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Abstract

Shocks to the demand for housing that originate in one region may seem important only for that regional housing market. We provide evidence that such shocks can also affect housing markets in other regions. Our analysis focuses on the response of Canadian housing markets to oil price shocks. We document that, at the national level, real oil price shocks account for 11% of the variability in real house price growth over time. At the regional level, we find that unexpected increases in the real price of oil raise real house prices not only in oil-producing regions, but also in other regions. We develop a theoretical model of the propagation of real oil price shocks across regions that helps understand this finding. The model differentiates between oil-producing and non-oil-producing regions and incorporates multiple sectors, trade between provinces, government redistribution, and consumer spending on fuel. We empirically confirm the model prediction that oil price shocks are transmitted to housing markets in nonoil-producing regions by the government redistribution of oil revenue and by increased interprovincial trade.

JEL-Codes: F430, Q330, Q430, R120, R310.

Keywords: house price, regional heterogeneity, oil price, redistribution, resource boom, Canada.

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1. Introduction

Housing markets in major economies exhibit substantial regional heterogeneity.[1] Since housing markets are regionally segmented, regional shocks tend to be the main determinant of house prices and housing investment. Although the literature recognizes the importance of regional shocks, shocks that are specific to a region are typically considered important only for that regional housing market (see, e.g., Head, Lloyd-Ellis and Sun 2014; Cunningham, Gerardi and Shen 2017). In this paper, we establish that shocks to one regional housing market can also affect housing markets in other regions, and we identify the channels responsible for this propagation. These insights provide a better understanding of the evolution of regional as well as national house prices and of the causes and consequences of the regional heterogeneity in housing markets. The fact that regional shocks are transmitted beyond the region where they originate has potentially important implications for the design of monetary and macroprudential policy responses, since housing is the single most important asset held by most households and households tend to borrow against their housing wealth.

Our analysis focuses on the response of Canadian housing markets to oil price shocks. Like most advanced economies, Canada has experienced substantial regional heterogeneity in housing markets. As a major net oil exporter, Canada is exposed to terms-of-trade shocks, as the price of oil fluctuates. An unexpected oil price increase raises Canadian real income overall, but the extent of these real income gains varies substantially by region, since oil production is concentrated geographically. Thus, oil price shocks constitute regional income shocks. We find that, at the national level, oil price shocks account for substantial variability in Canadian real

[1] For example, in the United States, house price growth varies drastically across different geographical locations (see Del Negro and Otrok 2007; Ferreira and Gyourko 2011; Bhutta and Keys 2016). For the Euro area, both house price growth and lending conditions have diverged across countries since the late 1990s (Nocera and Roma 2017). The regional heterogeneity of Canadian housing markets has been documented by Allen, Amano, Byrne and Gregory (2009).

house price growth over time. This result is not merely an artifact of the statistical aggregation across heterogeneous regions. We show that unexpected oil price increases not only raise house prices in regions where the oil sector is important ("oil-rich regions"), but also in all other regions ("oil-poor regions"). We develop a theoretical model of regional housing markets that helps us understand the propagation of oil price shocks across regions and we provide evidence in support of the channels of transmission highlighted in this model.

The starting point of our analysis is a structural vector autoregressive (VAR) model of Canadian national house prices. The model shows that positive shocks to the Canadian real price of oil are associated with persistently higher employment and real house prices, consistent with a shift in housing demand. Real oil price shocks at the national level account for 11% of the variability in the growth rate of real Canadian house prices, compared to 4% for employment shocks and 3% for mortgage rate shocks.

A natural question is whether the response of real house prices at the national level merely reflects higher housing demand in oil-rich regions, or whether housing demand shifts in other regions as well. To answer this question, we employ an empirical strategy in the spirit of Bartik (1991) that interacts time series variation in the real price of oil with regional variation in the size of the oil sector, measured by its employment share (at the city level) and its value added share (at the province level).

Both city-level and province-level data show that the positive effect of higher real oil prices on real house prices coincides with a significant increase in residential building permits and in housing starts in all regions, but there is an additional increase in real house prices, residential permits and housing starts in oil-rich regions. This evidence is important for two reasons: (1) It confirms the interpretation of oil price shocks as housing demand shocks because an increase in both the price and the quantity of housing can only be caused by increased demand. (2) It demonstrates that this shift in housing demand is not restricted to oil-rich regions, but is a national phenomenon. Although real house prices in oil-rich regions tend to increase the most, we provide evidence that, even in cities and provinces where the oil industry is nonexistent, house prices still increase in response to positive real oil price shocks. The latter evidence raises the question of how oil price shocks are transmitted from oil-rich provinces such as Alberta and Saskatchewan to housing markets in other regions of the country.

The existing literature suggests several potential channels of transmission including supply-chain dynamics, interprovincial trade resulting from higher consumer demand in oil-rich provinces, and the redistribution of government revenue across provinces in the form of transfers (known as "equalization payments" in Canada). We develop a theoretical model of the transmission of oil price shocks across regional housing markets that differentiates between oil-rich and oil-poor regions and incorporates multiple sectors, government redistribution, interprovincial trade, and commuting costs. The model allows for regional differences in the responses of the housing market to oil price shocks. Comparative static analysis highlights that supply-chain dynamics in general are not enough to explain the increase in real house prices in oil-poor regions in response to oil price increases, but a sufficient degree of government redistribution of oil income to households in the oil-poor regions is. The model also highlights the importance of the Keynesian labor demand channel. Even in the absence of government redistribution, interprovincial trade may raise real output, employment and hence real house prices in oil-poor regions if there is slack in the labor market. This effect is amplified when the government spends some of its oil tax revenue on consumer goods.

We provide empirical support for the channels of transmission of oil price shocks across regions highlighted in the theoretical model. First, government revenues in oil-rich provinces increase in response to positive oil price shocks by more than in other provinces, but government expenditures in oil-rich provinces increase by no more than in other provinces, consistent with an effective redistribution of oil income across provinces. Second, we provide evidence for slack in the labor market. Higher real oil prices cause a persistent expansion in employment and a decline in the unemployment rate in all regions. This effect is even more pronounced in the oil-rich regions. There is no evidence of net migration to oil-rich provinces in response to higher real oil prices, consistent with the literature on regional labor demand shocks (see Autor, Dorn and Hanson 2013; Dix-Carneiro and Kovak 2017). Third, we show that real GDP increases in response to higher real oil prices in all provinces, consistent with an increase in the domestic demand for goods and services. Not only do we find increases in the output of industries that produce inputs for the oil sector (such as machinery or fabricated metals), but output also increases in industries not closely tied to the oil sector through the supply chain. Our evidence suggests that the economic stimulus from higher oil prices extends to virtually all sectors of the economy.

Our analysis of Canadian housing markets contributes to the literature on the relationship between housing markets and the macro economy as well as to the literature on regional economics. Our work is part of a growing literature on the regional propagation of shocks. It is related to Feyrer, Mansur and Sacerdote (2017) who quantified the spatial effects of county-level drilling shocks associated with the U.S. fracking revolution on employment and income, but without discussing the implications for housing markets, and to Allcott and Keniston (2017) who conducted a similar analysis of the effects of oil and gas booms on a range of economic outcomes including housing rents. It is also related to Kehrig and Ziebarth (2017) who studied the effects of oil supply shocks on U.S. regional labor markets, including the implications for real house prices, based on regional differences in the dependence on oil as an input in production. Unlike in these earlier studies, our primary focus is on the housing market rather than on the labor market. We also employ a different empirical methodology and data set, we exploit a different source of cross-sectional variation, and we provide new theoretical insights and new evidence on how oil price shocks are transmitted across regions.

The remainder of the paper is organized as follows. In section 2, we estimate the effects of shocks to the Canadian real price of oil at the national level based on structural vector autoregressive (VAR) models. Section 3 reviews the economic mechanisms that allow oil price shocks to affect Canadian housing markets in all regions. Building on this discussion, in section 4, we develop a theoretical model of the propagation of real oil price shocks from oil-rich to oil-poor regions. The implications of this model are evaluated in sections 5 and 6. In section 5, we use quarterly panel regressions to quantify the effects of oil price shocks on Canadian housing markets at the city and province levels, respectively. Section 6 provides empirical evidence in support of the main channels of transmission highlighted in the theoretical model. The concluding remarks are in section 7.

2. The Effect of Oil Price Shocks on House Prices at the National Level

Crude oil produced in Canada is priced in U.S. dollars in global markets. Since Canadian housing demand is determined by real income measured in Canadian consumption units, our baseline structural VAR model of the determination of Canadian real house prices in section 2.1 expresses real oil price shocks in Canadian consumption units rather than U.S. consumption units. The real oil income generated in the oil-rich regions of Canada also depends on the real exchange rate, however. Even if the global price of oil remained unchanged, an exogenous change in the exchange rate would shift domestic income derived from oil production and shift the demand for housing. In section 2.2, we address this concern by showing that exogenous real exchange rate shocks are not an important source of the variation in the Canadian real price of oil, which allows us to focus on shocks to the Canadian real oil price in the remainder of the paper.

2.1. The Effects of Shocks to the Canadian Price of Oil on National House Prices

The upper panel of Figure 1 shows the evolution of the Teranet national house price index for Canada, deflated by the consumer price index (CPI), as reported by Statistics Canada.[2] We focus on data starting in March 1999 when this high-quality national house price index became available. This is also the approximate time when Canadian production of crude oil from tar sands became quantitatively more important. The lower panel of Figure 1 shows the Canadian real price of oil, obtained by deflating the Canadian dollar price for Western Canadian Select (WCS) crude oil by the CPI.[3]

We analyze the relationship between these time series based on a monthly structural VAR(6) model with intercept for $y_t = (\Delta rpoil_t, \Delta emp_t, \mathrm{infl}_t, \Delta rhp_t, \mathrm{i}_t)$, where $\Delta rpoil_t$ denotes the percentage change in the Canadian real price of oil, Δemp_t denotes the percentage change in total employment, as reported by Statistics Canada, infl_t denotes the rate of consumer price inflation, Δrhp_t denotes the percentage change in the real house price index, and i_t denotes the 5-year fixed mortgage rate quoted by major institutional lenders, as reported by the Canadian

[2]The Teranet National Bank Composite 11 House Price Index is constructed by the repeat-sales method based on the rate of change in home prices in 11 Canadian metropolitan areas (Calgary, Edmonton, Halifax, Hamilton, Montreal, Ottawa, Quebec City, Toronto, Vancouver, Victoria, and Winnipeg).
[3] The WCS price is the price for delivery at Hardisty, Alberta, expressed in Canadian dollars, and suitably extended back to 1999, as reported by the Canadian Association of Petroleum Producers. The WCS is representative for the types of crude oil produced in Canada.

Mortgage and Housing Corporation. This rate is the most common mortgage rate in Canada. Very similar results are obtained when using estimates of the corresponding average effective mortgage rate. The raw data cover March 1999 to August 2017. All data have been seasonally adjusted.[4] The VAR model is identified recursively. Given that Canada is a small open economy, we treat the percentage change in the real price of oil as predetermined with respect to the Canadian economy.[5] The real house price is allowed to respond to changes in employment and in the inflation rate contemporaneously, but employment is considered too sluggish to respond contemporaneously to unexpected changes in inflation, real house prices and in the nominal lending rate. Likewise, we rule out feedback within the current month from real house prices to consumer price inflation. The nominal mortgage rate is ordered last, allowing for the possibility that the central bank may respond contemporaneously to house prices as well as inflation and employment, thereby affecting the mortgage rate. All confidence intervals are constructed based on the conditional heteroskedasticity-robust residual block bootstrap of Brüggemann, Jentsch and Trenkler (2016).

Figure 2 focuses on three key determinants of real house prices. An unexpected increase in the real price of oil is associated with a statistically significant persistent increase in real house prices. The initial drop in real house prices is consistent with inflation rising faster than house prices on impact. An unexpected increase in total employment also causes a statistically significant persistent appreciation of real house prices, reflecting higher labor income and hence higher housing demand. Finally, an unexpected increase in the nominal 5-year mortgage lending rate causes a statistically insignificant persistent decline in real house prices with a delay of one

[4] The lag order choice coincides with the estimate that would be obtained based on the Akaike Information Criterion with an upper bound of 12 autoregressive lags.
[5] This assumption is valid even for the much larger U.S. economy (Kilian and Vega 2011).

quarter, as the mortgage cost rises.[6]

Figure 3 examines the effects of an unexpected increase in the real price of oil on Canadian macroeconomic aggregates. National employment increases persistently. There is only a short-lived increase in inflation, but there are no sustained inflationary pressures. The nominal lending rate also increases persistently, which could be driven by the response of monetary policy and by the higher demand for capital, as the economy expands. All responses are statistically significant. A variance decomposition based on the estimated VAR model shows that real oil price shocks account for about 11% of the variability in the growth rate in real house prices, which is larger than the contribution of employment shocks (4%) and mortgage rate shocks (3%).

2.2. The Role of the Exchange Rate in Measuring Oil Price Shocks

The role of exogenous changes in the real exchange rate may be quantified by replacing the Canadian real price of oil in the baseline recursive structural VAR(6) model of section 2.1 by the real price of oil in U.S. consumption units and adding the Canadian real exchange rate as the variable ordered last.[7] This allows the real exchange rate to respond to all other shocks contemporaneously. The residual shock is treated as a measure of exogenous real exchange rate variation. As Figure 4 shows, an unexpected increase in the U.S. real price of crude oil has much the same effect on employment, real house prices, inflation, and the mortgage rate as an unexpected increase in the Canadian real price of oil in Figure 3. Likewise, the share of the variability of real house prices explained by these real oil price shocks is almost the same. This is

[6] This result is consistent with evidence in Glaeser, Gottlieb and Gyourko (2010) that the empirical relationship between U.S. house prices and interest rates is weak.

[7] The nominal exchange rate data and the U.S. CPI are from FRED. The real price of Canadian crude oil in U.S. consumption units is measured by deflating the WCS price in U.S. dollars by the U.S. CPI, allowing for differences in the characteristics of Canadian crude oil from WTI or Brent crude oil (Kilian 2016).

direct evidence that exogenous exchange rate fluctuations may be ignored for the purpose of our analysis and lends credence to our approach of expressing the real price of oil in Canadian consumption units in the remainder of the paper.

3. Determinants of the Response of Housing Markets to Canadian Real Oil Price Shocks

The evidence in section 2 suggests that oil price shocks have statistically significant effects at the national level. Of course, an analysis at the national level obscures the fact that these effects may differ considerably across regions. It is not clear, for example, whether the responses of national house prices to oil price shocks merely reflects the responses in oil-rich regions or whether it reflects broader shifts in housing demand across Canada.

There are good economic reasons for the responses to differ by region. In this section, we outline the channels by which Canadian real oil price shocks would be expected to affect housing markets. We first review the channels through which real oil price shocks may affect real income and hence the demand for housing and real house prices both in oil-rich and in oil-poor provinces. We then discuss how at the same time higher real oil prices may reduce the demand for housing and lower real house prices through other channels. These insights will be used in section 4 to build a theoretical model of the regional effects of real oil price shocks that incorporates the empirically most relevant channels and that explains why higher real oil prices on balance tend to be associated with higher real house prices.

Over our sample period, as much as 78% of the crude oil produced in Canada is exported, while the share of crude oil used by the Canadian economy is only 2% of GDP on average. We therefore focus on the effects of oil price shocks on income and spending rather than on the cost of domestic production, consistent with the conventional view of how oil price shocks affect the economy (Kilian 2014).

3.1. How Higher Real Oil Prices May Cause Real House Prices to Increase

Since Canada historically has been a net exporter of crude oil, unexpected increases in the real price of oil measured in Canadian consumption units imply that Canada as a whole receives more real income. These real income gains, however, are not evenly distributed across the country. Whereas households in oil-rich provinces such as Alberta, Saskatchewan, and, more recently, Newfoundland and Labrador experience real income gains, households in oil-poor provinces do not. As real incomes rise in oil-rich provinces, the demand for housing expands in these provinces and residential investment increases (Kilian 2008). In oil-poor provinces, in contrast, all else equal, the demand for housing and residential investment remains unchanged in response to higher oil prices. The latter conclusion, however, ignores several complicating factors, including the government redistributing oil income across provinces, interprovincial trade, and migration within Canada, which may cause real house prices to increase in oil-poor provinces as well.

Government Redistribution. Oil production generates substantial revenues for provincial governments through (i) taxes and royalties on oil production, (ii) property taxes, (iii) lease payments, and (iv) fees for the use of public land. In Alberta, for example, oil and gas royalties alone accounted for 28% of the provincial government revenue in 2008. Oil booms also raise income tax revenue in oil-rich regions. These funds may be transferred to the federal government and redistributed across provinces, providing an economic stimulus in oil-poor provinces that increases housing demand and raises property values.[8]

[8] Canada, in particular, has used this mechanism for many years. The Canadian "equalization payments" across provinces are based on a formula that calculates the difference between the per capita revenue yield that a particular province would obtain using average tax rates and the national average per capita revenue yield at average tax rates. For example, according to the Department of Finance in Canada, in 2016-17, the provinces with the largest oil sector, Alberta, Saskatchewan, Newfoundland and Labrador, and British Columbia, collectively transferred tax revenues equivalent to $2,573 per capita to Prince Edward Island, $2,259 per capita to New Brunswick, $1,822 per

Trade between Provinces. An oil-poor province may also benefit from an oil boom in oil-rich regions to the extent that there is slack in the local labor market and higher demand for goods and services from oil-rich regions stimulates aggregate real output. The strength of this effect depends on the magnitude of both the supply-chain effects and of the consumption stimulus from higher real incomes in the oil-rich region.

Migration between Provinces. Finally, increases in the demand for labor in oil-rich provinces caused by higher oil prices may stimulate net migration toward oil-producing regions. This migration increases the demand for housing in oil-rich provinces and hence house prices. At the same time, all else equal, housing demand in other provinces should decline, resulting in lower property values elsewhere in the country. Given the robust finding in the literature on regional labor demand shocks that regional labor mobility is low, this channel is likely to be quantitatively unimportant. In section 6, we confirm that this stylized fact also applies to Canadian provinces, allowing us to ignore the role of labor migration in the theoretical analysis in section 4.

Risk sharing. Another potential channel of transmission is risk sharing, which occurs to the extent that residents of oil-poor regions hold assets of companies in oil-rich regions and residents of oil-rich regions hold assets of companies in oil-poor regions. Higher returns in oil assets, for example, allow residents in oil-poor regions to partake in the real income gains in the oil sector. The potential importance of risk sharing has been discussed in a variety of contexts.[9] There are no data on the regional dispersion of asset holdings in Canada that would allow us to assess the

capita to Nova Scotia, $1,328 per capita to Manitoba, $1,206 per capita to Quebec, and $166 per capita to Ontario. The transfers received by the provinces can be spent in any way the provincial government desires.

[9] For example, Adrubali, Sørenson, and Yosha (1996) document significant risk sharing across state borders in the United States that allows consumers to partially smooth state-level shocks. Kilian, Rebucci and Spatafora (2009) discuss risk sharing between oil-exporting and oil-importing countries at the global level. Fitzgerald and Rucker

quantitative importance of this channel.

3.2. How Higher Real Oil Prices May Cause Real House Prices to Fall

Although there are strong reasons to expect higher real oil prices to be associated with higher real house prices, as discussed in section 3.1, there are also several countervailing forces, including increases in the cost of commuting, higher costs of home heating, environmental externalities of the oil booms triggered by higher oil prices, the tightening of monetary policy in response to actual or anticipated inflationary pressures from higher oil prices, and the appreciation of the Canadian dollar in response to higher oil prices. Some of these channels can be shown to be quantitatively unimportant, while others need to be incorporated into theoretical models of the regional transmission of oil price shocks.

Commuting Costs. One channel of transmission is changes in the cost of commuting both in oil-rich and in oil-poor regions, as higher oil prices increase the cost of motor fuel, reducing the household income available for other purchases. For example, Larson and Zhao (2017) use a model incorporating changes in commuting costs to demonstrate that real house prices fall in oil-poor cities and rise in oil-rich cities in response to higher real oil prices.[10] Thus, it is important to incorporate changes in the cost of commuting into models of the regional transmission of real oil price shocks to the housing market.[11]

Environmental Costs. There is also evidence that the oil booms associated with higher oil prices may create negative externalities that lower property values in oil-producing regions. One

(2016) study the evidence that royalty income generated by U.S. shale oil producers is transmitted across state borders.

[10] In related work, Sexton, Wu and Zilberman (2012) show that an unexpected increase in the real price of crude oil increases the cost of commuting to work, lowering the real value of homes away from the city center and increasing foreclosure rates, as homeowners can no longer afford their mortgage payments. Molloy and Shan (2013) elaborate on this point, stressing the implications for housing demand and new housing construction.

[11] Similarly, increases in the real price of oil have a direct negative effect on house prices to the extent that homes are heated by heating oil, which is produced from crude oil (Halverson and Pollakowski 1981). Because, as of 2015, only 3% of Canadian households relied on fuel oil for home heating, this effect is not important for our analysis.

reason is the environmental degradation associated with oil production. For example, the risks of water contamination or other health hazards from oil production or from oil spills have been associated with lower property values, the inability to insure homes, and homeowners being denied mortgages.[12] Property values are also sensitive to local disamenities such as noise, traffic congestion, nighttime lights, air pollution, or the visual blight of oil rigs, oil pipelines, and land clearing. These effects, however, tend to be too local to be relevant for the transmission of oil price shocks to housing markets at the city or province level.

Monetary Policy Reactions. Actual or anticipated inflationary pressures triggered by positive oil price shocks may prompt the Bank of Canada to raise interest rates in response to higher oil prices. To the extent that such short-term interest rate responses are passed through to the 5-year mortgage rate, they may reduce the demand for housing and real house prices. Moreover, given the evidence in Allen, Clark and Houde (2014), one might expect the mortgage rate responses to oil price shocks to differ across regions. We abstract from monetary policy reactions in the theoretical analysis in section 4 for two reasons. First, the VAR model in section 2 shows that the mortgage rate responses to oil price shocks are too weak to offset the increase in real house prices caused by higher real oil prices. Second, we find no statistically significant regional heterogeneity in the response of mortgage rates to oil price shocks.[13] The latter result holds both for insured mortgages, consistent with the findings in Hurst, Keys, Seru and Vavra (2016) for the United States, and for uninsured mortgages.

Exchange Rate Effects. Finally, an exogenous shock to the real price of oil in global markets

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[12] Boxall, Chan and MacMillan (2005) document that property values in Alberta are negatively correlated with the number of sour gas wells and flaring oil batteries located in the vicinity of the property. Related work on the impact of the fracking boom on local housing markets in the United States includes Muehlenbachs, Spiller and Timmins (2015) and Cunningham, Gerardi and Shen (2017).

[13] The provincial average mortgage rates are from the Bank of Canada and were constructed based on loan-level micro data that provide information on the rate charged for each originated mortgage.

causes both the real price of oil in Canadian consumption units and the Canadian real exchange rate to appreciate, complicating the analysis because oil price shocks may affect Canadian real income and hence real house prices both directly and through their effects on the competitiveness of the tradable goods sector. The VAR model of section 2.2, however, implies that the latter effects are too small to offset the positive effect of higher global real oil prices on Canadian employment and real house prices.[14]

4. A Theoretical Model of the Regional and Sectoral Effects of Real Oil Price Shocks

This section introduces a stylized model of the regional and sectoral transmission of real oil price shocks to the housing market that incorporates many of the channels of transmission reviewed in section 3, including supply-chain links, interprovincial trade in consumer goods, government redistribution of oil income, and the cost of commuting. The model will be used in sections 5 and 6 to interpret the regression results. We do not incorporate all possible channels of transmission. For example, the model abstracts from the responses of migration and monetary policy to oil price shocks for the reasons discussed in section 3. The objective of the theoretical analysis is to shed light on the conditions under which real oil price shocks are transmitted to housing markets in oil-poor regions, even in the absence of real exchange rate responses. The model is simple enough to be analytically tractable. The sign of the effect of an increase in the real price of oil on real house prices in oil-rich and oil-poor regions, respectively, may be determined using comparative statics.

4.1. Outline of the Model

Consider a country with an oil-producing region (region 1) and a non-oil producing region (region 2). Oil is produced in region 1 by combining labor and intermediate goods. The

[14] This view is consistent with evidence in Fontaine and Nolin (2017) that only a small share of the depreciation of the Canadian dollar after 2014 can be attributed to the decline in oil prices.

production of intermediate goods and of consumption goods takes place in region 2. Their production uses labor only. Within region 2, labor may be freely allocated between the production of intermediate goods and the production of the consumption good. The intermediate good is sold to the oil sector in region 1. Oil and the consumption good are traded internationally. Any shortfall of these goods is met by imports. Any excess production is exported.[15] Since these goods are supplied elastically from abroad, their price is determined internationally. The price of the consumption good is normalized to 1. The real price of oil is exogenously given and is denoted by p. The cost of shipping goods domestically or internationally is zero.

In each region $i \in \{1, 2\}$, representative households supply labor and are compensated at the real wage rate w_i. Labor supply is inelastic in each region, implying a vertical labor supply curve.[16] Labor is immobile across regions. The supply of labor in region 1 is fixed.[17] In region 2, labor supply may be fixed or, alternatively, there may be slack in the labor market, which is represented as the labor supply in region 2 being an increasing function of p. Households purchase housing services and the consumption good. Consumption and housing services are assumed to be complements. The government redistributes wealth from the oil-rich region to the oil-poor region based on a tax on oil producers' revenue, which is in part spent on consumer

[15] Since oil is primarily exported, our model implies that consumer goods are imported by the Canadian economy. This assumption is consistent with evidence that, with the exception of the aircraft industry, Canada primarily exports mineral, farm, forestry, fishing and energy products. In contrast, the consumer goods industry, the chemical industry, the auto industry, and all other manufacturing industries are net importers, consistent with the model structure.
[16] An alternative would have been to model households' labor-leisure choices as endogenous under additional restrictions on the utility function. Such a model would imply a counterfactual reduction in employment in region 2 in response to higher real oil prices. The reason is that, when the government redistributes oil revenue from region 1 to region 2, the windfall income gain in region 2 causes a reduction in labor supply and, hence, in total employment, which is at odds with the data.
[17] This simplifying assumption could be relaxed without affecting the signs of the responses to real oil price shocks in region 1.

goods and in part is redistributed directly to households in region 2, adding to their income. Workers commute to work in both regions. The cost of commuting depends linearly on p.

Housing services are produced from land and imported capital. Land is in fixed supply. The endogenously determined real price of housing services in region $i \in \{1, 2\}$ is denoted by q_i. Since house prices in region i, hp_i, can be expressed as the discounted sum of all future prices of housing services, we focus on the determination of q_i.[18]

4.2. Region 1: Oil-Producing Region

Firms: Oil-producing firms are competitive and take p as given. Their technology is constant returns to scale (CRS). Oil is produced from intermediate goods, M, supplied by region 2 and regionally supplied labor, N_1. Let $O(N_1, M)$ denote the output of oil in region 1, where N_1 is the total labor supply in region 1. The two inputs are complements, which implies that $\partial^2 O / \partial N_1 \partial M > 0$. The government imposes a revenue tax at rate τ on oil revenue. Oil firms choose labor N_1 and M to maximize $(1-\tau) pO(N_1, M) - w_1 N_1 - p^M M$, where p^M denotes the price of the intermediate good. From the first-order conditions for profit maximization,

$$w_1 = (1-\tau) p \frac{\partial O}{\partial N_1}(N_1, M) \tag{1}$$

$$p^M = (1-\tau) p \frac{\partial O}{\partial M}(N_1, M). \tag{2}$$

Housing Service Providers: Housing services are produced from land and capital using a CRS technology.[19] The competitive providers of housing services in region 1 choose land, L_1, and

[18] For example, in the standard user cost model discussed in Glaeser, Gottlieb and Gyourko (2010) the house price is proportionate to the price of housing services.

[19] Although labor is an important input in building homes and apartments, it is not a major input in the production of housing from existing dwellings and is not considered in most urban models (Yinger 2015).

capital, K_1, to maximize $q_1 H_1\left(L_1, K_1\right) - r_1^L L_1 - r^K K_1,$ where H_1 denotes the quantity of housing services provided in region 1, r_1^L is the rental rate of land, and r^K is the rental rate of capital, which is assumed to be constant and determined in international capital markets. The functional form of $H_1\left(L_1, K_1\right)$ is general enough to accommodate differences in housing supply elasticities across regions. The fixed quantity of land in region 1 is owned by the households in region 1. Our model allows both the price and the quantity of housing services to adjust to housing demand shocks. Profit maximization implies that

$$r_1^L = q_1 \frac{\partial H_1\left(L_1, K_1\right)}{\partial L_1}. \tag{3a}$$

$$r^K = q_1 \frac{\partial H_1\left(L_1, K_1\right)}{\partial K_1}. \tag{3b}$$

Since r^K and L_1 are constant, equation (3b) implies that $\partial K_1 / \partial q_1 > 0.$ Given the solution for $K_1(q_1)$ from equation (3b), equation (3a) determines r_1^L for given $q_1.$ In addition, the production function for housing services implies that the housing supply curve is upward sloping, i.e., $\partial H_1 / \partial q_1 > 0.$

Households: Households in region 1 choose their consumption (c_1) and housing services (h_1) to maximize utility $U(c_1, h_1)$ subject to $c_1 + q_1 h_1 = w_1 n_1 + r_1^L(q_1) L_1 - k_1 p,$ where n_1 is the fixed labor supply, k_1 is a constant that reflects the inelastic demand for oil from commuting to work, $k_1 p$ is the cost of commuting, and $r_1^L L_1$ is the rental income from land. We assume that the utility function is concave and twice differentiable. Using equation (1) and the equilibrium condition in the labor market, the budget constraint can be expressed as

$$c_1 + q_1 h_1 = \left[(1-\tau) \frac{\partial O(N_1, M)}{\partial N_1} N_1 - k_1 \right] p + r_1^L(q_1) L_1 \equiv I_1(p, q_1),$$

where N_1 equals the fixed labor supply in region 1 and $I_1(p, q_1)$ denotes household income. The first-order condition for h_1 implies that

$$-q_1 U_c\left(I_1(p,q_1)-q_1 h_1, h_1\right)+U_h\left(I_1(p,q_1)-q_1 h_1, h_1\right)=0.$$

In equilibrium, housing demand h_1 equals housing supply $H_1(q_1)$, which allows us to derive the change in the equilibrium price of housing services in response to a change in the price of oil. By the implicit function theorem,

$$\frac{\partial q_1}{\partial p}=\frac{-q_1 U_{cc}+U_{ch}}{\left(-q_1 U_{cc}+U_{ch}\right)\left(H_1+q_1\frac{\partial H_1}{\partial q_1}-\frac{\partial I_1}{\partial q_1}\right)+U_c+q_1 U_{ch}\frac{\partial H_1}{\partial q_1}-U_{hh}\frac{\partial H_1}{\partial q_1}}\frac{\partial I_1(p,q_1)}{\partial p}, \tag{4}$$

where $H_1+q_1\,\partial H_1/\partial q_1-\partial I_1/\partial q_1=r^K\,\partial K_1/\partial q_1>0$ from the definition of I_1, the zero profit condition for housing service providers, and the assumption of CRS. Since wage income exceeds the cost of commuting in the data, $\partial I_1(p,q_1)/\partial p=\left(w_1 n_1-k_1 p\right)/\,p>0$ for suitably chosen parameters. It follows that $\partial q_1/\partial p>0$ (and hence $\partial hp_1/\partial p>0$). The smaller the own-price elasticity of housing supply, the smaller is $\partial H_1/\partial q_1$ and the more the price of housing services responds to the oil price. Moreover,

$$\frac{\partial c_1}{\partial p}=\frac{\partial I_1(p,q_1)}{\partial p}-\left(H_1+q_1\frac{\partial H_1}{\partial q_1}-\frac{\partial I_1(p,q_1)}{\partial q_1}\right)\frac{\partial q_1}{\partial p}>0,$$

because equation (4) implies that $\left(H_1+q_1\,\partial H_1/\partial q_1-\partial I_1(p,q_1)/\partial q_1\right)\partial q_1/\partial p\le\partial I_1(p,q_1)/\partial p$.

4.3. Region 2: Non-Oil-Producing Region

Firms: There are two types of competitive firms in region 2. Firms that produce the intermediate good employ labor, N_2^M, to maximize $p^M M-w_2^M N_2^M$ subject to $M=aN_2^M$, where a denotes labor productivity in the intermediate goods sector. Profit maximization implies $w_2^M=p^M a$.

Firms that produce the consumption good choose N_2^C to maximize $C - w_2^C N_2^C$ subject to $C = bN_2^C$, where b denotes labor productivity in the consumer goods sector. Profit maximization implies $w_2^C = b$.

Since there are no frictions, workers in region 2 are indifferent to working in either industry. Thus, the real wage must be equal. Given $w_2^M = w_2^C = w_2$,

$$p^M = b / a. \tag{5}$$

Hence, oil producers in region 1 can expand their production without driving up the price of intermediate goods. The quantity of the intermediate good is determined by equations (2) and (5):

$$b / a = (1-\tau)\, p\, \partial O \big/ \partial M\,(N_1, M). \tag{6}$$

Since the labor supply in region 1 is fixed, equation (6) determines M as a function of p. By the implicit function theorem, $\partial M \big/ \partial p > 0$ and hence $\partial N_2^M \big/ \partial p > 0$.

Housing Service Providers: The structure of this market resembles that in region 1 with suitable changes in notation.

Households: The government redistributes a fraction ω of the oil tax revenue τpO to households in region 2. Households in region 2 earn wage $w_2 = b$, receive the lump-sum transfer $\omega\tau pO$, and choose c_2 and h_2 to maximize $U(c_2, h_2)$ subject to $c_2 + q_2 h_2 = w_2 n_2 + r_2^L(q_2)L_2 - k_2 p + \omega\tau pO \equiv I_2(p, q_2)$, where $n_2 = n_2^M + n_2^C$. Imposing the labor market equilibrium condition, the budget constraint may be expressed as $c_2 + q_2 h_2 = bN_2(p) + r_2^L(q_2)L_2 + (\omega\tau O - k_2)p$, where $N_2(p)$ is the endogenous total labor supply in region 2. Note that

$$\frac{\partial I_2(p,q_2)}{\partial p} = b\frac{\partial N_2}{\partial p} + \omega\tau\left(O + p\frac{\partial O}{\partial p}\right) - k_2$$

is positive as long as the additional labor income and the additional government transfer received by the household exceed the additional commuting cost:

$$b\frac{\partial N_2(p)}{p} + \omega\tau\, p\frac{\partial O}{\partial p} + \omega\tau O > k_2,$$

where $\partial N_2(p)/\partial p \geq 0.$ In that case, $\partial q_2/\partial p > 0,$ $\partial hp_2/\partial p > 0,$ and $\partial c_2/\partial p > 0.$

4.4. Summary of the Model Implications

In the neoclassical version of the model, $\partial N_2(p)/\partial p = 0$ and in the Keynesian version $\partial N_2(p)/\partial p > 0.$ Depending on which of these assumptions holds, the model implications for region 2 differ substantially. The neoclassical version of the model treats labor supply as fixed in all regions. It implies that in the absence of government redistribution of oil revenue across regions, the effect on consumption and real house prices is positive in the oil-rich region, but negative in the oil-poor region. Supply-chain dynamics are not enough to raise real house prices in the oil-poor region because the expansion of the intermediate goods sectors comes at the expense of the consumer goods sector. Since aggregate real output and employment remain unchanged, so does labor income. Net income falls, as commuting costs rise. Only sufficient redistribution of oil income to the oil-poor region by the government will reverse this negative sign.

In contrast, in the Keynesian version of the model, the labor supply curve in region 2 shifts to the right, as the real price of oil increases. As a result, higher demand for intermediate goods and consumer goods by the oil-rich region raises aggregate real output and employment in the oil-poor region, even in the absence of government redistribution. As long as the sum of additional oil tax transfers and additional labor income in the oil-poor region exceeds the additional cost of commuting, real output, consumption, and real house prices will increase in region 2. Unlike in the neoclassical version of the model, employment and real output in the consumer goods sector in the oil-poor region need not contract, but may expand along with the intermediate goods sector.

The next two sections empirically evaluate these model predictions based on panel regressions models estimated on quarterly city and province level data, respectively. Section 5 focuses on the effects of oil price shocks on the regional housing markets, while section 6 considers the implications for employment, real output, and net migration. We will provide evidence that the Keynesian version of the model provides a better fit to the data.

5. Regional Differences in the Responses of Housing Markets to Oil Price Shocks

Regions in our empirical analysis may refer to provinces or cities. Our data set consists of 9 provinces or 33 Canadian cities, respectively. We focus on the provinces of Alberta (AL), British Columbia (BC), Newfoundland and Labrador (NL), Nova Scotia (NS), New Brunswick (NB), Quebec (QC), Ontario (ON), Manitoba (MB), and Saskatchewan (SK), which account for 99.2% of the Canadian population.[20] Cities are defined as metropolitan areas having at least 100,000 residents.[21]

5.1. Regional data

Our primary interest is the response of regional real house prices to oil price shocks. Quarterly city-level house price indices are obtained by averaging the quarterly house price index of all

[20] We do not include the Northwest Territories, Nunavut, Prince Edward Island, and Yukon, for which there are large gaps in the data.
[21] A precise definition of Census Metropolitan Areas (CMAs) can be found in the Census Dictionary of Statistics Canada.

Forward Sortation Areas (FSA) within a city.[22] The FSA-level house price indices are reported by Teranet-National Bank and are based on the repeat-sales method. Quarterly provincial data for house prices are constructed by averaging the monthly average sale price by province published by CREA. All nominal data are deflated using the appropriate provincial-level CPI from Statistics Canada. We also consider a range of other quarterly and annual outcome variables ranging from housing and mortgage market indicators to employment, real activity, government revenue and government spending that are useful in evaluating the predictions of the theoretical model.[23]

5.2. Panel Regression Model

Our panel regression analysis focuses on the period 1999Q2-2017Q2, consistent with the time series analysis in section 2. In estimating the response of real house prices (and other outcome variables) to Canadian real oil price shocks we exploit two sources of variation: the variability in real oil prices over time and the cross-sectional variation in the importance of the oil sector for the regional economy. We treat changes in the real price of oil as exogenous with respect to the Canadian economy. Our premise is that Canadian oil exports are too small to affect the global real price of oil and that the observed changes in the real price of oil were unpredictable to consumers. The latter assumption is consistent with recent research on how consumers predict the real price of oil.[24]

[22] The only exception is four cities in New Brunswick and Saskatchewan, for which no FSA data are available. We use house price data from the Canadian Real Estate Association (CREA) for these cities.

[23] The data for city-level employment, the unemployment rate, the number of residential building permits, and the number of housing starts are all from Statistics Canada. Data on the arrear rate are obtained from the Canadian Bankers Association. Quarterly chartered bank mortgages and personal loans by province, quarterly interprovincial migration, quarterly population by province, annual provincial government expenditures and revenues, and annual provincial real GDP and for real GDP classified by the North American Industry Classification System (NAICS) are all from Statistics Canada.

[24] This research builds on insights and evidence in Anderson, Kellogg, Sallee, and Curtin (2011), Anderson, Kellogg and Sallee (2013), and Alquist, Kilian and Vigfusson (2013), among others.

We measure cross-sectional differences in the exposure of regions to oil price shocks by the region-specific employment share of the oil sector or the region-specific share of the oil sector in value added prior to the shock. At the city level, there is no alternative to using employment shares. In practice, the employment share is defined as the most recent 2-quarter moving average of the employment share for "mining, quarrying, and oil and gas extraction", which represents the finest sectoral disaggregate of the employment data available. Figure 5 shows the standardized employment share weights for Calgary in Alberta, Saskatoon in Saskatchewan, and Vancouver in British Columbia. It documents substantial variation in the importance of the oil industry across cities and over time, which helps identify the regional responses to real oil price shocks.

At the province level, we instead interact real oil price changes with the share of "mining, quarrying and oil and gas extraction" in provincial value added prior to the change in the real price of oil. The value added share for Alberta, for example, rose from 19% in 1999 to a peak of 33% in 2005, before declining back to 17% by 2016, reflecting the rise and decline of the oil sands industry. In contrast, the value added share for Ontario remained at approximately 1% throughout the estimation period. The estimates at the province level are generally robust to the choice of the share measure, when both are available.[25] By allowing these shares to vary over time rather than fixing them at their average value, we capture changes in the importance of the oil industry in each region over time.

Our empirical strategy exploits the interaction of time series variation in real oil prices with cross-sectional variation in regions' exposure to the oil sector, in the spirit of Bartik (1991).

[25] The main substantive difference is that the value added share tends to produce more statistically significant estimates for government spending and revenues, which is expected since the latter respond to oil tax revenues rather than oil sector employment. Our results are also robust to using alternative proxies for the importance of the oil sector.

Because we are making use of a comparatively clean source of exogenous variation, the causal effects of changes in the real price of oil can be estimated using the panel regression model

$$\Delta^h y_{i,t} = \beta_0^h + \beta_1^h \Delta^h p_t + \beta_2^h \Delta^h p_t \times \overline{s}_{i,t-h} + \beta_3^h \overline{s}_{i,t-h} + \sum_{q=1}^{3} \delta_q^h D_q + \gamma_i + \varepsilon_{i,t}^h, \qquad (7)$$

where $\Delta^h y_{i,t}$ denote the percent change between $t-h$ and t in the economic outcome of interest in region $i,$ which may refer to a city or a province, $\Delta^h p_t$ denotes the percent change in the real price of oil over the same period, $\overline{s}_{i,t-h}$ denotes the standardized employment share (or value added share) prior to the change in the price of oil, and $D_q, q = 1,2,3,$ denotes a quarterly seasonal dummy variable, and γ_i denotes a set of regional fixed effects that absorb any time-invariant heterogeneity. The error term $\varepsilon_{i,t}^h$ denotes idiosyncratic shocks specific to region $i.$ Because the number of clusters is small in our analysis, conventional cluster-robust asymptotic standard errors are not valid. Throughout the paper, we therefore report fixed-design wild bootstrap p-values for $\hat{\beta}_1^h$ and $\hat{\beta}_2^h$ clustered at the regional level, as discussed in Cameron, Gelbach and Miller (2008).[26]

The maintained assumption in our analysis is that changes in the Canadian real price of oil are not correlated with exogenous changes in variables not included in the model.[27] As an additional robustness check, we replaced $\Delta^h p_t$ in equation (7) by quarterly fixed effects that absorb all common shocks at the aggregate level. The resulting time fixed-effects model,

[26] Because the number of clusters is small, the fixed effect cannot be estimated consistently, invalidating conventional bootstrap confidence intervals and standard errors. Asymptotically valid p-values may be constructed by bootstrapping the model under the null hypothesis of zero coefficients (Canay, Santos and Shaikh 2018).

[27] There is no plausible source of exogenous variation in the Canadian macro economy that is correlated with the real price of oil over our sample period. One may be concerned that changes in the price of oil may be correlated with changes in the prices of other important Canadian commodity exports. We identified the relevant commodities in the Canadian merchandise trade account and verified that for there is little co-movement between their prices and the price of oil during our estimation period.

$$\Delta^h y_{i,t} = \beta_0^h + \beta_2^h \Delta^h p_t \times \overline{s}_{i,t-h} + \beta_3^h \overline{s}_{i,t-h} + \gamma_i + \delta_t + \varepsilon_{i,t}^h,$$

produced very similar estimates of β_2^h. We therefore report only the estimates of model (7). The advantage of model (7) compared with the time fixed effect panel model is that it allows us to assess the total effect of changes in the real price of oil on each region. The impact of an increase in the real price of oil on real house prices in region i over horizon h is captured by

$$\beta_1^h + \beta_2^h \overline{s}_{i,t-h}, \tag{8}$$

where β_1^h denotes for effect for a region with $\overline{s}_{i,t-h} = 0,$ and $\beta_2^h \overline{s}_{i,t-h}$ the region-specific effect that depends on the importance of the oil sector for the regional economy, as measured by departures of the share from zero.[28]

5.3. Responses of Regional House Prices to Oil Price Shocks

The upper panel of Figure 6 shows estimates of β_1^h obtained from quarterly city-level data. Estimates that are statistically significant at the 5% level are marked as filled circles and estimates that are significant at the 10% are marked as empty circles. For a city with a zero standardized employment share, the estimate of β_1^h for real house prices is negative initially, which is driven by the increase in inflation shown in Figure 3, given that nominal house prices are sticky. At longer horizons, real house prices increase steadily in response to an increase in the real price of oil. After a few months, the response becomes statistically significant. The cumulative effect approaches 0.03 percentage points after one year and 0.06 percentage points after two years. The lower panel of Figure 6 shows the corresponding estimates of β_2^h. Oil-rich

[28] We also experimented with an alternative model specification that allows for asymmetric responses to changes in the real price of oil. We examined the alternative hypothesis that a decline in the real price of oil lowers house prices beyond the effect associated with any percent change in the real price of oil. To minimize the risk of data mining across horizons we focused on the two-year horizon. There was no statistically significant asymmetry in the response of real house prices for either β_1^h or β_2^h.

cities experience an additional increase in real house prices in response to higher real oil prices (and oil-poor cities a correspondingly smaller increase), but this incremental response is more gradual, reaching 0.03 percentage points after two years. The estimates of β_2^h become statistically significant at the 10% level at the two-year horizon.

While not all surges in the real house price growth in oil-rich cities are caused by changes in the real price of oil, our analysis shows that real oil price shocks are an important determinant of regional house price growth.[29] To illustrate the regional heterogeneity in the propagation of oil price shocks, consider the example of two cities: Vancouver with a standardized employment share near -0.6 in 2008Q2 and Calgary with a standardized employment share in excess of 3. From equation (8), the resulting total effect of a positive 1% real oil price shock on real house prices in Calgary is a 0.03% increase at the one-year horizon and a 0.16% increase at the two-year horizon, whereas the total effect on real house prices in Vancouver is a 0.03% increase at the one-year horizon and a 0.04% increase at the two-year horizon. Despite this heterogeneity, we find that, even for the lowest standardized employment share, the effect on real house prices remains positive.[30]

5.4. Responses of other Housing Market Variables to Oil Price Shocks

The regional effects of changes in the real price of oil on real house prices do not take place in isolation. Such shocks also affect residential investment. The upper panel of Figure 6 shows that, at the average employment share, the increase in city-level real house price caused by an increase

[29] One possible alternative explanation of these surges is shifts in expectations about future real house prices not directly tied to the real price of oil. For example Favilukis and Van Nieuwersburgh (2017) stress the role of out-of-town buyers in Vancouver who treat home purchases as speculative objects.

[30] An additional empirically testable implication of the theoretical model in section 4 is that, if there are multiple cities within a region, all else equal, the cities with a less elastic housing supply should experience higher house price growth in response to a positive oil price shock. Since we are not aware of a well-established measure for the Canadian housing supply elasticity at the city level, comparable to the estimates for U.S. metropolitan housing markets in Saiz (2010), we leave this question for future research.

in the real price of oil coincides with a temporary highly statistically significant increase in the number of building permits and housing starts for single-family homes. The lower panel of Figure 6 shows an additional statistically significant increase in new permits for houses and new housing starts in oil-rich cities. This evidence confirms the interpretation of real oil price shocks as housing demand shocks because an increase in both the price and the quantity of housing can only be caused by increased housing demand.

5.5. Implications for Mortgage Markets

Figure 7 focuses on the implications of real oil price shocks for mortgage markets. Based on data at the province level, higher real oil prices cause a declining percentage of mortgages in arrears as well as increased consumer borrowing and rising mortgage values, consistent with the view that Canadian households accumulate debt in response to higher oil prices.[31] There is no statistically significant regional heterogeneity in the responses of these financial variables.

6. How Do Oil Price Shocks Propagate Across Regions?

A testable implication of the Keynesian version of the model in section 4 is that that employment and real output in oil-poor regions increase in response to unexpected oil price increases, which in turn stimulates housing demand. In section 6.1, we use panel regressions to show that the Canadian data support the Keynesian version of our model, but not the neoclassical version. The positive response of employment and real output in the Keynesian model may occur (1) because of higher demand for the intermediate good from the oil sector, (2) because of higher demand for the consumption good by consumers in the oil-rich region and by the government, and (3) as a result of the government redistribution of oil revenue to households in oil-poor provinces.

[31] The mortgage value responses are based on a shorter sample ending in 2011.Q2, given a major change in the definition of mortgage values, as reported by banks, which results in a discontinuous jump in mortgage values in 2011Q3.

Although our regression framework does not allow us to quantify the contribution of each of these channels channel separately, in sections 6.2 and 6.3 we provide empirical support for the existence of these channels and for their importance for the transmission of oil price shocks across regions.

6.1. Regional Labor Market Responses

The Keynesian version of the model suggests that, as demand for goods produced in region 2 increases, the unemployed in that region are more likely to find gainful employment, while individuals who had left the labor force at an earlier stage may choose to return to the labor market in their region in response to more jobs becoming available. As employment and labor income rises, so does the demand for housing. Figure 8 examines the labor market responses to positive real oil price shocks based on quarterly city-level data. The upper panel confirms that cities with an average oil employment share experienced an increase in real house prices, a persistent decline in the unemployment rate, and an increase in employment. There is also a small but statistically significant increase in oil employment in response to higher real oil prices.[32] Based on equation (8), even for the city with the lowest standardized employment share, the effect of a positive oil price shock on total employment is positive. For oil-rich provinces, there is an additional decline in the unemployment rate and an additional increase in total employment and in oil employment, as shown in the lower panel of Figure 8.

Further regression results (not shown to conserve space) show that the responses of the labor force are similar to those for employment, suggesting that workers who previously left the labor force choose to return in response to better employment opportunities. Average hours worked increase in oil-rich provinces, but not elsewhere. Nominal wage increases everywhere,

[32] This increase is expressed as a share of total employment prior to the real oil price increase, since oil employment is small.

but more so in oil-rich provinces. The real wage, however, increases in oil-rich provinces only. These results are consistent with increases in employment being made possible by a combination of reductions in unemployment and increases in the labor force, which helps alleviate the upward pressure on the real wage.

Another possibility not considered in the theoretical analysis is that the labor supply in region 1 may increase as a result of net migration from oil-poor provinces. Additional regression analysis based on quarterly data by province (not shown to conserve space), however, shows that increases in the real price of oil did not cause net migration of population into oil-rich provinces, which motivates the exclusion of the migration channel from the model in section 4.[33] The lack of labor mobility across provinces in response to oil price shocks is consistent with the results of numerous studies on the effect of regional labor demand shocks (see, e.g., Autor, Dorn and Hanson 2013; Dix-Carneiro and Kovak 2017).[34]

6.2. Responses of Regional Real Value Added

The Keynesian version of the model in section 4 also predicts an increase in real output in both regions in response to an increase in the real price of oil. The first row of Table 1 shows estimates of β_1^h and β_2^h at the 1-year and 2-year horizon for real GDP at the province-level.[35]

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[33] It should be noted that the migration data underlying our analysis reflect the change in the tax residency of individuals. They do not include oil sector workers that spend only part of the year working in oil-rich regions. Such temporary migrant workers have to declare their employment in the oil sector in the oil-poor region where they officially reside. Figure 8, however, shows that oil employment in oil-poor regions does not increase in response to higher oil prices, suggesting that temporary migration is not important. This conclusion is also consistent with data on passenger flights in and out of major Canadian Metropolitan Area airports. There is no evidence that the number of flights into oil-rich cities increases by more in response to higher oil prices than for other cities.

[34] In related work, Kehrig and Ziebarth (2017) provided evidence in a different context that regional migration in the United States increases in response to oil supply shocks. Their study, however, focused on in-migration rather than net migration. We also find evidence of statistically significant positive coefficients for in-migration, but these effects are offset by the positive coefficients for out-migration, resulting in statistically insignificant coefficients for net migration that are close to zero.

[35] The data are annual. All sectoral responses have been expressed as a share of real GDP prior to the real oil price increase, since in many provinces the value added of one type or another is so small that percentage changes in sectoral value added paint a misleading picture when comparing across provinces.

Like the employment responses in section 6.1, the responses of aggregate real GDP are statistically significant and positive for all provinces, even those with the lowest exposure to the oil industry. This evidence corroborates the conclusions based on the labor market data and strengthens the empirical support for the Keynesian model. The economic expansion caused by positive real oil price shocks strengthens at longer horizons for oil-rich provinces, but weakens for oil-poor provinces, suggesting that the economic expansion in oil-poor provinces is comparatively short-lived. Next, we examine in more detail the empirical support for the interprovincial trade channels of the transmission of oil price shocks to oil-poor regions highlighted in the theoretical analysis. We start with the role of supply-chain dynamics and then examine the role of higher consumer demand.

6.2.1. The Role of Supply-Chain Dynamics

The Keynesian version of the model in section 4 implies that the intermediate goods sector should expand, but the consumer goods sector may expand or fall, depending on the strength of the regional transmission mechanism. Verifying the model prediction about increased growth in the intermediate goods sector in response to higher oil prices is difficult because we do not know the extent to which a given sector provides intermediate goods for oil-rich regions. In Table 1 we present results for the mining sector and for the manufacturing sector which, according to the analysis in Allcott and Keniston (2017), account for most of the inputs supplied to the oil sector.

As expected, Table 1 shows a tightly estimated positive response of mining quarrying, and oil and gas extraction, along with activities that directly support this industry. We also find highly statistically significant increases at the one-year horizon in a broad range of manufacturing activities that are related to oil production with little evidence of regional heterogeneity in this response. At the two year horizon, the responses of several of the components of manufacturing value added remain statistically significant. Thus, there is strong evidence in support of the supply-chain links highlighted in the theoretical analysis.

6.2.2. The Role of Higher Consumer Demand

Table 2 shows the remaining sectors of the economy that exhibit a statistically significant positive response to higher oil prices at the one-year horizon. The first three rows focus on wholesale trade, retail trade, and transportation and warehousing. The highly statistically significant responses in wholesale and retail trade, in particular, across all provinces are consistent with an increase in consumer demand, as predicted by the theoretical model. The next seven rows focus on the service sector. Again, there is a pattern of positive and statistically significant responses across the board. The particularly strong response of professional, scientific and technical services suggests that this sector may be providing additional support services for the oil industry in response to higher oil prices.

The positive response of construction may reflect the increase in residential housing demand, but could also be indicative of increased demand for roads and industrial infrastructure, while the positive response of utilities suggests increased demand for water and power. Finally, the positive response of public administration services in all provinces is suggestive of increases in government spending driven by the redistribution of oil tax revenue, as discussed in section 6.3.

6.3. The Role of Government Redistribution of Oil Tax Revenue

Canada pursues an active policy of redistributing oil revenue from rich provinces (which with the exception of British Columbia include only the oil-rich provinces) to its oil-poor provinces. These transfers are known as “equalizations”. The theoretical model in section 4 predicts that $\partial q_2 / \partial p > 0$ if

$$\underbrace{pb\frac{\partial N_2(p)}{\partial p}}_{+}+\underbrace{\omega\tau p^2\frac{\partial O}{\partial p}}_{+}+\omega\tau pO>k_2 p.$$

Since the first term is weakly positive by assumption and the second term is strictly positive for $0<\omega\tau<1,$ a sufficient condition for $\partial q_2/\partial p>0$ is $\omega\tau pO>k_2 p,$ i.e., the magnitude of the direct fiscal transfer to households in region 2 exceeds the commuting cost in region 2.

For expository purposes, suppose that the entire oil tax revenue were redistributed to households ($\omega=1$). Then we would expect an income stimulus whenever the equalization payments per capita received by an oil-poor province exceeds its per capita spending on motor fuel. Table 3 shows that, on average, the equalization payments are almost twice as large as the spending on motor fuel, suggesting that the degree of government redistribution is large enough to matter and that the equalization of government spending across provinces is likely to play a central role in the transmission of oil price shocks in Canada.

This conclusion is corroborated by more direct evidence on the responses of government revenue and government spending by province. Table 4 presents results of a formal test of the hypothesis of regional homogeneity in government revenues and in government expenditures by province. Regional homogeneity implies that β_2^h is zero in equation (7). At the 1-year horizon, a t-test of $H_0:\beta_2^h=0$ rejects the null of regional homogeneity at the 5% level for government revenue and at the 10% level for government expenditures. Since government revenues in oil-rich provinces increase much more than government expenditures, we may infer that the excess revenue is redistributed to other provinces, consistent with the evidence of a statistically significant increase in government expenditures in the average province, but no statistically significant increase in government revenue.

At the 2-year horizon, in the average province, an increase in the real price of oil causes a statistically significant increase in government revenue as well as in government expenditures, consistent with a general economic expansion. Whereas a t-test of $H_0 : \beta_2^h = 0$ rejects the null of regional homogeneity in government revenue at the 5% level, it does not reject this null for government expenditures. Notwithstanding the fact that government revenues in oil-rich provinces increase by more than in the average province in response to positive real oil price shocks, government expenditures in oil-rich provinces do not increase by more than in the average province. This pattern is consistent with the interpretation that the redistribution of income across provinces through interprovincial transfers is effective at the 2-year horizon. It should be noted that this redistribution occurs only at horizons beyond one year.

7. Conclusion

The traditional view is that shocks in housing markets that originate in one region are only relevant for that region. We made the case that regional shocks can have broader impacts on housing markets in other regions, even when housing markets are regionally segmented and heterogeneous. We illustrated this point using data from Canada, where oil price shocks constitute an important source of regional variation in real income. We documented that such shocks raise the demand for housing and hence real house prices even in cities and provinces where the oil industry is small or nonexistent. This empirical result stands in contrast to the implications of standard urban models of the transmission of oil price shocks to housing markets. In the latter models, higher oil prices raise commuting costs in all cities, but only oil-rich cities experience income gains. Thus, higher oil prices raise house prices in oil-rich cities, reflecting the net income gains in these cities, but lower house prices in oil-poor regions (e.g., Molloy and Shan 2013; Larson and Zhao 2017; Cunningham et al. 2017).

We developed a theoretical model of the transmission of oil price shocks across regions that helps explain why our empirical findings differ. The model differentiates between oil-rich and oil-poor regions and incorporated multiple sectors, commuting costs, government redistribution of oil income, and trade across provinces reflecting supply chain dynamics and higher consumer demand from oil-rich regions. Compared with standard urban models of housing markets, this model incorporates two additional transmission channels. In our model, the government redistribution of oil revenue across regions as well as higher demand for intermediate goods and consumer goods produced in the oil-poor regions will stimulate real output and employment (and thus housing demand and real house prices) even in the oil-poor region. Under weak conditions, these effects in conjunction will more than offset higher commuting costs in oil-poor regions, causing housing demand to expand, to varying degrees, across all regions.

We empirically validated our model by showing that existing Canadian policies of redistributing oil income from oil-rich to oil-poor provinces have succeeded at equalizing the government spending responses to oil price shocks across Canadian provinces. We also empirically confirmed the model prediction that increased demand for intermediate goods and consumer goods in the oil-rich region will stimulate real output and employment in the oil-poor region.

Our analysis adds to a growing literature on the regional transmission of shocks (see, e.g., Feyrer et al 2017; Allcott and Keniston 2017; Kehrig and Ziebarth 2017). Our work differs from these earlier studies not only because we focused on housing markets rather than labor markets and because we used different data, employed a different empirical methodology, and exploited a different source of cross-sectional variation. We also provided new insights about the mechanisms by which regional shocks may be propagated. An interesting question for future research will be to assess the empirical relevance of these mechanisms for other countries. The link between oil price shocks and housing markets is relevant not only for Canada and the United States, but also for other oil-producing countries including the United Kingdom, Norway, and Mexico. Moreover, oil price shocks are merely one example of regional shocks to real income. Going forward, it would be of interest to study the implications of other regional shocks for housing markets. Our analysis has been only one step along the road toward understanding the regional heterogeneity of housing markets in major economies.

References

Allen, J., Amano, R., Pyrne, D.P, and A.W. Gregory (2009), "Canadian City Housing Prices and Urban Market Segmentation," *Canadian Journal of Economics*, 42, 1132-1149.

Allen, J., Clark, R., and J.-F. Houde (2014), "Price Dispersion in Mortgage Markets," *Journal of Industrial Economics*, 62, 377-416.

Alquist, R., Kilian, L., and R.J. Vigfusson (2013), "Forecasting the Price of Oil," in: G. Elliott and A. Timmermann (eds.), Handbook of Economic Forecasting, 2, Amsterdam: North-Holland, 427-507.

Allcott, H., and D. Keniston (2017), "Dutch Disease of Agglomeration? The Local Economic Effects of Natural Resource Booms in Modern America," forthcoming: *Review of Economic Studies*.

Anderson, S.T., Kellogg, R. and J.M. Sallee (2013), "What Do Consumers Believe About Future Gasoline Prices," *Journal of Environmental Economics and Management*, 66, 383-403.

Anderson, S.T., Kellogg, R., Sallee, J.M., and R.T. Curtin (2011), "Forecasting Gasoline Prices Using Consumer Surveys," *American Economic Review Papers & Proceedings*, 101, 110-114.

Asdrubali, P., Sørensen, B.E., and O. Yosha (1996), “Channels of Interstate Risk Sharing: United States 1963-1990,” *Quarterly Journal of Economics*, 111, 1081-1110.

Autor, D., Dorn, D., and G. Hanson (2013), “The China Syndrome: Local Labor Market Effects of Import Competition in the United States,” *American Economic Review*, 103, 2121-2168.

Bartik, T. (1991), *Who Benefits from State and Local Economic Development Policies?* W.E. Upjohn Institute for Employment Research: Kalamazoo, MI.

Bhutta, N., and B.J. Keys (2016), “Interest Rates and Equity Extraction during the Housing Boom,” *American Economic Review*, 106, 1742-1774.

Boxall, P.C., Chan, W.H., and M.L. MacMillan (2005), “The Impact of Oil and Natural Gas Facilities on Rural Residential Property Values: A Spatial Hedonic Analysis,” *Resource and Energy Economics*, 27, 248-269.

Brüggemann, R., C. Jentsch, and C. Trenkler (2016), “Inference in VARs with Conditional Heteroskedasticity of Unknown Form,” *Journal of Econometrics*, 191, 69-85.

Cameron, A. C., Gelbach, J. B., and D.L. Miller (2008), “Bootstrap-Based Improvements for Inference with Clustered Errors,” *Review of Economics and Statistics*, 90, 414-427.

Canay, I.A., Santos, A., and A.M. Shaikh (2018), “The Wild Bootstrap with a “Small” Number of “Large” Clusters,” manuscript, Northwestern University.

Cunningham, C., Gerardi, K., and Y. Shen (2017), “Fracking and Mortgage Default,” Working Paper 2017-4, Federal Reserve Bank of Atlanta.

Del Negro, M., and C. Otrok (2007), “99 Luftballons: Monetary Policy and the House Price Boom across U.S. States,” *Journal of Monetary Economics*, 54, 1962-1985.

Dix-Carneiro, R., and B.K. Kovak (2017), “Trade Liberalization and Regional Dynamics,” *American Economic Review*, 107, 2908-2946.

Favilukis, J.Y., and S. Van Nieuwersburgh (2017), "Out-of-Town Home Buyers and City Welfare," CEPR Discussion Paper No. 12283.

Ferreira, F., and J. Gyourko (2011), "Anatomy of the Beginning of the Housing Boom: U.S. Neighborhoods and Metropolitan Areas, 1993-2009," NBER Working Paper No. 17374.

Feyrer, J., Mansur, E.T., and B. Sacerdote (2017), "Geographic Dispersion of Economic Shocks: Evidence from the Fracking Revolution," *American Economic Review*, 107, 1313-1334.

Fitzgerald, T., and R.R. Rucker (2016), "U.S. Private Oil and Natural Gas Royalties: Estimates and Policy Relevance," *OPEC Energy Review*, 40, 3-25.

Fontaine, J.-S., and G. Nolin (2017), "The Share of Systematic Variations in the Canadian Dollar – Part II," Staff Analytical Note No. 2017-1, Bank of Canada.

Glaeser, E.L., Gottlieb, J., and J. Gyourko (2010), "Can Easy Credit Explain the Housing Boom?." NBER Working Paper No. 16230.

Halverson, R., and H.O. Pollakowski (1981), "The Effects of Fuel Prices on House Prices," *Urban Studies*, 18,205-211.

Head, A., Lloyd-Ellis, H., and H. Sun (2014), "Search, Liquidity, and the Dynamics of House Prices and Construction," *American Economic Review*, 104, 1172-1210.

Hurst, E., Keys, B., Seru, A., and J.S. Vavra (2016), "Regional Redistribution through the U.S. Mortgage Market," *American Economic Review*, 106, 2982-3028.

Kehrig, M., and N. Ziebarth (2017), "The Effects of the Real Oil Price on Regional Wage Dispersion," *American Economic Journal: Macroeconomics*, 9, 115-148.

Kilian, L. (2008), "The Economic Effects of Energy Price Shocks," *Journal of Economic Literature*, 46, 871-909.

Kilian, L. (2014), "Oil Price Shocks: Causes and Consequences," *Annual Review of Resource Economics*, 6, 133-154.

Kilian, L. (2016), "The Impact of the Shale Oil Revolution on U.S. Oil and Gas Prices," *Review of Environmental Economics and Policy*, 10, 185-205.

Kilian, L., Rebucci, A., and N. Spatafora (2009), "Oil Shocks and External Balances," *Journal of International Economics*, 77, 181-194.

Kilian, L., and C. Vega (2011), "Do Energy Prices Respond to U.S. Macroeconomic News? A Test of the Hypothesis of Predetermined Energy Prices," *Review of Economics and Statistics*, 93, 660-671.

Larson, W.D., and W. Zhao (2017), "Oil Prices and Urban Housing Demand," forthcoming: *Real Estate Economics*.

Molloy, R., and H. Shan (2013), "The Effect of Gasoline Prices on Household Location," *Review of Economics and Statistics*, 95, 1212-1221.

Muehlenbachs, L., Spiller, E., and C. Timmins (2015), "The Housing Market Impacts of Shale Gas Development," *American Economic Review*, 105, 3633-3659.

Nocera, A., and M. Roma (2017), "House Prices and Monetary Policy in the Euro Area: Evidence from Structural VARs," ECB Discussion Paper No. 2073.

Saiz, A. (2010), "The Geographic Determinants of Housing Supply," *Quarterly Journal of Economics*, 125, 1253-1296.

Sexton, S., Wu, J.J., and D. Zilberman (2012), "How High Gas Prices Triggered the Housing Crisis: Theory and Empirical Evidence," manuscript, University of California at Berkeley.

Yinger, J.M. (2015), *Housing and Commuting: The Theory of Urban Residential Structure*, World Scientific Publishing, http://faculty.maxwell.syr.edu/jyinger/ebooks/housing_commuting/table_of_contents.htm.

Table 1: Sectoral real output responses (province-level): Supply-chain dynamics

	1-year horizon		2-year horizon	
	$\hat{\beta}_1^h$	$\hat{\beta}_2^h$	$\hat{\beta}_1^h$	$\hat{\beta}_2^h$
Real GDP	0.0452***	0.0266***	0.0473***	0.0467*
	(0.000)	(0.000)	(0.005)	(0.057)
Mining, quarrying & oil and gas extraction	0.0197***	0.0166	0.0176**	0.0251*
	(0.002)	(0.114)	(0.020)	(0.086)
- Supporting activities for mining and oil & gas extraction	0.0028*	0.0030*	0.0037**	0.0031*
	(0.057)	(0.062)	(0.023)	(0.090)
Manufacturing	0.0075***	-0.0011	0.0003	0.0045**
	(0.000)	(0.783)	(0.490)	(0.031)
- Computer and electronic Products	0.0012***	-0.0006	0.0004**	-0.0002
	(0.003)	(0.915)	(0.038)	(0.743)
- Machinery	0.0011***	0.0005	0.0015**	0.0011
	(0.000)	(0.260)	(0.049)	(0.135)
- Fabricated metal Products	0.0011***	-0.0002	0.0009**	0.0005
	(0.003)	(0.699)	(0.033)	(0.223)
- Transportation Equipment	0.0010***	-0.0006	0.0005	-0.0001
	(0.057)	(0.851)	(0.321)	(0.563)
- Electrical equipment, appliances, components	0.0004***	-0.0002	0.0001	-0.0001
	(0.000)	(0.991)	(0.185)	(0.792)
- Miscellaneous Manufactures	0.0003*	-0.0002	0.0000	0.0000
	(0.014)	(0.950)	(0.384)	(0.444)

NOTES: Bootstrap *p* -values in parentheses. *, **, and *** denotes statistical significance at the 10%, 5%, and 1% level, respectively.

Table 2: Sectoral real output responses (province-level): Other industries

	1-year horizon		2-year horizon	
	$\hat{\beta}_1^h$	$\hat{\beta}_2^h$	$\hat{\beta}_1^h$	$\hat{\beta}_2^h$
Wholesale trade	0.0034***	0.0019	0.0044***	0.0033
	(0.000)	(0.122)	(0.000)	(0.122)
Retail trade	0.0018***	0.0006	0.0023***	0.0016
	(0.001)	(0.121)	(0.006)	(0.116)
Transportation and warehousing	0.0005*	-0.0002	-0.0006	0.0006**
	(0.057)	(0.361)	(0.878)	(0.035)
Information and cultural industries	0.0012***	-0.0002	0.0011***	0.0002
	(0.000)	(0.178)	(0.000)	(0.257)
Professional, scientific and	0.0019***	0.0012	0.0024**	0.0023*
technical services	(0.002)	(0.109)	(0.021)	(0.094)
Business Management	0.0002**	0.0001	0.0005***	0.0001
	(0.017)	(0.291)	(0.000)	(0.234)
Administrative, support, and other	0.0009**	-0.0005	0.0016***	0.0001
services	(0.016)	(0.949)	(0.000)	(0.395)
Educational services	0.0008***	0.0001	0.0019***	-0.0002
	(0.004)	(0.307)	(0.001)	(0.811)
Other services (except public	0.0007***	0.0002	0.0009***	0.0004
administration)	(0.000)	(0.130)	(0.002)	(0.130)
Public administration	0.0006**	-0.0004	0.0027***	-0.0007
	(0.025)	(0.928)	(0.000)	(0.982)
Utilities	0.0018***	-0.0002	0.0019***	-0.0006
	(0.000)	(0.713)	(0.000)	(0.961)
Construction	0.0053*	0.0075*	0.0095**	0.0071
	(0.091)	(0.051)	(0.021)	(0.109)
Agriculture, forestry, fishing and	0.0023*	0.0011	0.0023	0.0025**
hunting	(0.081)	(0.148)	(0.222)	(0.037)

NOTES: Bootstrap p-values in parentheses. *, **, and *** denotes statistical significance at the 10%, 5%, and 1% level, respectively.

Table 3: Average magnitude of equalization transfers received and average motor fuel expenditures in 2016 dollars (by province), 2009-2016

Province	Equalization Transfer $ per capita	Motor Fuel spending $ per capita	Excess Transfer $ per capita
Manitoba	1,507	656	851
Ontario	161	708	-547
Quebec	1,108	609	499
New Brunswick	2,243	830	1,413
Nova Scotia	1,585	718	867
Average	1,321	708	613

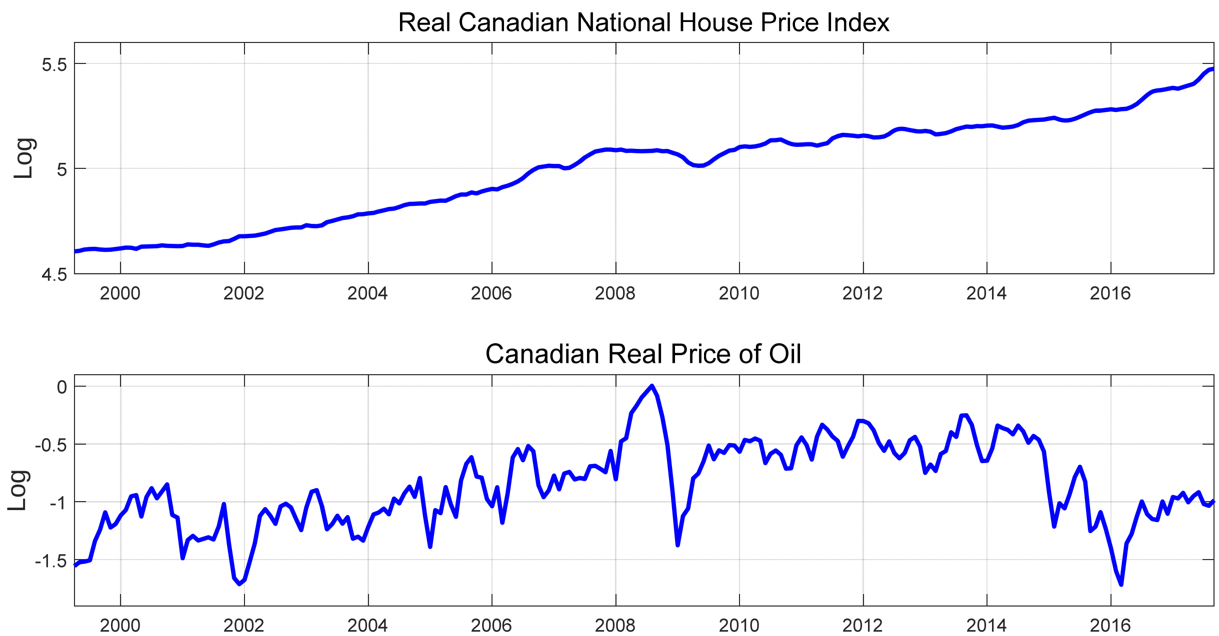
NOTES: The data on the equalization transfers are from the Canadian Department of Finance. Gasoline spending is from household surveys, as reported by Statistics Canada. The motor fuel spending per household has been divided by the average number of household members.

Table 4: Government revenue and government spending responses to real oil price shocks (province-level)

	1-year horizon	
	$\hat{\beta}_1^h$	$\hat{\beta}_2^h$
Revenue	0.038 (0.199)	0.123 (0.007)***
Expenditure	0.026 (0.091)*	0.028 (0.068)*
	2-year horizon	
	$\hat{\beta}_1^h$	$\hat{\beta}_2^h$
Revenue	0.075 (0.067)*	0.100 (0.032)**
Expenditure	0.034 (0.006)***	-0.010 (0.708)

NOTES: Bootstrap *p* -values shown in parentheses. *, **, and *** denotes statistical significance at the 10%, 5%, and 1% level, respectively.

Figure 1: Real house prices and the real price of oil in Canada, 1999.3-2017.8

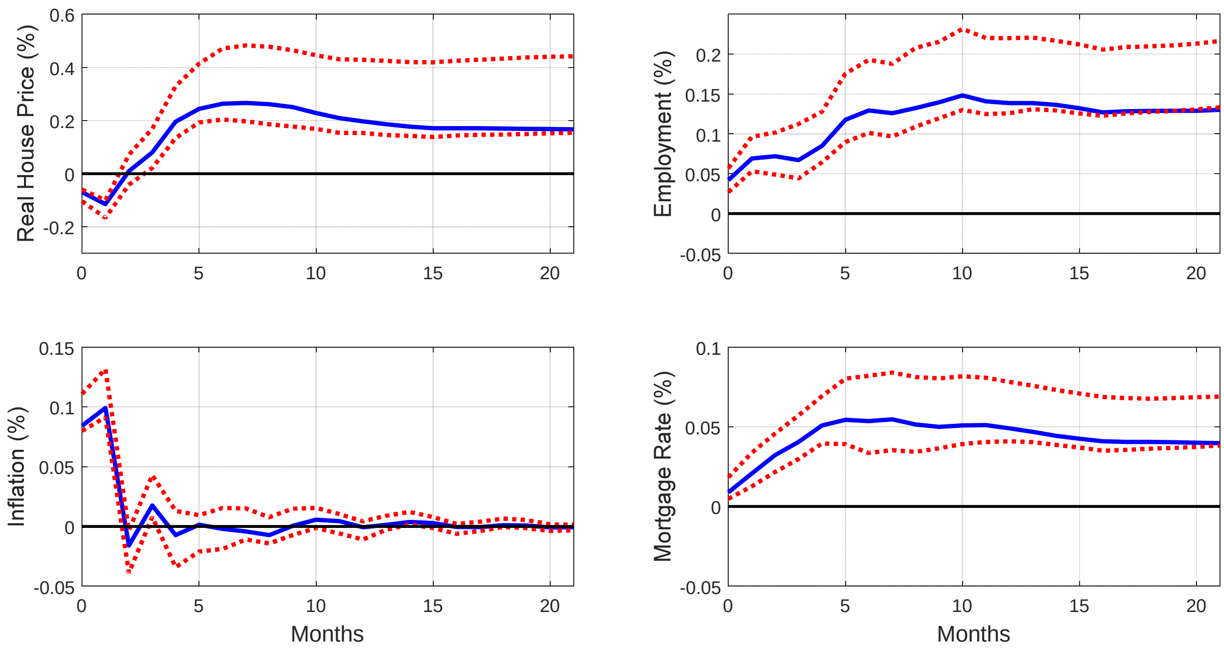


NOTES: The monthly Canadian national house price index is from Teranet-National Bank and is based on the change in home prices in 11 metropolitan areas. The nominal price of oil is the price of Western Canada Select (WCS) crude oil. Both time series have been deflated by the CPI.

Figure 2: The effect of selected shocks on real national house prices, 1999.3-2017.8

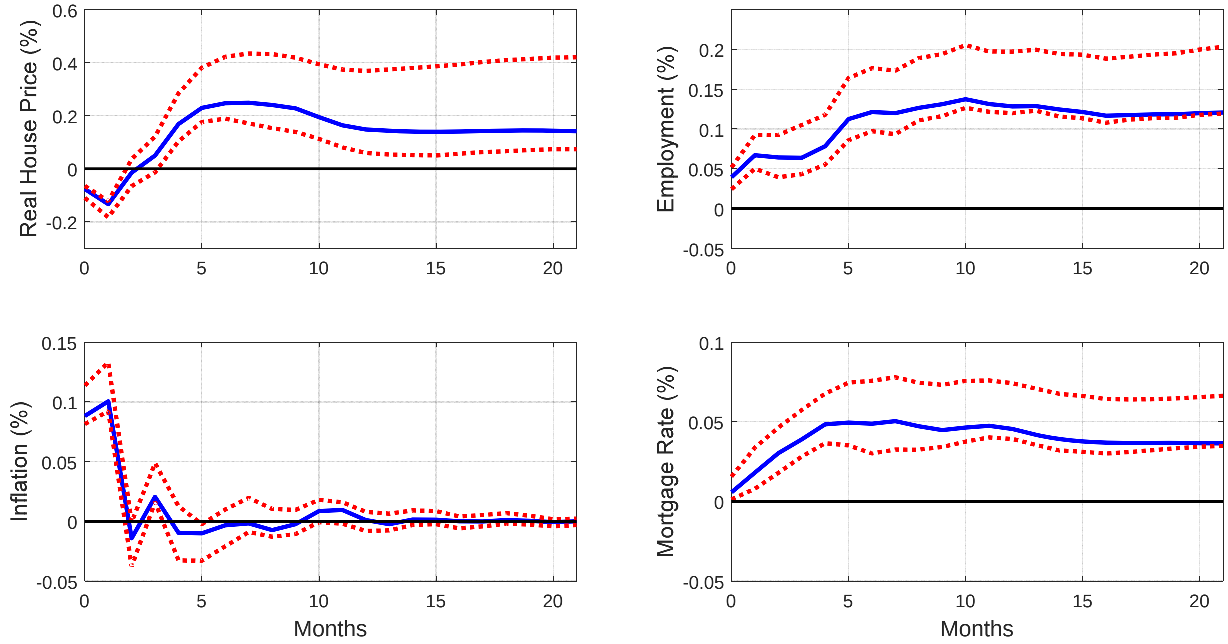
NOTES: Responses to one standard deviation shocks based on the VAR model in section 2.1. The 68% confidence intervals were constructed based on the conditional heteroskedasticity-robust residual block bootstrap of Brüggemann, Jentsch and Trenkler (2016) with block size 24.

Figure 3: The effect of an unexpected increase in the Canadian real price of oil on selected Canadian macroeconomic aggregates, 1999.3-2017.8



NOTES: Responses to one standard deviation shock based on the VAR model in section 2.1. The 68% confidence intervals were constructed based on the conditional heteroskedasticity-robust residual block bootstrap of Brüggemann, Jentsch and Trenkler (2016) with block size 24.

Figure 4: The effect of an unexpected increase in the U.S. real price of oil on selected Canadian macroeconomic aggregates, 1999.3-2017.8



NOTES: Responses to one standard deviation shock based on the VAR model in section 2.2. The 68% confidence intervals were constructed based on the conditional heteroskedasticity-robust residual block bootstrap of Brüggemann, Jentsch and Trenkler (2016) with block size 24.

Figure 5: Standardized employment shares for selected Canadian cities

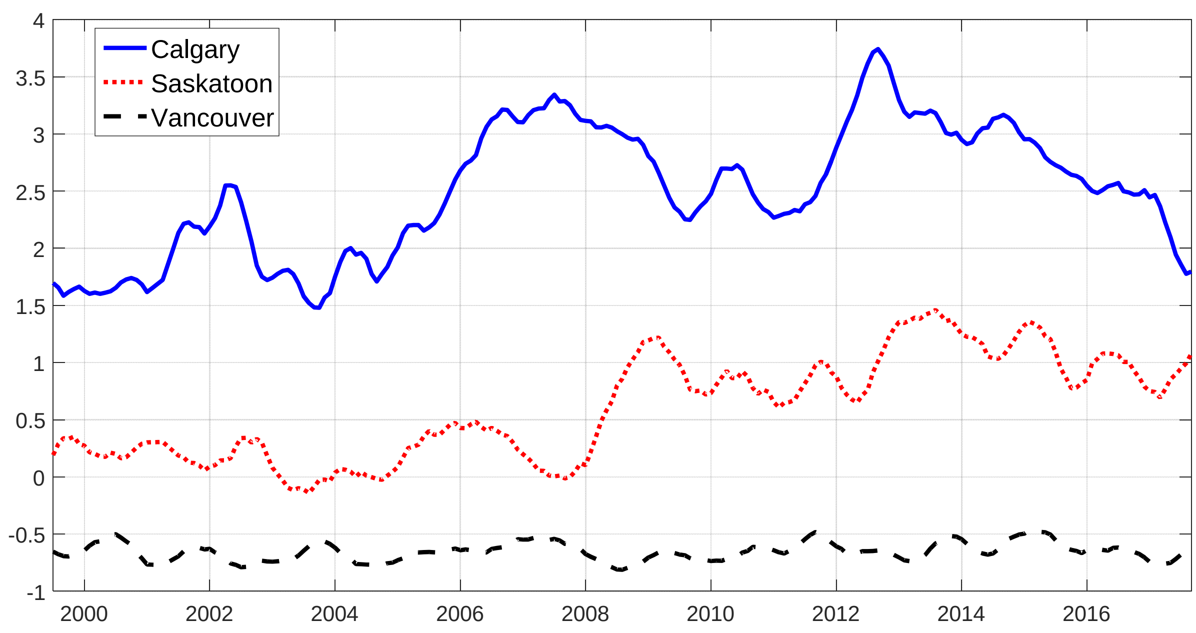


Figure 6: Housing market responses to a positive 1% real oil price shock (city-level)

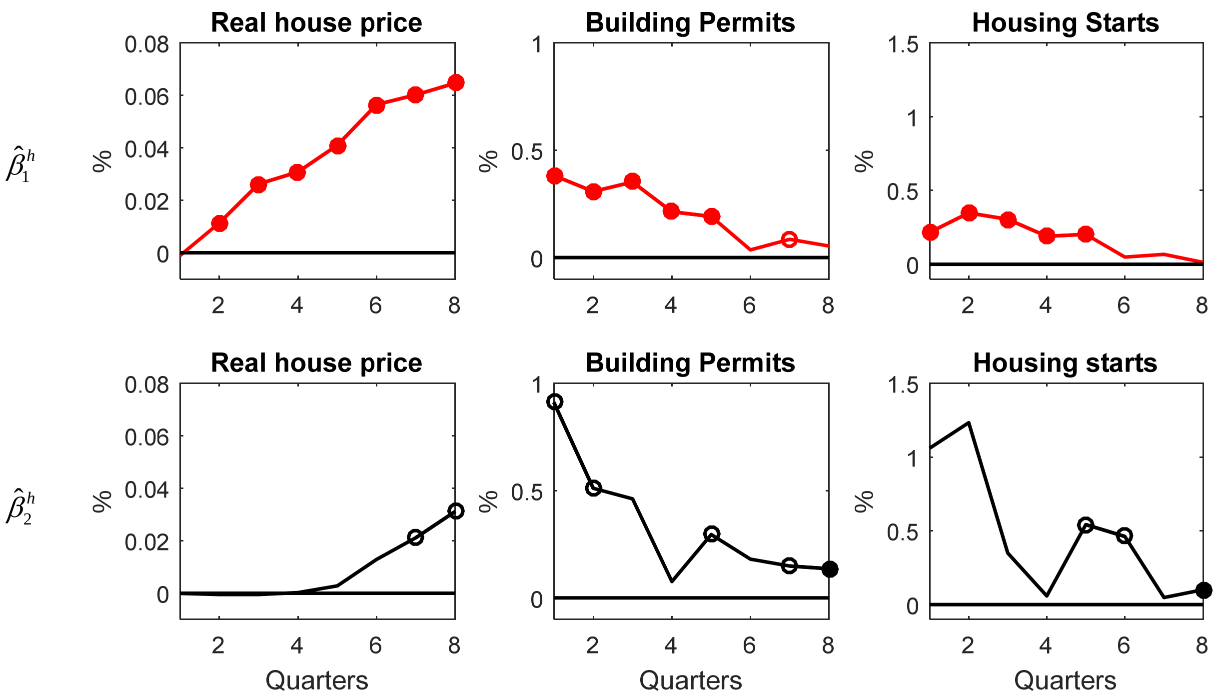


Figure 7: Responses of mortgage markets to a positive 1% real oil price shock (province-level)

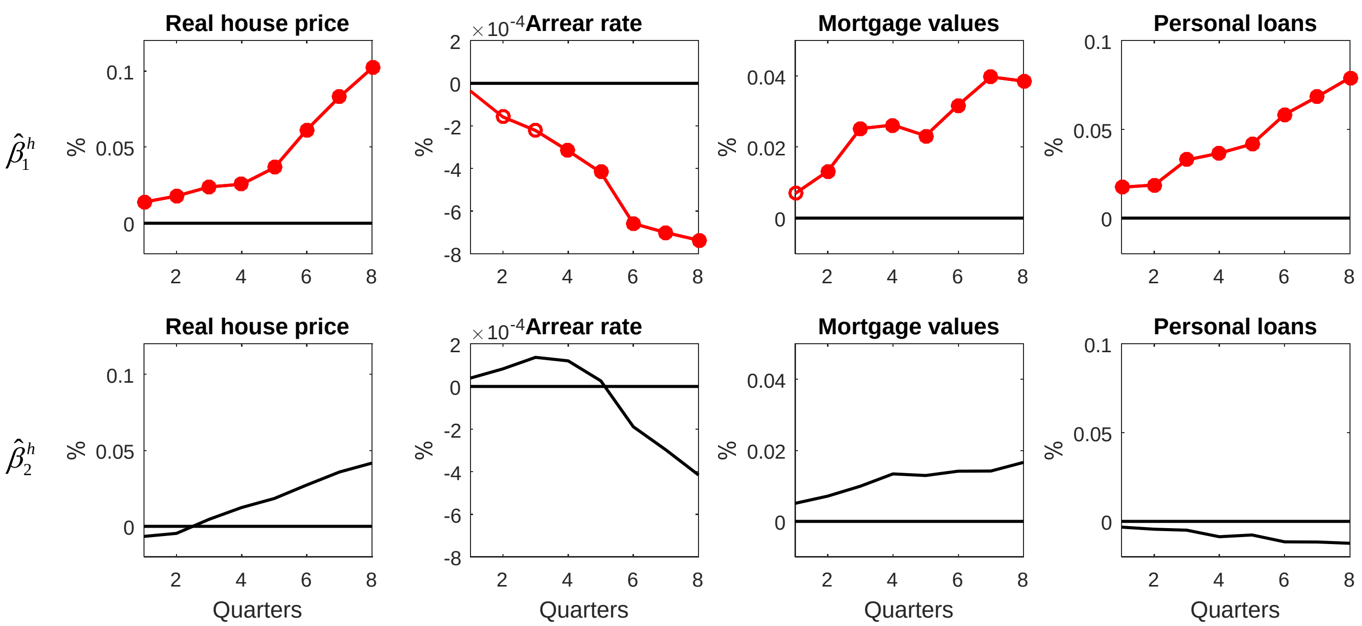


Figure 8: Labor market responses to a positive 1% real oil price shock (city-level)