generally, the result of a shock in period t on response variables in period $t+s$ is reflected in the relationship $\Delta y_{t+s} = (B_1^s + B_2^{s-1} + \ldots + B_{s-1}^2 + B_s)C^{-1}\Delta\epsilon_t$ thus if there is a bias present in any B, it is straight forward to see to what extent this bias will be magnified when extrapolated forward.

In practice, when computing s responses, I estimate s distinct models. Equation 2 reflects the local projection model in the context of the present analysis. The matrix of coefficients, M_1^{s+1}, can be interpreted as the matrix of "reduced form" responses in horizon s. I assume that structural shocks, ϵ_t, are exogenous to this system, and as a consequence that housing price responses in each reduced-form local projection can be interpreted as structural. A more detailed discussion of this specification can be found in the robustness and sensitivity analysis section.

$$HP_{t+s} = \alpha^s + \Gamma^s \epsilon_t + M_1^{s+1} HP_{t-1} + \ldots + M_p^{s+1} HP_{t-p} + v_{t+s}^s \quad (2)$$

At each horizon, s, p is set to 12. In order to investigate the heterogeneity of responses to oil price shocks, I extend the analysis specified above across a selection of representative metropolitan regions in Canada.

V. Results

A. *International oil price shocks*

Figure A3 depicts the structural shocks obtained from the point estimates of the parameters of the VAR in Equation 1 after recursive orthogonalization. The structural shocks associated with global economic activity appear to be greater in magnitude after 2009 than before, suggesting that the global economy was less predictable after the financial crisis than before (this is unsurprising given that the period directly proceeding the financial crisis of 2009 was referred to as the "Great Moderation" (Bernanke, 2004). On the other hand, structural shocks to world oil production appear to be, on average, smaller in magnitude after 2010. Finally, shocks to the WCS oil price are similar in magnitude throughout, though perhaps slightly less frequent after 2010.

Impulse response functions resulting from a recursive identification of the three variable VAR model, equation Equation 1, are outlined in Figure A4. These responses support the intuition behind the ordering, and the results are qualitatively similar to those reported in Kilian (2009): an innovation in oil production yields a response in the opposite direction in the price of oil (the top-right panel); an innovation in real economic activity produces an initial increase (ranging between roughly three to five percent) in oil price (the middle-right panel); while an innovation in the oil-specific precautionary demand yields the most substantial increase in the price of oil (the bottom-right panel). Figure A5 shows the forecast error variance decomposition of each of these shocks. The bottom panel reveals first, that shocks to the global demand for commodities play a larger role in explaining the forecast error variance of WCS price than shocks to the global supply of oil. Second, that the relative importance in the role that demand shocks play in explaining the WCS oil price forecast error variance increases over time, reaching maximum after about 12 months. This is largely consistent with Kilian (2009), who reports that oil price shocks are driven by oil-specific precautionary demand shocks and aggregate demand shocks.

The impulse response functions resulting from the local projection method outlined in equation Equation 2 can be found in the Appendix. I bootstrap all local projection impulse response functions using a block bootstrap with a fixed length equal to the maximum number of lags and horizons forward, similarly to Kilian and Kim (2011). All variables representing growth rates have been annualized, and all responses represent the percentage reaction to a positive one standard deviation shock to a given international variable.

B. Disentangling oil price shocks

Why is disentangling oil price shocks important when analyzing the effect of oil price shocks on Canadian macroeconomic aggregates? Kilian states that "Implicit in this approach [of simply analyzing exogenous oil price changes] is a thought experiment, in which one varies the price of oil, while holding all other variables constant.", and goes on to underline that this may be flawed by construction due to reverse causality (Kilian, 2009, page 1053). Hamilton (2003) points to Barsky and Kilian (2001)'s findings, mentioning that oil prices can be statistically predicted by the U.S. macroeconomy. This is because the economy in the U.S. is large enough to influence international demand for oil. Canada's economy, on the other hand, is roughly a factor of ten times smaller than that of the U.S., and as such, is often treated as a small open economy in models, unable to affect international prices. In the context of oil prices, such an assumption could be invalid. Consider the fact that Canada is the fifth largest crude oil producer in the world, and exports roughly 75 percent of its production.[11] Fluctuations in Canadian oil supply, then, could contribute to the those of global oil production, and to some degree affect international oil prices. In such an environment, it would no longer be reasonable to assume that international oil prices are exogenous to the Canadian economy. By accounting for changes in world oil production in the identification of oil price shocks, I can rule out the possibility of supply-related endogeneity in other measures of oil price shocks, induced by aggregate demand and precautionary demand for oil.

Additionally, any analysis that simply estimates the effect oil price changes have on a macroeconomic variable implicitly estimates the effect of an aggregate shock, a weighted average of several structural shocks. These shocks — oil supply shocks, oil-specific precautionary demand shocks, and aggregate demand for commodity shocks — could induce responses in a variable of interest that move in different directions or evolve differently over time. As a result, the estimate of an aggregate shock would not capture the heterogenous effects of individual structural shocks. Disentangling oil price shocks into structural shocks allows me to explore whether they induce responses in house prices that move in different directions, and to see to what extent they vary over response horizons.

Consider, for example, the effect of an oil price shock induced by the aggregate demand for commodities versus that of precautionary demand. If we believe the expansionary effect of a positive shock to the global demand for commodities to dominate the negative income effect of increased commodity prices on a global scale, then such a shock could increase foreign demand for real estate in Canada (if investors abroad demand more foreign assets). If so, there is no obvious reason why international investors would prefer buying property in oil-rich regions. On the other hand, a shock to the WCS-specific precautionary demand would only increase demand for Canadian housing domestically (as it would correspond with a negative income shock with most advanced economies, who use imported oil as an input to production), and most likely in regions with oil producing sectors. To this extent, the relative difference in responses to international demand shocks and precautionary demand shocks could vary by region, as it is plausible to think that Calgary house prices, for example, might exhibit similar responses as the rest of Canada given a global demand shock, but different responses given a precautionary demand shock. Allowing WCS-precautionary demand shocks and aggregate demand shocks to have a unique effect on each metropolitan region allows me to address this possibility.

[11] See www.nrcan.gc.ca/energy/oil-sands/18086.

C. The aggregate Canadian market

How are Canadian real estate markets affected by the identified oil shocks? Figure A documents responses to these shocks at the Canadian level. The left-most panel reveals that a positive oil production shock does not deliver any significant effect to house prices. It is possible that this is because lower oil prices associated with greater supply globally yield a negative impact to Canada's oil sectors, and a positive impact to households and producers that use oil as an input; as a result, the net income effect (assumed to drive the demand for housing) is unclear. Equally, it is possible that the impact is simply not substantial on either side. A shock to the global demand for commodities yields a significant effect on the composite real estate index after 3 months, but becomes negative and insignificant thereafter. Kilian states that this response agrees with the intuition that, initially, the "...stimulating effect of higher global demand" (Kilian, 2009, page 1066) dominates the corresponding increase in commodity prices, but as time progresses the effect ends and higher commodity prices produce a contractionary response. A positive one percent shock to the WCS price, outlined in the right-most panel, significantly increases aggregate Canadian house prices in the first five periods, but becomes significantly negative over the next ten months before becoming roughly zero. It is unclear what is driving the lagged negative effect, which is observed neither in Killins, Egly and Escobari (2017) nor Kilian and Zhou (2018), whose respective analyses both suggest strictly positive responses to oil price shocks. These studies use four and six lags respectively. The former uses a different measure of oil price (the West Texas Intermediate or WTI), as well as a different span of years (1992 to 2015 versus 2000 to 2017 in the present analysis). Both level values and the variation of oil prices are strikingly different in the 1990s relative to directly after. Oil prices were in the range of two to four times lower than subsequent decades, and displayed essentially no volatility over the course of the 90s.[12] Such differences in the raw data that span a large number of periods could lead to substantial differences in the estimated parameters. Kilian and Zhou (2018), on the other hand, analyze the effect of an oil price shock that is roughly equivalent to a weighted average of the three structural shocks that I estimate, and includes a suite of controls.[13]

D. Regional housing markets

Figure A7 displays the results for the Toronto housing market, which are qualitatively very similar to those of aggregate Canadian market. The magnitude of responses to all three types of oil shocks is larger. A WCS-specific precautionary demand shock in the right-most panel, for example, elicits the same significant initial increase in house prices, followed by a larger, negative significant drop before levelling off to roughly zero after about 15 months. This same pattern in response to a precautionary demand shock is also exhibited in Figure A12, the responses in the Vancouver housing market, suggesting that the responses of the aggregate Canadian market, particularly to a precautionary demand shock, are being driven by Vancouver and Toronto markets. This is a reasonable conclusion since Table A1 demonstrates that together, Toronto and Vancouver make up about 50 percent of the house sales across all periods. Furthermore, these two regions are two of the most expensive in the country; and as Figure A1 indicates, the C11 composite moves in tandem with and between these two cities.

[12]See, for example, the evolution of the WTI (the oil price measure used in their analysis): https://fred.stlouisfed.org/series/DCOILWTICO.

[13]Western Canada Select oil price, employment, CPI inflation, real housing price index, and the 5-year fixed rate mortgage rate.

Responses of particular interest are those within oil-rich areas. I posited that there could be regional heterogeneity in the responses of house prices to oil price shocks. The main results support this notion: there appears to be response heterogeneity between Calgary and other metropolitan regions, particularly in the face of a precautionary demand shock. The response, in the right-most panel, becomes significant after five months, and reaches a maximum roughly twice as large as that of Toronto. As the response evolves over time, there is a short duration in which the response is negative (about three months), after which point the response once again becomes positive, although insignificant. This result suggests that the cyclical nature present in the responses to WCS-specific precautionary demand shocks of Toronto, Vancouver, and the aggregate composite are less present in Calgary. This result, however, is paralleled by the fact that responses of Calgary house prices are largely insignificant, so it would be unwise to infer too much from this result. Edmonton, the only other city in our data that is closely linked to oil production, does not respond similarly to Calgary across all shocks: the response remains insignificant throughout the response horizon and vacillates about zero. It does not, however, exhibit the same negative response to a WCS-specific precautionary demand shock as Vancouver, Toronto, and the aggregate measure.

Furthermore, I outlined the possibility that responses to aggregate demand could be similar across regions, but responses to precautionary demand shocks could vary by region. It would be unwarranted to infer too much from the responses to aggregate global demand for commodity shocks as responses are largely insignificant. To the extent that there is some variation in responses, it suggests that Calgary house prices respond more to aggregate demand shocks for commodities, with a magnitude of roughly one percent for the first few months. This result is initially significant, but after roughly three months loses significance.

Results from Montréal, outlined in Figure A9 are largely ambiguous. Given a positive shock to global oil production (resulting in downward pressure on the price of oil), there is a significant negative response in house price after six months (outlined in the left-most panel). The magnitude, however, is small, and all other months in the impulse response function are insignificant. The responses given a global demand shock or WCS-precautionary demand shock are largely the same, with no significant, discernible effect.

Housing markets in Halifax and Québec City (Figure A10 and Figure A11 respectively) display similar responses in that they are largely insignificant and vacillate about zero. One of the only noteworthy differences between the estimates is the response to a global demand shock (in the middle panel), which is initially negative in Québec City but positive in Halifax. Responses in Vancouver given global supply and demand shocks are essentially insignificant. The response in the wake of a WCS-specific precautionary demand shock closely follows, as previously stated, the national aggregate and Toronto.

The results can be summarized as follows: first, there is response heterogeneity in house prices in the wake of oil price shocks across Canada, consistent with Kilian and Zhou (2018). Second, aggregate responses seem to be driven largely by Toronto and Vancouver, which is consistent with their total value share of sales in Canada. Third, responses from smaller metropolitan areas are largely insignificant and I am cautious to infer anything from these ambiguous results. Finally, the heterogeneity of the WCS-specific precautionary shocks across regions suggests that accounting for the differences in the three types of oil price shocks as per Kilian (2009) could be important in identifying regional responses in housing markets, as WCS-specific precautionary demand shocks seem to increase house prices more in Calgary relative to other regions, while oil price increases due to global demand shocks are more ambiguous.

VI. Robustness and sensitivity analysis

Analysis thus far has made no distinction between the channels through which estimated structural shocks could affect house prices. The effect of oil price shocks could be passed on to housing markets vis-à-vis macroeconomic variables that affect national and regional house prices (Killins, Egly and Escobari, 2017). As a departure from my initial analysis, I explore two new possible channels through which these shocks could be transmitted by introducing a control block, X, into the local projection model outlined in Equation 2.

$$HP_{t+s} = \alpha^s + \Gamma^s \epsilon_t + X M_1^{s+1} HP_{t-1} + \ldots + M_p^{s+1} HP_{t-p} + C(L)^s X_t + v_{t+s}^s \tag{3}$$

Interprovincial migration, employment, wage growth, and exchange rates are just some examples of channels through which oil price shocks could elicit changes in house prices. I explore two of these channels: the unemployment rate and the exchange rate between the U.S. and Canada. Accordingly, X is first filled with the growth rate of unemployment of the province in which the responses to oil price shocks are estimated. If an oil price shock decreases (increases) unemployment in a region, this could increase (decrease) the demand for housing. Changes in the responses of house prices after the inclusion of this variable would suggest that employment is an important channel through which oil price shocks are transmitted to house prices.

Next, I introduce the growth of the exchange rate between Canada and the U.S. Koh (2017) highlights that, in the face of an oil price shock, there is an important relationship between the response of output and exchange rates in oil exporting countries, as countries with flexible exchange rates exhibit smaller decreases in output and government consumption given an oil price decrease. Zhao and Shi (2017) underline the likely positive relationship between the strength of the Canadian Dollar and oil prices. In the context of the present analysis, if oil prices increase sufficiently to raise the value of the Canadian Dollar, Canadians could initially experience an increase in income relative to the rest of the world. While the specifics of how such a response would unravel across the economy is beyond the scope of the present analysis, I account for the possibility that it could play an important role in the relationship between Canadian house prices and oil price shocks.

For the final sensitivity test, I include both of the above controls in the block X. Results of all the aforementioned configurations of block X are displayed in Figure A14 through Figure A17. I reestimate the responses for a suite of representative regions: Canada, Toronto, Calgary, and Montréal, which are outlined in Figure A14 through Figure A17. None of the results are substantially affected by the inclusion of any of the configurations of block X, suggesting that in the context of my analysis, the channel through which house prices are related to oil price shocks are affected neither by employment nor the value of Canadian Dollar relative to that of the U.S. This is consistent with Killins, Egly and Escobari (2017), who find that their main results are robust to the inclusion of measures of unemployment, the Bank of Canada Bank Rate, industrial production, and the U.S./Canada exchange rate. Kilian and Zhou (2018) also include a specification of their national model accounting for exchange rates but find their results unchanged in spite of this.

VII. Conclusion

I estimate the impact of orthogonalized oil price shocks on Canada house prices, both at the national level and in a selection of representative metropolitan areas. These estimates capture the distinct nature of oil price shocks brought on by supply disruptions internationally, global demand for commodities, and oil specific precautionary demand shocks. Results at the international level are qualitatively consistent with Kilian (2009), who finds that oil price shocks are driven primarily by shocks to the global demand for commodities and oil-specific demand shocks. At the national level, I explored the possibility that the price of houses in metropolitan areas respond differently to oil price shocks based on the regional importance of the oil sector. I also addressed the possibility that these responses vary based on the source of the oil price. Results suggest that the national response to housing price shocks are being driven largely by the housing markets in Toronto and Vancouver. Additionally, that Calgary, the financial hub of Canada's largest oil producing region, exhibits the most pronounced response to a one percent positive oil-specific precautionary demand shock: a positive and significant (at the 95 percent confidence level) effect of roughly two percent annualized increase in house price growth. The responses of Montréal and smaller metropolitan regions are largely ambiguous and insignificant. While Kilian and Zhou (2018) find similar heterogeneity in their results, they find more unambiguously positive responses to oil price shocks. This could be due to the fact that oil price variations are globally treated as predetermined to the Canadian economy, and thus there is no differentiation in the source of oil price shocks. Further research would explore this possibility, and an attempt to identify the cause of the lagged negative impact of a oil-specific precautionary demand shock on aggregate Canadian house prices.

REFERENCES

Allen, Jason, Robert Amano, David P Byrne, and Allan W Gregory. 2009. "Canadian city housing prices and urban market segmentation." *Canadian Journal of Economics/Revue canadienne d'économique*, 42(3): 1132–1149.

Apergis, Nicholas, and Stephen M Miller. 2009. "Do structural oil-market shocks affect stock prices?" *Energy Economics*, 31(4): 569–575.

Barsky, Robert B, and Lutz Kilian. 2001. "Do we really know that oil caused the great stagflation? A monetary alternative." *NBER Macroeconomics annual*, 16: 137–183.

Baumeister, Christiane, and Gert Peersman. 2013. "Time-varying effects of oil supply shocks on the US economy." *American Economic Journal: Macroeconomics*, 5(4): 1–28.

Beine, Michel, Charles S Bos, and Serge Coulombe. 2012. "Does the Canadian economy suffer from Dutch disease?" *Resource and Energy Economics*, 34(4): 468–492.

Bernanke, Ben. 2004. "The great moderation." *Washington, DC.*

Bjørnland, Hilde C. 2009. "Oil price shocks and stock market booms in an oil exporting country." *Scottish Journal of Political Economy*, 56(2): 232–254.

Bodenstein, Martin, Christopher J Erceg, and Luca Guerrieri. 2011. "Oil shocks and external adjustment." *Journal of International Economics*, 83(2): 168–184.

Burbidge, John, and Alan Harrison. 1984. "Testing for the effects of oil-price rises using vector autoregressions." *International Economic Review*, 459–484.

Canadian Association of Petroleum Producers. 2000-2017. "5-04 Reference Crude Price and XR Datase: Western Canada Select at Hardisty." *https://www.capp.ca/publications-and-statistics/statistics/statistical-handbook*, [Online; accessed 2018/03/02].

Gisser, Micha, and Thomas H Goodwin. 1986. "Crude oil and the macroeconomy: Tests of some popular notions." *Journal of Money, Credit and Banking*, 18(1): 95–103.

Hall, Robert E. 1991. "Labor demand, labor supply, and employment volatility." *NBER macroeconomics annual*, 6: 17–47.

Hamilton, James D. 1983. "Oil and the macroeconomy since World War II." *Journal of political economy*, 91(2): 228–248.

Hamilton, James D. 1985. "Historical causes of postwar oil shocks and recessions." *The Energy Journal*, 6(1): 97–116.

Hamilton, James D. 2003. "What is an oil shock?" *Journal of econometrics*, 113(2): 363–398.

Hamilton, James D. 2011. "Historical oil shocks." National Bureau of Economic Research.

Hooker, Mark A. 1996. "What happened to the oil price-macroeconomy relationship?" *Journal of monetary Economics*, 38(2): 195–213.

Innis, Harold Adams. 1999. *The fur trade in Canada: An introduction to Canadian economic history.* University of Toronto Press.

Jordà, Òscar. 2005. "Estimation and inference of impulse responses by local projections." *American economic review*, 95(1): 161–182.

Kilian, Lutz. 2000-2017. "Updated version of the index of global real economic activity in industrial commodity markets." *http://www-personal.umich.edu/~lkilian/reaupdate.txt*, [Online; accessed 2018-01-04].

Kilian, Lutz. 2009. "Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market." *American Economic Review*, 99(3): 1053–69.

Kilian, Lutz, and Xiaoqing Zhou. 2018. "The Propagation of Regional Shocks in Housing Markets: Evidence from Oil Price Shocks in Canada." Unpublished manuscript.

Kilian, Lutz, and Yun Jung Kim. 2011. "How reliable are local projection estimators of impulse responses?" *Review of Economics and Statistics*, 93(4): 1460–1466.

Killins, Robert N, Peter V Egly, and Diego Escobari. 2017. "The impact of oil shocks on the housing market: Evidence from Canada and US." *Journal of Economics and Business*, 93: 15–28.

Koh, Wee Chian. 2017. "Oil price shocks and macroeconomic adjustments in oil-exporting countries." *International Economics and Economic Policy*, 14(2): 187–210.

Natural Resources Canada. 2016. "Crude oil facts." *http://www.nrcan.gc.ca/energy/facts/crude-oil/20064*, [Online; accessed 2018/03/07].

Natural Resources Canada. 2017*a*. "Crude Oil Industry Overview." *http://www.nrcan.gc.ca/energy/oil-sands/18078*, [Online; accessed 2018/03/07].

Natural Resources Canada. 2017*b*. "Key Facts and Figures on the Natural Resources Sector." *http://www.nrcan.gc.ca/publications/key-facts/16013*, [Online; accessed 2018/03/07].

Oil Sands Magazine. 2017. "Western Canadian Select Explained."

Ramey, Valerie A. 1991. "Nonconvex costs and the behavior of inventories." *Journal of Political Economy*, 99(2): 306–334.

Ravazzolo, Francesco, and Joaquin L Vespignani. 2015. "A new monthly indicator of global real economic activity."

Ronayne, David, et al. 2011. "Which impulse response function?" *Warwick Economic Research Papers*, , (971).

Sims, Christopher A. 1980. "Macroeconomics and reality." *Econometrica: Journal of the Econometric Society*, 1–48.

Statistics Canada. 2000-2017*b*. "Consumer Price Index (CPI), seasonally adjusted." *http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=3260022*, [Online; accessed 2018/03/17].

Statistics Canada. 2017*a*. "Canada at a Glance 2017." *https://www.statcan.gc.ca/pub/12-581-x/2017000/pop-eng.htm*, [Online; accessed 2018/03/11].

Teranet and National Bank of Canada. 2000-2017. "House Price Index." *http://housepriceindex.ca/*, [Online; accessed 2018/02/18].

U.S. Energy Information Administration. 2000-2017. "Total World Petroleum Production, Standard Tables 3a." *https://www.eia.gov/outlooks/steo/*, [Online; accessed 2018/01/13].

World Bank. 2016. "4.2 World Development Indicators: Structure of output." *http://wdi.worldbank.org/table/4.2#*, [Online; accessed 2018/04/28].

Zhao, Jing, and Savannah Wei Shi. 2017. "The impact of world oil price shocks on the Canada/US real exchange rate." *The International Trade Journal*, 1–20.

Appendix

Table A1—House Price Descriptive Statistics

Statistic	N	Mean	St. Dev.	Min	Max
C11	216	129.899	41.273	67.940	223.070
C11 Count	216	12,539.250	4,660.806	4,304	25,527
Victoria	216	121.595	36.369	60.640	199.120
Victoria Count	216	391.198	147.808	112	890
Vancouver	216	142.824	55.924	67.700	284.640
Vancouver Count	216	3,038.488	1,000.681	944	5,671
Calgary	216	138.711	40.057	71.250	188.350
Calgary Count	216	601.691	285.161	144	1,806
Edmonton	216	139.322	42.842	64.380	187.910
Edmonton count	216	810.765	269.959	117	1,520
Winnipeg	216	140.727	49.412	66.460	209.190
Winnipeg Count	216	658.350	297.061	220	1,513
Hamilton	216	123.378	39.549	70.190	237.510
Hamilton Count	216	426.369	263.854	42	1,135
Toronto	216	127.163	43.765	71.760	254.930
Toronto Count	216	2,965.705	1,989.594	230	8,272
Ottawa	216	115.747	25.929	65.470	153.370
Ottawa Count	216	644.447	468.806	57	2,069
Montreal	216	119.205	33.235	60.970	167.940
Montreal Count	216	2,382.037	1,466.783	851	7,494
Quebec	216	130.259	42.409	64.490	183.590
Quebec Count	216	455.641	378.978	107	1,938
Halifax	216	114.570	25.098	68.240	147.620
Halifax Count	216	164.562	83.221	15	378
C6	216	129.615	41.721	68.460	227.320
C6 Count	216	9,796.931	3,797.814	3,507	21,111

Table A2—Descriptive Statistics of Western Canada Select Oil Price

Statistic	N	Mean	St. Dev.	Min	Max
Deflated WCS	216	60.386	20.963	23.484	131.320

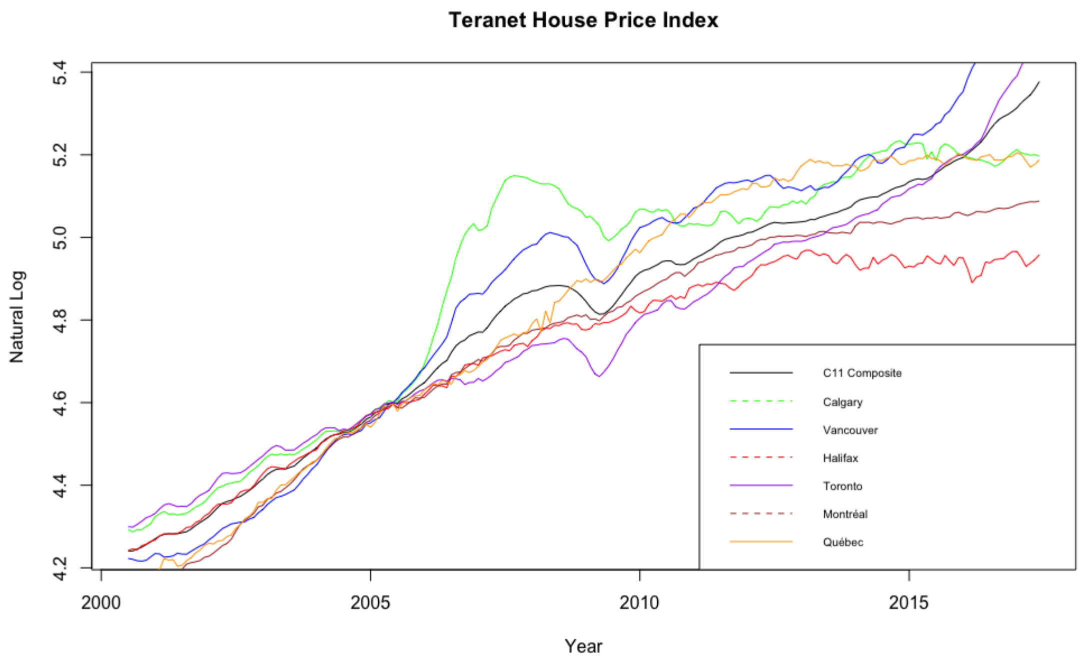

Figure A1. depicts the evolution the Teranet and National Bank housing price indices of six representative cities in addition to a national aggregate of 11 cities (Victoria, Vancouver, Calgary, Edmonton, Winnipeg, Hamilton, Toronto, Ottawa, Montréal, Québec City, and Halifax). The series has been transformed using the natural log function.

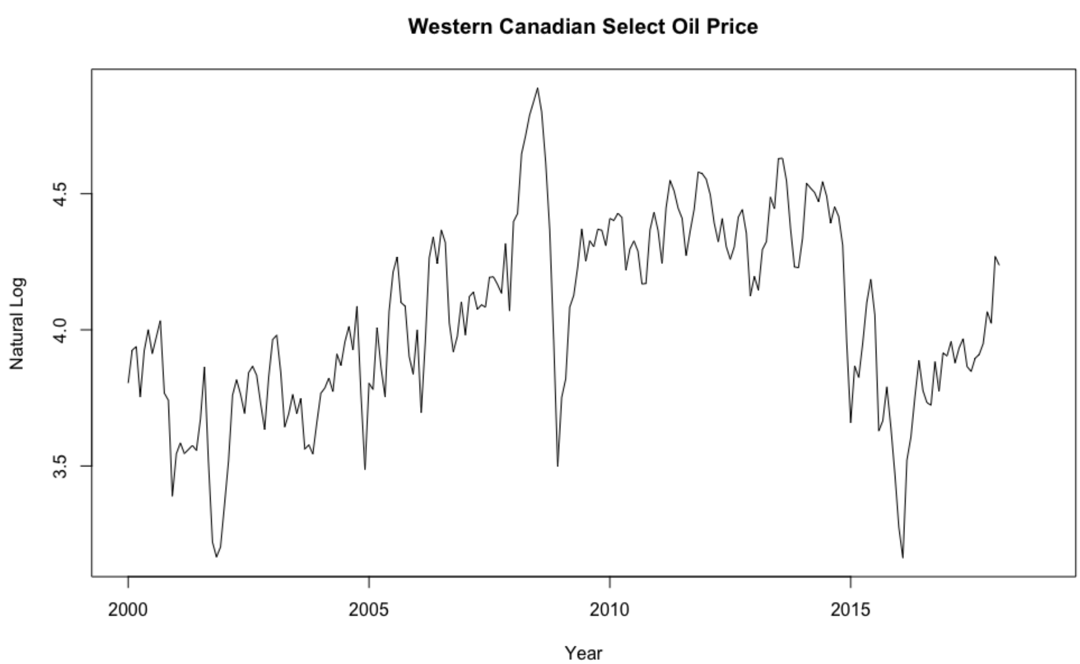

Figure A2. depicts the natural log Western Canada Select oil prices.

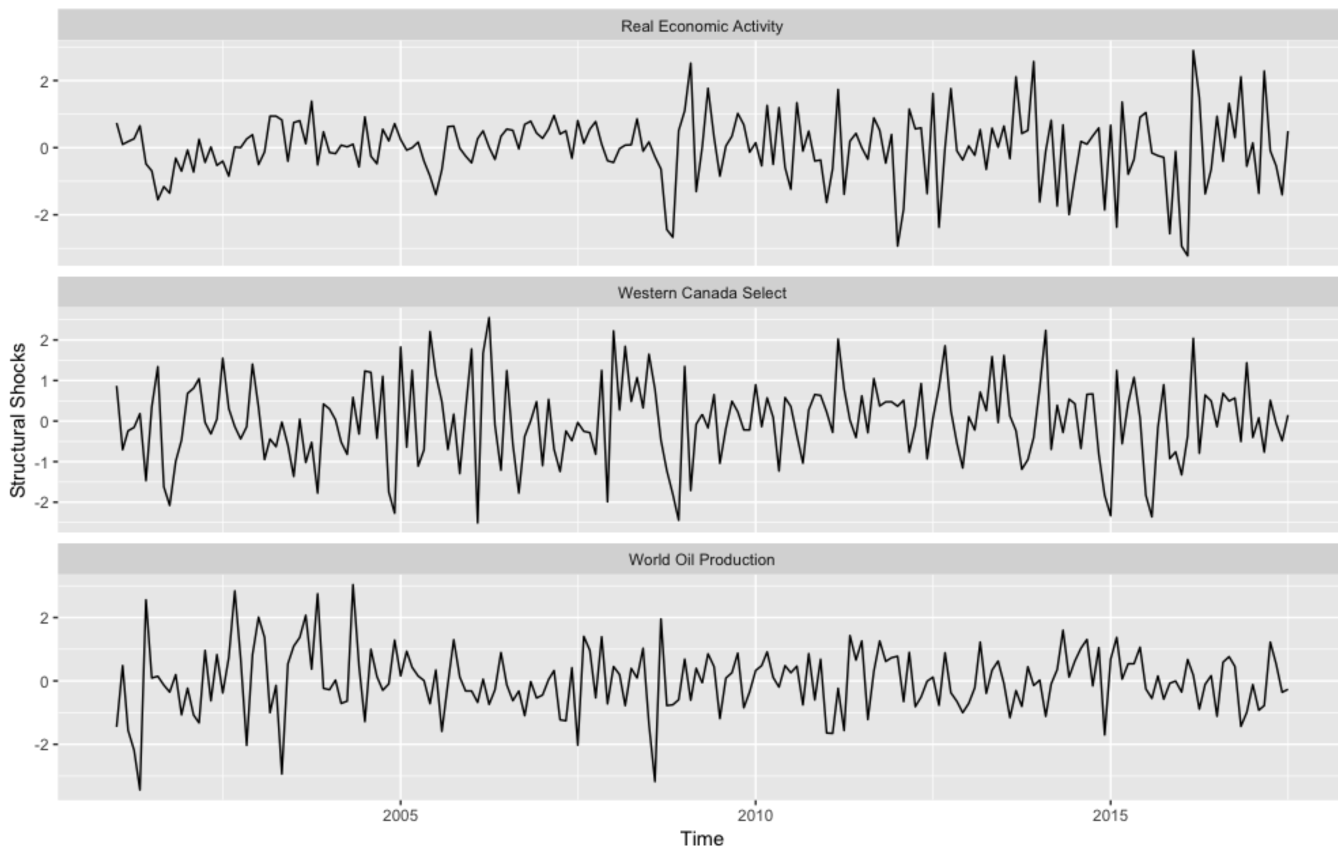

Figure A3. depicts estimated orthogonalized shocks estimated from the recursively identified SVAR comprised of world oil production, real economic activity, and WCS oil price.

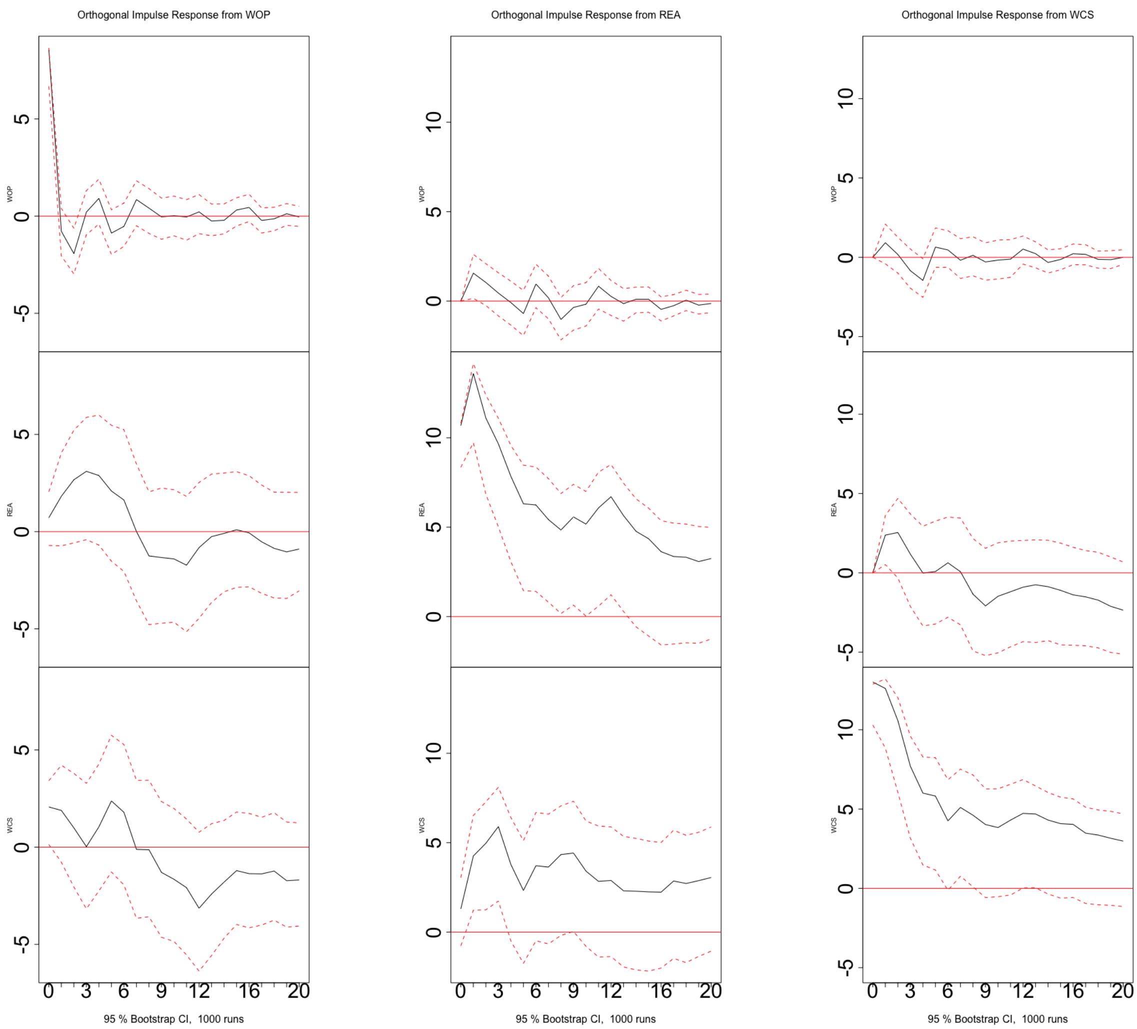

Figure A4. International impulse response functions

Notes : Figure A4 depicts the impulse responses of world oil production (column 1), real economic activity (column 2), and WCS oil price (column 3). Rows represent impulses and are organized from top to bottom as follows: world oil production (row 1), real economic activity (row 2), and WCS oil price. All responses represent the annualized percentage change in the wake of a positive one standard deviation shock to an aforementioned impulse variable.

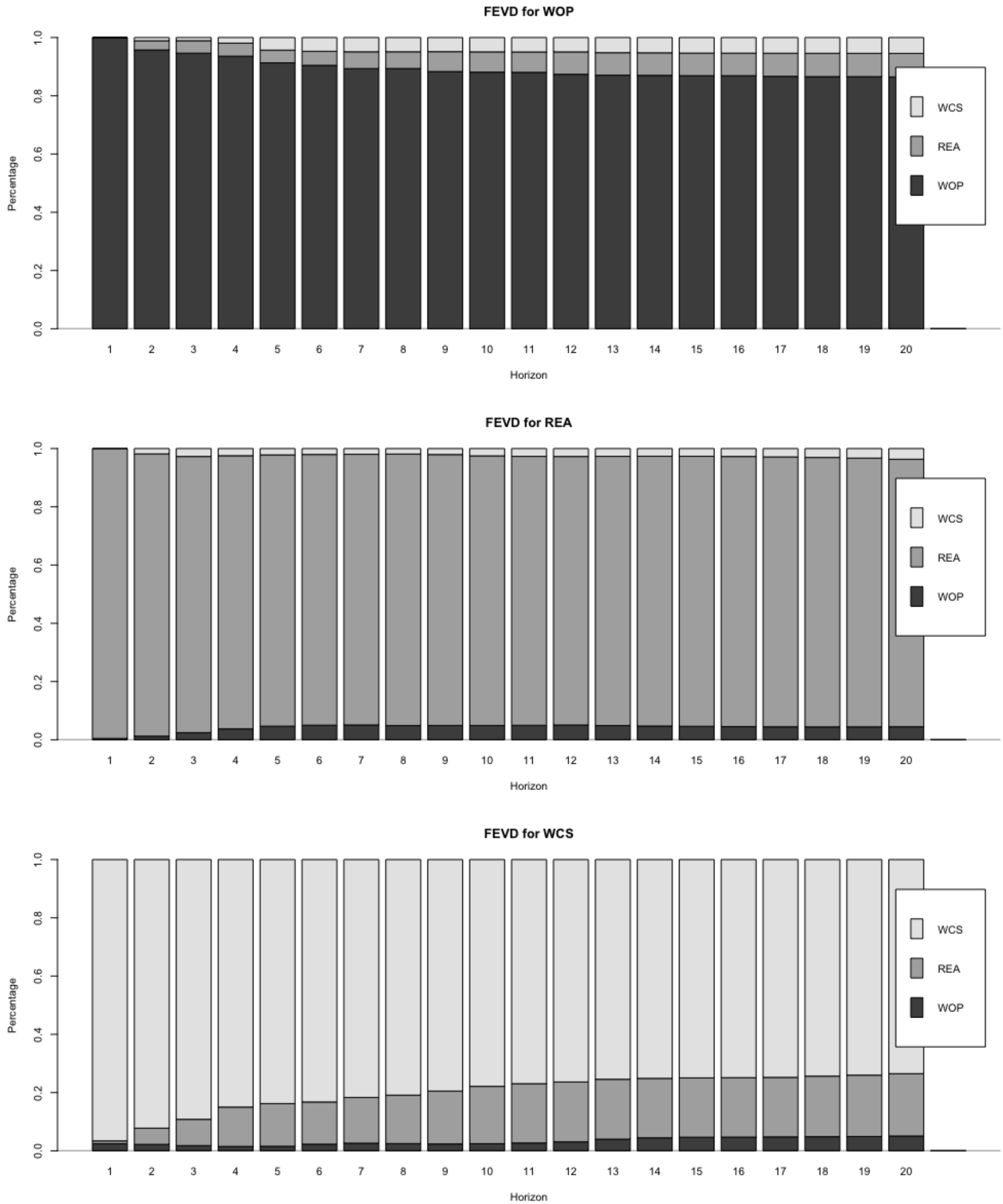

Figure A5. the forecast error variance decomposition of global oil production, real economic activity, and WCS oil price.

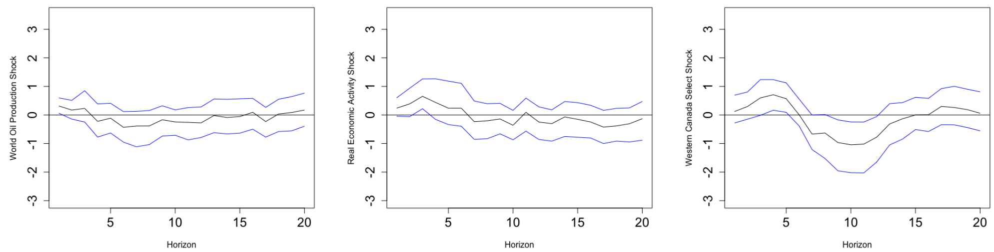

Figure A6. Canadian house price index (C11 composite)

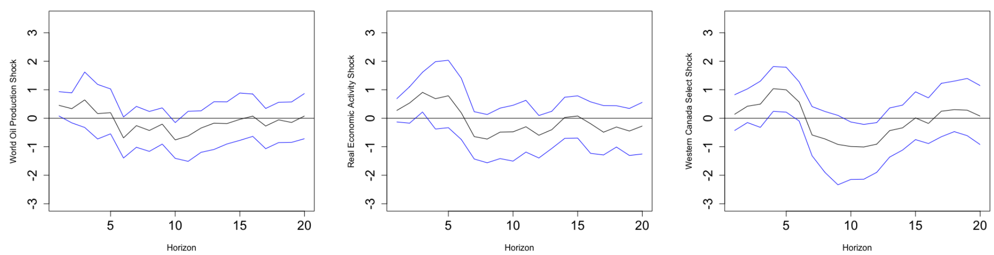

Figure A7. Toronto house price index responses

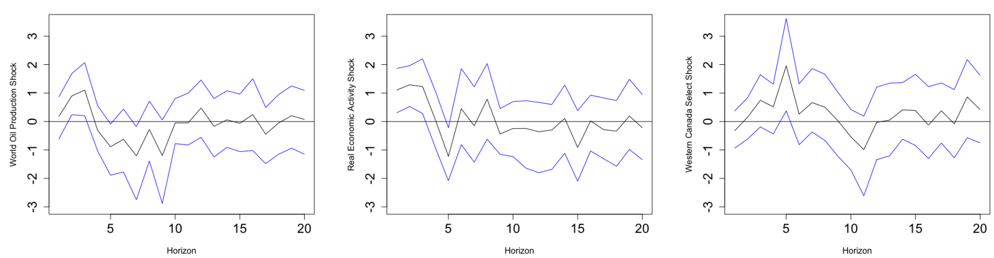

Figure A8. Calgary house price index responses

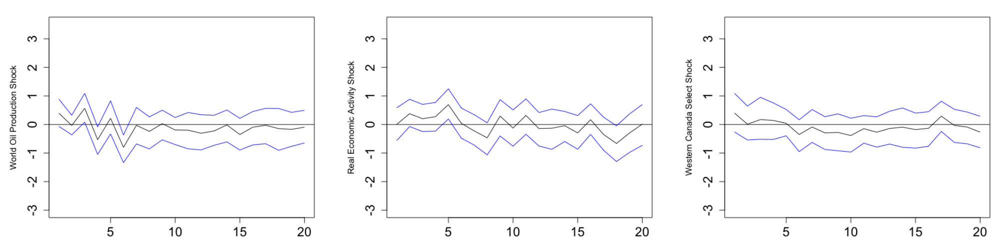

Figure A9. Montréal house price index responses

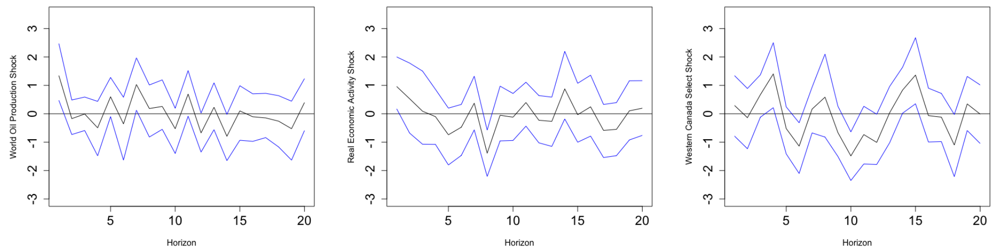

FIGURE A10. HALIFAX HOUSE PRICE INDEX RESPONSES

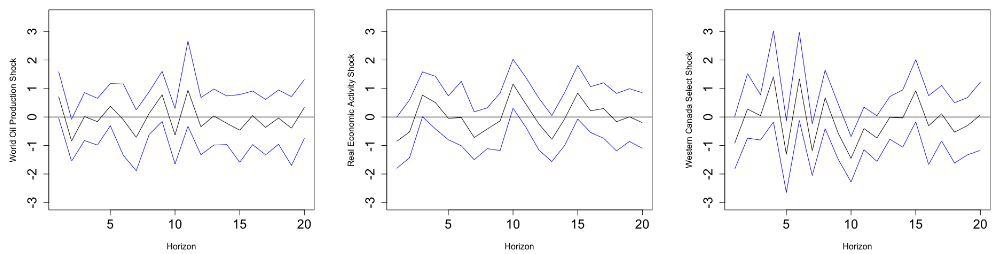

FIGURE A11. QUÉBEC CITY HOUSE PRICE INDEX RESPONSES

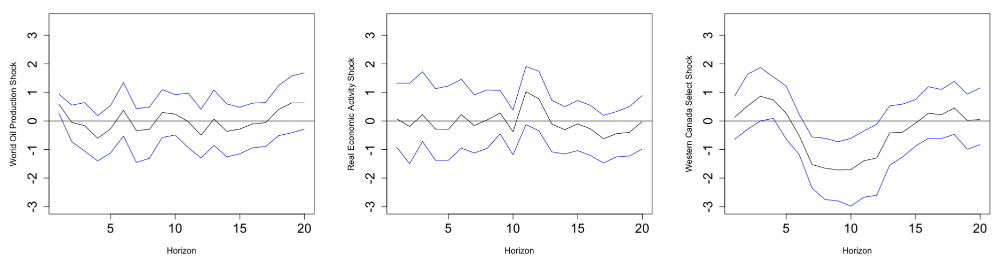

FIGURE A12. VANCOUVER HOUSE PRICE INDEX RESPONSES

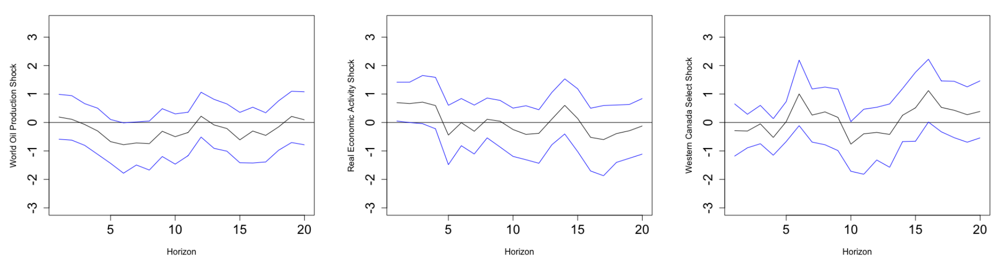

FIGURE A13. EDMONTON HOUSE PRICE INDEX RESPONSES

Notes : All house price response figures depict the change in annualized house price growth rates given a positive one standard deviation shock to world oil production, real economic activity, or Western Canada Select oil price. Confidence bands represent the 95 percent confidence interval.

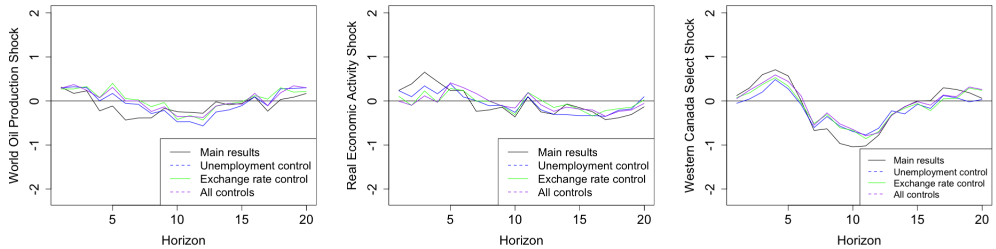

Figure A14. Canadian (C11 composite) house price index sensitivity tests

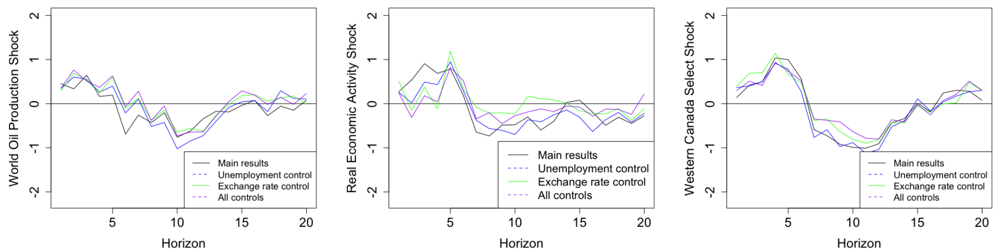

Figure A15. Toronto house price index sensitivity tests.

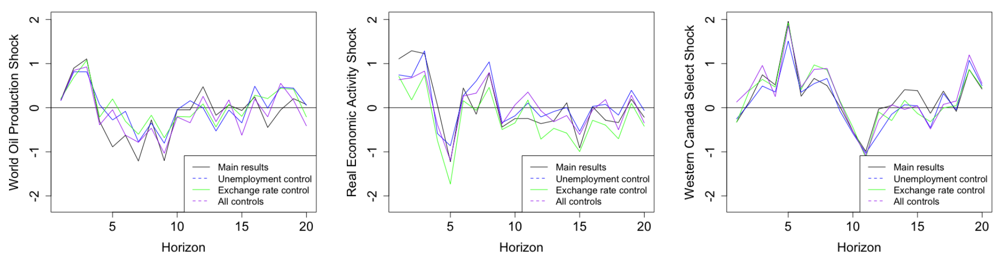

Figure A16. Calgary house price index sensitivity tests.

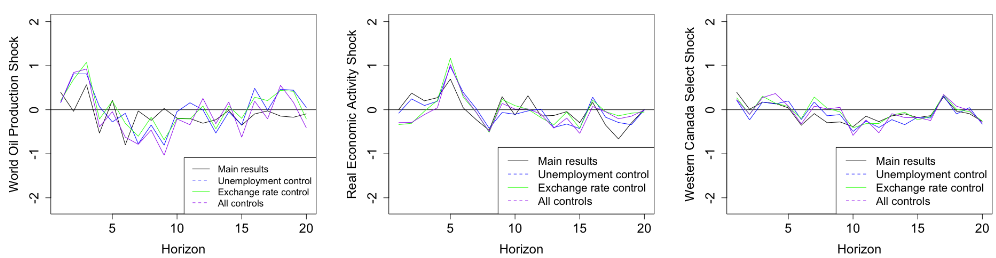

Figure A17. Montréal house price index sensitivity tests.

Notes : All sensitivity tests depict the change in annualized house price growth rates given a positive one standard deviation shock to world oil production, real economic activity, or Western Canada Select oil price, with control variables included as outlined in figure legends.