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Oil Prices and Urban Housing Demand

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Working Paper 16-03

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Abstract

We develop a model of a monocentric, oil-exporting city. The model predicts producer price and transportation cost effects of oil price changes on the house price gradient. Empirical findings support the predictions, with house price changes positively linked to the price of oil in cities specialized in oil and gas-related industries, and negatively linked in suburban areas of all cities. These results quantify the large and differential risks to house prices associated with oil price changes both within and across cities.

Keywords: transportation cost, gasoline price, industrial specialization, input-output model, economic base model

JEL Classification: R30 · Q4

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1. Introduction

Households have varying exposure to fluctuations in the price of oil. For instance, some workers are employed in businesses related to the production of oil, while others are not, leading to substantial and differential income risk from price changes. On the expenditure side of the budget constraint, identical households may commute different distances to their place of work, leading to greater oil (via gasoline) expenditure shares for households commuting longer distances. Because housing demand is theoretically tied to location-specific factors related to both incomes and transportation costs – a relationship highlighted in the standard urban model (SUM) of Alonso (1964), Mills (1967), and Muth (1969) – oil prices are predicted, based on theory, to have different effects on house prices in different locations.

The empirical literature has examined both the income and commuting cost links to house prices individually, but not together within a cohesive modeling framework. For instance, Smith and Tesarek (1991) investigate the earnings hypothesis and find that house prices in Houston, TX, a city specializing in oil-related industries, are directly related to the price of oil, and Coulson and Engle (1987), Dodson and Sipe (2008), Molloy and Shan (2013), and Gillingham (2014), each consider the transportation cost hypothesis, find housing demand to be inversely related to the price of gasoline when commute lengths are long.[1] However, no study brings together the simultaneous effects of oil price changes on house prices including both earnings and commuting cost effects.

In this paper, we develop a theoretical model of an oil-exporting monocentric city. In this model, the city lies on a featureless plane with three concentric regions: a central business district (CBD) where firms locate and to which households commute, a residential district where households live, and an agricultural hinterland, which does not contribute to the city. Households are homogeneous, consuming a composite commodity and housing. Housing quality is one-dimensional, varying by size, and is produced by profit-maximizing producers using structure and land inputs. CBD firms produce oil for export at a global price. The framework gives the classic iso-utility and iso-profit conditions in the SUM, but with an added focus on the export price of the produced good. Comparative statics give predictions related to effects of oil price shocks through two channels: an earnings effect through export prices, and a transportation cost effect through higher gasoline costs, the primary input of

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[1] McCollum and Upton (2016) investigate the mortgage performance effects of rising oil prices in oil-rich regions, finding mortgage default rates and missed payments declining relative to the national average.

which is oil.

We test the model using a new database of ZIP code-level house price indices from Bogin, Doerner, and Larson (2016).[2] We find evidence that oil prices interacted with various measures and proxies for commuting distance are predictive of house price changes. Estimates indicate a 50 percent rise in the oil price decreases relative house prices in the suburbs (>15 miles from the CBD) by a total of 1.2 percent after 3 years and 2 percent after 6 years. Because the distance-to-CBD measure includes substantial measurement error, this estimate is likely attenuated and is thus a lower bound. Estimates also suggest that when a city's export employment share in oil-producing sectors is 50 percent (for context, Williston, ND has a 60 percent share in 2013), a 50 percent increase in the oil price causes house prices in all areas of the city to rise by about 11 percent after 3 years and 20 percent after 7 years. Effects of oil price changes are robust and relatively constant across time periods (1975 to 1990, 1990 to 2000, 2000 to 2010, and 2010 to 2015) regarding the transportation cost effect, suggesting symmetry in terms of positive versus negative oil price changes. The oil export effect is robustly positive, though more highly variable across time periods. Additional robustness tests are broadly consistent with the theoretical model, with each additional set of estimates serving to highlight the differential sensitivities of housing demand in different locations to changes in the price of oil.

Both our theoretical predictions and empirical findings support the following view of the relation between rising oil prices and house values. In cities not linked to oil production, relative demand for housing rises in center-cities and falls in the suburbs. In oil exporting cities, however, the entire housing demand profile changes with the price of oil. Because the differential slope effects on suburban vs center-city prices are relatively small compared to the shift effect from export prices, the demand effects from oil price changes are skewed across the cross-section of American cities. Overall, there is much greater potential for high-magnitude negative house price changes when the price of oil falls than when it rises. Therefore, when it comes to housing demand, house prices, and mortgage credit risk, negative oil price shocks are potentially much more harmful than positive oil price shocks.

The remainder of the paper is organized as follows. In Section 2, we present our monocentric

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[2] The indices are published by the Federal Housing Finance Agency and can be downloaded at: `http://www.fhfa.gov/papers/wp1601.aspx`.

model which is used to generate comparative static predictions. Section 3 describes the oil, house price, industry data, and relevant stylized facts in the series. Section 4 presents the stochastic specification of the comparative static predictions from Section 2. In Section 5, we describe the results of the estimated equations, and in Section 6, we show these results to be robust to a variety of different specifications, samples, and measurements. We conclude in Section 7 with some final thoughts and applications of our research.

2. Conceptual Framework

The model presented in this section is based on the standard model of a monocentric city following Alonso (1964), Mills (1967), Muth (1969), and the systems of cities model of Henderson (1974).[3] The city contains three distinct regions: a singularity at the center termed the central business district (CBD) where export firms are located, a residential zone where households locate in order to be as close as possible to their place of employment, and an agricultural hinterland that does not contribute to the city.[4] The city is circular and identical at every distance from the center point of the city. This allows expression of variables in terms of the radius of an annulus (ring) or the distance to the CBD.

A representative, perfectly competitive export firm optimizes output production with respect to the price of the exported good, in this case, oil, and the local labor wage. Firms produce output using labor alone. Housing producers construct housing using structure and land inputs in a perfectly competitive market. Households consume housing and a composite commodity, and undertake costly commutes to the CBD for employment. Migration of people and goods is costless. All firm and factor input owners are absentee and do not contribute profits to household incomes in the city.

In equilibrium, all households and firms are as well off at their current location as any other. The iso-utility condition, along with a fixed quantity of land in each annulus, gives the familiar "Muth's Equation" (1969, p.22). This equation shows house prices falling the further a home is from the center of the city, at a rate equal to the ratio of marginal transportation costs to housing expenditures.

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[3] Notation and derivations are based on Henderson (1974) and Brueckner (1987).

[4] The CBD is assumed to occupy no land area in this model. This assumption can be made without effects on comparative statics as long as there is no traffic congestion in the city. Constant transportation costs over a fixed land area for all households is simply a fixed cost of residing in the city. On the other hand, when traffic congestion is present in a city of endogenous size, it is important to model a CBD that occupies land.

In order to incorporate the price of oil into this framework, we assume that both the pecuniary price of commuting and the price of the exported good are linearly related to the oil price.[5] Harmonizing these two parameters in the model allows for several interesting comparative static predictions. In the standard urban model (SUM), the price gradient results from the consumer's maximization problem vis-a-vis bid rent curves. Therefore, instead of deriving the entire model, it is possible to arrive at comparative static predictions relating house prices to oil prices by analyzing only the export firm's maximization problem and the household maximization problem. Other comparative statics from the model can be found in Brueckner (1987).

Export Firms

The central business district (CBD) is a single point and is occupied by a representative firm which produces output Q under a constant returns-to-scale production function using labor N inputs, where a is a city-specific productivity parameter.[6,7]

$$Q = aN \tag{1}$$

Firms maximize profits by selling output at a globally determined, exogenous price p^O and hiring workers at a city-specific, endogenously determined wage rate w. The first order condition of the export firm's profit function gives the wage rate equal to labor productivity multiplied by the export price, which in this case, is the oil price.

$$w = ap^O \tag{2}$$

Households

Households achieve utility by consuming housing q, a composite commodity z, and leisure l under a strictly quasi-concave utility function $U(z, q, l)$ subject to a budget constraint.

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[5] In reality, oil production is distributed unevenly across space, not just in the CBD, but the monocentric city assumption is tenable based on the following logic. While oil production itself is diffuse, support activities and endogenous local goods and services are likely to be governed by inter-relationships that result in the existence of a CBD. In the monocentric model presented here, we model the production of one good for export, but this could easily be generalized to include multiple sectors that ultimately rely on the price of the goods and services produced by the economic base, in this case, oil.

[6] City-specific subscripts on a and all endogenous variables are omitted for ease of exposition.

[7] The city-specific nature of productivity induces firms to locate in particular cities. Some other mechanisms for city formation are described in Abdel-Rahman and Anas (2004), including public good provision, production agglomeration, or local amenities.

Households earn the same base income w and have identical preferences. Workers must commute to the CBD by car with variable pecuniary cost t per unit of distance k. Following Brueckner and Rosenthal (2009), it is assumed that leisure time is fixed at $\bar{l}$, with the time cost of commuting subtracted from earnings. The time spent commuting is not without some pseudo-leisure benefit, so the time cost of commuting is less than the foregone income. The time cost of commuting is specified as a fraction of ϕ of the full work period income per unit of distance k, with the total time cost of transport of ϕkw. The incurred commuting cost for a household living at radius k is therefore

$$T(k) = (t + \phi w)k \tag{3}$$

Normalizing the price of z to 1, the household's utility maximization problem is

$$\max U(z(k), q(k), \bar{l}) \qquad s.t. \quad w = z(k) + p(k)q(k) + (t + \phi w)k \tag{4}$$

Marginal transportation costs are related in a linear fashion to the price of oil according to $t = bp^O$. Substituting for z in the utility function using the budget constraint, $z = w - (t + \phi w)k - p(k)q(k)$, for wages $w = ap^O$, and for marginal transportation costs $t = bp^O$, the first order conditions give

$$\frac{U_2(p^O(a - bk - a\phi k) - p(k)q(k), q(k))}{U_1(p^O(a - bk - a\phi k) - p(k)q(k), q(k))} = p(k) \tag{5}$$

The intra-city iso-utility condition implies households have identical utility levels and are indifferent between living in different locations within the city. Additionally, under the assumption of an open city, the utility level of households must equal to the prevailing utility level u^*, which is exogenously given. Therefore,

$$U(p^O(a - bk - a\phi k) - p(k)q(k), q(k)) = u^* \tag{6}$$

An Oil Price Shock in an Oil Exporting City

After establishing the relevant first order conditions and urban equilibrium conditions, comparative static analysis can be conducted to predict the effects of an oil price shock on the housing price and the urban spatial structure.

First, the slope of the house price gradient can be derived by totally differentiating (6) with respect to k. This gives

$$-U_1((b+a\phi)p^O + p(k)q'(k) + q(k)p'(k)) + U_2 q'(k) = 0 \tag{7}$$

substituting $U_2 = U_1 p(k)$ from equation 5 into equation 7 and rearranging gives our version of Muth's equation

$$p'(k) = \frac{-(b+a\phi)p^O}{q(k)} \tag{8}$$

This equation shows house prices falling at a rate where households are indifferent between consuming more housing at higher commuting expenditures or less housing with reduced commuting expenditure. In our rendition of the model, the marginal commuting expenditure is a constant term (pecuniary costs b plus time costs $a\phi$) multiplied by the oil price p^O. When oil prices increase, the house price gradient steepens.

But overall, what happens to the *level* of house prices, not just the gradient? The effect of the oil price p^O on housing prices $p(k)$ can also be derived by totally differentiating equation 6, but this time with respect to p^O. This gives

$$U_1\left(a - bk - a\phi k - p(k)\frac{\partial q(k)}{\partial p^O} - q(k)\frac{\partial p(k)}{\partial p^O}\right) + U_2\frac{\partial q(k)}{\partial p^O} = 0 \tag{9}$$

Substituting equation 5 into equation 9 gives

$$\frac{\partial p(k)}{\partial p^O} = \frac{a - bk - a\phi k}{q(k)} \tag{10}$$

The sign of $\frac{\partial p(k)}{\partial p^O}$ depends on the sign of $a - bk - a\phi k$. However, we know $a - bk - a\phi k > 0$ for every k in the city due to the budget constraint. Therefore, an oil price change results in a level shift of house prices that outweighs any gradient rotation.[8]

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[8] Other gradients in the SUM, such as population density, may be found recursively once the house price gradient is known. This requires solving the housing producer's problem.

In this model, an oil price increase causes an increase in earnings and smaller increases in commuting costs. New households migrate to the city until the diseconomies of the higher population offset the rising incomes. The new city has a greater population and higher house prices. This scenario is illustrated in Figure 1, which shows the rotation in housing price along with a level shift in Panel A. House price increases at every k indicate that the city boundary and population are increasing endogenously.[9]

An Oil Price Shock in a non-Oil Exporting City

In most cities, oil is not produced – it is only consumed. It is therefore important to consider the case where the oil price is related only to marginal transportation cost and not household earnings. In this case, the model reduces to the standard rendition of the SUM with the oil content of transportation costs substituted for marginal transportation costs as discussed in the previous section.[10]

Equation 8 becomes equation 11, where the slope of the gradient is different because earnings, and therefore the time cost of commuting, are no longer tied to the price of oil.

$$p'(k) = \frac{-bp^O - \phi w}{q(k)} \tag{11}$$

Equation 10 is also modified in an important way. Because the oil price no longer enters into earnings, the total derivative of equation 6 shown in equation 9 becomes

$$U_1 \left(-bk - p(k)\frac{\partial q(k)}{\partial p^O} - q(k)\frac{\partial p(k)}{\partial p^O} \right) + U_2 \frac{\partial q(k)}{\partial p^O} = 0 \tag{12}$$

and 10 changes to

$$\frac{\partial p(k)}{\partial p^O} = \frac{-bk}{q(k)} \tag{13}$$

In the case of a non-oil producing city, house prices fall everywhere, and more so when k is large such as in suburban locations. This is depicted in Figure 2. A positive oil price shock

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[9] Derivations available upon request. As with the other gradients, this involves solving the housing production problem, which is not the focus of this section. Additionally, our model omits the effect of oil prices on the size of the CBD. Obviously, a positive oil price shock that raises demand for labor will raise demand for commercial space in the CBD, which reinforces the upward pressure on housing prices. However, this does not affect Muth's equation governing the price gradient.

[10] It is also possible to consider an export good production function that uses oil as an input. In this case, an industry with high oil input requirements would have incomes that are negatively affected by oil prices. This question is left for further research.

causes a rotation of the house price gradient around the CBD.

Testable Predictions

Two main testable predictions result from this model. First, an oil price change will increase house prices at every radius in an oil exporting city. Because earnings are a function of the oil price, and negative transportation costs occur in all cities, house prices will rise with the oil price relative to non-oil exporting cities.

Second, an oil price change will cause a fall in house prices in the suburbs relative to areas near the center-city. Because households living far from the CBD must commute farther than households near to the CBD, the iso-utility condition forces house prices to fall in the suburbs in order to compensate for a loss of purchasing power when oil prices rise. This rotation in the house price gradient should occur in all cities, regardless of export industry.

3. Stochastic Specification

In order to test the predictions resulting from the theoretical model, we rely on a standard two-way fixed effects panel specification, following Blanchard and Katz (2002), Saks (2008), and others.[11] This empirical model relates annual changes in house price appreciation, $\Delta p_t \equiv lnP_t - lnP_{t-1}$, in ZIP code z, in city i, as a function of changes in the oil price Δp^O interacted with a city-specific oil export share $\tilde{e}$ measure, and changes in the oil price interacted with a measure of distance to the CBD, k. Because the transaction price for housing is related to the expected long-run price of commuting, we specify the oil price as the *expected future* oil price. It may take some time for the oil price to affect the housing market, so we include lags of the oil price change variables. Our baseline specification is

$$\Delta p_{izt} = \alpha_z + \alpha_t + \sum_{h=1}^{H} \delta_h \Delta p^O_{t-h} \times k_z + \sum_{h=1}^{H} \gamma_h \Delta p^O_{t-h} \times \tilde{e}_i + \epsilon_{izt} \tag{14}$$

with residuals clustered by city.

Equation 8, governing the house price gradient in the city, implies that, when oil prices rise, the house price gradient steepens. This gives the hypothesis that $\delta < 0$ in equation 14, individually and in summation. Similarly, equation 10 predicts a city that specializes in

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[11] However, due to concerns of Nickell (1981) bias, we omit lagged dependent variables in the main specification.

oil exports has house prices that are positively related to the price of oil due to the export price effect. But not all cities are fully specialized, so we include a continuous measure of oil export intensity, $\tilde{e}$. Under the hypothesis in equation 10, the share of exports dedicated to oil interacted with the oil price is positively related to house prices, or $\gamma > 0$, again, both individually and summed over time.

Several potential complications may result from this specification. First, the distance to the CBD may be an inaccurate measure of commuting costs. This can occur in cases of city polycentricity or road networks that are non-radial (i.e. gridded or restricted due to topography). It is therefore important to include other measures as robustness checks, including commuting time. Second, while the model hypothesizes direct effects of the oil export share interacted with the oil price, there are also potential indirect effects. For instance, if a city acts as a regional financial center in a region that specializes in oil exports, direct effects of oil price changes would be small, but regional spillovers would make for large indirect effects. Therefore, it is also useful to consider the state oil export share in certain specifications.

Another consideration is the elasticity of housing supply. Our theoretical model is long-run in nature and therefore gives equivalent predictions for supply elastic versus inelastic regions. However, a large body of research has found short-run price dynamics for housing to be different in areas with high regulation (Saks, 2008), topographic interruptions (Saiz, 2010), urban decline (Glaeser and Gyourko, 2015; Notowidigdo, 2011), and other construction constraints (Glaeser, Gyourko, Morales, and Nathanson, 2014). The general finding in this literature is that when supply is constrained, the construction response is limited in some fashion, either in the short run through regulatory barriers, or in the long run due to shifts in the long-run supply curve. This causes demand changes to be capitalized into prices to a greater degree in supply-inelastic areas.

Because oil price changes are assumed to act as housing demand shocks, based on the above theories, we would expect greater short-run price effects in areas where the supply elasticity is smaller, including large, highly regulated, topographically interrupted, or declining cities. We leave a broad investigation of the interacted effects of the predictions of our model with supply elasticity factors to future research due to the numerous complications with estimating such a model.[12] However, many elasticity factors are also correlated with city size, which we do examine.

4. Data

Our unit of measure for a city is the core-based statistical area (CBSA), and for submarkets within cities, the 5-digit ZIP code. Some ZIP codes span more than one city, so we restrict the sample of ZIP codes to those that exist in a single city. The data necessary to estimate the empirical model are found in various source databases. The first is the 1990 Decennial Census, which includes information on demographics, commuting patterns, and housing unit counts at both the county and ZIP code level. This allows segmentation of ZIP codes into various city and neighborhood types. Other data consist of information on oil prices, oil export shares, and house prices, with each described below.

Oil Prices

Oil price data are accessed via Bloomberg and consist of the 3-year forward and spot oil price for delivery at Cushing, Oklahoma between 1975 and 2015. Figure 3 shows real oil prices by year, deflated by the urban goods consumer price index giving oil prices in terms of 2015 USD. As a measure of long-run price expectations, the 3-year forward price is preferable. Unfortunately, this series begins in 1990, necessitating alternative measurement for prior years. Because the spot price tracks the 3-year price reasonably well, (see Figure 3), we use the spot price prior to 1990 as our expectations measure.

Export Shares

Export shares are calculated in 1990 using from the Bureau of Labor Statistic's Quarterly Census of Employment and Wages (QCEW). The QCEW contains tabulations of employment for all establishments that report into national unemployment insurance programs. This includes about 97 percent of all civilian (both full and part-time) employment in the United States.[13]

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[12] Direct measures of housing market regulation are recent, such as the Wharton Land Use Regulatory index (WRLURI) of Gyourko, Saiz, and Summers (2008), and presumably endogenous with respect to changes in house prices. Historical decline is correlated with industrial structure, which in turn may have interactions with the oil price beyond the export price effects we examine. Finally, large, highly regulated cities also tend to be topographically interrupted, whereas the majority of oil-producing regions are inland with low regulation and few topographic interruptions, making it difficult to identify a natural experiment given the lack of variation along these dimensions.

[13] Over-counting may arise if a single worker holds jobs in more than one sector. Counts exclude self-employed, many workers on small farms, the military, and other sectors where informal employment arrangements are common.

Employment that is considered to be generating exports is calculated using the location quotient approach (see Brown, Coulson, and Engle, 1992, for instance). This method assumes that for each area, any employment in an industry that is in excess of the national average is used to produce goods and services for export, for instance, by physically exporting goods, inducing tourists to visit, or provide services that are relatively unbound by geography. It also assumes that consumer preferences are Leontief and identical across locations, leading to no substitution due to differential relative prices of consumer goods.

The location quotient L for city i, industry j in time period t is calculated as follows, where e is employment and omitted subscripts denote totals.

$$L_{ijt} = \frac{e_{ijt}/e_{jt}}{e_{it}/e_t} \tag{15}$$

A $L_{ijt} > 1$ indicates the presence of export employment. Export employment x is then calculated as

$$x_{ijt} = \left(\frac{L_{ijt} - 1}{L_{ijt}} \right) e_{ijt} \tag{16}$$

if $L_{ijt} > 1$, otherwise $x_{ijt} = 0$. Export employment shares are then calculated as

$$\tilde{e}_{ijt} = \frac{x_{ijt}}{x_{it}} \tag{17}$$

Export employment shares are calculated at the 3-digit NAICS level in 1990.[14] Figure 4 shows oil export shares for CBSAs in the U.S. for the sum of four sectors: oil and gas extraction (NAICS 211), support activities for mining (213), petroleum and coal products manufacturing (324), and pipeline transportation (486). These sectors are chosen because they are each fundamentally related to the supply-side of the oil market – when the price of oil rises, demand for extraction increases, which directly causes demand for support activities

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[14] While we would prefer to calculate them for our initial period (1975), 1990 is the earliest available. We therefore must make the standard weak exogeneity assumption that house price changes do not lead to changing export shares for observations in 1991 through 2015, but also an additional assumption that house price changes between 1975 and 1990 do not affect export shares either. While this assumption may be problematic for other locally endogenous variables, such as levels of housing stock or earnings, we do not believe this to significantly bias our estimates. Export shares are fairly stable over time and are therefore presumably not materially affected by short-run house price movements.

and pipeline transportation to rise.[15]

Shares are highest in areas commonly known to be centers of oil and gas extraction and refining, including Texas, Oklahoma, Colorado, Wyoming, North Dakota, California, and Pennsylvania. In 13 of the 858 CBSAs where export shares are calculated, shares are above 30 percent, with a further 40 between 10 percent and 30 percent. The vast majority of all locations (722) have less than 0.1 percent export employment in these sectors.

House Prices

The source for house price information is the Bogin, Doerner, and Larson (2016) (BDL) house price database produced by the Federal Housing Finance Agency. The BDL database includes constant-quality, repeat-sales house price indices at an annual frequency, calculated for 914 CBSAs, including all 381 MSAs and 533 MicroSAs. It also includes 17,936 ZIP code level house price indices, including nearly 9,000 prior to 1990, making it ideally suited to measure the effects of oil prices on house price changes within cities over long time horizons. The BDL database also includes a measure of the distance to the CBD of the CBSA, allowing this to enter as a covariate in empirical specifications.[16]

Figure 5 shows 15-year appreciation rates for two periods, 1985 to 2000 and 2000 to 2015, as a function of the distance to the CBD, averaged over all ZIP codes available. House price gradients are steepening more between 2000 and 2015 than between 1985 and 2000. In the context of Figure 3, which shows higher oil price levels in the later period, house price gradients appear steepen as the same time as oil prices are high. This is suggestive of a relationship similar to equation 8, which posits that an increase in oil prices steepens the house price gradient.

Across cities, there exists some preliminary evidence of export price effects of oil prices as well. Figure 6 shows oil and house prices for Williston, ND, which has famously seen a rise in

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[15] Other sectors are presumably related to the price of oil through demand for oil inputs. For instance oil is a primary input in production for transportation services, rubber manufacturing, and gas stations. In this case, all else equal, oil demand, labor demand, and therefore housing demand, should fall when oil prices rise. Other industries may also have a procyclical correlation with the price of oil due to aggregate demand factors.

[16] The distance-to-CBD measure in the BDL database is constructed as the distance between the ZIP code's centroid and the CBD centroid. The CBD ZIP code is identified using the standardized sum of two density measures. The first is the standardized fraction of housing units in 20+ unit structures. The second is the (negative) standardized land area of the ZIP code. Because ZIP codes have roughly similar numbers of postal customers, the area gives an approximate measure of density.

oil production in recent years due to innovations related to hydraulic fracturing ("fracking") and horizontal drilling. This figure illustrates the high correlation between the oil price level and house prices in this city. Figure 7 shows that this case may be generalizable, as house price appreciation by CBSA between 2000 and 2015 appears to have a high partial correlation with oil export shares, controlling for rapid appreciation in California, the mid-Atlantic, and the Sun Belt states.

5. Main Results

This section presents estimates of equation 14, calculated over the full panel of ZIP codes in 781 CBSAs between 1975 and 2015. These estimates enable hypothesis tests of both the export price effect, estimated using the city export employment share for oil, and the transportation cost effect, estimated based on several different commuting cost measures. Table 1 presents the estimates and the results of these tests. The presentation of this table includes each lag of the interacted variables, along with the sum of the lagged coefficients and F-tests of the null hypothesis of no effect.[17]

Column 1 presents parameter estimates where the commuting cost variable is defined as the log of the distance to the CBD. The oil export share interaction terms start small at one lag, rise to a peak at two lags, and remain positive and significant through lag seven. The sum of the lags is approximately 1, indicating a 7 year oil price - house price elasticity of 0.5 in a city where the export employment share for oil is 50 percent. All individual parameters are positive and most are statistically significantly different than zero, indicating support for the first prediction of our theoretical model. These estimates are not statistically different than in the other three models, with the sum of lags varying between 0.96 and 0.98.

In column 1, the distance-to-CBD measure's interacted effect is negative at the first lag, peaking at period two, and declining through period six. The sum of the lags is -0.01 with F-tests indicating rejection from a sum of zero at the 99.9 percent level of significance, lending support to the second hypothesis. Overall, it appears oil prices increase relative house prices in oil producing areas, and decrease relative house prices in suburban areas.

A clear pattern emerges when the lagged interaction term parameters are graphed in Figure

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[17] The lag length of 7 is chosen based on a sequence likelihood ratio tests comparing the sum of squared residuals with n versus $n+1$ lags. When there is no statistical difference in fit, which occurs at $n = 7$, n lags are deemed sufficient.

8. Effects start small after one year, peak in year two, and slowly fall through year seven. Combined, these suggest a permanent change in oil prices results in a permanent change in house prices, despite any new construction that may have taken place in the intermediate time period. However, it is clear from Figure 3 that real oil prices tend to rise and fall in cycles and there is no case of a "permanent" oil price increase in the 40-year history of the series, meaning house price gains may be illusory in practice.[18]

We also estimate house price changes as a function of location in one of three concentric rings around the CBD: the center-city from 0 to 5 miles to the CBD; the mid-city, from 5 to 15 miles; and the suburbs, which are defined as 15+ miles from the CBD. The base estimate is the center-city area, so parameter estimates in column 2 are interpreted as appreciation relative to this group. The sum of the interacted variable coefficients for mid-city areas is negative (-0.01) and significant at the 10 percent level. In the suburbs, the sum of the coefficients is -0.049 and highly significant, indicating that suburban areas face a house price effect that is about -1/20th of the oil price change.

While these first two models give significant estimates of the predicted sign, CBD distance alone may be imprecise due to city polycentricity, suburbanization of employment, or other factors. We therefore attempt to determine the robustness of results in columns 1 and 2 with an alternative measure of commuting costs – the commute time itself. Columns 3 and 4 show this measure gives similar results to the CBD measure, with log commute time and commute times greater than 24 minutes (the measure used by Molloy and Shan, 2013) associated with negative relative house price effects when the price of oil rises.

These results echo those in Coulson and Engle (1987), who found that the increase in gasoline prices in the late 1970s led to steepening price gradients in cities, and Molloy and Shan (2013), who use ZIP code data and find negative but insignificant effects of gasoline prices interacted with commute times on house prices. Molloy and Shan's (2013) specification estimates difference in house prices as a function of the 0/1 indicator for commute times interacted with changes in gasoline prices, with 1 to 4 lags. The sum of these four coefficients is negative as predicted by our theoretical model, (-0.009) but is not statistically significant.

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[18] It is possible that many areas have homes that are priced below replacement costs when a positive oil price shock arrives, leading to little new construction, at least initially (Glaeser and Gyourko, 2005). Were oil prices to be fully mean-reverting, this would also prevent house prices from falling below pre-shock levels if the oil price returned to its prior level.

We speculate the lack of significance in their model is the result of a more limited sample of house prices available at the time. Our database has house price indices through 2015 while their sample ends in 2008; ultimately, we have available nearly three times the number of time period-ZIP code house price index observations (approximately 336,000 vs 119,000).

6. Robustness Exercises

Robustness across Time Periods

It may be possible for the relationship between oil prices and house prices to change over time. For instance, during periods of relatively stable oil prices, small changes may not be as salient for an average homebuyer, attenuating effects. It may also be the case that oil price changes have asymmetric effects in periods of increasing versus decreasing prices. Table 2 presents estimates from four different time periods. Overall, estimates show the city oil export share interacted with the price of oil to have a positive effect on house prices in every period, though the effect is not statistically significant for some. In addition, the effect of the oil price on the house price gradient is negative in every time period considered.

Column 1 presents estimates calculated using the sample of house price observations from 1975 through 1990. This period is defined by the large declines in oil prices from the peak in the late-1970s and the beginning of a period of relative calm starting in the late-1980s. In this sub-sample, the sum of the city oil export share coefficients is positive and close to one, much like the main results in Table 1. The sum of the CBD proximity coefficients is negative with a p-value of 0.101, indicating robustness in terms of the point estimate. Because prices were falling during the time period, these estimates indicate falling relative house prices in oil-rich areas and perhaps slightly rising prices in suburban locations.

Column 2 considers the 1990s, which is characterized as a period of mostly flat oil prices. This lack of variation coincides with a small, positive but statistically insignificant, effect of oil price changes on house prices in oil-exporting cities. The effect on suburban house prices is robust, with a significant point estimate of approximately -0.02.

Parameters estimated during the rapid rise in oil prices in the first decade of the 2000s are presented in column 3. The sum of the oil export share parameters is similar to the 1975 to 1990 period and the baseline estimate of approximately 1, and similar to the proximity effect in the 1990s and the baseline with an effect of about -0.016. During this period, the rise in the price of oil causes relative appreciation in oil-producing cities and in center-cities.

Finally, the 2010 to 2015 period considers a set of years where the price of oil is first high, at approximately \$100 per barrel in 2011, eventually falling to \$50 per barrel in 2015. Parameters are again generally robust, despite the short time horizon for the estimates. The oil export price effect is positive but not significant, and the transportation cost effect is negative and highly significant.

Overall, these results suggest oil price effects on house prices to be somewhat noisy concerning the oil export price effect, but symmetric and stable when it comes to the effects on city-suburb price differentials. The effect of oil prices on suburbs is particularly noteworthy because the last 30 years has been broadly identified as one with steepening house price gradients in large cities. Our estimates here suggest that recent oil price declines have served to mitigate some of this steepening, making suburban locations relatively more attractive places to live between 2010 and 2015.

City Export Specialization Sensitivity

While it has been assumed that four NAICS sectors sum to give the “oil export employment share” in Table 1, it is certainly possible that other industries may interact with oil prices to produce either positive or negative effects on house prices. In order to examine effects of oil prices on house prices in cities with different export specializations, we estimate equation 14 with a particular 3-digit NAICS sector in place of the oil export employment share variable, and repeat this estimation for each sector. Summed parameters from this set of estimates are found in Table 3, sorted by p-values from F-statistics. All sectors with p-values less than 0.05 are presented; the rest are omitted for the purpose of brevity. Sectors related to oil and gas are listed in **bold**.

The four sectors used to construct the oil export share variable, NAICS sectors 211, 213, 324, and 486, include 3 of the top 7 sectors where house prices have the strongest empirical relationships with oil prices. Among the sectors most harmed by high oil prices are two transportation-related sectors and two related to agriculture. This includes air transportation (NAICS 481), transit and ground passenger transportation (485), crop production (111), and support activities for agriculture and forestry (115). Each of these sectors has high oil input requirements according to the Bureau of Economic Analyses’ total requirements input-output table.[19] Overall, these estimates suggest our oil export share variable is based on sound underlying correlations with individual sectors.

Direct vs Indirect Effects of Oil Price Changes

In the baseline specifications, we include only the local effect because this is a direct test of our theoretical model. There may be additional, indirect effects related to production in other nearby areas. The indirect effects are particularly important to consider in large cities that serve as financial and distribution centers. Cities of this type include Billings, MT, Denver, CO, and Dallas, TX, to name a few.[20] To compute indirect effects, we use a measure of the state export employment share, calculated the same as the local measure only with the state as the unit of geography.

The major issue with the inclusion of both measures in a single model is they are often highly correlated. While some cities have large variation between state and local oil production, many do not. This creates issues of collinearity and potential dominance of one variable over another for reasons related to measurement error or some other concern.

Table 4 presents three columns, the baseline model from Table 1, a model with the state-level export employment variable, and a model with both. Controlling for state effects, the local variable does not add statistically relevant explanatory power after the second lag. This can be interpreted in two ways. Either the local effect dominates in the early years, giving way to state-level indirect effects, or that both variables are simply highly collinear and the state-level measure dominates the local measure by chance. Either way, it suggests that city house price performance is potentially affected by developments nearby but outside the city, though evidence is not conclusive.

Effects of City Size

The size of the city may affect the extent to which oil prices affect house prices for three main reasons. First, at a given distance, commute times in a large city will likely be higher due to road congestion. Second, cities that are larger tend to have more diverse economies,

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[19] The table contains numerous other significant estimates, suggesting other factors besides oil inputs and oil production may be at play. One concerning possibility is the violation of the parallel trends assumption inherent in fixed effects models that would cause a correlation between house price appreciation and oil price increases in cities with particular industrial structures. However, due to the fact that the oil supply industries behave as expected, we proceed with this framework.

[20] Another potential explanation for indirect effects is though state-level government revenues, which tend to increase in oil-rich states when the price of oil is high.

leading to greater indirect effects of oil price changes. Finally, as discussed previously, the elasticity of housing supply is often lower in larger cities, leading to potentially larger export price effects in larger cities.

Empirical findings in Table 5 give mixed evidence suggesting larger cities are more sensitive to oil price changes. The parameter estimate of the effect of the oil price interacted with distance is about three times as large in large cities than small cities. Smaller effects of physical distance in small cities are consistent with lower fuel consumption per mile compared to large cities, and suggest that physical proximity matters more in large cities. The point estimate for oil export employment is of a larger magnitude in large cities, though F-statistics indicate a lack of statistical significance.

Similar to the commuting cost findings, the point estimate of the sum of the lags of the interaction terms is greater in large cities than in small cities, but the effect is not statistically significant. Combined with the commuting cost differential, we cautiously interpret these findings as suggesting potentially greater sensitivity of house prices to oil price changes in large cities.

Specification Robustness

There are two specification issues we consider in this section. First, it is common in the empirical regional economics literature to include lagged dependent variables in panel models. While a lagged dependent variable is potentially an important control variable, it is also results in endogeneity bias when it is included along with fixed effects. This occurs because the calculation of the area fixed effects rely on data for all periods, including the contemporaneous error, leading to correlation between the lagged dependent variable and the error (Nickell, 1981). We do not anticipate this bias to be substantial in practice, because we have a fairly large number of time periods, a large number of ZIP codes, and we also include time period fixed effects. Column 2 of Table 6 presents estimates of equation 14 with lagged change in house prices as an independent variable.

Estimates in this model are similar to the the baseline. The sum of the coefficients for CBD proximity are similar, at about -0.01. The sum of the lags of the city oil export employment share fall from 0.97 to 0.78, which is a difference nearly equal to the autoregressive parameter multiplied by the baseline estimate (0.18 vs 0.19). While the estimate is smaller, it is more persistent, with almost zero cumulative difference ($\frac{1}{1-0.18}0.78 = 0.96$). This suggests that the lagged dependent variable provides potentially useful explanatory power while introducing negligible endogeneity bias.

The second specification-related robustness exercise we perform is related to the the differencing of the oil price change. Rather than modeling house price changes as the sum of the lags of oil price changes and interactions, it is possible to collapse the changes into a single level variable. This specification does not allow for dynamics, but is potentially more efficient due to the smaller number of parameters estimated. A difference-level parameter is interpreted as follows: a change in the *level* of the real oil price causes an *acceleration* in house prices. That is, as long as oil prices are high, house prices will grow above mean levels in every year. The converse is also true – when the level of oil prices is low, house prices fall each year.

The level estimate of the export price effect is 0.22. To compare this estimate to the differenced estimates, consider a 7-year oil price change, leading to an interacted effect of 0.22 in each year, or 1.54 over 7 years. This is about 0.57 larger than the sum of the differenced estimates. The estimate of the CBD distance effect is -0.0023, or -0.016 after 7 years, which is again about 50 percent greater than the sum of the differenced estimates of -0.01. Overall, level estimates appear to give similar qualitative results that are slightly higher in magnitude than the differenced results.

Do Particular States Drive the Results?

Certain states tend to dominate discussions of the oil industry in the United States. Oklahoma and Texas have been major oil producers since the early 1900s, and North Dakota, Montana, and Pennsylvania have seen increasing oil production due to the “fracking” boom of the early 2000s. Due to this geographic concentration, it is possible that state-level house price changes are related to state-specific factors that drive estimates for the entire sample. Therefore, we sequentially exclude three states from the samples in order to determine the sensitivity of estimates.

Table 7 shows that omission of Texas, Oklahoma, and North Dakota does not significantly affect estimates of the commuting variables, suggesting these results are robust. Estimates for local export shares indicate that Texas may be less sensitive along this dimension, as the parameter rises by about 10 percent when Texas ZIP codes are omitted. On the other hand, Oklahoma may be more sensitive as the same parameter falls by about 8 percent when Oklahoma is omitted. None of these effects are statistically significant, however, so we conclude that no particular state is driving any of the reported results.

City Sensitivity to Oil Prices

The final exercise we perform is to evaluate city-by-city sensitivities to different oil price changes. Estimates from a model tailored to this purpose are used to construct oil price - house price elasticities for each CBSA in the United States. This involves estimating the model with the level of the oil price on the right-hand side of the equation, a lagged dependent variable with parameter ρ, and the addition of Texas-specific effects.[21,22] CBSA-level elasticities σ^O are calculated as follows, with additional fixed effects for Texas

$$\hat{\sigma}^O = \frac{1}{1-\rho}(\tilde{e}_{i,s,2013} \times \hat{\gamma}_1 + \tilde{e}_{s,2013} \times \hat{\gamma}_2) \tag{18}$$

Employment shares in 1990 are used to estimate the model but shares in 2013 are used to construct the elasticities. When a city spans more than one state, the maximum share value is used, with the exception of the Washington DC-MD-VA-WV MSA, which has an exceptionally small fraction of its households in West Virginia. These estimates therefore give the maximum oil price exposure. Elasticities for housing units within cities are given by the relevant $\hat{k}_{iz}$ parameter, which depends on center-city (0 to 5 miles from the CBD), mid-city (5 to 15 miles), or suburban (15+ miles) status.

Table 8 shows estimated elasticities, separated into groups of cities with greater than or less than 250,000 housing units in 2014. The state with greatest oil exposure is Oklahoma, followed by Texas, North Dakota, and Wyoming. Among large cities, Oklahoma City, OK, and Houston, TX, have the highest local oil export employment share, followed by Tulsa, OK. Small cities often have greater industrial specializations in oil-related sectors, with Bartlesville, OK, occupying the top spot with 73 percent oil export employment. Following this city are Williston, ND, Hobbs, NM, Midland, TX, Carlesbad-Artesia, NM, Alice, TX, and Vernal, UT. Overall, the highest magnitude elasticities among large and small cities are

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[21] The estimated model is:

$$\Delta \hat{p}_{zt} = \hat{\alpha}_z + \hat{\alpha}_t + 0.187\Delta p_{zt-1} + 0.047 p_t^O \times \tilde{e}_{is} + 0.176 p_t^O \times \tilde{e}_s +$$

$$-0.025 p_t^O \times \tilde{e}_{is} \times Texas_{zs} - 0.001 p_t^O \times k_{iz}^{5to15} - 0.004 p_t^O \times k_{iz}^{15+}$$

[22] The choice of including the level of oil prices instead of changes is due to the desire to have efficient estimates. With the inclusion of so many varying parameters, 7 lags for each oil price term is undesirable.

-0.079 in Oklahoma City and -0.054 in Bartlesville, respectively.

This table highlights the significant house price risk in cities and states with high oil industry exposure. The recent decline in 3-year forward oil prices from $91 per barrel in 2011 to $51 per barrel (log difference of 0.58) in 2015 therefore suggests an annual decline in house prices of 4.5 percent per year in Oklahoma City versus the national and city averages (recall the specification includes time and city fixed-effects).

7. Conclusion

This paper makes two primary contributions. The first is theoretical, bringing together models of systems of cities and local export production such as Henderson (1974) with the standard urban model of Alonso (1964), Mills (1967), and Muth (1969). While this has been done before, it has never been explicitly derived in terms of the oil price. This allows the derivation of comparative statics giving house prices in cities of different industrial structures and at different locations within the city as a function of exogenous oil price changes. The second is empirical, finding strong evidence that house prices react positively to oil price changes in oil exporting areas, and negatively the further a house is from the center of the city.

The theoretical model predicts that an oil price change has two main effects. In a city that specializes in oil supply – that is the production, refining, and transportation of oil – there is a positive export price effect of increasing oil prices on wages, leading to house price appreciation in the city relative to other cities. However, because oil is also indirectly consumed by commuters in the form of gasoline, an increase in the price of oil increases the differential commuting costs between the center-city and suburban locations. This transportation cost effect steepens the house price gradient. Overall, the model predicts a “twist” in house prices due to an oil price change – a level shift combined with a rotation of the house price gradient. In cities that do not specialize in oil production, the model predicts the transportation cost effect will remain, but without the export price effect, leading to a rotation that leaves house prices below prior levels in all locations, but more substantially in the suburbs.

We then test the model using a new ZIP code level house price index (the Bogin, Doerner, and Larson, 2016, dataset produced by the FHFA) along with measures of export employment shares from the Bureau of Labor Statistics’ Quarterly Census of Employment and Wages.

Export shares are calculated using location quotients. Proximity measures to the central business district (CBD) are calculated as well. Overall, estimates suggest house prices to be positively related to the oil export employment share interacted with changes in the oil price, and proximity to the CBD interacted with changes in the oil price, conditional on other factors. The estimates are robust to alternative export employment aggregation (local vs state), time periods, states considered, different CBD proximity measures, city size, and model specifications. The estimates show a strong, robust relationship between oil prices and house prices over a broad panel of states over a long time horizon that consists of periods of relatively stable, rising, and falling oil prices.

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Figure 1: Predicted Effects of an Oil Price Shock on House Prices – Oil Exporting City

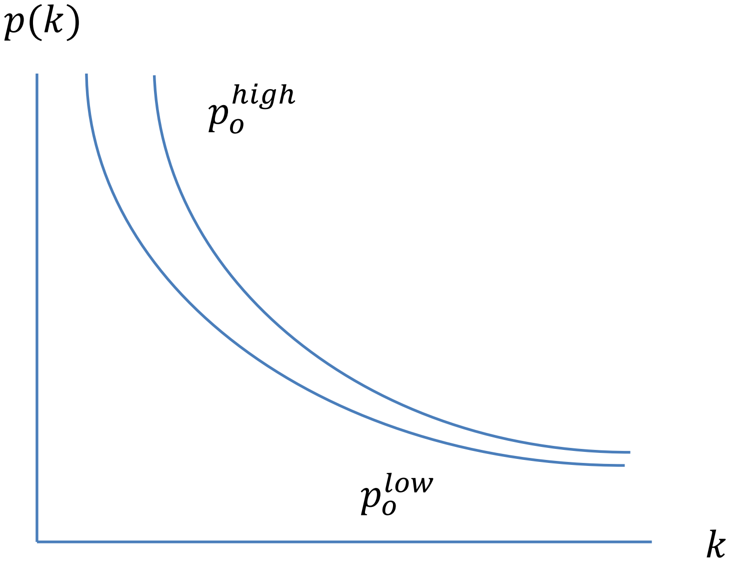


Figure 2: Predicted Effects of an Oil Price Shock on House Prices – non-Oil Exporting City

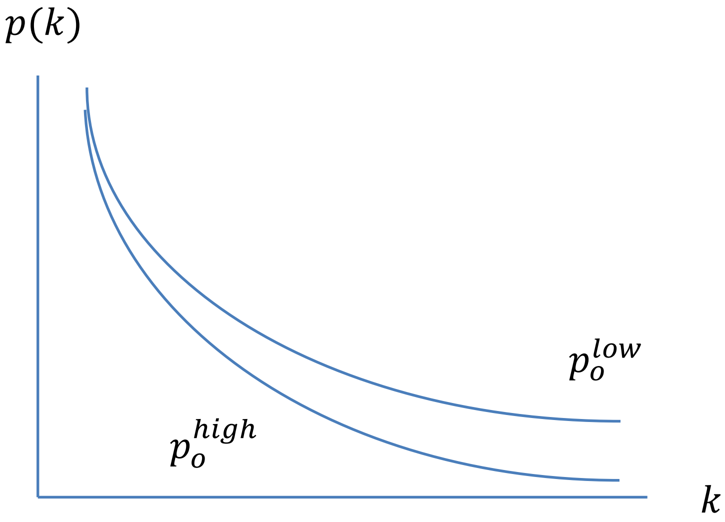


Figure 3: Oil Prices (Cushing, OK)

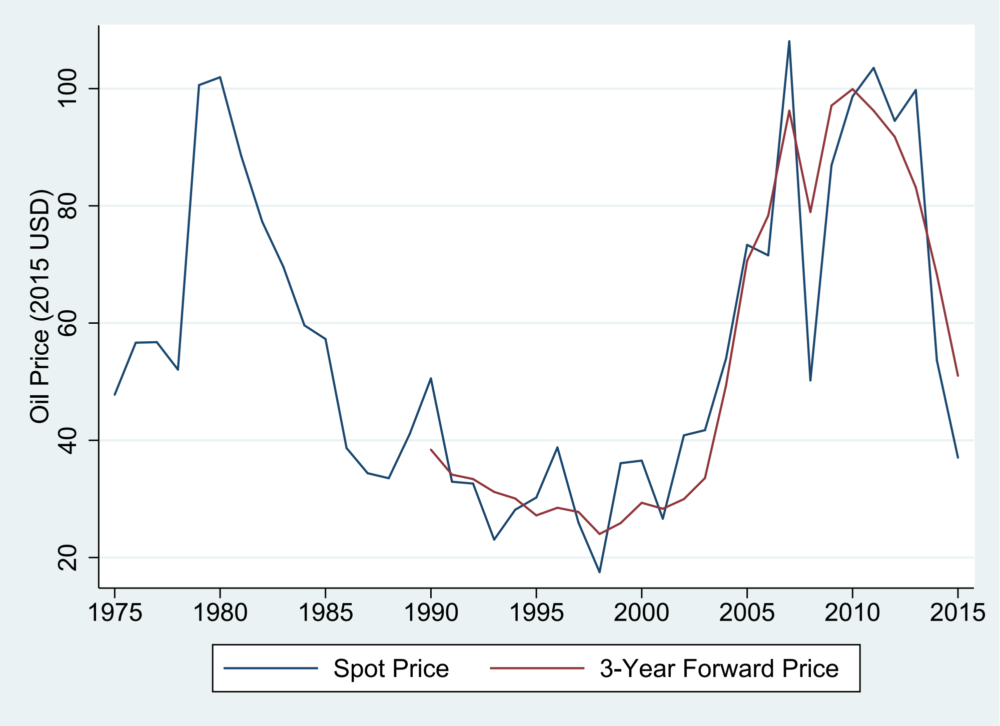


Figure 4: Oil Export Employment Shares

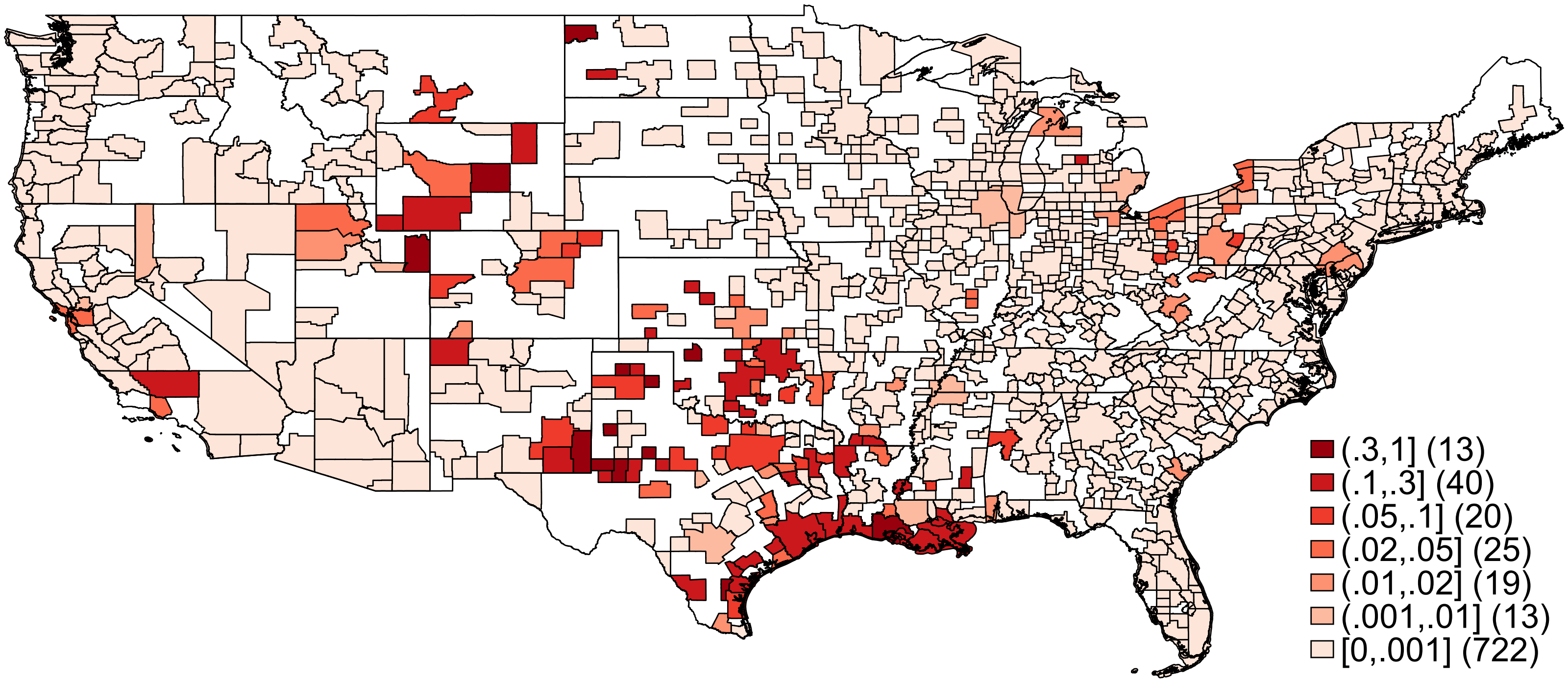
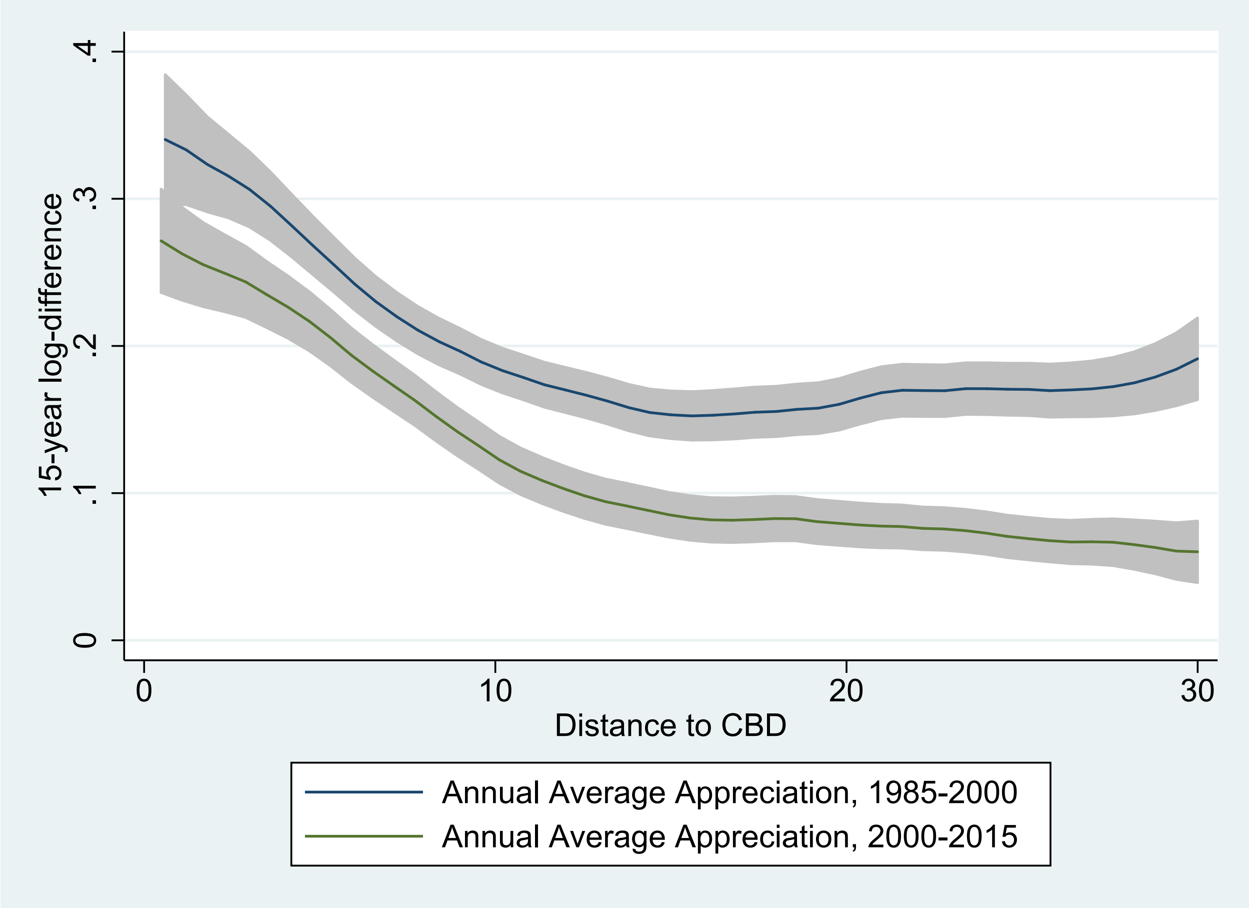


Figure 5: 15-Year Real House Price Appreciation Rates in Large Cities



Note: Large cities are defined as CBSAs with population greater than 500,000 in 1990. The figure presents local polynomial-smoothed log differences in real (inflation-adjusted) house prices over the respective 15-year period ($\ln HPI_t - \ln HPI_{t-15}$) at the ZIP code level.

Figure 6: House Prices and Oil Prices, Williston, ND, CBSA 48780

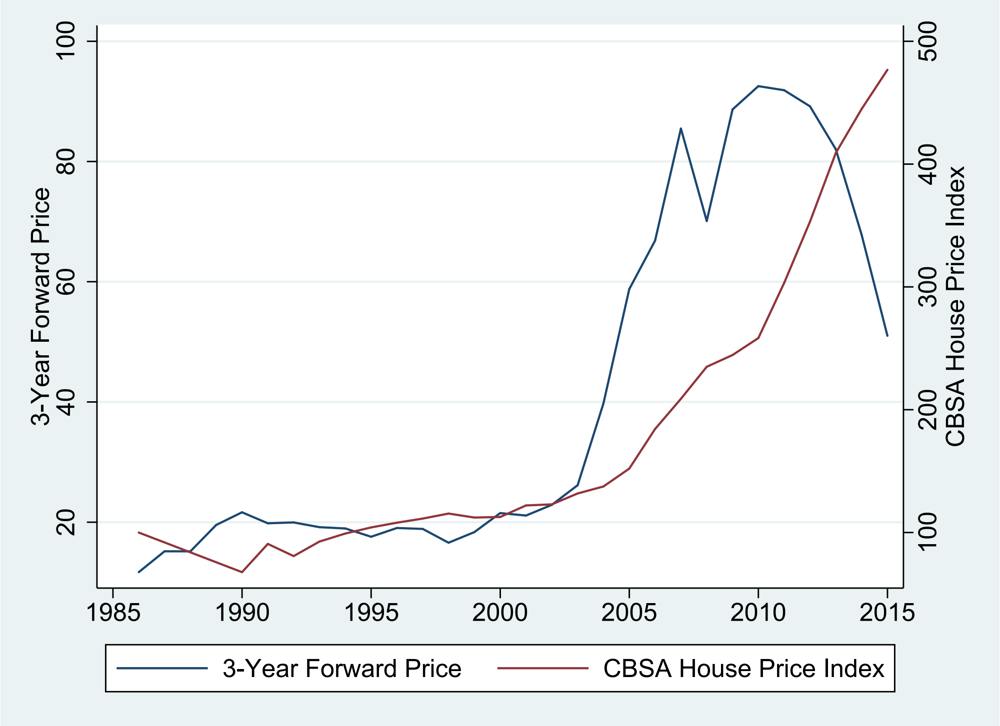


Figure 7: Real House Price Appreciation, 2000-2015

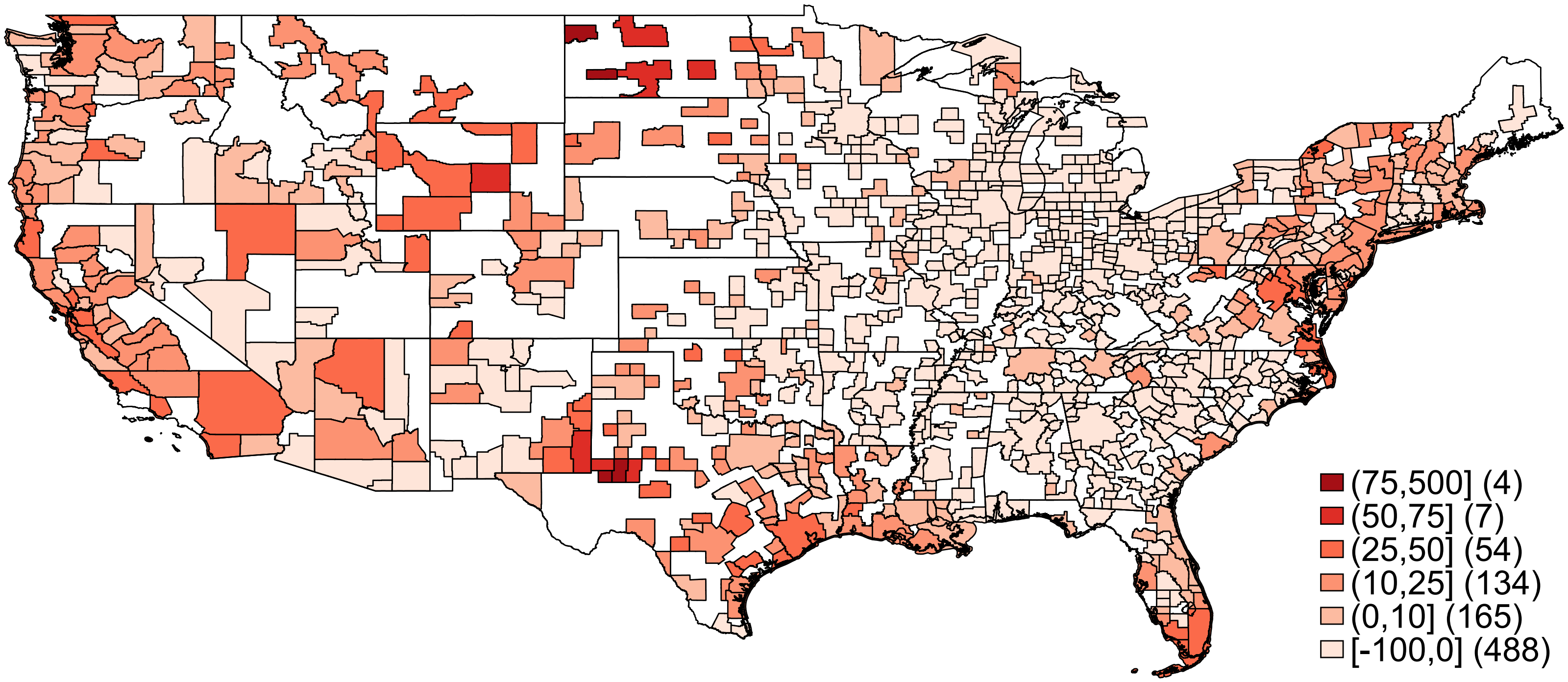
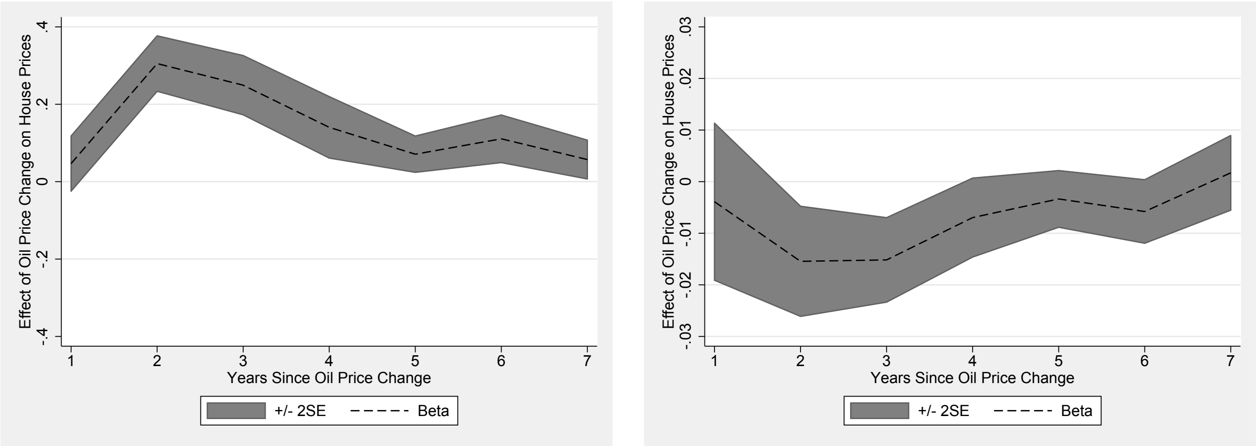


Figure 8: Dynamic Effects of Oil Price Changes on House Prices


(a) Oil Export Price Effect

(b) Transportation Cost Effect

Note: Figures present coefficients from Table 1, column 1. Panel (a) considers the partial effect of a city's oil export share interacted with an oil price change (log difference) on house prices. Panel (b) considers the partial effect of a ZIP code's log distance to its CBD interacted with an oil price change.

Table 1: Effects of Oil Prices on House Prices - Main Results

Dependent Variable: Δ ln HPI(t)

	[1]	[2]	[3]	[4]
Commuting Variable:	CBD Dist. (log, Miles)	CBD Dist. > 15 Miles	Commute (log, Min.)	Commute > 24 Min.
City Oil Export Share X:				
Δ ln Oil Price (t-1)	0.0459	0.0467	0.0579	0.0578
	[0.0356]	[0.0363]	[0.0367]	[0.0370]
Δ ln Oil Price (t-2)	0.302***	0.305***	0.303***	0.305***
	[0.0358]	[0.0365]	[0.0312]	[0.0329]
Δ ln Oil Price (t-3)	0.247***	0.249***	0.247***	0.249***
	[0.0391]	[0.0390]	[0.0353]	[0.0368]
Δ ln Oil Price (t-4)	0.138***	0.140***	0.130***	0.132***
	[0.0405]	[0.0405]	[0.0355]	[0.0369]
Δ ln Oil Price (t-5)	0.0699***	0.0709***	0.0666***	0.0677***
	[0.0237]	[0.0239]	[0.0209]	[0.0222]
Δ ln Oil Price (t-6)	0.110***	0.111***	0.105***	0.105***
	[0.0313]	[0.0313]	[0.0295]	[0.0304]
Δ ln Oil Price (t-7)	0.0572**	0.0571**	0.0524**	0.0525**
	[0.0255]	[0.0256]	[0.0251]	[0.0253]
Sum of Coefficients	0.97	0.98	0.962	0.969
F-Statistic	31.49	31.71	42.29	37.44
P-Value	<0.001	<0.001	<0.001	<0.001
Commuting Variable (in column header) X:				
Δ ln Oil Price (t-1)	-0.000982	-0.00389	-0.00539	-0.00328
	[0.000922]	[0.00775]	[0.0204]	[0.00911]
Δ ln Oil Price (t-2)	-0.00283***	-0.0154***	-0.0463***	-0.0181***
	[0.000681]	[0.00544]	[0.00945]	[0.00493]
Δ ln Oil Price (t-3)	-0.00252***	-0.0152***	-0.0523***	-0.0185***
	[0.000504]	[0.00417]	[0.0133]	[0.00556]
Δ ln Oil Price (t-4)	-0.00198***	-0.00696*	-0.0491***	-0.0160***
	[0.000450]	[0.00390]	[0.00999]	[0.00440]
Δ ln Oil Price (t-5)	-0.000963***	-0.00335	-0.0279***	-0.00913***
	[0.000326]	[0.00280]	[0.00596]	[0.00283]
Δ ln Oil Price (t-6)	-0.00102**	-0.00579*	-0.0180**	-0.00635
	[0.000399]	[0.00314]	[0.00884]	[0.00433]
Δ ln Oil Price (t-7)	0.000181	0.00171	-0.000336	1.50E-05
	[0.000432]	[0.00369]	[0.0104]	[0.00444]
Sum of Coefficients	-0.0101	-0.0489	-0.199	-0.0713
F-Statistic	32.86	13.18	62.71	27.99
P-Value	<0.001	<0.001	<0.001	<0.001
ZIP Code FEs	Yes	Yes	Yes	Yes
Time Period FEs	Yes	Yes	Yes	Yes
Observations	336,077	336,077	309,274	309,274
R-squared	0.336	0.335	0.333	0.331

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors (CBSA) in brackets. Cross-section includes all ZIP codes within a single CBSA. Data are at an annual frequency between 1975 and 2015. Model (2) also includes a category for ZIP codes between 5 and 15 miles from the CBD. These estimates are smaller than the suburban (>15 miles) estimates and jointly significant at the 10% level, but are omitted for brevity.

Table 2: Effects of Oil Prices on House Prices - Time Period Sensitivity

Dependent Variable: Δ ln HPI(t)

Variable / Sample	[1] 1975-1990	[2] 1991-2000	[3] 2001-2010	[4] 2011-2015
City Oil Export Share X:				
Δ ln Oil Price (t-1 +...+ t-7)				
Sum of Coefficients	1.063	0.346	1.002	0.373
F-Statistic	26.56	0.71	24.52	0.847
P-Value	<0.001	0.4	<0.001	0.358
ln CBD Distance X:				
Δ ln Oil Price (t-1 +...+ t-7)				
Sum of Coefficients	-0.00417	-0.021	-0.0164	-0.0162
F-Statistic	2.699	7.609	12.18	12.68
P-Value	0.101	0.006	<0.001	<0.001
ZIP Code FEs	Yes	Yes	Yes	Yes
Time Period FEs	Yes	Yes	Yes	Yes
Observations	61,780	94,792	119,551	72,180
R-squared	0.275	0.277	0.486	0.484

Notes: Cross-section includes all ZIP codes within a single CBSA. Data are at an annual frequency between 1975 and 2015. Full estimates are available upon request but summarized here.

Table 3: Effects of Oil Prices on House Prices - Sector Effects

NAICS	Description	Sum of Coefficients	P-Value
447	Gasoline Stations	3.45	<0.001
212	Mining (except Oil and Gas)	1.26	<0.001
213	**Support Activities for Mining**	1.90	<0.001
211	**Oil and Gas Extraction**	1.76	<0.001
484	Truck Transportation	1.71	<0.001
441	Motor Vehicle and Parts Dealers	3.34	<0.001
486	**Pipeline Transportation**	5.70	<0.001
722	Food Services and Drinking Places	0.57	<0.001
811	Repair and Maintenance	2.99	<0.001
424	Merchant Wholesalers, Nondurable Goods	1.69	0.001
812	Personal and Laundry Services	3.98	0.001
515	Broadcasting (except Internet)	7.34	0.002
337	Furniture and Related Product Manufacturing	0.45	0.002
237	Heavy and Civil Engineering Construction	1.23	0.003
488	Support Activities for Transportation	1.30	0.005
452	General Merchandise Stores	0.75	0.010
113	Forestry and Logging	0.85	0.011
445	Food and Beverage Stores	0.94	0.011
453	Miscellaneous Store Retailers	2.98	0.032
511	Publishing Industries (except Internet)	-1.29	0.049
814	Private Households	-4.21	0.025
481	Air Transportation	-1.42	0.010
485	Transit and Ground Passenger Transportation	-3.36	0.003
721	Accommodation	-0.29	0.001
523	Securities and Other Financial and Related Activities	-1.08	0.001
238	Specialty Trade Contractors	-1.00	0.001
339	Miscellaneous Manufacturing	-0.76	0.001
541	Professional, Scientific, and Technical Services	-0.51	0.001
111	Crop Production	-0.54	0.001
115	Support Activities for Agriculture and Forestry	-0.69	<0.001
512	Motion Picture and Sound Recording Industries	-5.76	<0.001
712	Museums, Historical Sites, and Similar Institutions	-15.01	<0.001

Note: Table presents regression-by-regression estimates of the local export employment share X oil price (7 lags entered separately) on changes in house prices, conditional on time period and ZIP code fixed effects, and distance to the CBD. Presented estimates are those with summed lagged industry effects with f-statistics with p-values < 0.05 and with an average export employment share of > 0.1%. Sectors related to oil and gas production are in bold.

Table 4: Effects of Oil Prices on House Prices - Indirect (State) Effects

	Dependent Variable: Δ ln HPI(t)		
Variable / Sample	[1] Baseline (City Share)	[2] State Share	[3] Both
City Oil Export Share X:			
Δ ln Oil Price (t-1 +…+ t-7)			
Sum of Coefficients	0.97		0.061
F-Statistic	31.49		0.099
P-Value	<0.001		0.753
State Oil Export Share X:			
Δ ln Oil Price (t-1 +…+ t-7)			
Sum of Coefficients		1.154	1.122
F-Statistic		102.3	117.5
P-Value		<0.001	<0.001
ln CBD Distance X:			
Δ ln Oil Price (t-1 +…+ t-7)			
Sum of Coefficients	-0.0101	-0.0093	-0.00929
F-Statistic	32.86	40.31	40.07
P-Value	<0.001	<0.001	<0.001
ZIP Code FEs	Yes	Yes	Yes
Time Period FEs	Yes	Yes	Yes
Observations	336,077	336,077	336,077
R-squared	0.336	0.344	0.344

Notes: Cross-section includes all ZIP codes within a single CBSA. Data are at an annual frequency between 1975 and 2015. Full estimates are available upon request but summarized here. In model 3, the first two lags of the city oil export share X ln oil price sum to 0.24 with a p-value of 0.025.

Table 5: Effects of Oil Prices on House Prices - Effects of City Size

	Dependent Variable: Δ ln HPI(t)		
Variable / Sample	[1] Baseline	[2] Small City	[3] Large City
City Oil Export Share X:			
Δ ln Oil Price (t-1 +…+ t-7)			
Sum of Coefficients	0.97	0.944	1.067
F-Statistic	31.49	42.58	12.65
P-Value	<0.001	<0.001	0.001
ln CBD Distance X:			
Δ ln Oil Price (t-1 +…+ t-7)			
Sum of Coefficients	-0.0101	-0.00337	-0.00836
F-Statistic	32.86	11.25	2.384
P-Value	<0.001	<0.001	0.131
ZIP Code FEs	Yes	Yes	Yes
Time Period FEs	Yes	Yes	Yes
Observations	336,077	167,699	168,378
R-squared	0.336	0.28	0.411

Notes: Cross-section includes all ZIP codes within a single CBSA. Data are at an annual frequency between 1975 and 2015. Small and large city is defined as a CBSA with fewer than or greater than 500,000 households in 1990, respectively.

Table 6: Effects of Oil Prices on House Prices - Specification Robustness

	Dependent Variable: Δ ln HPI(t)		
Variable / Sample	[1] Baseline	[2] Lagged Dep. Var.	[3] Level
Δ ln HPI(t-1)		0.194***	
		[0.0174]	
City Oil Export Share X:			
ln Oil Price (t)			0.220***
			[0.0275]
Δ ln Oil Price (t-1 +…+ t-7)			
Sum of Coefficients	0.97	0.78	
F-Statistic	31.49	28.28	
P-Value	<0.001	<0.001	
ln CBD Distance X:			
ln Oil Price (t)			-0.00227***
			[0.000477]
Δ ln Oil Price (t-1 +…+ t-7)			
Sum of Coefficients	-0.0101	-0.00814	
F-Statistic	32.86	36.55	
P-Value	<0.001	<0.001	
ZIP Code FEs	Yes	Yes	Yes
Time Period FEs	Yes	Yes	Yes
Observations	336,077	322,176	336,077
R-squared	0.336	0.371	0.334

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors (CBSA) in brackets. Cross-section includes all ZIP codes within a single CBSA. Data are at an annual frequency between 1975 and 2015.

Table 7: Effects of Oil Prices on House Prices - Do Certain States Drive Results?

	Dependent Variable: Δ ln HPI(t)		
	[1]	[2]	[3]
Variable / Sample	No ND	No TX	No OK
City Oil Export Share X:			
Δ ln Oil Price (t-1 +…+ t-7)			
Sum of Coefficients	0.969	1.117	0.912
F-Statistic	31.46	28.39	29.49
P-Value	<0.001	<0.001	<0.001
ln CBD Distance X:			
Δ ln Oil Price (t-1 +…+ t-7)			
Sum of Coefficients	-0.01	-0.0101	-0.00999
F-Statistic	32.19	39.78	31.64
P-Value	<0.001	<0.001	<0.001
ZIP Code FEs	Yes	Yes	Yes
Time Period FEs	Yes	Yes	Yes
Observations	335,547	315,967	332,427
R-squared	0.336	0.35	0.338

Notes: Cross-section includes all ZIP codes within a single CBSA. Data are at an annual frequency between 1975 and 2015. Full estimates are available upon request but summarized here.

Table 8: Urban House Price/Oil Price Elasticities in the United States

CBSA	Name	Oil Export Employment Share (CBSA)	Oil Export Employment Share (State)	Oil Price/House Price Elasticity (σ)	5-Year Effect of Doubling the Oil Price
Medium to Large CBSAs (250,000+ population; top 2 per state)					
36420	Oklahoma City, OK	29.5%	28.5%	0.079	26%
46140	Tulsa, OK	11.9%	28.5%	0.069	23%
26420	Houston-Sugar Land-Baytown, TX	28.8%	25.8%	0.067	22%
19100	Dallas-Fort Worth-Arlington, TX	4.1%	25.8%	0.061	20%
35380	New Orleans-Metairie-Kenner, LA	8.6%	19.5%	0.048	16%
12940	Baton Rouge, LA	0.3%	19.5%	0.043	14%
10740	Albuquerque, NM	0.0%	13.1%	0.029	10%
19740	Denver-Aurora, CO	4.0%	7.1%	0.018	6%
17820	Colorado Springs, CO	0.0%	7.1%	0.015	5%
Large CBSAs (500,000+ population), non-oil exporting					
	Less than 5 miles from CBD	0.0%	0.0%	-	-
	Between 5 and 15 miles from CBD	0.0%	0.0%	-0.002	-1%
	Over 15 miles from CBD	0.0%	0.0%	-0.007	-3%
Small CBSAs (up to 250,000 population; top 2 per state)					
12780	Bartlesville, OK	73.3%	28.5%	0.105	35%
48780	Williston, ND	60.1%	27.5%	0.095	32%
49260	Woodward, OK	50.5%	28.5%	0.092	30%
40540	Rock Springs, WY	39.5%	25.7%	0.079	26%
16220	Casper, WY	38.6%	25.7%	0.079	26%
33260	Midland, TX	59.2%	25.8%	0.076	25%
10860	Alice, TX	52.7%	25.8%	0.074	25%
29180	Lafayette, LA	48.4%	19.5%	0.071	24%
33500	Minot, ND	15.1%	27.5%	0.069	23%
26020	Hobbs, NM	60.3%	13.1%	0.064	21%
16100	Carlsbad-Artesia, NM	53.7%	13.1%	0.060	20%
34020	Morgan City, LA	27.6%	19.5%	0.059	20%
11260	Anchorage, AK	9.2%	22.3%	0.054	18%
21820	Fairbanks, AK	1.8%	22.3%	0.050	16%
46860	Vernal, UT	51.3%	2.6%	0.036	12%
24300	Grand Junction, CO	24.3%	7.1%	0.030	10%
24540	Greeley, CO	24.3%	7.1%	0.030	10%
30580	Liberal, KS	30.2%	2.5%	0.023	8%
17220	Clarksburg, WV	13.6%	5.9%	0.021	7%
24460	Great Bend, KS	22.1%	2.5%	0.019	6%
26860	Indiana, PA	28.3%	0.0%	0.017	6%
29860	Laurel, MS	24.0%	1.1%	0.017	6%
16620	Charleston, WV	5.5%	5.9%	0.016	5%
14620	Bradford, PA	25.8%	0.0%	0.015	5%
13740	Billings, MT	6.5%	4.0%	0.012	4%
20980	El Dorado, AR	14.6%	0.7%	0.010	3%

Note: Reported cities have elasticities greater than |0.01| and are limited to two per state. Estimates are calculated using methods described in the text. Elasticities for non-exporting areas are relative to the "less than 5 miles from CBD" category. The 5-year effect is calculated as: σ x (5 - (1-ρ)2ρ^2-(1-ρ)ρ) x (ln(100)-ln(50)) , with the ρ terms necessary for the infinite sum representation truncated in the 5th year. Terms at or beyond ρ^3 are assumed zero.