DO GASOLINE PRICES AFFECT RESIDENTIAL PROPERTY VALUES? *

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ADELE C. MORRIS
The Brookings Institution

HELEN R. NEILL
University of Nevada, Las Vegas

ED COULSON
University of California, Irvine

ABSTRACT

We construct a new version of the standard monocentric city model that recognizes the asymmetry of expansions and contractions of the urban area in the fact of changing transportation costs. We use data from the Las Vegas metro area to test the implications of the model, and find our qualitative predictions confirmed in all respects. However, simulating the effect of a 10% increase in gas prices (as from a carbon tax) we find that households overcapitalize changes in transportation costs, a finding similar to that of Coulson and Engle (1987).

KEYWORDS: commuting cost; residential value; asymmetrical response; and carbon tax policy

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1. INTRODUCTION

A large and growing literature addresses policymakers' keen interest in how climate and energy policies would affect households.[1] One key policy option to reduce the carbon dioxide emissions that threaten the earth's climate is an excise tax on the carbon content of fossil fuels. Imposing a carbon tax, or increasing existing gasoline taxes, would change the relative costs of different transportation options and commuting patterns and thereby incentivize emissions reductions. At the same time, higher gasoline prices could also affect housing markets by making close-in neighborhoods more attractive relative to neighborhoods farther from employment centers.

Evidence in related contexts suggests that gasoline prices capitalize into the value of durable fuel-using assets. For example, a number of studies have shown that gasoline prices significantly influence the type and price of vehicles purchased[2] and vehicle miles traveled.[3] The connections between gasoline prices (including as amplified by fuel excise taxes) and housing values is less explored. Some studies suggest that the connections could be significant, such as those that have linked gasoline price spikes to lending risks and the 2008 housing bust.[4] Other work shows that higher gas prices amplify the price differential between central city and suburban homes[5] and lead to smaller metropolitan areas.[6] Gasoline prices may also explain other findings in the urban economics literature. [7]

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[1] Economic and distributional effects of potential climate policies could vary importantly by household income class and region. See EPA (2010), Hassett et al. (2009), Rausch et al. (2011), and Mathur and Morris (2014).

[2] Langer and Miller (2013); Busse et al. (2013) find that a $1 per gallon increase in the gasoline price is associated with an increase of $354 in the average price of the highest fuel economy quartile of cars relative to that of the lowest fuel economy quartile. They found an estimated relative price difference of $1,945 for used cars.

[3] Hughes et al. (2008), Goldberg (1998), Donna (2012)

[4] Kaufmann et al. (2011) show that spikes in gas prices can contribute to mortgage non-performance. Cortright (2008) correlates the initial collapse of the housing bubble with the run-up in oil prices in 2008, and Sexton et al. (2012) connect the rapid run-up of gasoline prices in 2007 to 2008 to the bursting of the U.S. housing market bubble. Simulations support their theory that the greater the commuting distance from the central business district, the more a gasoline price spike causes home values to decline.

[5] In a sample of six cities, Coulson and Engle (1987) find that increases in gas prices between 1974 and 1979 boosted the differential between central city and suburban house prices.

[6] McGibany (2004), Tanguay and Gingras (2012)

[7] For example, Glaeser et al. (2012) find that during the last two housing booms, home prices rose significantly less in areas distant from the central business district. Gasoline prices could help explain why their result was far more pronounced during the 1996-2006 housing boom (a period in which real gasoline prices tripled) than during 1982-89 housing boom (a period in which real gasoline prices fell) and why, during the second boom, the price growth gradient was flatter in areas in which more adults take public transit.

Molloy and Shan (2013) find that an increase in gasoline prices lowers housing supply growth in areas with long commutes. They estimate that a 10 percent increase in gasoline prices leads to a 10 percent decrease in construction in locations with a greater than 24-minute average commute time relative locations with commute times lower than 24 minutes. They find no significant effect of gasoline prices on house prices, except in areas where the housing supply is constrained by regulation or geography and where demand for housing is growing. In those conditions, higher gasoline prices negatively affect home prices where commutes are long.

In this paper, we develop a theoretical model for the effect of transport costs on rent gradients (and thus home values) across a city, and we review the model's testable implications. The primary innovation of this theoretical model is that we assume that gas price decreases trigger housing construction at the edge of the city, but that housing is inelastically supplied (at the edge and elsewhere) when gas prices rise.[8] Therefore, some of the testable implications of the model are dependent on the sign of the change in gas prices.

We test the hypotheses with models of home sales prices with data from 907,647 home sales in Clark County, Nevada from January 1980 through December 2010. Our approach is similar to studies of how home heating oil prices and energy efficiency investments could be capitalized into home values.[9] Our empirical findings support several implications of the theoretical model. First, we find that distance to the business center of Las Vegas has a negative and significant effect on home values, all else equal. We also find that when gasoline prices increase, home values increase in areas with relatively low distances and decrease further out. Likewise, when gasoline prices fall, home values fall in areas with relatively low distances and increase further out. We estimate the distance at which the effect of gasoline prices on home values changes sign, i.e. the pivot distance. Tests of the pivot point estimations provide evidence that home values do not respond equivalently to increases and decreases in gasoline prices. Pivot distance for an increase in gas prices is greater than it is for decreases in the price of gasoline, consistent with an inelastic housing supply in the urban core relative to more outlying areas. We apply our results to estimate the potential housing price outcomes of an illustrative carbon tax.

[8] Thus gas prices act like the demand shocks in Glaeser and Gyourko (2005).

[9] Walls et al. (2013) review this literature and find that households do value the energy-related costs of home ownership as reflected in the price premium associated with energy efficiency certification. Eicholtz et al. (2013) find that rents and asset prices of certified green buildings are higher than for conventional office space. Similarly Kahn and Kok (2014) show homes with a green label transact at a small premium relative to otherwise comparable, non-labeled homes.

This study makes several contributions to the literature. The first is the theoretical model that illustrates how rent gradients can pivot and shift as transportation costs increase and decrease. The second contribution tests the theoretical model in a detailed location-specific exploration of the relationship between gasoline prices and home values and finds support for its hypotheses. This study complements Malloy and Shan (2013) in several ways. Using zipcode level data across the United States, Malloy and Shan compare the effect of gasoline prices on the price and quantity of housing in location with a long average commute time to other locations within the same metropolitan area. As the authors note, gasoline price capitalization may be more likely in areas where short run housing supply is inelastic. According to Saiz (2010), of the 95 largest metropolitan areas in the United States, Las Vegas has the 32nd most-constrained housing supply. This is in part owing to the fact that as of 2015, the U.S. federal government controlled 87.5 percent of the land in Clark County.[10] Although the Las Vegas metropolitan area expanded significantly in the period of our observations, many of the new developments required protracted changes in land ownership from the U.S. federal government to private sector developers.[11]

In addition, our approach allows for a continuous and non-linear relationship between distance and home value rather than a binary distinction between neighborhoods with short and long commutes. Finally, we allow the relationship between home values and gasoline prices to differ depending on whether gasoline prices rise or fall from purchase to sale. This accounts for an essential asymmetry in the optimality of the built environment in that the supply of homes is much more inelastic when demand falls than when it rises.

This paper proceeds as follows. Section 2 presents the theoretical model and the testable hypotheses that derive from it. Section 3 explains the estimation models we use to test the hypotheses. Section 4 describes the data, including the individual property sales, gasoline prices, commuting data, and macroeconomic variables. Section 5 reviews the results of the core estimations, and Section 6 presents analyses over sub-periods and other robustness checks. Section 7 concludes. The appendix describes the treatment of the data in more detail.

2. THEORY OF HOME VALUES AND TRANSPORT COSTS

In this section, we provide a simple theory of how rent gradients (and thus residential property values) shift with the cost of transport. This is squarely in the tradition of the canonical

[10] Nevada Legislative Counsel Bureau (2016)

[11] Ibid. documents the legal authorities under which these transfers take place.

structures of Alonso (1964), Muth (1972), and Mills (1972), also laid out in Brueckner (1987), Henderson (1985) and Fujita (1989). We simplify the models of these authors to clarify the empirical predictions. In particular, we assume there are only two housing technologies, one with low density and one with high density, instead of the continuous substitution of land and capital assumed by some of these authors.

A major theme in some of these works is the difference between cities that are "closed" and "open." In the former, the population of the city is fixed. Changes in exogenous variables induce comparative static changes in the utility level of residents and other endogenous variables, but do not change population. In an open city, the equilibrium level utility level of residents is fixed at some national level. Changes in exogenous variables can raise or lower the local utility level, which in turn induces changes in population, until equilibrium utility is restored.

Some think of closed city models as representing short run outcomes and open city models more representative of the long run. In the context of this paper, changes in gasoline prices apply nationwide, so they have only a second order effect on cross-city mobility even over the longer run, for example as higher gasoline prices give people marginally greater incentives to move to areas with denser housing and less dependence on cars and driving. Thus we argue that a closed city model is best suited to the context of this study.

All households commute to the central business district (CBD), which is distance t from their housing unit. The unit cost of commuting is k. For drivers, k includes the value of the driver's time plus the cost of the drive itself, including wear and tear on the car and the cost of gasoline consumed during the commute. The gasoline cost of a commute is the product of the distance traveled, the fuel intensity of the vehicle, and the price of gasoline. We return to the role of gasoline prices later and simply use k in the model.

Housing technology is such that everyone consumes a single unit of housing (although we will introduce two different housing types) so that h is normalized to one. The variable x is the numeraire, and so has price normalized to one.

The household budget constraint can therefore be written as

$$y = R + x + kt$$

where

y = income
R = total rent paid for housing
x = consumption
kt = expenditure on transportation.

Income is identical across households in this model. Since in equilibrium utility is equal across households—in particular across all locations— and the utility from a unit of housing is assumed identical everywhere, households must all have the same composite consumption x (call it x*) and the same total expenses on rent plus transport. This also means that the equilibrium rent per unit housing across locations must satisfy

$$R = y - kt - x^*$$

and therefore, in equilibrium,

$$dR/dt = -k. \tag{1}$$

Housing units that are further from job locations pay less rent, by an amount equal to the increase in transport costs.

Suppose there are two types of housing. Type D (detached) uses one unit of land and one unit of capital to build a unit of housing. Type A (apartments) uses a<1 unit of land and b>1 units of capital to produce a unit of housing. Equation (1) must be true for both types of housing.

Let r be the unit price of capital. Imagine a developer who owns land at distance t (land costs are therefore assumed sunk). The profit for a type D dwelling per unit of land (and per unit housing, since each D house takes a unit of land) is

$$\begin{aligned} \Pi(D) &= R - r \\ &= (y - kt - x^*) - r. \end{aligned}$$

A developer who builds Type A property can expect a profit, again per unit of land, that also subtracts capital costs from rent per unit land:

$$\Pi(A) = (1/a)\ (y - kt - x^*) - (b/a)r$$

So that:

$$d\Pi(D)/dt = -k$$

$$d\Pi(A)/dt = -k/a$$

Because $a < 1$, this implies that profits fall off more sharply with distance from the CBD for apartments than for detached homes, i.e., that the profit gradient for apartments is steeper. Noting the linearity in distance of both profit functions in distance t, and assuming developers maximize profits on each unit of land (ignoring divisibility issues), then type A houses will be closer to the CBD than type D, if both types exist.

For both types of housing to exist, the vertical intercept of the profit for type A homes plotted against t should be greater than that for type D. These vertical intercepts are found by setting $t = 0$ in the profit functions:

$$\Pi_0\ (D) = y - x^* - r$$

$$\Pi_0\ (A) = (1/a)(y - x^*) - (b/a)r$$

where Π_0 is profit right at the CBD, where t is zero. If $\Pi_0\ (A) > \Pi_0\ (D)$, then

$$x^* < y - r(b-a)/(1-a) = y-rq \qquad (2)$$

where

$$q= (b-a)/(1-a).$$

Assuming this condition holds and both types of housing exist, the crossing point of the two profit functions is at distance t^*, which is:

$$t^* = (y-x^*-qr)/k.$$

This means that from the CBD to t^*, developers maximize profit by building apartments. They build detached homes past t^* to the outside edge of the city.

Consistent with a closed city model, we assume the number of households in the city is fixed at N. The otherwise identical households fall into two groups: those living in apartments in the high density area, from 0 to t*, and those living in detached homes from t* to t', the low density area. The distance t' marks the outer edge of the city; it is the point at which developers' profit for type D homes goes to zero:

$$t' = (y - x^* - r)/k. \qquad (3)$$

In a linear city[12] of width one and length t', the number of households living in Type A houses is:

$$N_A = (1/a)[(y-x^*-qr)/k].$$

The number living in Type D houses is:

$$N_D = [(y - x^* - r)/k]-[(y- x^*-qr)/k].$$

The sum of N_A and N_D is the exogenous total population of households N. Rearranging the equations above, we can solve for equilibrium consumption x*:

$$x^* = y-kaN - br$$

This means that composite consumption increases in income y, but decreases in transport costs k, capital costs r, and the total number of households N, all of which are sensible outcomes. Condition (2), the criterion for two kinds of housing in equilibrium, is satisfied as long as:

$$N > br/ak.$$

High density housing is more profitable than detached homes at short distances from the CBD as long as population and transportation costs are high enough, and the cost of capital and the capital-land ratio of high-density housing are low enough.

Substituting the value of x* into (3), we get an expression for the size of the city:

[12] The linear city literature begins with Solow and Vickrey (1971).

$$t' = (y - (y - kaN - br) - r)/k$$
$$= aN + (b-1)r/k. \quad (4)$$

This means that the equilibrium geographic size of the city increases with the number of households and the amount of land used in units of high and low density housing, but decreases with transportation costs. City size also increases with the capital costs r. This is because as capital costs rise, developers switch at the margin from building high-density high-capital apartments to lower-density lower-capital detached homes.

We are interested in the predictions of the model for housing prices in relation to transport costs, k. These are straightforward given the linearity of the model. In equilibrium, the rent per unit of housing is:

$$R = y - x^* - kt$$
$$= y - [y - kaN - br] - kt$$
$$= y - y + kaN + br - kt$$
$$= kaN + br - kt$$

According to this, rents fall to zero at

$$t'' = aN + br/k. \quad (5)$$

However, the city boundary stops at t′, which is unambiguously smaller than t″, because rents between t′ and t′′ would not cover capital costs.

Consider a *decrease* in transport costs from k_1 to k_2. The absolute value of the slope of the rent gradient decreases from k_1 to k_2, as per Equation (1). To the extent that developers and residents believe the decrease in k is permanent, developers can profitably expand the size of the city, according to (4), from t'_1 to $t'_2 = aN + (b-1) r/k_2$.

There is, therefore, a point t** at which the rent gradient pivots as k falls. Rents increase past t** when transport costs fall, and rents decrease interior to t**. The distance t** lies at the intersection of the rent gradients associated with the two different transport costs, and is determined from:

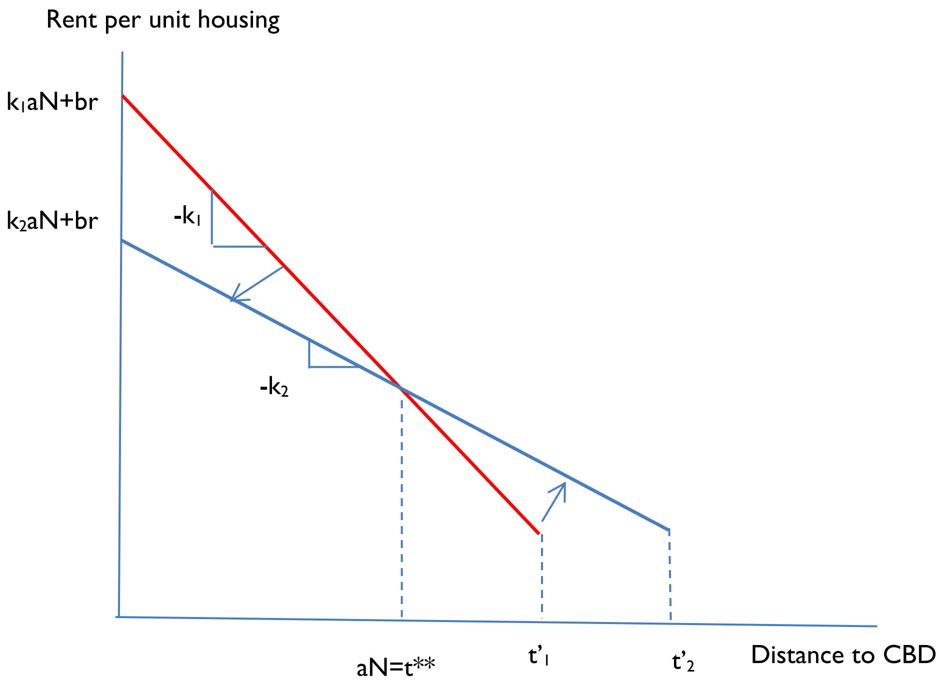
$$k_1aN+br - k_1t^{**} = k_2aN+br - k_2t^{**}$$

and

t**= aN.

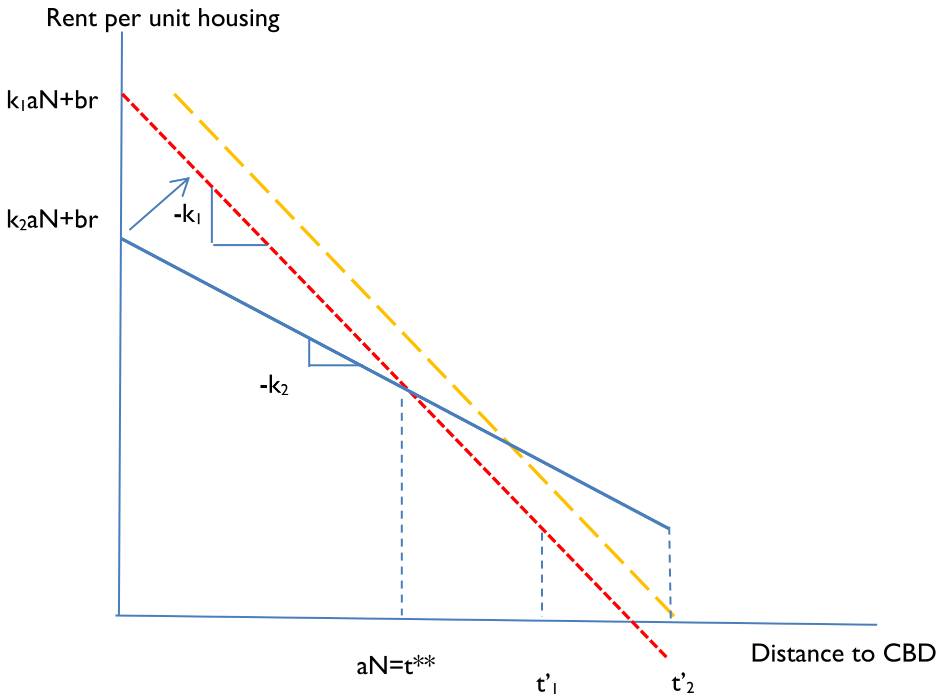
Given the linear structure of the model, the distance t** from the CBD at which the rent gradient rotates is invariant to housing technology and the magnitude of the change in k. Figure 1 below illustrates the pivot of the rent gradient and expansion of the city when transport costs fall.

FIGURE 1: RENT GRADIENT PIVOTS COUNTERCLOCKWISE WITH A DECREASE IN TRANSPORTATION COSTS FROM K_1 TO K_2



Now suppose transport costs go up, for example from k_2 to k_1, in a city that is built out to t'_2, as in the blue line of Figure 1. The effects of an increase in transport costs are not symmetric to the effects of the decrease in transport costs shown in Figure 1. Although the optimal size of the city declines when transport costs rise, durable housing at the city's edge will (by assumption) not be demolished (Glaeser and Gyourko, 2005). Figure 2 shows what may happen because of the mismatch between the optimal size of the city and its existing capital stock.

FIGURE 2: RENT GRADIENT PIVOTS CLOCKWISE AND SHIFTS OUT WITH AN INCREASE IN TRANSPORTATION COSTS



The model suggests that the slope of the rent gradient rises to k_1. This appears as a clockwise rotation in Figure 2 from the blue line to the dashed red line, which is similar to the solid red line in Figure 1, but extends to the city boundary at t'_2. However, this cannot be an equilibrium; the opportunity cost of the land and structure is (at least) zero, so any units earning negative rent will be shut down. But this cannot be an equilibrium either, since the city is closed, and there will be unhoused persons. Clearly, these unhoused persons will then bid up rents until all rents are non-negative within distance t'_2. This is the situation depicted by the yellow line in Figure 2. Some landlords are earning negative cash flow, because rents are not covering capital costs, but this is superior to paying capital costs without any offsetting rent in light of their inability to tear down the unit.[13]

The discussion so far assumes that all capital costs are fixed. To the extent that they are variable (i.e. ongoing, operating) costs, it is possible that this new rent gradient will shift up

[13] Similarly, some landlords around the original t** would earn higher profit if they could switch from type D to type A, but they cannot. They still earn positive profit from the Type D property, and so will not shut down.

further, because rents must now exceed those variable costs. If r consists entirely of variable costs, then the new rent gradient will shift up so that the rent at t'_2 equals r.

We can be agnostic on the exact landing point of the new equilibrium rent gradient. The important predictions are these:

- The effect on home values (positive or negative) of a change in commuting costs k depends on the distance of the unit to the CBD, and
- there is a fulcrum distance from the CBD at which the sign of that effect flips.

These two predictions should hold regardless of whether commuting costs rise or fall, but the fulcrum distance is larger when commuting costs increase than when they decrease.

This model offers two testable hypotheses:

A) First, the negative slope of the rent gradient leads us to hypothesize that, all else equal, homes in more distant neighborhoods (in time or space) will be less valuable than homes closer to the CBD. This is a hypothesis about the effects of distance t, conditional on transport costs k.

B) Second, we test for effects on home values from rising and falling gas prices. In Figure 1, the pivot of the rent gradient following a gas price decrease occurs at distance $t^{**}=aN$. With an increase in gasoline prices, the pivot is at a distance greater than aN. The exact point depends on how capital costs are treated. In the limit, where capital is part of variable costs, all properties, except those at the very edge, will experience price gains, and the rent gradient will shift out even further. In any case, we expect that, all else equal, that the pivot point for an increase in gas prices will be greater than it is for decreases in the price of gasoline. Note that these are the hypothesized effects of positive and negative changes in k at varying distances.

3. EMPIRICAL METHODOLOGY

Hedonic regression is a standard method to estimate the relationship between the sales prices of houses and their characteristics.[14] We can use this approach to investigate the implications of our theoretical model.

[14] Rosen (1974), Campbell et al. (2011)

An important modeling decision is the measure of "distance." In the theoretical model, this was simply the geographic distance to the CBD, which was the location of all market activity, in particular jobs. However, in practice, complications arise. One is whether such a central point exists. No city is strictly monocentric (though see Yinger (1979) and Coulson (1991), so in any given location, residents travel a range of distances to their respective destinations. One measure that weights these different accesses is a census tract-specific measure of average commuting time.

There are at least two objections to using such a measure. The first is that households pick residential location based partly upon job location, and therefore commuting time is an endogenous characteristic in a hedonic model. The second is that Las Vegas is largely a monocentric city, with a CBD composed of many tourist resorts and attractions along the corridor of Las Vegas Boulevard known as The Strip. It is largely access to this area that commands value in the MSA, not only because of its primacy as the location for jobs, but also for its destination as an entertainment and retail center. It is the latter set of urban functions that matter for our choice of access measure, given the large number of vacation and retirement properties in the metropolitan area. Average commuting time would likely not pick up the demand for access to the strip that drives location premia. For that reason, here we will use distance to McCarran Airport, which directly abuts the Strip, as our primary measure of distance. We will discuss other measures in a later section of the paper.

Hypothesis A: Negative Slope of Rent Gradient

Our first testable hypothesis suggests that, all else equal, homes in neighborhoods with more-costly travel will be less valuable than homes in neighborhoods with lower cost travel. The standard hedonic property price model postulates that the inflation-adjusted selling price of a house is a function of its physical characteristics and other factors, so we can put distance in such a model for our test.

We estimate a hedonic model with data that include 908,205 home sales in Clark County, Nevada, from 1980 through 2010, along with key characteristics of those homes. Clark County has a population of over two million residents and includes the two largest cities in Nevada, Las Vegas and Henderson. Its expansive metropolitan area epitomizes large automobile-dependent Western-U.S. cities.

Owing to its intrinsically reduced form nature, no particular theory governs the structure or functional form of hedonic price models. A hedonic price schedule is simply the locus of tangencies between consumers' bid functions and suppliers' offer functions. We specify a typical log-log hedonic estimation equation for y_{isz}, the log price of house *i* in census tract *s* in the month of sale *z* (which falls in year w):

$$y_{isz} = c + \delta_1 T_i + \delta_2 [T_i]^2 + \gamma_w + \beta' X_i + \lambda_s g_z \alpha_s + \mu_s u_z \alpha_s + \varphi_s V_z \alpha_s + \epsilon_{isz}. \qquad (6)$$

The variable *c* is a constant. The terms T_i are the property-specific distances to the airport, thus reflecting the fuel cost to residents' of driving to their destinations. The terms γ_w are year indicators, and they control for broad trends in the Clark County housing market.[15] Period *z* (the month of sale) falls in year *w*. The vector X_i includes property characteristics such as lot size and square footage of living space that are standard in hedonic models, with coefficients β. The vector X_i also includes an indicator for a foreclosure-related sale. The terms $g_z \alpha_s$ capture the time and fuel expense of traveling.

The variable g_z is the log price of gasoline in the month in which the home is sold, and the $g_z \alpha_s$ terms are its interactions with the census tract indicators, α_s. The coefficient λ_s is the elasticity of the price of homes in census tract *s* with respect to the price of gasoline. We examine the variation in and spatial patterns of these estimated elasticities. We expect λ_s will be relatively higher in locations that become more attractive when gasoline prices are higher (all else equal) and λ_s will be relatively lower in locations that are less attractive when gasoline prices rise. The absolute value of λ_s will be larger in areas most sensitive to gasoline prices, and it will be closer to zero in areas that are insensitive to gasoline prices. Equation 6 imposes no *a priori* restrictions the gasoline-dependent location premia (or discounts) in each tract, such as a particular functional relationship with the distance from central business districts. This function-free approach is appropriate to Clark County, which has multiple major employment centers.

Equation 6 assumes that the effects of gasoline prices on home values are constant over part the period of the data. We discuss the potential for relaxing these assumptions in Section 6.

Broad macroeconomic fluctuations could drive both housing demand and oil demand, and that will shift the distribution of our estimated elasticities. By itself, that is not a problem for our study because we are focused on the relative value of homes in different neighborhoods, not area-wide average property values. However, in principle a strong economy could result in higher demand for housing in some neighborhoods than others. Likewise, a weak economy could depress the value of homes in some neighborhoods more than it would others, while also being correlated with lower gasoline prices. If this occurs, then the estimated coefficients on the location-gasoline price interaction terms could be biased.

Thus, we include the terms $\mu_s u_z\ \alpha_s$ and $\phi_s V_z \alpha_s$ to help control for macroeconomic conditions that may affect home values differently in different neighborhoods. The variable u_z, is the unemployment rate in Nevada in the month of the property purchase, and we interact it with the location indicators α_s. The term V_z controls for the change in economic activity in the hospitality industry as reflected in the log of the month-specific number of visitors to the Las Vegas area, (V_z), also interacted with the location indicators.

Home values in the urban core could depend more directly on a cyclical tourist economy than home values on the outskirts of town, and thus be more positively related to gasoline prices. Ideally, we would employ an instrument for gasoline prices that is uncorrelated with macroeconomic conditions, but such an instrument is elusive. Rather we simply note that the magnitude and distribution of the estimated elasticities may be skewed if home values in some neighborhoods are more procyclical than in others, even when controlling for statewide unemployment and the local tourism economy. Lastly, the variable ϵ_{isz} is an error term that reflects random variation in house prices.

Under Hypothesis A, we expect that the joint effect of the estimated coefficients δ_1 on δ_2 distance T_i to be negative and significantly different from zero. We also expect the elasticities of home values with respect to gasoline prices, λ_s, to be jointly statistically significantly different from zero, but we do not a priori put any particular spatial structure on them. In other words, we expect gasoline prices to matter differently in different neighborhoods, but we do not assume anything about which neighborhoods have longer average travel times.

Hypothesis B

Our second hypothesis is that, all else equal, a decrease in travel costs from lower gas prices will cause the rent gradient to fall (the slope becomes flatter) and pivot at a distance at which the sign of the effect gasoline prices changes. We also expect that higher gasoline prices will cause the rent gradient to rise (slope becomes steeper), but with a pivot point at some further distance. Because the magnitude of the effect differs at different locations, it is convenient to test with a two-stage analysis. In the first stage we estimate a repeat sales model that postulates that the inflation-adjusted appreciation of a house from one sale to the next is a function of its location interacted with the percent change (over the same period) in gasoline prices and other factors. This repeat sales approach fully controls for time-invariant unobserved characteristics of the home. We also allow home price appreciation to be asymmetric with the direction of change in gasoline prices. We write this model:

$$_{\Delta}y_{is} = \zeta_t + \Psi_i + \eta^{+}_{s}\alpha_s + \eta^{-}_{s}\alpha_s + \lambda^{+}_{s\Delta}g^{+}\alpha_s + \lambda^{-}_{s\Delta}g^{-}\alpha_s + \mu_{s\Delta}u\alpha_s + \phi_{s\Delta}V\alpha_s + \epsilon_{is} \quad (7)$$

The dependent variable, $_{\Delta}y_{is}$, is the difference in the log price of a home from one sale to the next. This is the appreciation of the price of property i in census tract s over the period between sales.

The year indicators ζ_w are -1 if the home was purchased in year w, +1 if it was sold in year w, and zero otherwise as is standard in repeat sales models (Bailey, Muth and Nourse (1961) In effect, Equation 7 is the first difference of the hedonic model in Equation 6. Thus, we also include foreclosure year indicators Ψ_i that are -1 if home was a foreclosure only upon purchase, +1 if it was a foreclosure only upon sale, and zero otherwise. If both purchase and sale were foreclosure, or neither purchase nor sale was a foreclosure, this term is zero.

The term $_{\Delta}g^{+}$ is the change in real log gasoline prices from the month of purchase to the month of sale if the change is positive, and zero otherwise. Likewise, the term Δg^{-} is the absolute value of the change in real log gasoline prices from the month of purchase to the month of sale if the change is negative, and zero otherwise. Both terms are interacted with census tract indicators. The estimated coefficients λ^{+}_{s} and λ^{-}_{s} are the tract-specific price elasticities of properties with respect to the price of gasoline, with the first set applying when gasoline prices rise from purchase to sale and the second set applying when gasoline prices fall from purchase to sale. Similarly, the estimated coefficients η^{+}_{s} and η^{-}_{s} are the tract-specific constant terms when gasoline prices rise and fall, respectively.

The λ_s coefficients are interpretable as the log vertical distances between the rent gradients in Figures 1 and 2. In using the absolute value of falling gasoline prices, the λ^{-}_{s} will be negative where falling gasoline prices negatively affect home values and positive where falling gasoline price positively affect home values. Thus, according to our theory, we expect the λ^{+}_{s} to be positive and the λ^{-}_{s} to be negative in areas with the shortest distances.

Like Equation 6, Equation 7 assumes that the tract-specific distances and the effects of gasoline prices on home values are constant over the period of the data. We discuss this further in Section 6.

The variable $_{\Delta}u_z$, is the change in the unemployment rate in Nevada from the month of the property purchase to the month of the property sale, and we interact it with the location indicators α_s. The term $_{\Delta}V_z$ controls for the change in economic activity in the hospitality industry as reflected in the change in the log of the month-specific number of visitors to the Las Vegas area, (V_z), also interacted with the location indicators

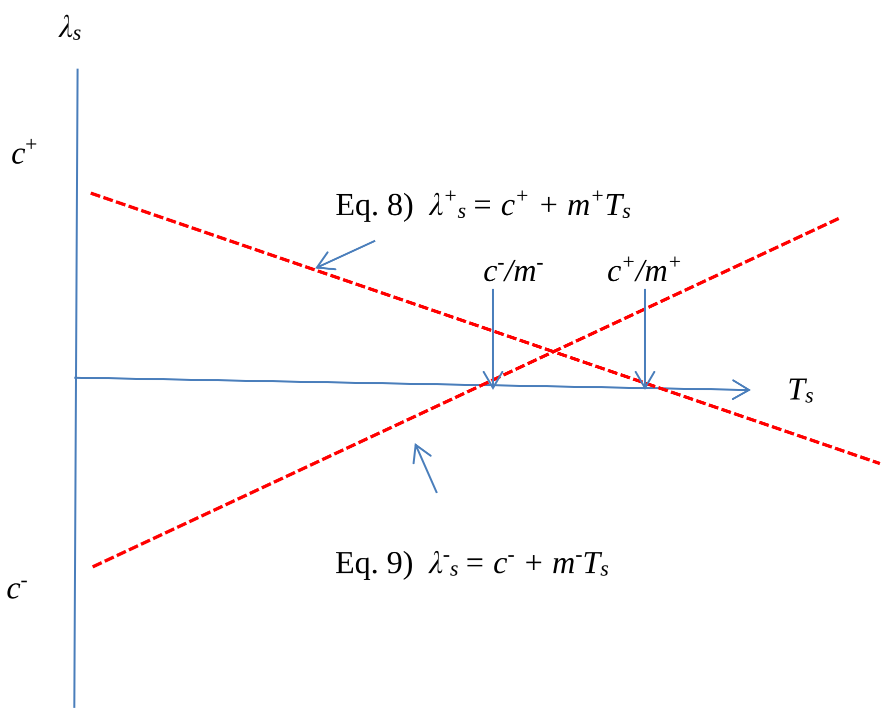
The second stage analysis for this hypothesis separately characterizes the relationship between the estimated two sets of elasticities (the λ^+_s and λ^-_s) and average distance to the airport in different neighborhoods:

$$\lambda^+_s = c^+ + m^+T_s + \epsilon_s \quad (8)$$

$$\lambda^-_s = c^- + m^-T_s + \epsilon_s \quad (9)$$

According to the theory and the structure of Equation 7, we expect the regression lines in the second stage to look something like Figure 3 below.

FIGURE 3: ILLUSTRATION OF EXPECTED REGRESSION LINES IN 2ND STAGE OF HYPOTHESIS B



In this second stage, we estimate the vertical intercept and slope for Equations 8 and 9, and we test three implications of the theory, as depicted in Figure 3:

- The first hypothesis is that $m^+ < 0$ and $m^- > 0$ and that, accordingly, we can reject the null hypotheses that $m^+ = 0$ and $m^- = 0$.
- The second hypothesis is that the absolute values of the two estimates of m are identical. That is, we cannot reject the null that $|m^+|=|m^-|$.
- The third hypothesis is that the horizontal intercept of the regression lines, the values of T_s at which the λ's change sign, is greater in the rising gasoline price regression (Equation 8) than in the falling price regression (Equation 9). In other words, the null is that $c^+/m^+ = c^-/m^-$, which we suggest will be rejected in the direction of the alternative $c^+/m^+ > c^-/m^-$.

4. DATA

This study combines several different data sources for property transactions, gasoline prices, macroeconomic conditions, and distance to the airport.

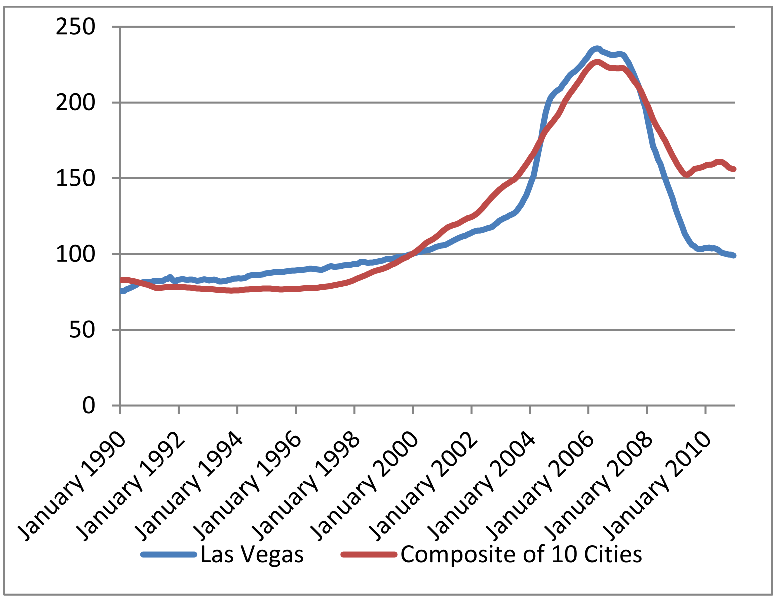
Property data

The data we use to estimate the hedonic model for the first hypothesis derive from about 907,647 arm's length home sales in Clark County, Nevada, from January 1980 to December 2010, obtained from the Clark County Assessor's Office. The data for the other models are the 430,087 repeat home sales in the data set.

Clark County has a population of over two million residents and includes the two largest cities in Nevada, Las Vegas and Henderson. Its sprawling metropolitan area epitomizes large automobile-dependent Western-U.S. cities. In 2010, there were 487 census tracts. We have repeat sales data for 476 tracts. Most census tracts are small, so in general the tract indicators control for location well; the median census tract is only 0.63 square miles in area. Tract areas range from 0.14 to 2,182 square miles, and nine of our census tracts have land areas over 100 square miles. If we focus on tracts within the Las Vegas Metropolitan Area and tracts with more than 50 transactions the median miles is 0.62 and areas range from 0.14 to 222 square miles. For these census tracts, only 6 tracts are greater than 10 square miles. Despite the large size of two of the tracts (222 and 129, respectively), the observations are clustered close to the Las Vegas metropolitan area, and the terms α_s are good indicators for location.

Clark County is an extreme example of the boom and bust U.S. housing market experience, and real home prices exhibit strong variation. The population of Clark County grew dramatically over the duration of the data, with an average annual growth rate of 5 percent from 1990 to 2009. The county population more than doubled from about 780,000 in 1990 to more than two million in 2009.[16] To illustrate the broad market context of our study, Figure 4 shows the S&P/Case-Shiller Home Sales Price Indices for Las Vegas and a broader Case-Shiller composite index for ten large U.S. cities. The boom was steeper and the freefall in 2008 was more dramatic in Las Vegas than in most other cities.

FIGURE 4. S&P/CASE-SHILLER HOME PRICE INDICES, JANUARY 1990 TO DECEMBER 2010



Notes: Data for this figure are the S&P/Case-Shiller Seasonally Adjusted Home Price Index Levels, downloaded August 2, 2011, from http://www.standardandpoors.com/indices/sp-case-shiller-home-price-indices/en/us/?indexId=spusa-cashpidff--p-us----.

The data include the actual selling price of the property, the sale date, and detailed characteristics of the home. The property characteristics include lot size, square footage of living area, number of full baths, the age of the home at the time of sale, and indicators for amenities such as a pool.

[16] Population data downloaded from Clark County Assessor on September 22, 2010, from http://www.accessclarkcounty.com/depts/comprehensive_planning/demographics/Pages/Demographics.aspx.

We also include an indicator for transactions the Clark County Assessor designates as linked to a foreclosure. Campbell et al. (2011) note that illiquidity in the housing market can depress prices of forced sales. Using data from over 1,800,000 home sales in Massachusetts from 1987 to March 2009, they find foreclosed homes sold at substantial discounts relative to other sales, about 27 percent less on average. We therefore include an indicator in this study to estimate a similar average discount for the Clark County foreclosure transactions from 1980 through 2010.

We removed outliers from the data as detailed in the Appendix. For example, given the specialized market for such properties, we exclude very large homes (greater than 8,000 sq. ft. of living area) and homes on very large lots (greater than five acres). We also drop sales of properties with prices under $40,000 or over $5 million ($2010). These dropped observations collectively represent less than five percent of the raw dataset.

Gasoline prices

Many hedonic studies seek to infer the implicit price function for non-market factors, such as air quality and natural open space. In that context, consistent estimation is difficult because unobserved factors (such as crime rates) could covary with both the non-market factors and housing prices.[17] Here, one might be concerned that, say, seasonality in gasoline prices and seasonality in housing markets could produce spurious correlation and compromise the interpretation of our estimated coefficients. Gasoline prices show the expected seasonal pattern of systematically higher levels in summer months, but property sales prices in Clark County, Nevada, do not show a strong seasonality; there is less than one percent variation in sales price by calendar month of sale. The climate, the large share of new home sales in the data, and the attractiveness of Las Vegas for retirement and second homes could all contribute to this.[18]

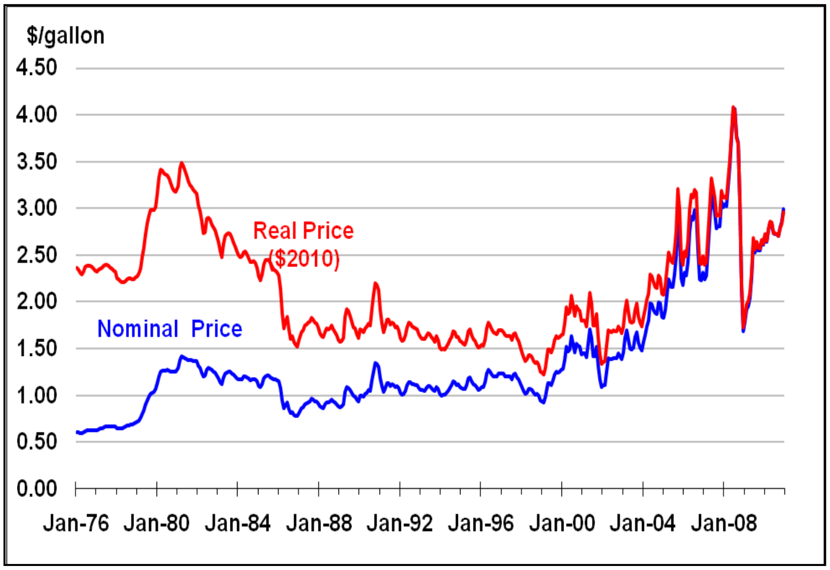
Potential misspecifications could also arise with local gasoline prices, which are a function of specific neighborhood characteristics, such as the scale and competitiveness of the local retail economy. We avoid this problem by using national average gasoline prices, which are unaffected by neighborhood characteristics in Clark County, Nevada. Another reason to use national gasoline prices in this study is that a key goal of this paper is to understand how

[17] For example, see Gayer et al. (2002). Chay and Greenstone (2005), Halvorsen and Pollakowski (1981), and Cropper et al. (1988) discuss the challenges of misspecification of hedonic price models.

[18] We estimated Equation (1) both with and without calendar month indicators and find that they add no appreciable explanatory value.

national climate and energy policies can affect local housing markets. In that context it makes sense to exclude within-city gasoline price deviations, which are unlikely to be affected by national or state-level energy policy. Figure 5 shows the U.S. national average of gasoline prices from the U.S. Energy Information Administration (EIA) in nominal and 2010 dollars. The figure shows significant variation in real gasoline prices over the period of this study, from a low of $1.22 in February 1999 to a high of $4.08 per gallon in June 2008.

FIGURE 5. MONTHLY U.S. AVERAGE MOTOR GASOLINE RETAIL PRICE, JANUARY 1976 TO DECEMBER 2010



Notes: Data for gasoline prices are from EIA's *Short-Term Energy Outlook - Real Energy Prices* data series, February 2011 update. See http://www.eia.gov/EMEU/steo/realprices/index.cfm. Prices are for regular grade gasoline.

Households should consider the *expected* price of gas when deciding where to live and what to pay for a home. Malloy and Shan(2013) and others review the evidence on the formation of gasoline price expectations and conclude that empirically, the current level of gas prices is a good proxy for the expected future price.[19] Anderson et al. (2011) find that the average consumer expects the future real price of gasoline to equal the current price, and consumers exhibit a reasonable forecast in most instances.[20] Following up on our repeat sales model results under a subsection labeled robustness checks, we report alternative results to

[19] Alquist and Kilian (2010), Bopp and Lady (1991), and Chinn and Coibion (2010)

[20] The results we present below are robust to including lagged values of gasoline prices in the model.

the contemporaneous gasoline price, including lagged gasoline prices and forward-looking gasoline prices.

In addition, to control for macroeconomic conditions, we use data on the unemployment rates in Nevada from the U.S. Bureau of Labor Statistics and data on the number of visitors to the Las Vegas area from the Las Vegas Convention and Visitors Authority.[21]

Distance to McCarran Airport

For the hedonic model, we use the Pythagorean theorem to calculate miles (as the crow flies) to the airport for each home in our data using their x and y coordinates. Using these values, we calculate the observation average miles to the airport for each census tract. In the second stage of the repeat sales analysis, the unit of analysis is at the census tract level. In that regression, distance is the average across [properties or sales observations] within each tract.

Econometric considerations

The estimation models impose no *a priori* restrictions the gasoline-dependent location premia (or discounts) in each tract, such as a particular functional relationship with the distance from central business districts. This function-free approach is appropriate to Clark County, which has multiple major employment and entertainment centers.

The variance of the error term may not be constant for a number of reasons, including because the fit of the model could be systematically worse for certain property sub-markets than others. For example, Goodman and Thibodeau (1997) demonstrate strong heteroscedasticity in hedonic housing price models that is related the age of the dwelling. If the hedonic model fits transactions in one neighborhood in a year better than another neighborhood in that same year, errors would not be independent and identically distributed; the OLS estimates would be unbiased but the standard errors would be wrong. We conducted a Breusch–Pagan test, which confirmed heteroscedasticity. Accordingly, we estimate robust standard errors, and we cluster the errors by tract-year.[22]

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[21] We calculated these percentages based upon type of commuter (e.g. drives alone, carpool, public transportation, walks and divide by total number of commuters for 487 census tracts. The summary statistics are similar for census tracts within the Las Vegas metropolitan area 79%, 90%, 3% and 1%, respectively for 442 tracts)

[22] For more information on clustered errors, see Nichols and Schaffer (2007)

Summary Statistics

TABLE 1: SUMMARY STATISTICS OF HOME SALES

	mean	sd	min	max
Property price	246,398.64	147,253.20	40,005.00	2,309,210.90
Living area (square feet)	1,908.32	761.15	280.00	7,988.00
Lot size in acres	0.16	0.14	0.01	5.00
Age of the home	9.41	12.54	0.00	109.00
Pool indicator	0.21	0.41	0.00	1.00
Number of full baths	2.19	0.58	1.00	6.00
Foreclosure indicator	0.06	0.25	0.00	1.00
Townhouse indicator	0.07	0.26	0.00	1.00
Multiplex indicator	0.01	0.09	0.00	1.00
Price per gallon of gasoline	2.18	0.62	1.22	4.08
Nevada state-level unemployment rate (percentage points)	6.39	3.12	3.80	14.90
visitors to Las Vegas area	2,781,049.32	580,895.61	702,555.00	3,456,738.00
Distance to airport in miles (by observation)	9.73	8.83	0.94	80.99
N	907,647			

TABLE 2 – REPEAT SALES MODEL
SUMMARY STATISTICS

Number of Observations = 430,087

	Mean	Standard Deviation	Min	Max
Δln(Property price)	-0.05	0.49	-2.90	3.46
Δln(Price per gallon of gasoline)	0.11	0.29	-1.04	1.21
ΔNevada state-level unemployment rate (percentage points)	1.53	3.72	-8.40	11.10
Δln(visitors to Las Vegas area)	0.13	0.23	-0.51	1.58

5. RESULTS

In this section, we present the results from the hedonic and repeat sales models and the related hypothesis tests.

Hypothesis A: Negative slope of rent gradient

The estimated coefficients on the housing characteristics shown in Table 3 are broadly consistent with other hedonic studies such as Walls et al. (2013).

TABLE 3: HEDONIC RESULTS FOR EQUATION 6

	All
ln(living area in square feet)	0.5710***
	(0.0037)
ln(lot size in acres)	0.1418***
	(0.0025)
Age of the home	-0.0090***
	(0.0002)
(Age of the home)^2	0.0000***
	(0.0000)
Pool indicator	0.0668***
	(0.0010)
Number of full baths	0.0220***
	(0.0014)
Multiplex indicator	-0.0159**
	(0.0075)
Townhouse indicator	-0.0057
	(0.0035)
Foreclosure indicator	-0.1279***
	(0.0028)
Distance to airport	-0.0263***
	(0.0058)
(Distance to airport)^2	0.0003***
	(0.0001)
Constant	9.1625***
	(0.0937)
N	907,647
adj. R^2	0.829

Regression also includes the interactions of census tract indicators with gasoline prices, Las Vegas visitors, and the unemployment rate. All three sets of interaction terms are jointly significant. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

For example, the results suggest that a one percent increase in the square footage of the home, all other factors equal, translates into about a 0.6 percent increase in the sales price of the property. The estimated coefficient on the foreclosure indicator suggests that distressed property sales produce a 13 percent lower selling price than sales of comparable properties not in foreclosure. Our result is smaller but of the same order of magnitude as the results of Campbell et al. (2011).

For each set of interaction terms of tract indicators and explanatory variables, we conducted a joint F-test. In each case, the terms are jointly statistically significantly different from zero at a 1% confidence level. This means that with great confidence we can reject the null that the tract-level effects of gasoline prices on housing values are collectively zero.

The other result of interest is the estimated coefficient on Distance to Airport. The linear term is -.026 and the quadratic term is .0003; they are individually and jointly significant, thus confirming Hypothesis A. The impact of distance is therefore negative up to 43 miles, which is larger than the vast majority of the units in our data. At the mean distance of 9.7 miles the discount to home value is about .22 log points, or about 20%. At the mean house value of about $246,000, this amounts around $49,000, or around $5,400 per mile. The effect is therefore economically as well as statistically significant. This is comparable (accounting for inflation, with the effect found in Coulson (1991).

Hypothesis B: Home Value Response to Increases and Decreases in Gasoline Price

Table 4 reports the variables in the repeat sales model estimation, consistent with Equation 7, along with the R-squared values of the regression. The foreclosure indicator estimates a similar negative effect on home values that appeared in the hedonic regression.

TABLE 4: REPEAT SALES RESULTS FOR EQUATION 7

	All
Foreclosure sale indicator	-0.133^{***}
	(0.004)
N	430,087
R^2	0.664
adj. R^2	0.662

Eqn 7: $\Delta y_{is} = \zeta_t + \psi_i + \eta^{+}{}_{s}\alpha_s + \eta^{-}{}_{s}\alpha_s + \lambda^{+}{}_{s\Delta}g^{+}\alpha_s + \lambda^{-}{}_{s\Delta}g^{-}\alpha_s + \mu_{s\Delta}u\alpha_s + \phi_{s\Delta}V\alpha_s + \epsilon_{is}$

& VCE cluster by tract & year

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

As with the hedonic regression for Hypothesis A, for each interaction term of tract indicators and explanatory variables, we conducted a joint F-test. In each case, the terms are jointly statistically significantly different from zero at a 99% confidence level. Again, with strong confidence we can reject the null that the tract-level effects of rising and falling gasoline prices on housing values are collectively zero.

We can now turn to the tests of Hypothesis B, which involve the regression models in Equations 8 and 9. In the first stage, we estimate the tract specific elasticities separately for rising and (the absolute value of) falling gas prices. Figures 6 and 7 display maps that present these elasticities.

Figure 6: Elasticities of home prices with respect to rising gas prices, by tract. White spaces are locations with small numbers of transactions.

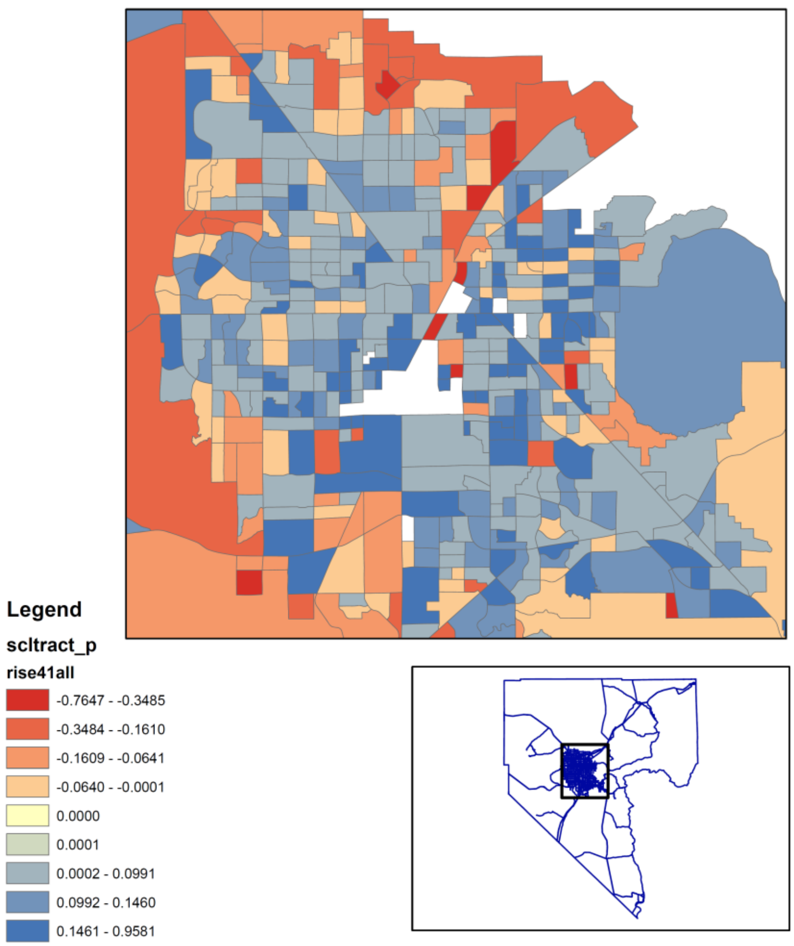
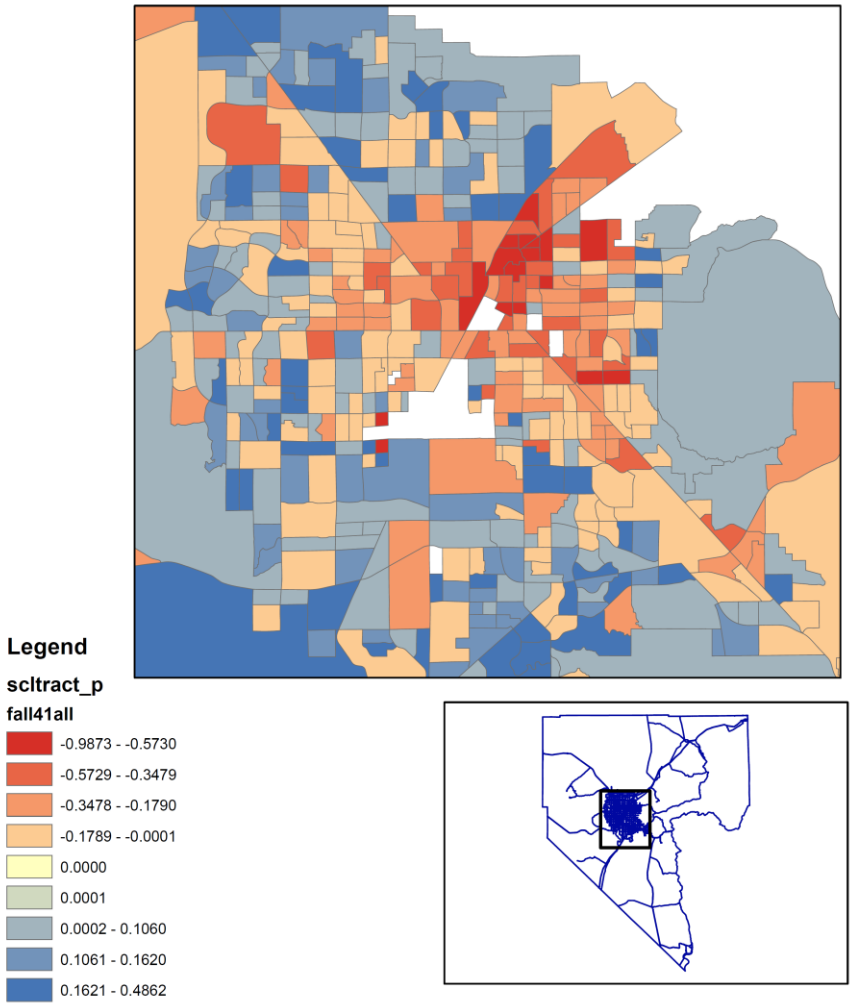


FIGURE 7: TRACT SPECIFIC ELASTICITIES WITH RESPECT TO ABSOLUTE VALUES OF FALLING GAS PRICES. SEE NOTE TO FIGURE 6.



As the figures show, the responses of house prices largely conform to the theoretical prediction. When gas prices rise, Figure 6 shows that properties that are close to the center of the city rise and those that are further away fall. Figure 7 shows an opposite coloration, a fall in the price of gasoline leads to increases in home prices that are sufficiently distant from the center, and the increase is greater, the farther the property.

Table 5 shows the results from estimating equations 8 and 9.

TABLE 5: SECOND STAGE REGRESSION RESULTS

	Equation 8: Rising gasoline prices	Equation 9: Falling gasoline prices
Distance to airport (in miles, tract-level average)	-0.0089***	0.0120***
	(0.0028)	(0.0027)
Constant	0.1253***	-0.1606***
	(0.0247)	(0.0266)
N	453	453
adj. R^2	0.039	0.033

As Table 5 shows, the signs of the coefficients on distance in the two regressions are as predicted by the theoretical model. The elasticity of house prices to gas price rises is most positive near the city center, and most negative at the fringe, while the opposite is true for (the absolute values of) gas price declines.

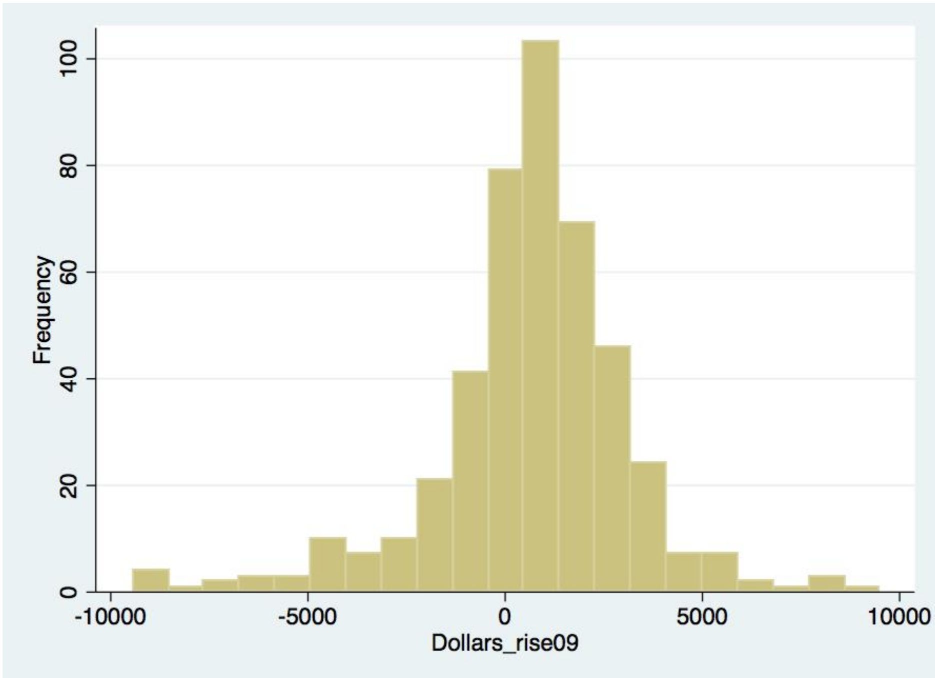
The theoretical model predicts that the slope coefficients of the two regressions in Table 5 should be the same in absolute value, and this hypothesis is not rejected with a prob-value of 0.81 (despite the fact that the individual standard errors are quite small). The second prediction is that the horizontal intercepts of these regressions are different, with the intercept from the rising regression being greater than that of the falling regression. Inspection of Table 4 reveals that this is the case. The rising regression reveals an intercept of (.1253/.0089)=14.1 miles, while the falling intercept is (.1606/.012)=13.4 miles. The hypothesis that these are equal is rejected with a Chi-squared statistic of 105.4 (and one degree of freedom). The estimates conform to the theory model in all respects.

Comparative Statics of a carbon tax

Figure 8 is a histogram of tract-specific responses to a carbon tax that increases gasoline prices by 10%, applying the positive and negative elasticities shown in Figure 6. Excluding some outliers, the range of responses runs from about -$10,000 to about +$10,000 over a range of tract-average distances from the airport from 2 to 26 miles (after outliers are excluded).

Figure 7: Tract specific elasticities with respect to absolute values of falling gas prices. See note to Figure 6.

FIGURE 6: HISTOGRAM OF TRACT-SPECIFIC HOME PRICE EFFECTS OF CARBON TAX ($)



The question arises how our estimated range of $20,000 corresponds to actual travel costs in the city. As a rough calculation, imagine a household that commutes from the farthest outskirts of the city to the center of Las Vegas, a distance of about 24 miles. Let us assume 250 driving days per year per driver in a household, 1.5 drivers per household, and two 24-mile trips per driving day per driver. That implies about 9,000 miles per year per household. If we estimate the incremental travel costs associated with those miles using 10% of the average real gasoline price of $2.18 in our data and an average fuel economy of 20 mpg per vehicle, we get about $196 per year in greater gasoline costs.[23] At a five percent discount rate, the present value of that stream of incremental gasoline costs over, say, 30 years is roughly $3,500.[24] Thus, our estimated $20,000 range of the effects of 10% higher gasoline costs between homes that are close in and those far out is significantly larger than one would expect. This overcapitalization of gas price increases was also observed in Coulson and Engle (1987).

[23] According to the U.S. Bureau of Transportation Statistics, Average U.S. light duty vehicle fuel efficiency in 2005 was 20.2 miles per gallon. https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_23.html

[24] A long time period is appropriate because the land value and location are the asset flows being capitalized.

6. ROBUSTNESS CHECKS

Temporal heterogeneity

The sensitivity of home prices to gas prices might vary over the sample period for a number of reasons. One is that the fuel efficiency of the extant fleet of automobiles has improved considerably over that period. The empirical importance of fuel economy standards for new vehicles is muted in any given year because new cars form only a small share of the current fleet, but the effects of the policy do accrue over long periods. Another factor is the increasing reliance on home work and telecommuting, which has also gained traction during the time frame of our data. A third factor, more specific to Las Vegas, is the wild swings in the housing market as documented above. It is plausible that during the extraordinary rise and even more extraordinary fall in house prices that property buyers paid less attention to fundamental attributes of the property that they might have in more stable conditions.

To investigate potential variation in our results across time, we divide the sample into three periods: pre-boom, from the beginning of our sample until 1999; boom, from 1999 through 2006; and bust, from 2006 through the end of our sample in 2010. The recovery of the housing market did not begin until after 2010.

The results of the second stage regressions specified in Equations 8 and 9 appear in Tables 6 and 7, respectively.

TABLE 6: SECOND STAGE RESULTS: RISING GAS PRICES

	Pre-boom	Boom	Bust
Distance to airport (tract-average)	-0.0096	-0.0042	-0.0063^{**}
	(0.0085)	(0.0039)	(0.0031)
Constant	0.0931	0.1622^{***}	0.0786^{***}
	(0.0663)	(0.0321)	(0.0276)
N	262	405	441
adj. R^2	0.002	0.003	0.011

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

TABLE 7: SECOND STAGE RESULTS: FALLING GAS PRICES

	Pre-boom	Boom	Bust
Distance to airport (tract-average)	0.0031	0.0066	0.0092***
	(0.0038)	(0.0049)	(0.0030)
Constant	-0.0919***	-0.1543***	-0.0959***
	(0.0311)	(0.0412)	(0.0310)
N	262	405	441
adj. R^2	-0.001	0.003	0.015

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

In both tables, the signs of all the coefficients are consistent with their counterparts in the regressions across the whole sample period, and they are roughly of the same order of magnitude as the full-period results. The results do not consistently show conventional levels of precision; this only occurs, surprisingly enough, in the bust period. The observed increase in sensitivity goes against our original suspicion that such sensitivity would decrease in the later periods. It may simply be due to the greater number of tract-level observations in the later periods (as a result of the expansion of the developed area in Clark County).

Alternative measures of gasoline prices

Despite the literature cited above that suggests that the current price of gasoline is an acceptable measure of the long run expectations of gas prices, we explore differing measures of such expectations. We use (a) measures of adaptive expectations, based on moving averages of 3, 6, 12 and 36 month lags; and (b) forward-looking measures, based on 3, 6, and 12 month leads.

The results appear in Table 8, which presents only the slope coefficient and the goodness of fit from each of the estimates of Equations 8 and 9.

TABLE 8: VARYING MEASURES OF GAS PRICE EXPECTATIONS

Coefficient on miles to airport	R^2	lag # months	Rising or falling prices
0.0102	0.025	3	Fall
0.0072	0.012	6	Fall
0.003	0.0028	12	Fall
0.0097	0.0223	36	Fall
-0.01	0.039	3	Rise
-0.0145	0.087	6	Rise
-0.0105	0.040	12	Rise
0.00305	0.0018	36	Rise
		lead # months	
0.0101	0.027	3	Fall
0.0087	0.027	6	Fall
0.0058	0.010	12	Fall
-0.005	0.014	3	Rise
-0.0086	0.039	6	Rise
-0.0057	0.019	12	Rise

Three conclusions arise from this table. First, the sign of the coefficient is as predicted in the theory model, and our baseline results, with one exception, and the magnitude is roughly the same as in the baseline, with a few exceptions. Second, there is little pattern to the changes in that magnitude or in the goodness of fit measures. That is, more information in the form of a greater number of lags or leads, does not lead to better fit. Third, that fit is only rarely better than that of the baseline model, particularly the use of a modest lags during times of rising gas prices. Thus, we find that our approach in using contemporaneous gas prices in the base model appears to be an acceptable measure of expectations.

7. CONCLUSION

In this paper, we revisit the question of home price response to changes in gasoline prices, a topic that has taken on a renewed importance in light of proposals to implement carbon taxes. We construct a new version of the traditional Alonso-Muth-Mills monocentric city model that makes new predictions with respect to that response, that take into account the asymmetric response of the housing market to changes in housing demand. We use data on a large number of transactions in Las Vegas and find the model confirmed in all respects. The results are robust to alternative specifications of gasoline price expectations. In an analysis of sub-periods of the data, we find some differences in the estimated coefficients over time, but these do not seem to be related to changes in commuter behavior or gas mileage.

Our back of the envelope calculation suggests that consumers over-capitalize changes in gas prices. An illustrative carbon tax that would raise gasoline prices by 10% would lead to an estimated range of changes in home values of -$10,000 to +10,000, a range in excess of the roughly $3,500 span in the present value of extra travel costs.

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APPENDIX

Data discussion

This section discusses the construction of the dataset used in the regressions. This study combines data from four separate data sources. For transaction information, the study uses data from home sales in Clark County, Nevada, from January 1980 to December 2010, obtained from the Clark County Assessor's Office (CCAO).[25] We use the x and y coordinates to map every property to the most recent available census tract boundaries. Thus, we ensure that the tract identifier for each property is constant for all the sales of the property in our data, even if the official census tract of the property has changed over time. The geographic distribution by census tract of the observations in the dataset appears in Figures A.1 and A.2.

[25] Further documentation on the data set is available at the Clark County Assessor's website. Information about the residential records appears at: http://www.clarkcountynv.gov/Depts/assessor/Pages/ResidentialRecordLayoutInformation.aspx. Information about the specific sales codes appears at: http://www.clarkcountynv.gov/Depts/assessor/Documents/Sales%20Codes.pdf.

FIGURE A.1. GEOGRAPHIC DISTRIBUTION OF PROPERTY TRANSACTIONS:
CLARK COUNTY, NUMBER AND LOCATION OF REPEAT PROPERTY SALES

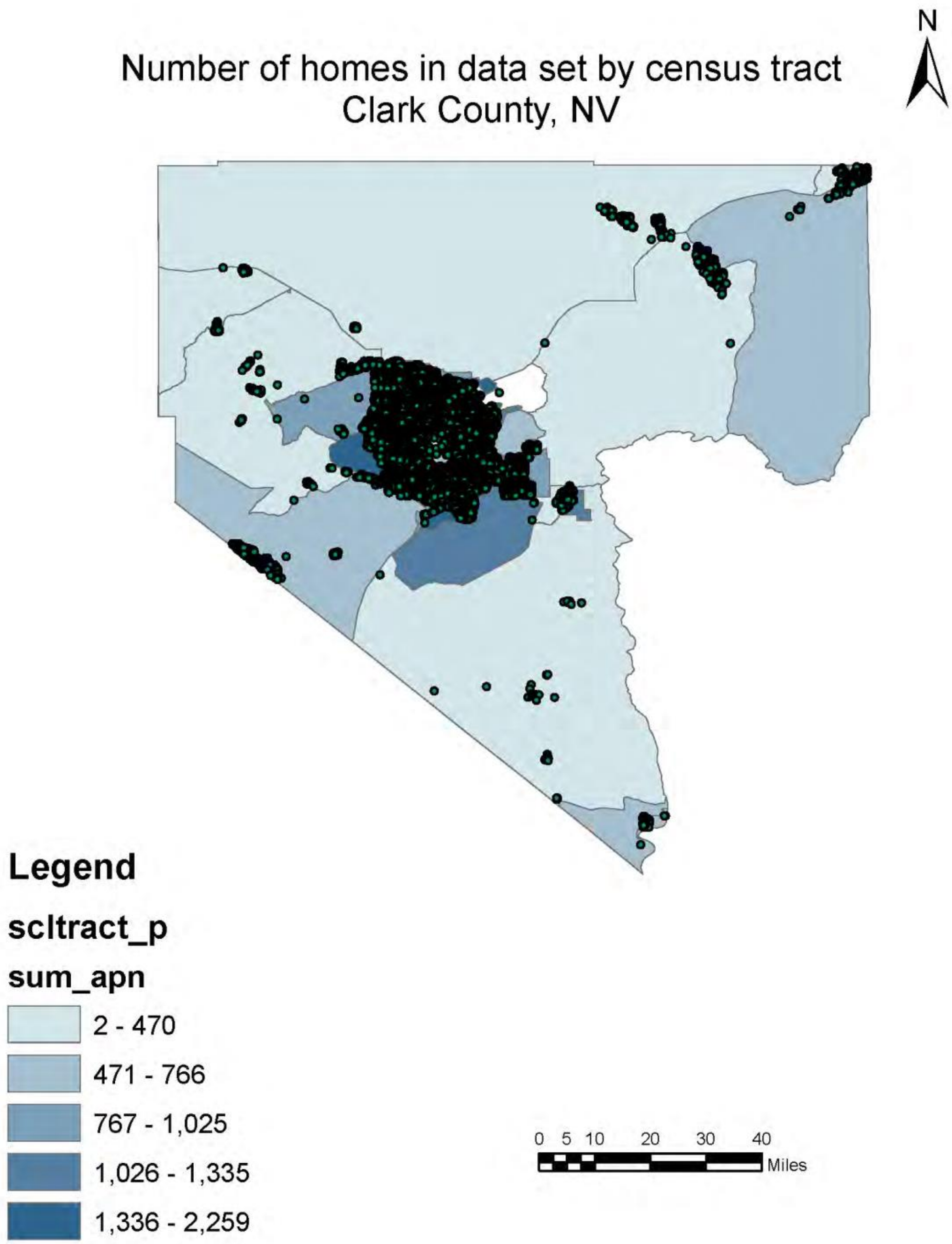
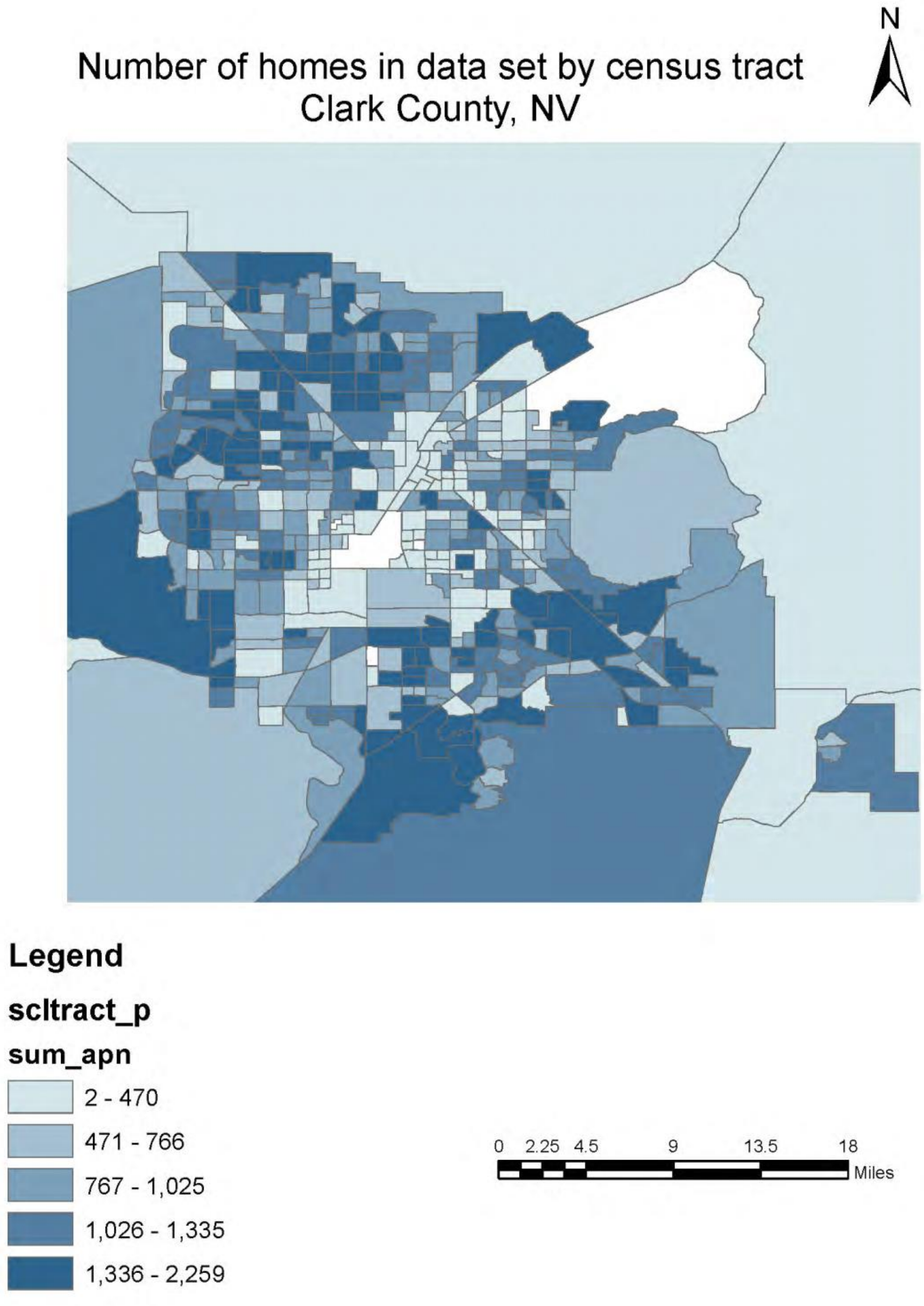


FIGURE A.2: GEOGRAPHIC DISTRIBUTION OF HOMES IN DATA SET: LAS VEGAS METROPOLITAN AREA



We exclude observations that are unlikely to represent ordinary arms' length transactions or vacant land. To do this, we use the CCAO codes that indicate the type of sale for improved properties. Sale types included in the dataset are listed in Table A.1.

TABLE A.1 – CCAO SALES CODES INCLUDED IN RAW DATA
(985,837 OBSERVATIONS)

Sale Code	Description
R	Regular sale
Y	Resale in the market range
Z	First time sale in the market range
T	Contract sale, includes land and new construction
N	First time sale or resale above or below market, includes sacrifice, second mortgage, introduction sales
X	Foreclosure resale, tax sale, estate sale in the market range
W	Foreclosure resale, tax sale, estate sale above or below market
M	Sales price is the total purchase price for many or numerous parcels being transferred on the same deed or one purchase price was paid for several parcels conveyed on several deeds.

We constructed a separate foreclosure indicator using the CCAO Foreclosure code. We also create indicator variables for the years in which the transaction occurs and convert all price variables to real 2010 dollars using the Consumer Price Index (All Urban Consumers: U.S. city average deflator) from the U.S. Bureau of Labor Statistics.[26]

We dropped observations with values that suggest the property is likely to be extremely unusual, a non-arms'-length transaction, or coded in error. Thus we drop properties with a real price of less than $40,000 or less than one full bath.

Given the specialized market for such properties, we exclude homes on lots larger than five acres and greater than 8,000 square feet of living space. We also drop sales of homes with

[26] http://www.bls.gov/cpi/cpid10av.pdf. BLS Table 1A.

prices over \$5 million (\$2010) or with more than six full baths. We also drop properties with an unusually high price per square foot of over \$300 per square foot. The deleted observations collectively represent about 7.3 percent of the raw data set.

Using the year and month of the transaction, we merge the property data with data for the national average gasoline price, the Nevada state unemployment rate, and the number of visitor to the Las Vegas area. We created logged values for continuous variables, including the sales price of the property, gasoline prices, living area, lot size, and visitors. To compute the age of the home in years, we subtract the year of the transaction from the variable in the data that indicates the year the home was built. In some cases the property is sold before the home is built, for example through an advance property sale. In that case we set the age to zero.