The Distribution of Urban Land Values: Evidence from Market Transactions*

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Abstract

We analyze land values from market transactions across the United States. Across space, land values are distributed widely and almost log-normally. The strongest predictor of value per acre is lot size, followed by location, and then time. Urban and agricultural land markets appear unified after accounting for fixed conversion costs. Monocentric-city theory predicts how central land values depend on metro population and agricultural land values. Estimates using distance from center within metros are consistent with estimates using population across metros. They suggest land receives 7 percent of income and the cost elasticity of urban population is 4 percent of income.

JEL Codes: D24, R1, R31, R52

1 Introduction

Land values are possibly the most fundamental price in urban economics. The price of unimproved land measures the value of property rights over space itself. Much of the theoretical literature in urban economics seeks to explain the determinants of land prices, including the value of local amenities, access to employment, and land-use regulations affecting land's residential or commercial viability. Land values are central to understanding property prices and assessments, and the economic impact of land-use policies and taxes levied on property. In some contexts, land values may also be used to determine the costs of urban agglomeration, the optimal level of public good provision, and even the optimal size of a city.

Despite the importance of land values, data on urban land values have remained rare and are typically collected for a single area at a time. This paper provides a detailed decription of land values using a novel data-set of land values taken directly from market transactions. It is the first of its kind to use market transactions to compare land values cross-sectionally across a wide range of U.S. cities. The paper describes the wide variation in land values within and across metropolitan areas, considering how the value of a particular lot depends on its acreage, quarter of purchase, intended use, local regulations, metro area, and proximity to the center of that metro area. The paper also examines how average land values relate to population and area across counties and metro areas, as well as the relationship between land values, local amenities, and their variation. Finally, the paper considers whether urban values are related to agricultural land values in nearby areas.

The analysis illustrates several striking features of land values. First, the statistical distribution of land values per acre appears to be roughly log-normal, both nationally and within metropolitan areas. Second, the standard deviation of log prices within metro areas is greater than one and roughly similar across different cities. Therefore, differences between cities in the log price of land are roughly constant across quantiles of the within-city price distribution.

Lot size is the strongest predictor of price per acre at the parcel level, explaining over 40 percent of the variation in a simple regression. Controlling for metropolitan area increases the explanatory power of the regression to 57 percent. Additional controls such as quarter of sale, travel time from city center, and proposed use give modest improvements in explanatory power. Even over the boom and bust period of our sample, space is a much more important determinant of land values than time. When comparing various measures of distance from the city center, distance measured in driving time appears to predominate versus straight-line distance and driving distance.

At the county level, we find that land values for urban uses at the 10th percentile are strongly and positively related to values for agricultural uses. Non-linearity in the relationship is likely to reflect costs of converting agricultural land to urban use.

The paper is organized as follows. Section 2 reviews some of the literature on urban land values. Section 3 describes the dataset and presents a simple variance decomposition of the primary determinants of land values. Section 4 describes how land values vary within metropolitan areas, focusing on lot size, time of sale, and distance from city center. Section 5 examines how land values vary across metropolitan areas, with a focus on metropolitan attributes such as commuting time, climate, and geography. The section also examines whether urban and agricultural land values co-vary in the manner predicted by urban theory. Section 6 concludes.

2 Literature Review

This paper stands out from the rest of the literature for being one of the only cross-sectional analyses of land values across the United States using transaction data. Cross-sectional studies on land values have typically focused on a single city and most have not used data from market transactions.

Difficulties in measuring land values have led researchers, as well as assessors, to employ a variety of approaches to land value measurement. Davis and Heathcote (2007) and Davis and Palumbo (2008) construct land price indices for a large number of metro areas across the United States using a residual approach. In this approach, land values are inferred from observed housing prices by subtracting imputed structure values, and attributing the residual to land. Case (2007) uses a similar approach to assess the combined value of land in residential and non-residential uses. He notes that the residual method can easily produce negative values for land underneath commercial properties. On some properties, the value assigned to land can also be very high, which may reflect physical or regulatory burdens involved with building on acquired land, rather than the costs of acquistion itself.

Measuring land values using market transactions avoids many of the difficulties inherent in the residual approach, but in practice it faces the difficult problem of selection bias. If market transactions were randomly distributed across space, they could be used to produce an ideal index. Yet instead, we only observe land that has been put up for sale and bought.

Traditional methods of correcting for sample selection bias have not been used, as no one has yet created a data set with unsold lots. Previous studies of selection bias find mixed results. Using data from late 19th and early 20th century Chicago, McMillen et al. (1992) argue that land converted from agricultural to urban use tends to be below average quality for agricultural purposes, but above average quality for urban use. Colwell and Munneke (1997) find no evidence of selection bias using more recent data from Cook County, Illinois, while Munneke and Slade (2000, 2001) also find little evidence of selection bias in the Phoenix office market. Finally, Fisher et al. (2007) find no evidence of selection bias in their study of commercial real estate properties. Although in theory the selection bias problem appears to be rather difficult, the evidence available suggests that it may be less problematic in practice.

A small number of papers have used the data we have here to examine land values in New York (Haughwout Orr, Bedall 2008) and the San Francisco Bay Area (Quigley, Kok, Monkokken 2010). They regress land prices on various characteristics, and find, among other results that land prices decline in lot size, distance from the city center. Nichols et al. (2013) use the data to construct time series for commercial and residential land prices using market transactions across 23 metropolitan areas. However, the indices in their paper are not comparable cross-sectionally. This paper complements that work by considering a broader group of metropolitan areas, although over a shorter time period, and focusing on research questions related more to variation in land values over space rather than time. Sirmans and Slade (2011) construct a time series index of land prices using observed market transactions, but do not examine variation across or within metropolitan areas. Combes, Duranton, and Gobillon (2012) use land transaction from France to estimate the costs of urban agglomeration in the context of a monocentric city model.

3 Data Description

3.1 Source of Land Data

We collect data on land transactions recorded in the CoStar COMPS database.[1] The database includes transaction details for all types of commercial real estate, including what CoStar terms "land." Here, we take every land sale in the COMPS database provided by CoStar University, which is provided for free to academic researchers. The use of data

[1]This is the same source data as in Albouy and Ehrlich (2012).

from CoStar University, rather than through CoStar's paid service, limits the data we are able to collect for each parcel.[2] Appendix figure A1 illustrates a typical brochure, which lists information concerning address, sale date, sale price, lot size, and proposed use.[3]

We restrict the sample to transactions that occurred between 2005 and 2010 in a Metropolitan Statistical Area (MSA).[4] Dropping sales prior to 2005 excludes over 80,000 observations, substantially reducing the sample size. We study the period since 2005 because most of the MSAs in the COMPs database are missing or have extremely sparse coverage until 2005. Thus, we study a large group of MSAs over a relatively short timespan, rather than a smaller group of MSAs over a longer timespan, as in Nicols et al. (2013), consistent with our desire to compare land values within and across a wide range of metropolitan areas. The dataset further excludes all transactions CoStar has marked as non-arms length or without complete information for lot size, sales price, county, and date, or that appear to feature a structure. It also excludes observations we could not geocode successfully, and those that were recorded to have zero distance or more than 90 miles or 100 minutes of driving time away from the center of their respective MSA,[5] leaving us with 68,757 observed land sales. Finally, in order to improve the comparability of land sales across MSAs, we exclude sales with a lot size less than an eighth of an acre or more than 320 acres (one half a square mile), for a final sample of 57,157 land sales.

3.2 Non-Price Characteristics of the Land Parcels

Unweighted non-price statistics of the market transactions are shown in Table 1. The average lot is 16 acres, but the lot size distribution is highly right-skewed, with a median of only 3.4 acres. The average property is 23 miles in driving distance, or half an hour in driving time, from the city center. The average straight-line distance is only 15 miles, roughly the distance from central Los Angeles to Santa Monica or from central Washington DC to Fairfax City, Virginia. While the plots appear to be somewhat peripheral, there is still substantial coverage in the central city. Appendix figure A2 provides maps of the sales

[2]We collect the data from summary brochures produced by the COMPs database. The brochures are produced in pdf format, which we read into a format suitable for analysis using commercially available optimal character recognition software.

[3]Unfortunately, the brochures do not contain data regarding greenfield versus brownfield status or grading and paving status.

[4]We use the June 30, 1999 definitions provided by the Office of Management and Budget. The data are organized by Primary Metropolitan Statistical Areas (PMSAs) within larger Consolidated Metropolitan Statistical Areas (CMSAs).

[5]Approximately 4,000 otherwise valid observations are excluded by this requirement.

distribution for selected cities, which show a mix of central and peripheral lots.

There is a strong cyclical pattern in the timing of land sales in the sample. There are roughly twice as many sales per year during the housing-boom years of 2005 to 2007 than during the housing slump period of 2008 to 2010. We present evidence regarding the extent to which this pattern might raise selection concerns later in the paper. The observations cover metro areas across a range of sizes, although the coverage appears to be slightly more representative of cities with over 1 million inhabitants.

The dataset includes a field for the property's 'intended use', which while far from exhaustive or complete, contains some potentially useful indicators. 11 percent of parcels are intended for single family development, 8 percent each for retail and industrial, and 6.5 percent each for multifamily and for office, with smaller percentages for restaurants, hotels, and parking. These categoreis are not mutually exclusive, and 16 percent of parcels have no stated intended use.

3.3 The Statistical Distribution of Land Prices

This section considers the statistical distribution of land values, keeping in mind that there may be different ways of weighting the sample in order to produce a representative sample. While various studies have considered the spatial distribution of urban land values, to our knowledge none has considered the statistical distribution of land values explicitly.

ideally, a random sample of all plots of urban land would be used to obtain a consistent estimate of the distribution. With randomly selected lots, weighting parcels by their size would allow an approximation of all urban land. However, there are reasons to believe that the plots in the dataset are not randomly selected, which may provide an argument for considering alternative weighting schemes. More generally, different weighting schemes may help to answer different questions.

Table 2 contains descriptive statistics for the data sample under different weighting schemes, corresponding to different concepts of a representative sample. The first column displays unweighted statistics. The arithmetic mean price per acre is $468,000, versus a geometric average of $181,000, consistent with the presence of right-skewness in the distribution. However, the skewness of the distribution of log prices is negative, with some excess kurtosis. Column 2 displays the summary statistics weighted by lot size, so the results may be conceived as representing the typical acre of land within the sample. The most notable effect is to reduce the average value per acre substantially, to $98,000 for the arithmetic mean and $26,000 for the geometric mean. This reduction stems from the so-called 'plattage effect', discussed in detail in section 4. This pattern may stem from larger plots being of lower quality than smaller plots.[6] Even absent such selection issues, the strong spatial correlation of land prices suggests that weighting by land area will provide less representative statistics than an unweighted average.

An alternative weighting scheme is to weight each plot according to the area of a pre-defined geography. Column 3 displays statistics weighted by county area, so that sales in larger counties will have more weight relative to sales in smaller counties. Therefore, these statistics are more representative of the typical acre of land in an urban area. However, there may still be concerns that the land values are somewhat peripheral within each county.

Next we consider weights that depend on economic values. Column 4 displays statistics weighted by parcel value, giving more weight to larger plots, or plots with higher value per acre. These statistics may be considered to represent the typical dollar of land value in the sample. The arithmetic mean property value rises to $2.5 million, while the geometric average rises to $410,000. Notably, the skewness and excess kurtosis of the distribution in logs both fall in magnitude relative to the unweighted case.

Finally, column 5 shows summary statistics weighted by population density of the Census PUMA where the land sale is located. This measure may therefore be conceived as representing the distribution of land values where people currently live. It is representative of residential urban land and perhaps most useful when considering land as input into housing production. The arithmetic mean price per acre is $1.3 million in this scheme, with a geometric mean of $333,000. The skewness of the log distribution is near zero, although there is non-trivial excess kurtosis.

Regardless of which weighting scheme is used, it is striking that the skewness is generally close to one and the kurtosis is to three. While formal tests of normality will strongly reject that log land values are normally distributed, the lognormal distribution may still be useful as a first approximation. Furthermore, the roughly symmetrical distribution of log values implies that the distribution of level values is largely convex, particularly at the high end, as most urban models would suggest.

Figure 1 displays the cumulative distribution of land values both nationally and for four metropolitan areas, Detroit, Atlanta, San Francisco, and New York, for the period 2006 to 2008. The x-axis of the figure is in logs, so the relatively smooth, 's'-shaped distributions

[6] It is worth noting that Combes et al. (2012) find a similar pattern in a dataset of French land values that is less likely to suffer from selection bis than the CoStar COMPs dataset.

suggest lognormally distributed land values. Detroit and Atlanta have lower than national average land values at nearly every quantile of the distribution. The two cities similar low end land values, with 25 percent of lots in each city valued at less than \$100,000 per acre. Atlanta's upper end is considerably higher, with a share of land valued at more than \$400,000 per acre nearly 10 percentage points higher. As expected, San Francisco and New York have much higher land values than the national average at almost all quantiles of the distribution. Visually, the figure suggests there may be some evidence of "fanning out" in land values across cities, in the sense that the distributions are not equally far apart at each quantile.

To examine this possibility in more detail, figure 2 plots the mean, median, 10th percentile, and 90th percentiles of land values per acre by MSAs against the geometric mean. We include only data from 2006 to 2008 from cities with at least 50 land sales in that time. The slopes of the lines of best fit are surprisingly close to one another. Table 3 shows that one cannot reject the hypothesis that the slopes of the median, 10th, and 90th percentiles are equal to one. The slope of the line for the arithmetic average is statistically larger than one, but it is not statistically distinguishable from the slopes of the individual quantiles. We interpret these results as consistent with the hypothesis that land values are distributed lognormally within metropolitan areas.

4 Intra-Metropolitan Variation in Urban Land Values

In this section, we consider the within-metropolitan area determinants of land values, focusing on the influence of lot size, distance from the city center, time of sale, proposed property use, and regulatory environment. We examine alternative specifications for lot size and find that the elasticity of land values with respect to lot size is not constant. We also examine alternative specifications for distance from downtown, and find that driving time appears to predominate versus other distance measures in determining land values.

4.1 Lot Size and Distance

Two of the major determinants of land values are plot size and distance from city center. The relationship with plot size is very strong empirically, although it does not have a strong theoretical basis. The relationship with distance has always had a strong basis theoretically, although the empirical basis has not always been as strong.

The finding that lot size plays a key role in determining land values is quite robust to the inclusion of the other controls we consider. This finding is consistent with the so-called "plattage effect" that is well-documented in the literature, for instance by Colwell and Sirmans (1980, 1993, and references therein). They attribute the tendency for parcel value to increase less than proportionately with parcel size to holdout effects and the costs of subdividing and developing land. Nichols et al. (2013), who find similar plattage effects to those we estimate, argue that the effects are likely to stem from the existence of an optimal scale for buildings of a certain type, which reduces the value of land beyond the necessary scale. Another possibility is unobserved heterogeneity in parcel quality: if smaller parcels tend to be of higher quality, the observed plattage effect could arise from ommitted variable bias.

To provide a basic picture of the data, Figure 3 illustrates the pattern of land values across lot sizes and distances from downtown. The solid line in Figure 3A shows predicted value per acre as a function of lot size estimated over the entire sample, while the blue circles show corresponding cell means. Here we see the elasticity of prices with respect to lot size is not quite constant, as previous research has indicated. The downward slope is not quite constant and appears to grow weaker with lot sizes greater than four acres. This suggests that the plattage effect is weaker for very large lot sizes, although this could be due to omitted variables rather than plot size itself. The left panel also shows the estimated functions for the sub-sample that is closer than average to the city center, as the green dashed line, and the sub-sample that is farther than average from downtown, as the dotted yellow line. The nearness of these lines to the full sample line illustrates how important lot size is relative to distance in determining prices. It also suggests that plattage effects are weaker for large lots closer to city centers than away from them.

The right panel, Figure 3B, shows the estimated distance function, measured as the Google Maps-reported driving time from downtown. The solid line and blue circles show the estimated function and cell means, respectively, for the whole sample. The estimated function is steep at first, flattens out slightly after about 20 minutes from downtown, and flattens out more after 40 minutes. The dotted yellow and dashed green lines show the estimated distance functions for the sub-samples with larger and smaller than average lot sizes. These lines suggest that the distant gradient may be exaggerated by the plattage effect, as larger lots tend to be further away. The 'small' and 'large' curves are similarly shaped, and suggest that land at the city center is worth four times than land an hour away. The gradient also appears to be slightly convex, weakening with distance, as standard monocentric city models would suggest.

Table 3 shows regression results confirming the visual evidence in figure 3. Column 1 shows results from a regression of land values on a set of MSA fixed effects; the R^2 of the regression is 0.15. Column 2 shows results from the same regression, adding single variables for log lot size and linear distance from the city center. The elasticity of price per acre with respect to lot size is estimated to be -0.6, implying that a 10 percent increase in plot size is associated with only a 4 percent increase in the price of the plot. This estimate is consistent with other estimates in the literature.

The semi-elasticity of price per acre with respect to hours' drive to downtown, β_d, is -1.5, which corresponds to the 75 percent reduction in value from the city center to the urban fringe seen in Figure 3B. Standard urban theories imply that the value of this coefficient should equal the ratio of the cost of an hour of commuting to the share of income derived from land (e.g., Combes et al. 2012).

In this model, the indirect utility function is linear in income, w, metropolitan quality of life, Q, a function, $\tilde{v}(d)$, of distance, d, from the central business district (CBD), and is decreasing in an index of price of housing $p(d)$, with power η. $V(w,p;Q,d) = wQ\tilde{v}(d)/[p(d)]^{\eta}$. In logarithms, that is

$$\ln V = \ln w + \ln Q + \ln \tilde{v}(d) - \eta \ln p(d) \tag{1}$$

η is the household expenditure share on residential housing. Housing is produced with a constant-returns-to-scale technology. Its cost is determined by the price of land $r(d)$, the price of labor w, and housing productivity A_Y, according to the unit cost function $c_Y(r,w;A_Y) = r^{\phi}i^{1-\phi}/A_Y$. We assume markets are competitive, and firms make zero profits, so that the price of housing in logarithms is

$$\ln p(d) = \phi \ln r(d) + (1-\phi)\ln w - \ln A_Y \tag{2}$$

Note the parameter ϕ is the cost share of land in housing. Using these formulae, it is straightforward to show that the land rent gradient is

$$\ln r(d) = \ln r(0) - \frac{1}{\phi\eta}[\ln \tilde{v}(0) - \ln \tilde{v}(d)] \tag{3}$$

The term $[\ln \tilde{v}(0) - \ln \tilde{v}(d)]$ captures how much the quality of location declines with distance to the CBD. Meanwhile, the term $\phi\eta$ captures the share of income that accrues to residential land.

If commuting is solely responsible for changes in location quality within a metro area, and d is measured by hours, then, then the formula can be converted into the regression function

$$\ln r(d) = \ln r(0) - \frac{1}{\phi\eta}\frac{\tilde{v}'(\bar{d})}{\tilde{v}(\bar{d})}d \tag{4}$$

Here $\tilde{v}'(\bar{d})/\tilde{v}(\bar{d})$ is equal to the marginal cost from an hour of commuting, as expressed as a fraction of total income. We approximate this with the average cost. About 10 percent of the working day (25 minutes each way) and 5 percent of labor income is spent commuting according to the American Community Survey and Survey of Income and Program Participation. Netting out federal taxes from the time cost and accounting for non-labor income suggests that commuting costs are equal to roughly 9 percent of total income. If the typical two-way commute is indeed 50 minutes and the monetary cost of commuting is proportional to commute time, then an hour of commuting is worth 10.8 percent of total income. Then our coefficient estimate implies that the share of income accruing to land should be equal to 0.108/1.49, or 7.3 percent. While this is a rough calculation based off of a precariously simplified model, the resulting income share to land is very close to the one produced by Case (2007).

Column 3 adds dummy variables for several common categories of controlled use, namely, industrial, retail, single family, office, and 'hold for development', in addition to a dummy for no proposed use. These categories do not partition the data, as a parcel can have multiple proposed uses or no proposed use, and we do not include several proposed uses, such as parking or medical, that are rare in the data. Controlling for proposed use does not meaningfully change the coefficients on lot size or distance from downtown, and increases the explanatory power of the regression only marginally. Therefore, column 3 may be interpreted as consistent with the hypothesis of a unified market for vacant land. Column 4 shows the results of a regression that includes quadratic terms in lot size and distance from downtown, as well as an interaction between the two. The addition of the quadratic terms reduces the magnitude of the coefficient on lot size slightly, while the squared terms yields a surprisingly concave shape. The estimates for the distance from downtown coefficients show that the distance effect is initially very negative, but that it falls off with distance. The interaction term is insignificant.

4.2 Intended Use and Land-Use Regulations

In table 5, we examine the roles of property type, intended use, and the regulatory environment in determining land values. The table displays two columns, in both of which we have controlled for cubic polynomials in lot size and driving distance from downtown, interactions between the two up to a quadratic term, and MSA fixed effects. In column 1, we also include a set of dummies for common intended uses in the sample: industrial, retail, single family development, office, and 'hold for development'. Additionally, we include a dummy for no proposed use, as well as the Wharton Residential Land Use Regulatory Index of Gyourko et al. (2008) for the county where the parcel is located. As noted in section 3, a property can have more than one intended use, and the categories considered here are not exhaustive of all intended uses in the sample.

Having no intended use lowers a parcel's predicted value per acre by 21 log points, while an industrial intended use lowers the predicted value by 41 log points. An intended use of single family development is roughly neutral as a predictor of price, while intended uses of office and hold for development predict roughly 5 log points higher prices. An intended use of retail predicts a price 24 log points higher, the strongest positive association of the considered intended uses. A one standard deviation increase in the Wharton Index, a measure of regulatory stringency related to local land use, predicts a nearly 7 log point decrease in price per acre.

In column 2, we examine whether the relationship between price and intended use depends on the regulatory environment by interacting the intended use dummies with the Wharton Index. Including the interaction terms does not substantially change the coefficients on the level terms in the regression. Most of the interaction terms are not statistically significant, but the interaction between an intended use of single family and the Wharton Index is estimated to be positive 5%, implying that an increase in the Wharton Index is associated with slightly higher prices for properties intended for single family development. The interaction term on an intended use of hold for development is negative 9%, implying that a more stringent regulatory environment is associated with lower prices for such properties. This interaction may reflect greater costs of navigating the zoning process for properties that are not yet developed.

4.3 Overall Co-variation of Land Values with Space, Time, and other Observables

Before examining the determinants of land values within and across metropolitan areas in detail, we present a simple variance decomposition of log price per acre. The results are displayed in table 6. In the first column, we regress prices on a cubic polynomial in lot size and a set of intended use dummies. The adjusted R^2 of the regression is 0.57, implying that these variables alone predict 57% of the variation in log prices in our sample. In column 2 we add a cubic polynomial in driving distance from downtown and a set of MSA fixed effects. Controlling for space in this manner increases the adjusted R^2 of the regression noticeably to 0.73. In column 3, we control for time rather than space, by adding a set of quarter of sale dummies to the controls in column 1. The adjusted R^2, 0.60, is only modestly higher than in column 1, and substantially lower than in column 2. We take this as evidence that space is more important than time in predicting urban land values. In column 4, we include both the space and time controls from columns 2 and 3. The explanatory power of the regression is slightly higher than in column 2, with an adjusted R^2 of 0.743. Finally, in column 5, we examine whether a flexibly estimated model with several interactions can improve substantially on the predictive power of the model in column 4. Accordingly, we add controls for MSA-lot size interactions, MSA-driving time interactions, quarter of sale-lot size interactions, and quarter of sale-driving time interactions. Despite the flexibility of this model in pedicting land values, the predictive power of this specification is only modestly higher than in column 4, with an adjusted R^2 of 0.76. Therefore, it appears that a relatively small number of variables can predict most of the variation in land values in our sample. The relatively parsimonious model of column 4 accounts for nearly three-quarters of this variation for instance. Furthermore, lot size and spatial location have a stronger association with land values than does time of sale.

These results are quite interesting because a number of studies have documented substantial time series variation in United States land values. Davis and Palumbo (2007) and Davis and Heathcote (2007) document a large increase in the price of residential land in the United States in the years prior to 2005 using residual methods described in the introduction. Using the same source data as in this paper, Nichols et al. (2013) document that land transaction prices peaked in 2006-2007 in the cities that they study, before falling an estimated 50% from their peak by mid-2011. In figure 5, we document a similar decline in our dataset, which spans the period 2005 through 2010 and considers a larger sample of MSAs.

The figure displays the fitted time trend for land values per acre for the second quarter of 2005 through the fourth quarter of 2010. The time trend for the entire sample, displayed as the solid blue line both in panels A and B, shows that the land values peaked in the second quarter of 2006 at a geometric average value of $326,146, and fell to a low of $161,168 in the fourth quarter of 2009. One natural question is whether this trend complicates inference using this sample. We interpret figure 5 as indicating that inference is unlikely to be meaningfully complicated by the time trend in land values over the sample period. Panel A shows the fitted time trend for larger than average parcels, as the green dashed line, and smaller than average parcels, as the dotted red line. Panel A suggests both that the time trends for small and large lots were quite similar over the sample period, and that the time series variation in that period was small relative to the variation associated with different lot sizes. Similarly, panel B displays the fitted time trend for parcels closer (red dotted line) and farther (dashed green line) than average to downtown. Again, the time trends for the two types of parcels are broadly parallel. Visually, the log price variation between close and far parcels is of roughly the same magnitude as the variation over time. These results are consistent with the decomposition of variance in table 6, in which including quarter of sale dummies increases the explanatory power of the regression only modestly. Overall, we interpret the evidence as indicating that time variation in land values over the sample period is unlikely to pose problems for the other results in the paper.

5 Inter-Metropolitan Variation in Urban Land Values

We now examine variation in land values across metropolitan areas. Two topics of particular interest are the degree of unification between the urban and agricultural land markets, and the role of metropolitan attributes in determining land values.

5.1 The Urban Fringe and Agricultural Land

Standard urban theory suggests that in the presence of a unified land market, the value of land on the urban fringe, say $\underline{d}$, should equal the land's value in agricultural use. Since we cannot identify exactly where the urban fringe is located, we instead take land values at the 10th percentile for each county as a measure of fringe land values $r(\underline{d})$. Figure 4 plots these 10th-percentile land values on the y-axis against average agricultural land values on the x-axis.[7] The agricultural land values are from the USDA Economic Research Service for the year 2007. Table 7 presents regression results for the relationship between urban and agricultural land values. Column 1 reports that the elasticity of the 10th percentile of urban land values with respect to agricultural values is 0.66, significantly below one, and the regression constant is significantly above one. Assuming the 10th percentile of urban land values can be taken to represent the urban fringe, these values suggest a deviation from a perfectly unified land market. Simply put, the variation in urban land values is greater than the variation in agricultural values across counties, as visual inspection of figure 4 illustrates.

Deviations between urban and agricultural land values may occur if there are considerable costs to converting agricultural land to urban land. Agricultural land may need to be cleared and surveyed before being used for urban purposes. These costs are likely to vary little across cities, and are likely to be large relative to agricultural land values where the latter are small. To examine whether conversion costs drive a wedge between agricultural and urban land values, we estimate the non-linear equation:

$$\ln(10^{th}\text{perc.urb-value}_i) = \beta_a \ln(c + \text{ag-value}_i) + \epsilon_i$$

where c represents the cost of converting agricultural land to urban use. The line of best fit from the non-linear regression is displayed as the dashed green line in figure 4. The results in column 2 of Table 7 imply an estimate of c of \$3,972 per acre. This number is roughly equal to the median agricultural land value of \$3,979. Thus, for the typical city, an acre of land at the urban fringe (i.e. the 10th percentile) appears to derive roughly half of its value from improvements. This result is surprisingly consistent with Mills' (1998) "guess" that land at the urban fringe derives roughly 50 percent of its value from improvements. The slope coefficient β in the non-linear regression increases to 1.10, which is statistically larger than but much closer to one.

Note that this equation does not have a constant term. A constant might be justified theoretically if there is a conversion cost proportional to the agricultural land value, which would produce a positive constant, or if there is a conversion cost to agriculture, which would produce a negative constant. Column 3 of table 7 displays the non-linear regression with a constant term. The constant is estimated to be negative but statistically indistin-

[7] The figure and lines of best fit omit counties with the lowest and highest one percent of agricultural land values.

guishable from zero, with a level value of only -$35. The standard errors on the other coefficients also increase substantially with the addition of the constant term. Overall, we believe the specification in column 2, which does not allow for conversion costs to vary with agricultural land values, is most accurate.

We conclude that although there is some evidence of frictions that impede a perfectly unified market for land, the land market appears to be much more unified across uses after accounting for conversion costs. Furthermore, it would appear that these conversion costs account for a substantial fraction of observed land values at the urban fringe.

5.2 Central Land Values, Population, Size, and Amenities

This section considers the value of land at the urban center. According to the standard monocentric city model, the value of this land should be proportional to the per-capita costs of urbanization, typically measured through commuting. The elasticity of land values with respect to metropolitan population can then be taken as a measure of the diseconomies of scale experienced in cities. Recent work by Combes et al. (2012) has tried to estimate this elasticity using a rather different set of French land values; we do the same using our estimates for land transactions.

We follow their theory by allowing the elasticity of commuting costs with respect to total income $d\tilde{v}'(d)/\tilde{v}(d) \approx \tau$ to be constant. However, in our regressions we allow for observable agricultural land prices $r(\underline{d})$, so that our method is much more direct. In this case, land values at the city center are given by

$$\ln r(0) = \text{constant} + \frac{\tau}{\phi\eta} \ln \underline{d} + \ln r(\underline{d}) \tag{5}$$

We do not typically observe a single well-defined radius for a metro area. It is not clear exactly where a city ends, and where agricultural uses being. Nor is it guaranteed to be uniform and different directions. Thus, it is more practical and interesting to use population N as a regressor. Avoiding complications, assume that area of the city is given by $S = \pi\Theta\underline{d}^2$. The parameter Θ measures the angle in radians that land is provided around the CBD. In that case, it is possible to show that the downtown land values are related to the population size N through the following formula

$$\ln r(0) = \text{constant} + \frac{\tau}{2\phi\eta} \ln N + \ln r(\underline{d}) - \ln \Theta \tag{6}$$

If this model is correct, then $\tau/2$ measures the diseconomies of scale that accrue from having a larger city. Furthermore, according the theory the coefficient on log population should be related to that on estimated driving time, β_d. Namely, it should be minus half of that coefficient times the average commute time in hours, or -(-1.4)/2(5/6) = 0.61. In addition, the urban land value should increase proportionally with agricultural values and inversely with the number of radians available.

In addition, we consider the role of natural amenities. Typically, urban economists believe that land values should rise with the value of an urban amenity, for example, living by the coast. However, in a local market, the distribution of amenities should also matter. Because land values arise generally from differences in amenities, places with a greater variance of amenities may have greater land values overall. More concretely, if everyone can have a house on a hill, land values may be lower than if only some people can have a house on a hill. If the supply of hills is limited, then the price paid for the hill may be higher.

In the model above, uniform levels of amenities, seen in Q, are already accounted for in the population level, and thus should not appear in the above equation. Variation in amenities, however, changes the local value $\tilde{v}(d)$. Just as transportation costs raise land values by giving relative advantages in some areas relative to others, so do natural amenities.

We use two methods of estimating land values at the urban core. In the first, we simply take the 90th percentile of log price per acre within the MSA. In the second, we estimate the regression

$$\ln(r_{ijt}) = \alpha_j + \delta_t + \beta_A A_{ijt} + \beta_d d_{ijt} + \beta_X X_{ijt} + \epsilon_{ijt}$$

where r_{ijt} is the price per acre of parcel i in metro area j sold in quarter t, α_j is a set of MSA fixed effects, δ_t is a set of quarter of sale fixed effects, A_{ijt} is a cubic polynomial in log lot size, d_{ijt} is a cubic polynomial in driving time from the city center, X_{ijt} is a set of intended use dummies, and ϵ_{ijt} is a stochastic error. We take the average residual from this regression plus the estimated MSA fixed effect for each MSA as our second index of urban land values at the urban core.

The two indices serve as the dependent variables in the regressions on table 8. The first index requires less of a stand in us determining what the value of central land is. The second index is more appropriate for looking at the impact at variation in amenities, since it is more based on representative land values.

In column 1, we regress the 90th percentile of MSA land values on log MSA population. Land values are increasing in population, with an estimated elasticity of 0.65. In column 2, we also control for log agricultural land values, which determine a city's land area in the standard monocentric city model with endogenous city size. We adjust the USDA's estimated agricultural land values by adding the estimated conversion costs from column 2 of table 7. In turn, city land area helps to predict land values at the urban core. Higher agricultural land values are associated with higher land values at the core, with an elasticity of 0.83. This value is not statistically different from 1 at standard significance levels. Inclusion of agricultural land values reduces the elasticity of core land values with respect to population to 0.50, which is rather close to the value predicted from the distance from CBD regression of 0.61. These regressions lend credence to the possibility that the elasticity of urban costs, $\tau/2$, with respect to population growth are somewhere around 3.7 to 4.5 percent of gross income.

In column 3, we add a measure for the fraction of the MSA's potential land area that cannot be developed because of a coastline or major body of water from Stephen Malpezzi. The semi-elasticity of core land values with respect to the fraction of *un*developable land is a positive 0.85. This is consistent with the prediction that the fraction of developable land has a negative elasticity of one. inclusion of this measure does not qualitatively change the other coefficients.

In column 4 of table 8, we drop the fraction of area lost to coastline and water and add the average slope of land and its standard deviation at the PUMA level from Albouy et al. (2012), and average slope of land within a 50 kilometer radius of the city center. [8] The estimates indicate that variation in this amenity within metro areas is more important in explaining land values as the average level of the amenity across metro areas, as predicted.

In column 5, we add variables for average commute times and their within-MSA standard deviations to see if they account for some of the association between MSA population and land values at the urban core. Ultimately these regressors do little to improve the explanatory power of the regression, and neither is statistically significant. In column 6, we estimate the regression from column 5 without the controls for MSA population. The explanatory power of the regression falls noticeably, but the standard deviation of land slope and the standard deviation of commuting times both predict significantly higher land values. We interpret this evidence as being consistent with the standard monocentric city

[8] The measure is slightly different than that measured by Saiz (2010), which is the fraction of land over water or with a slope greater than 15 percent.

model of land values, in which variation in amenities, not simply their levels, gives rise to land values.

Finally, in columns 7 and 8 we use the land value at the urban core index calculated as we describe above as the dependent variable. Column 7 mimics column 2; the results are broadly similar, although the coefficients both on MSA population and on adjusted agricultural land values are smaller when using the land value index rather than the 90th percentile land values. Column 8 mimics column 4. The results are again qualitatively similar, but the coefficient on the standard deviation of the average slope of land is now positive and statistically significant. Again, we interpret this result as reinforcing the classical insight from Ricardo (1817) that land values ultimately stem from differences in the quality of locations.

6 Conclusion

Despite the many problems that are likely to arise when measuring land values, it appears that the market transactions are consistent with several predictions of neoclassical urban theory. The overall distribution of land values is convex, and may be roughly approximated by a log-normal distribution, with a wide standard deviation that widens slightly in higher value cities. The association of lot size with price per acre is strong and largely consistent with previous studies. Even though many commutes do not occur between suburbs and central cities, Land values still fall with travel time from downtown as the monocentric city would predict. Furthermore, under stricter assumptions, the estimate implies and a share of income for residential land that is entirely plausible at around 7 percent.

We fully believe that variation in land values over time as examined by Oliner et al. (2013) and others is extremely important in understanding the urban as well as macro economy. Yet, even over the housing boom and bust cycle, we still found that space is a much greater determinant of land values than time is.

At the metropolitan level, we found compelling evidence that value of urban land at the fringe is close to that of agricultural land after accounting for conversion costs. As suggested by Mills decades ago, these costs appear to be about half of the value of land on the fringe, albeit a much smaller fraction of more central land values.

When considering urban land values at the city center, we find that they increase at roughly the square root of urban population, which is consistent with various forms of the monocentric city model, including the one examined here. In the model we use, the elasticity of urban costs as a fraction of total income appears to be around 4 percent of income. We also find interesting evidence that within metro areas, land values rise not only with the average level of amenities but also with their variance. While there are certainly many imperfections with data and theory used in this analysis, the results of this paper suggest that the prices of observable land transactions do exhibit many regularities consistent with economic theory and intuition.

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TABLE 1: DESCRIPTIVE STATISTICS OF NON-PRICE CHARACTERISTICS OF LAND MARKET TRANSACTIONS, UNWEIGHTED, 2005-2010

Total Observations	57,157	*Intended Use*	
		Hold for Development	19.2%
Average lot size in acres	15.96	None	16.2%
(std. deviation)	(35.47)	Single Family	10.8%
Median lot size in acres	3.42	Retial	8.3%
		Industrial	7.6%
Average Distance from Center		Multi-family	6.5%
Driving Time in Minutes	30.59	Office	6.5%
(std. deviation)	(16.36)	Hold for Investment	3.6%
Driving Distance in Miles	22.85	Food/Restaurant	1.6%
(std. deviation)	(15.71)	Hotel	1.0%
Euclidean Distance in Miles	15.47	Parking	0.9%
(std. deviation)	(11.48)		
Year of sale 2005	20.6%	*Metro Area population*	
2006	20.8%	< 500,000	8.8%
2007	20.4%	500,000 to 1,000,000	11.0%
2008	15.9%	1,000,000 to 2,000,000	19.9%
2009	10.7%	2,000,000 to 4,000,000	24.9%
2010	11.6%	> 4,000,000	35.5%

TABLE 2: BASIC DESCRIPTIVE STATISTICS ON PRICE PER ACRE OF LAND: NATIONAL SAMPLE

Weights Used	None	Area of Property	Cty Area/ Observs	Value of Property	Population Density
	(1)	(2)	(3)	(4)	(5)
Arithmetic Mean (thousands)	$1,280	$165	$518	$13,587	$10,177
Standard Deviation (thousands)	$9,516	$1,504	$1,994	$59,957	$41,884
Geometric Mean (thousands)	$272	$48	$150	$801	$1,077
Mean of Logarithm	12.5	10.8	11.9	13.6	13.9
Standard Deviation of Logarithm	1.61	1.44	1.63	2.13	2.06
Skewness of Logarithm	0.04	0.22	-0.29	0.69	0.24
Kurtosis of Logarithm	3.62	3.13	3.25	3.43	2.97

TABLE 3: REGRESSIONS OF MSA-LEVEL MEASURES OF LAND VALUES WITH MEAN LOG PRICE PER ACRE.

Dependent Variable	Log Mean Price per Acre - Arithmetic Avg. (1)	Standard Deviation of Log Price per Acre (2)	10th Percentile Log Price per Acre (3)	50th Percentile Log Price per Acre (4)	90th Percentile Log Price per Acre (5)
Mean Log Price per Acre :Geometric Avg.	1.108	0.095	0.910	0.989	1.160
	(0.038)	(0.033)	(0.054)	(0.011)	(0.053)
Constant	13.919	1.380	11.290	13.033	14.740
	(0.054)	(0.046)	(0.070)	(0.014)	(0.072)
Number of Observations	231	219	231	231	231
Adjusted R-squared	0.933	0.123	0.845	0.985	0.895

Robust standard errors, clustered by CMSA, reported in parentheses.

TABLE 4: LAND VALUES AND OBSERVABLE SITE CHARACTERISTICS: METROS ARES, ACREAGE AND DISTANCE WITH INTEDNED USE CONTROLS

	Dependent Variable: Log Price per Acre (1)	(2)	(3)	(4)
Log lot size (acres)		-0.607	-0.593	-0.569
		(0.003)	(0.003)	(0.006)
Log lot size (acres) squared				-0.008
				(0.002)
Driving time from city center (hours)		-1.487	-1.416	-2.837
		(0.024)	(0.023)	(0.063)
Driving time from city center (hours) squared				1.317
				(0.058)
Log lot size (acres) x Driving time from city center (hours)				-0.008
				(0.013)
Number of Observations	57,157	57,157	57,157	57,157
Adjusted R-squared	0.462	0.709	0.726	0.729
CMSA Fixed Effects?	Yes	Yes	Yes	Yes
Controls for Intended Use?	No	No	Yes	Yes

TABLE 5: LAND VALUES AND OBSERABLE SITE CHARACTERISTICS: INTENDED USE AND LAND-USE REGULATION

	Dummy Only (1)	Dummy Level (2a)	Interaction w/WRLURI (2b)
No intended use	-0.206	-0.203	-0.029
	(0.013)	(0.013)	(0.020)
Intended use: industrial	-0.411	-0.420	0.042
	(0.017)	(0.017)	(0.024)
Intended use: retail	0.243	0.247	-0.026
	(0.016)	(0.016)	(0.024)
Intended use: single family	-0.011	-0.039	0.050
	(0.015)	(0.019)	(0.022)
Intended use: office	0.042	0.037	0.032
	(0.018)	(0.018)	(0.026)
Intended use: hold for development	0.051	0.070	-0.091
	(0.013)	(0.013)	(0.020)
WRLURI	-0.067	-0.048	
	(0.012)	(0.015)	
Number of Observations	51,209	51,209	
Adjusted R-squared	0.649654	0.649896	
CMSA Fixed Effects?	Yes	Yes	

Includes a third-order acreage effect. WRLURI is the Wharton Residenail Land Use Regulatory Index

TABLE 6: ACCOUNTING FOR VARIANCE IN LAND VALUES

	Dependent Variable: Log Price per Acre				
	(1)	(2)	(3)	(4)	(5)
Lot size polynomial	Yes	Yes	Yes	Yes	Yes
Intended use dummies	Yes	Yes	Yes	Yes	Yes
Driving time polynomial		Yes		Yes	Yes
CMSA Fixed Effects		Yes		Yes	Yes
Quarter of sale dummies			Yes	Yes	Yes
CMSA-lot size interactions					Yes
CMSA-driving time interactions					Yes
Quarter of sale-lot size interactions					Yes
Quarter of sale-driving time interactions					Yes
Adjusted R-squared	0.569	0.730	0.596	0.743	0.761

TABLE 7: AGRICULTURAL AND NON-AGRICULTURAL LAND VALUES

	Dependent Variable: 10th Percentile Log Price per Acre		
	Linear Specification (1)	Non-linear Specification (2)	Non-linear Specification (3)
Log agricultural land value per acre	0.662		
	(0.087)		
Log of combined agricultural land and implied conversion costs per acre		1.095	1.430
		(0.017)	(0.209)
Implied conversion costs per acre		3,792	7,216
		(1,097)	(2,779)
Constant	4.335		-3.538
	(0.744)		(2.211)
Number of Observations	442	439	439
Adjusted R-squared	0.173		

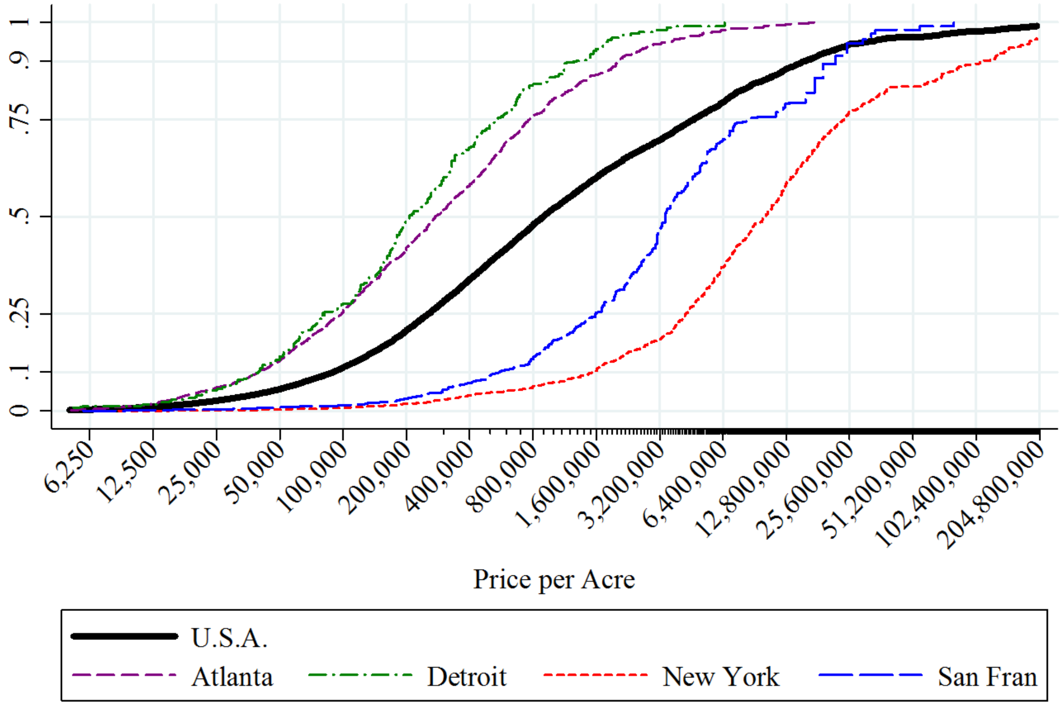
County-level observations. Standard errors clustered at MSA level.

TABLE 8: CENTRAL LAND VALUES, POPULATION, AREA, AND AMENITIES

Dependent Variable:	90th Percentile MSA Land Values						Land Values at MSA Center Index	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log MSA population	0.653 (0.057)	0.496 (0.064)	0.455 (0.061)	0.483 (0.058)	0.468 (0.063)		0.379 (0.038)	0.359 (0.036)
Log agricultural land values plus conversion costs		0.829 (0.188)	0.838 (0.192)	0.742 (0.164)	0.777 (0.173)	1.264 (0.216)	0.777 (0.134)	0.678 (0.117)
Degrees lost to coast or major water/360			0.845 (0.263)					
Average slope of land				0.000 (0.039)	0.000 (0.038)	-0.043 (0.042)		0.018 (0.022)
Standard deviation of slope of land				0.084 (0.062)	0.070 (0.061)	0.167 (0.068)		0.121 (0.041)
Commuting time					-0.279 (0.368)	0.566 (0.441)		
Standard deviation of commuting time					0.824 (0.707)	2.961 (0.770)		
Number of Observations	239	237	219	235	235	235	237	235
Adjusted R-squared	0.431	0.480	0.548	0.487	0.491	0.389	0.497	0.519

All regressions include a constant term. Dependent variable is MSA average residual from regression of log price per acre on a cubic polynomial in lot size, a cubic polynomial in driving time from downtown, a set of quarter of sale dummies, and a set of intended uses. Degrees lost to coast or major water from Stephen Malpezzi.

Figure 1: Cumulative Distribution of Land Values by Metro Area: 2006-2008



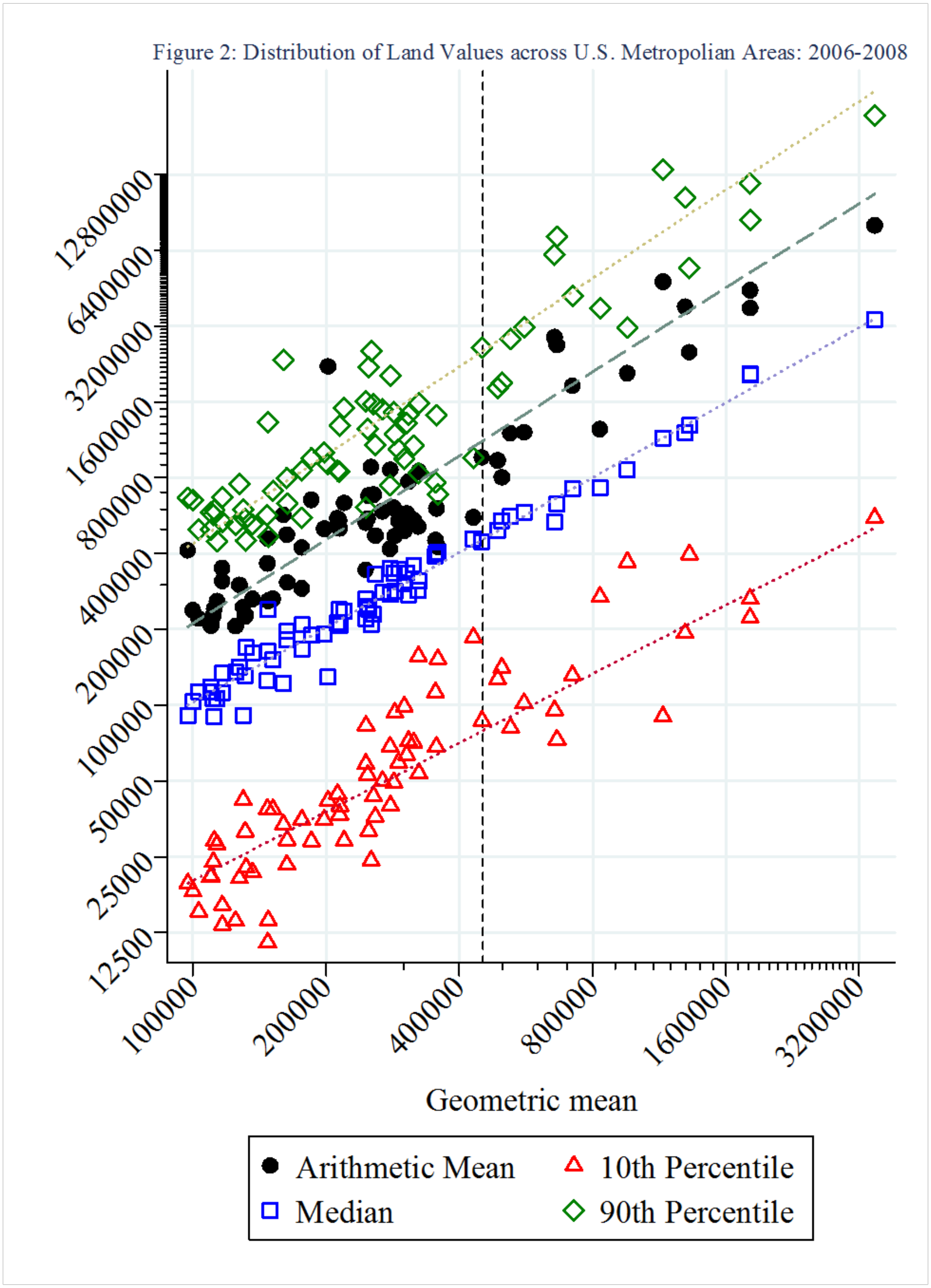


Figure 2: Distribution of Land Values across U.S. Metropolian Areas: 2006-2008
12800000
6400000
3200000
1600000
800000
400000
200000
100000
50000
25000
12500
100000
200000
400000
800000
1600000
3200000
Geometric mean
Arithmetic Mean
10th Percentile
Median
90th Percentile

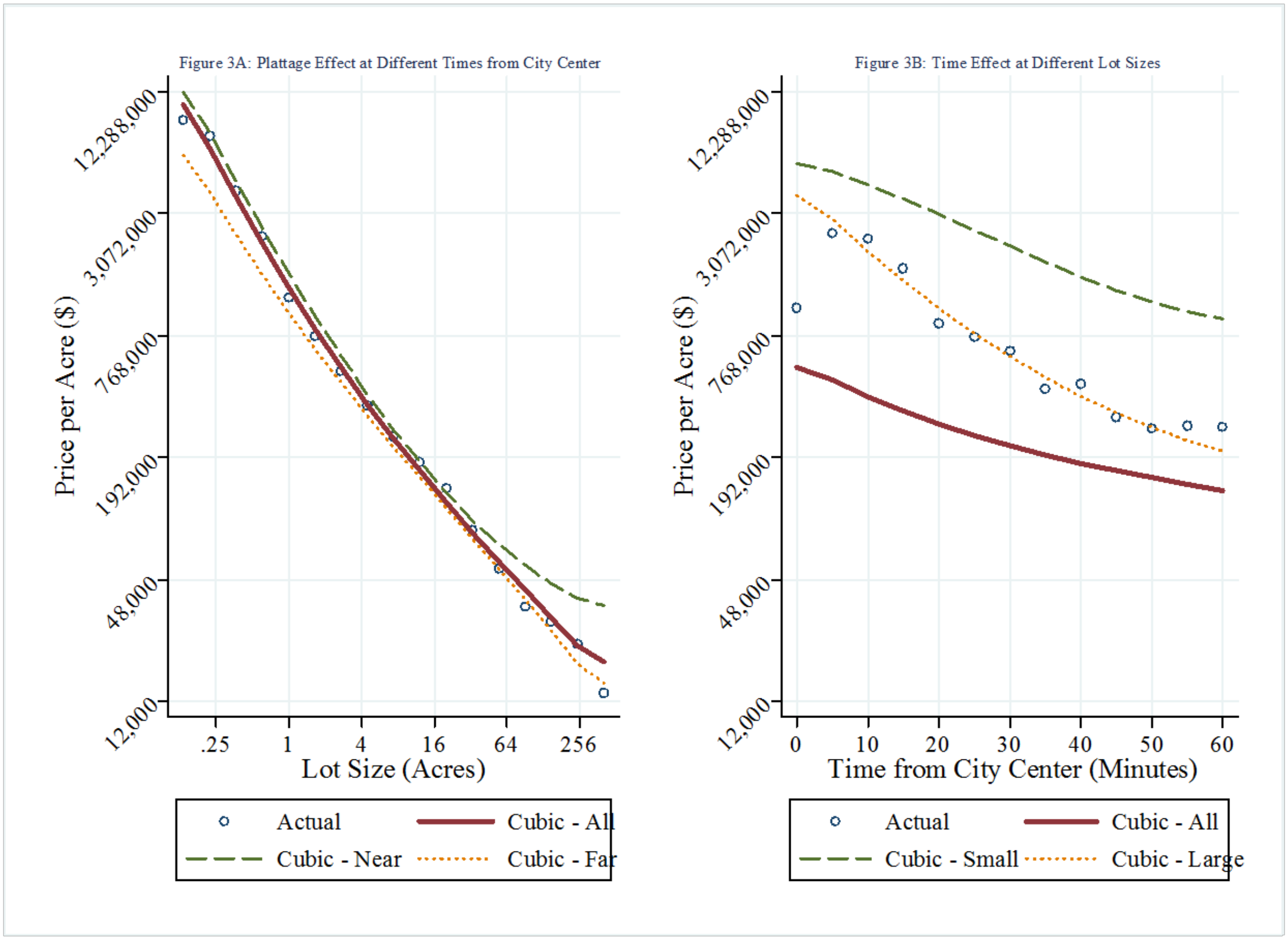
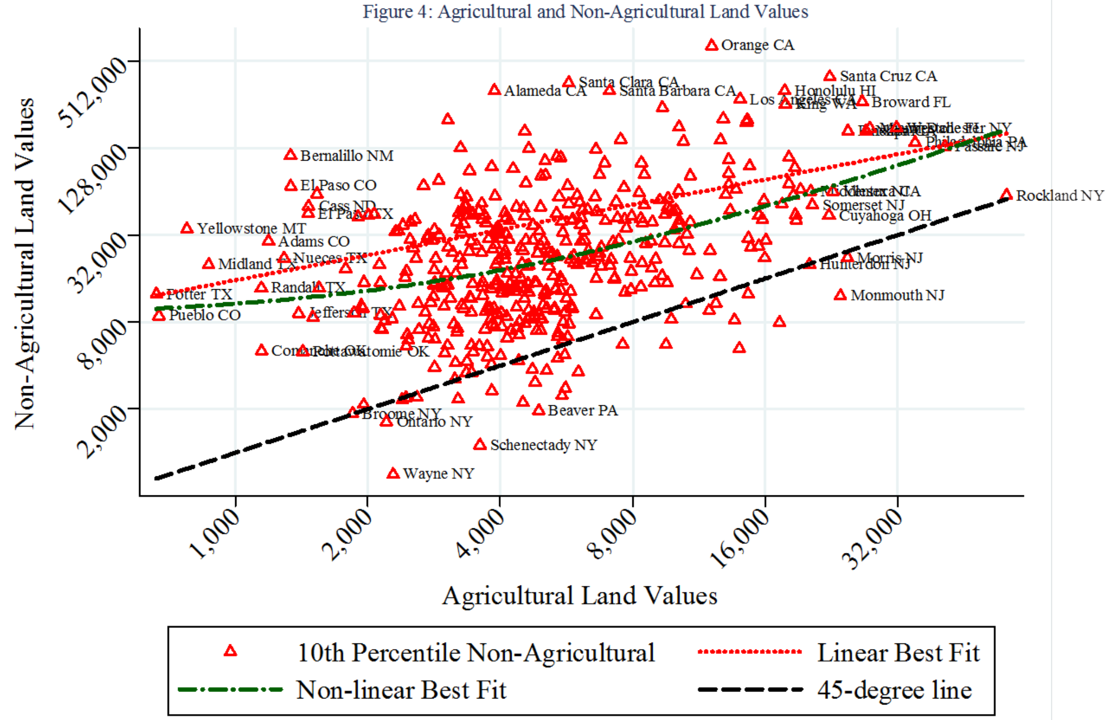


Figure 3A: Plattage Effect at Different Times from City Center
Price per Acre ($)
12,288,000
3,072,000
768,000
192,000
48,000
12,000
.25
1
4
16
64
256
Lot Size (Acres)
Actual
Cubic - All
Cubic - Near
Cubic - Far
Figure 3B: Time Effect at Different Lot Sizes
Price per Acre ($)
12,288,000
3,072,000
768,000
192,000
48,000
12,000
0
10
20
30
40
50
60
Time from City Center (Minutes)
Actual
Cubic - All
Cubic - Small
Cubic - Large

Figure 4: Agricultural and Non-Agricultural Land Values



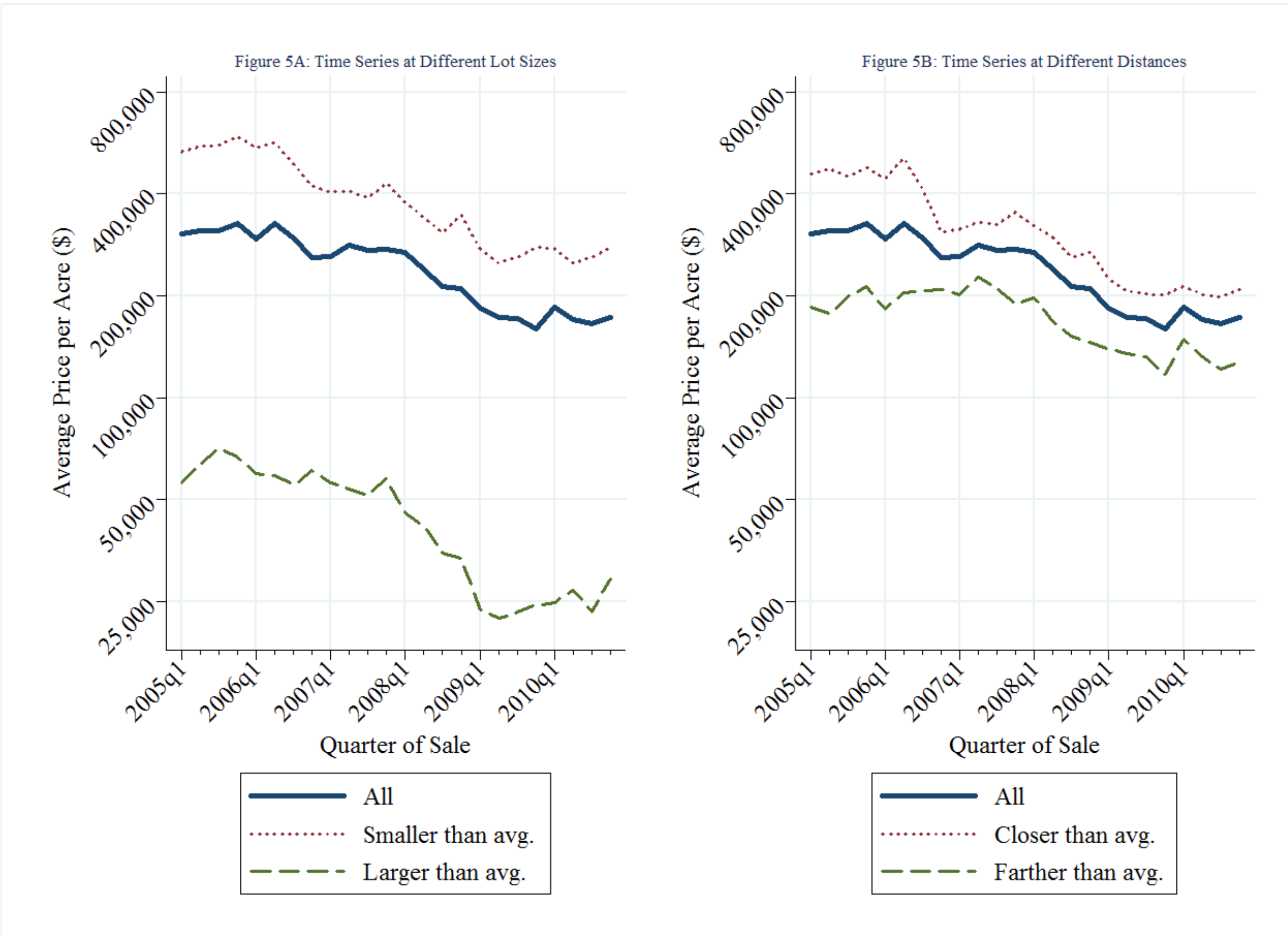


Figure 5A: Time Series at Different Lot Sizes
Figure 5B: Time Series at Different Distances
Average Price per Acre ($)
800,000
400,000
200,000
100,000
50,000
25,000
2005q1
2006q1
2007q1
2008q1
2009q1
2010q1
Quarter of Sale
All
Smaller than avg.
Larger than avg.
Closer than avg.
Farther than avg.

Figure A1: Sample Brochure from CoStar COMPs Database

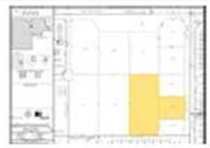
31 SW 75th Ave & Deer Valley Rd — SOLD

Glendale, AZ 85308 — Maricopa County

Sale Date: 12/08/2008
Sale Price: $2,500,000 - Affidavit
$/AC Land Gross: $381,679.39 ($8.76/SF)
Land Area: 6.55 AC (285,318 SF)
Lot Dimensions: -
Proposed Use: -

Parcel No: 200-19-004J, 200-19-014

Comp ID: 1624780
Research Status: Research Complete
Sale Conditions: -



32 SW 75th Ave & Roosevelt St — SOLD

Phoenix, AZ 85043 — Maricopa County

Sale Date: 06/11/2008
Sale Price: $31,981,393 - Confirmed
$/AC Land Gross: $428,623.41 ($9.84/SF)
Land Area: 74.61 AC (3,250,195 SF)
Lot Dimensions: -
Proposed Use: -

Parcel No: 102-43-002G

Comp ID: 1543026
Research Status: Research Complete
Sale Conditions: -

33 NW 75th Ave & Rose Garden Ln - 68 Lots, The Reserve at Eagle Heights — SOLD

Glendale, AZ 85308 — Maricopa County

Sale Date: 09/30/2008
Sale Price: $6,650,000 - Affidavit
$/AC Land Gross: $356,625.73 ($8.19/SF)
Land Area: 18.65 AC (812,263 SF)
Lot Dimensions: Irregular
Proposed Use: Hold for Development [Partial List]

Parcel No: 200-19-274, 200-19-275, 200-19-276, 200-19-277, 200-19-278, 200-19-279, 200-19-280, 200-19-281, 200-19-285, 200-19-286, 200-19-287, 200-19-288 [Partial List]

Comp ID: 1595885
Research Status: Research Complete
Sale Conditions: -

34 NE 82nd St & Princess Dr - I-1/pcd Zoned Acreage — SOLD

Scottsdale, AZ 85255 — Maricopa County

Sale Date: 08/08/2008
Sale Price: $1,612,660 - Confirmed
$/AC Land Gross: $1,490,443.62 ($34.22/SF)
Land Area: 1.08 AC (47,132 SF)
Lot Dimensions: Irregular
Proposed Use: Office

Parcel No: 215-07-219

Comp ID: 1572119
Research Status: Research Complete
Sale Conditions: -

35 SE 83rd Ave & Thomas Rd - Hispanic Conference Center — SOLD

Phoenix, AZ 85035 — Maricopa County

Sale Date: 11/26/2008 (153 days on mkt)
Sale Price: $2,103,816 - Confirmed
$/AC Land Gross: $111,077.93 ($2.55/SF)
Land Area: 18.94 AC (825,026 SF)
Lot Dimensions: -
Proposed Use: Commercial

Parcel No: 102-38-006

Comp ID: 1619982
Research Status: Research Complete
Sale Conditions: -

36 10610 N 84th St — ESCROW

Scottsdale, AZ 85260 — Maricopa County

Asking Price: -
$/AC Land Gross: -
Days on Market: 41
Sale Status: Escrow
Sale Type: Owner/User
Land Area: 1.00 AC (43,429 SF)
Lot Dimensions: -
Proposed Use: -

Parcel No: 202-22-009Q
Sales Condition: -

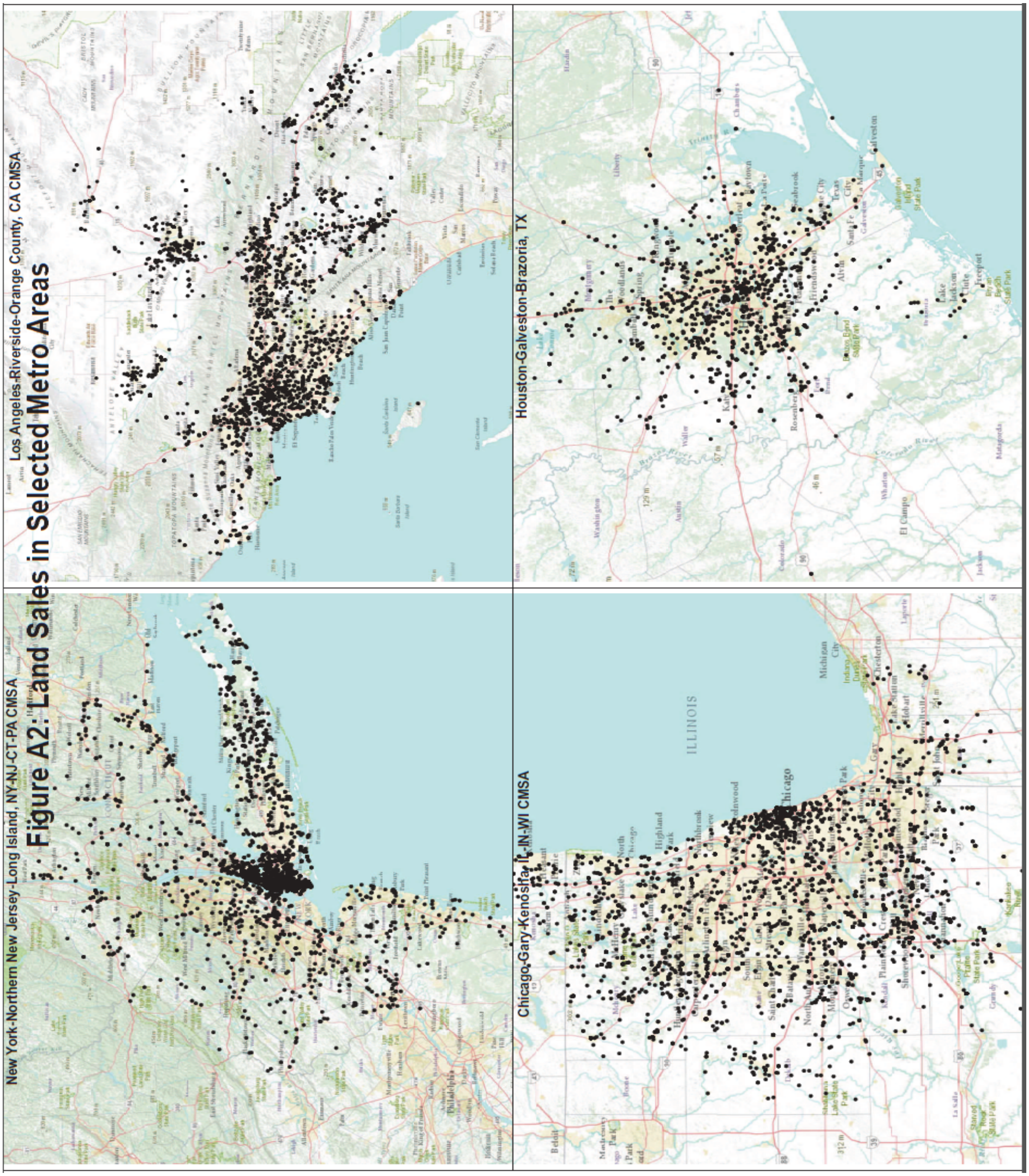


Figure A2: Land Sales in Selected Metro Areas