Sclerosis of the City: Land Assembly and Urban Change

Leah Brooks and Byron Lutz

Lincoln Institute of Land Policy
Working Paper

Lincoln Institute Product Code: WP10LB1

Abstract

Markets are efficient when prices and quantities are free to respond to shocks. Does this type of efficiency hold for urban land markets? We ask whether the amount of land assembled – the quantity of individual pieces of land legally joined together – is consistent with that of a competitive market. If economic forces cannot modify the size and shape of land – and the roads, buildings and homes that land borders dictate – cities forfeit economic growth. Our simple theoretical framework describes land assembly under the assumption of perfect competition in the market for assembly. We compare this equilibrium to an environment in which frictions, such as holdouts and public regulation, inhibit market forces. The model yields two empirically testable hypotheses. First, the price of land sold for assembly should not exceed the price of land sold for other uses. Second, because the opportunity cost of assembling large parcels exceeds that of small parcels, small parcels should be more likely to assemble. We test these conjectures using a novel dataset: we follow each of the 2.2 million parcels in Los Angeles County over an eleven year period and observe all instances of assembly. We find that to-be-assembled land trades at a 50 to 65 percent premium, and developers prefer to assemble larger, not smaller, parcels. This robust repudiation of efficiency in land assembly suggests a sclerosis in urban development and a rejection of an efficient model of urban land markets.

About the Authors

Leah Brooks
Department of Economics
University of Toronto
Max Gluskin House, Rm. 326
100 St. George St.
Toronto, ON M5S 3G7
CANADA
leah.brooks@utoronto.ca

Byron Lutz
Research Division
Federal Reserve Board of Governors
Stop # 83
20th and C Streets, NW
Washington, DC 20551-0001
USA
Byron.F.Lutz@frb.gov

Acknowledgements

We are extremely grateful to Bulmaro Borrero, Rex Hartline, and Alan Santos at the Los Angeles County Assessors office for providing data and guidance while we endlessly assembled the dataset for this paper. We are also appreciative to the Lincoln Institute of Land Policy, McGill University and the John Randolph Haynes and Dora Haynes Foundation, all of which contributed funds towards the construction of the dataset. We thank Robert Inman, Jaren Pope, Raven Saks, Hui Shan, and participants at the Lincoln Institute's October 2010 conference for helpful suggestions. This paper would not exist but for the superior research assistance of Brian McGuire.

The analysis and conclusions set forth are those of the authors and do not indicate concurrence by the Board of Governors of the Federal Reserve.

Table of Contents

Cities are composed of individual pieces of land called parcels. Just as atoms constrain the shape of matter, parcel delineations constrain the size and shape of cities' built infrastructure: roads, buildings and homes. Fundamental changes in this infrastructure cannot occur without changes to parcel boundaries. In already built areas, infrastructure changes require the assembly of individually-owned parcels into one singely-owned parcel. This process of joining individual parcels together into one legally-defined piece of land is known as land assembly.

Any understanding of the long-run economic development in cities must therefore contend with whether parcel delineations respond efficiently to market conditions. In this paper, we ask whether the amount of land assembled is efficient: do assemblies that result in more profitable use of land take place? At its heart, we ask whether prices and quantities in the urban land market respond to market forces.

Economic historians give us many reasons to believe that the ability to assemble or concentrate land ownership is a crucial pre-requisite for economic growth. Rosenthal (1990) shows that fragmented powers of eminent domain in pre-Revolutionary France inhibited profitable irrigation projects. Bogart and Richardson (2009) contend that the British Parliament's willingness to "assemble" ownership interests in land following the Glorious Revolution of 1688 yielded dividends in economic growth. In a more recent period, Field (1992) argues that the land subdivision boom of the 1920s and the subsequent problems of land assembly it caused in the 1930s exacerbated the United States's exit from the Great Depression.[1]

In the modern city, failure to assemble land can impede growth along many pathways. If insufficiently little land is assembled, cities may become sub-optimally dense at the center. This causes cities to expand at the edge, yielding congestions and assorted environmental ills

[1] Relatedly, Libecap et al. (2010) argue that differences in systems of land demarcation across former British colonies yield divergent economic outcomes.

(Miceli and Sirmans, 2007). Many urban planners advocate "transit oriented development" – denser housing near transit hubs. An inability to assemble means that public transport systems may fail to generate denser housing. As a further consequence, the transit system then lacks the high ridership that yields economies of scale and makes transit viable. Jane Jacobs argues that insufficiently dense cities do not benefit from agglomeration economies (Jacobs, 1961). Such misallocation also means that land is not put to its highest and best use and is thus undervalued.

Our work has important implications for land taxation. First, the taxation of land is predicated on the belief that the value of land is, or can be, efficiently priced by the market. If the price revealed in the marketplace is distorted, the base – and premise – of land value taxation is called into question. Second, it has been argued that regulations impose a significant tax on land (Glaeser et al. (2005) and Glaeser and Gyourko (2002)). The methodology used to estimate this regulatory tax assumes that the wedge between actual land prices and land prices under perfect competition arises solely due to regulation. Our work, though, suggests that private market frictions – such as holdouts – may be an important contributing factor to the wedge.

Theorists have long been interested in the question of land assembly and suggest that the amount of land assembly is inefficiently low. Strange (1995) highlights inefficiencies due to asymmetric information and sellers who hold out for higher prices. Eckart (1985) also suggests that holdouts may prevent profitable assemblies. O'Flaherty (1994) highlights inefficiency due to the external effects neighboring parcels – potential members of the assembly – receive when an assembly occurs.[2]

[2]Other theoretical work on land assembly includes Asami (1988) and Grossman et al. (2010). Cadigan et al. (2010) conduct experimental research on the potential private market inefficiencies in land assembly. A distinct literature explores whether the price per square foot of land increases in the size of the plot and is indirectly related to assembly (Colwell and Munneke, 1999, 1997; Colwell and Sirmans, 1993; Brownstone and DeVany, 1991). A positive relationship between the per square foot price and the size of the lot is a necessary condition for assembly, as we discuss in detail in section 1.

Practitioners concur with this dour assessment: Nelson and Lang (2007) write that land assembly is the "single biggest obstacle to central city redevelopment." Shigley (2007) agrees, writing that Florida "has a number of very old cities, and some of them are crowded with dilapidated buildings on tiny lots. In addition, the state is crisscrossed with antiquated subdivisions drawn up during the first half of the 20th century that do not come close to meeting today's standards." Thus, problems with land assembly prevent land being put to productive use. Similarly, Philadelphia has almost 60,000 vacant parcels and most are too small to be redeveloped. Land assembly is therefore crucial "to the stabilization and rebuilding of Philadelphia's neighborhoods" (Philadelphia Neighborhood Transformation Initiative; cited in Shoup (2008)).

Despite this theoretical and practical interest, there is extremely limited empirical evidence on land assembly, and none that directly addresses the central question of whether there is an efficient amount of assembly. Munch (1976) analyzes how land taken by eminent domain in Chicago is priced relative to market prices by the court. Cunningham (2010) and Fu and Somerville (2002) document that the final seller in a land assembly receives a premium.[3]

Our limited understanding of the efficiency, or lack thereof, of land assembly is a major gap in our understanding of urban areas. Figure 1 presents the total number of assemblies in Los Angeles County divided by the total number of permits issued for residential construction by year from 1999 to 2008. We expect that this number actually underestimates the importance of land assembly. While one permit allows for construction of one unit, one assembly may (and frequently does) result in more than one unit. For instance, three parcels of land may be assembled to construct a multi-story 30-unit condo building. Thus, while three parcels are assembled, permits are given for 30 units.[4] Even given this likelihood of

[3]Harding et al. (2003) provide evidence of more general deviations from the competitive equilibrium in the market for housing.

[4]It is also possible that this number overstates the impact of assembly, since permits include only res-

underestimation, assemblies account for between 6 and 16 percent of residential permits per year.

Our paper makes three primary contributions. First, we directly address the question of central economic concern: is there an efficient amount of land assembly? Second, we use what is, to the best of our knowledge, the best existing dataset to study such a question. We have assembled a panel dataset that traces each of the 2.2 million parcels in Los Angeles County across an 11-year period. The dataset is based on annual cross-sections containing all parcels in the county and a database, provided by the county assessor, which identifies all instances of changes to parcel boundaries and provides a mapping between parcels which have changed. Our dataset allows us to follow each individual piece of land in the county over this entire period. Third, we use novel, theoretically motivated tests to evaluate whether there is inefficiently little land assembly.

We begin with a simple model of the decision to assembly land. The heart of the model is the intuition that parcel definitions were decided long ago, and now no longer represent the optimal division of land. Prices of land are now such that larger pieces of land are worth more, per square foot, than smaller pieces of land. We assume free entry into the market for assembly and that, correspondingly, developers earn zero profits and all surplus from assembly goes to the landowner. This model yields two assertions about outcomes when land assembly is efficient.[5] First, in a market free of frictions, the price of land sold for assembly should not differ from the price of land that is sold not for assembly. Regardless of the final use, any differences in price per square foot across land since should be arbitraged away. Second, the model suggests that absent frictions, all else equal, small parcels should be more likely to assemble than large parcels because the opportunity cost of assembling is

idential construction and our data include all land for assembly. However, the majority of assembly land (like all land) is used for residential purposes.

[5]Clearly, assembly is also a function of the value and vintage of the capital on a given lot. We address this issue both theoretically and empirically below.

lower for smaller parcels.

To evaluate the first contention – that the price of land sold for assembly does not differ from the price of land sold not for assembly – we require a method to value land. We rely on the technique pioneered by Rosenthal and Helsley (1994) and refined by Dye and McMillen (2007) that identifies the price of land as the price of parcels sold when the structure is torn down. Because the structure is worthless to the new owner, the sale value represents only the land value. We compare the price of properties sold as "teardowns" to properties sold for assembly, conditional on small neighborhood (tract or block group) fixed effects that net out the main component of land value: location. In addition, we control for intra-neighborhood differences in amenities. We find that land sold for assembly exceeds the price of land sold for teardown by 50 to 65 percent. We interpret this as evidence of inefficiently low levels of land assembly.

To evaluate the second contention – that in a competitive market developers should prefer to assemble smaller parcels – we use a cross-section of all parcels existing at the beginning of our sample (1999) and ask whether future assembly is a function of initial parcel size. Specifically, we ask whether a parcel will be assembled in the future, controlling for small neighborhood (tract or block group) fixed effects, capital vintage and structure size effects, and even for intra-neighborhood amenities. Regardless of controls, we find that, within a small neighborhood, a 10 percent increase in lot size yields a 0.1 percent increase in the likelihood of assembly. This is a very large effect, given that the baseline probability of assembly is one percent. Such a finding, like the previous one, is inconsistent with a competitive market for land assembly.

Finally, given our resounding rejection of land assembly as an efficient process, we offer suggestive evidence about the sources of this inefficiency. Deviations from the competitive equilibrium could result from imperfections in either the public or private markets. Public market failures are due to the regulation of land by local government, such as zoning restrictions, development fees, and building codes. Private market failures stem from bargaining problems between the developer of the assembled land and the land sellers. We find compelling evidence that private market imperfections are substantial: we show that developers prefer to assemble larger parcels suggesting that the transaction costs or bargaining costs in assembly are substantial. Furthermore, we find that smaller parcels sold for assembly command a higher price per square foot than larger properties, consistent with Strange (1995) and Eckart (1985). Although these two findings together suggest that private market failures are substantial, we do not interpret them as evidence against an equally substantially role of public market failures.[6]

1 Theoretical Framework

We begin our analysis with a simple theoretical framework to generate testable predictions about the efficiency of land assembly. We first consider the case where the market for land is perfectly competitive and where no frictions preventing land prices or quantities from reaching the competitive equilibrium. This competitive equilibrium case is our baseline for an "efficient" outcome.[7] Thus, in our terms, an efficient level of land assembly is the level of assembly consistent with competitive clearing of the land market. We then consider cases where frictions prevent the a competitive equilibrium and call these outcomes "inefficient."

Assume that land was developed at time $t-j$ $(j > 0)$ into identical parcels of size p. The parcel size optimally reflected market conditions at time $t-j$ and was initially immutable. At time t, however, a new technology is developed which allows two parcels to be assembled into one. We use this framework as a rough approximation for a neighborhood where parcels are defined at the time of substantive residential development. As time passes, those initial

[6] We plan to return to the relative importance of public and private market failures in future work.

[7] Efficiency is a broad concept. We emphasize that we use "efficient" only as a label for the case in which the market for assembly reaches a competitive equilibrium.

parcel definitions may become sub-optimal. In this vein, we further assume that market conditions have evolved such that larger assembled parcels sized $2p$ command a premium relative to smaller parcels. In other words, the relationship between land value and parcel size has become convex, such that

$$V(2p) > 2V(p), \tag{1}$$

where $V(x)$ is the market price of a parcel of size x. Consistent with our empirical approach, which focuses on the value of land and not capital, we assume that any capital placed on the land at time $t - j$ has depreciated to zero by time t. The convexity of land prices is presented graphically in figure 2.

Land values tend to become convex when the optimal capital to land ratio increases. Convexity arises because the density implied by high capital to land ratios requires large lots. Builders may require large lots for technical reasons; e.g. a footprint of a given size may be required to construct a building of a given height. Similarly, builders may require large lots in order for buildings to be of sufficient size to absorb fixed costs such as elevators.

The optimal capital to land ratio in a metropolitan area may increase for any number of reasons. Population growth will tend to increase the optimal capital to land ratio (Henderson (1977)). Similarly, increased commute times in an urban area may push the optimal ratio up in the urban core. Convexity may also arise when the optimal use of land use shifts with time. For instance, land initially developed into small single family lots may eventually become more valuable for commercial purposes. Commercial uses typically require larger buildings and thus lot sizes, introducing convexity in the land value function.

The convexity in the land value function implies that assembly generates a surplus relative to the land in its current state. The surplus value, s, is defined as

$$s = V(2p) - \delta - 2V(p), \tag{2}$$

where δ is equal to the cost of assembly and captures factors such as transaction costs and conversion costs (e.g. demolition, grading to-be assembled parcels with different slopes). Convexity in land price function is a necessary condition for land assembly to occur (see Colwell and Munneke (1999)). The cost of assembly, δ, can only be covered when the value of the assembled parcel, $V(2p)$, exceeds the value of the unassembled parcels, $2V(p)$.

In a frictionless, competitive world arbitrage ensures that all surplus is realized and that assemblies continue until the market price of land has adjusted such that any surplus is eliminated. Specifically, as assemblies occur the supply of lots sized 2p expands and the price of these lots falls. Assembly ceases when the return to assembled and unassembled lots has equalized: $V(2p) = \delta + 2V(p)$ and $s = 0$. It is also possible that the market reaches a corner solution such that all parcels have been assembled. As we do not see this solution in practice, we do not further analyze this case.

The no-surplus situation detailed above is the competitive equilibrium. In an imperfectly competitive world, all surplus available from assembly may not be arbitraged away. For instance, holdouts may ask excessive prices for their parcel and thereby make projects infeasible for the developer (Eckart, 1985; Strange, 1995). Similarly, strategic delay on the part of individual landowners may cause assemblies to fail (Menezes and Pitchford, 2004; Miceli and Segerson, 2007; Miceli and Sirmans, 2007). The public goods aspect of land assembly – the fact that assembly may increase the value of neighboring parcels not participating in the assembly – may also block arbitrage opportunities (O'Flaherty, 1994). Finally, land use regulations may systematically block arbitrage opportunities. For example, regulation could bar a large building that would optimally occupy an assembled site.

Given this framework, we now lay out three strategies for assessing whether the level of land assembly is consistent with competitive equilibrium. Our first test estimates the magnitude of the surplus s accruing to successful assemblies in order to obtain a rough sense of the magnitude of the frictions in the market for assembly. A large estimate of s is consistent with substantial frictions in the market for assembly. This approach is similar in spirit to the work of Glaeser et al. (2005) and Glaeser and Gyourko (2002) on the regulatory tax. Glaeser et. al. reason that in the absence of regulation the extensive value of land – the value of land with a house on it – will equal the intensive value of land – the value of a marginal increase in the area of a lot. If the extensive value exceeds the intesive value, landowners should optimally choose to subdivide their land and sell a portion of it. Our approach applies what is, in essence, the reverse of this logic: in the absence of market imperfections, if land is worth more combined than divided, owners will choose to assemble land.

This first test requires two assumptions. The first assumption is free entry into the market for development (or assembly). Developers earn zero profits and the owners of the initial parcels size p therefore capture any surplus s available from assembly. The value of an assembled parcel is $V(2p) + K$, where K is the level of capital placed on the newly assembled parcel. If the developer earns zero profits, this post-assembly value must equal his costs. The developer's costs are capital (K), assembly costs (δ), and the purchase price of the unassembled land, p_u. Thus, $V(2p) + K = K + \delta + p_u$ which yields $p_u = V(2p) - \delta$. We can therefore estimate surplus as the difference between the sales price of to-be-assembled parcels, $V(2p) - \delta$, and the sales price of not assembled parcels, $2V(p)$: $V(2p) - \delta - 2V(p)$.

The second assumption is that the frictions in the urban land market operate purely as a supply constraint on assembly. This occurs if regulation prohibits assembly or if landowners cause assemblies to fail by asking prices that drive the developer profits below zero. These supply restraints prevents arbitrage from eliminating the surplus to assembly.

If these two assumptions fail to hold we will likely *understate* frictions in the market for assembly. First, if there are barriers to entering the market for development, developers may capture a portion of the assembly surplus. The portion of the surplus accruing to the developer is reflected in the post-assembly sales price of the newly assembled parcel, not in the pre-assembly price we use to infer surplus. As a result, our estimate of s would be biased downward. Second, although the frictions described above almost certainly act as supply constraints on assembly, there may be other types of market frictions. For instance, frictions such as regulatory costs (e.g. the time spent getting approval for a project) and strategic delay may increase the developer's cost of assembly, δ. An increase in δ reduces our measured value of surplus. A given assembly may have no measurable surplus under our methodology, but a much larger surplus in the absence of the friction-induced increase in δ. Thus, even a finding of no price premium paid for to-be-assembled parcels does not rule out the possibility of an inefficiently low level of land assembly.

Our second and third strategies analyze the size of parcels assembled. Assume that at time t parcels of size $\frac{p}{2}$ and p exist. Assembly technology allows for generating parcels of size $2p$ through any combination of parcels yielding an area of $2p$. The convexity of the land value function suggests that

$$V(p) > \; 2V(\frac{p}{2}). \tag{3}$$

The assembly surplus is therefore higher for assemblies involving only parcels of size $\frac{p}{2}$ because the opportunity cost suffered by the initial land owner is lower. In essence, smaller parcels are cheaper. (Returning to equation 2 and concentrating on the negative final term which represent the opportunity cost, we see that $2V(p) > 4V(\frac{p}{2})$). As a result, in a competitive market small parcels should be more likely to be assembled than larger parcels.

However, small parcels may also tend to increase the likelihood of private market inefficiencies. Theoretical work argues that owners of small parcels are more likely to ask excessive prices (Eckart 1985, Strange 1995). Similarly, the greater number of parcel owners involved in an assembly, the greater the odds of strategic delay (Miceli and Sirmans 2007). Both these factors may cause assemblies with positive surplus to fail. Our second test therefore examines the influence that parcel size has on the probability of assembly. A finding that larger parcels are more likely to be assembled suggests that private market inefficiencies cause an inefficiently low level of assembly.[8]

Our third test examines the relative sales prices of to-be-assembled parcels by size. Evidence that small parcels command a significant price premium over large ones would support the theoretical predictions that small parcels owners are unusually likely to ask excessive prices and engage in strategic delay. An attractive aspect of these final two tests are that they shed light on the causes of the inefficiency, as both focus on frictions likely caused by private market failures.

2 Empirical Approach

Our first test compares the land value of assembled and unassembled parcels. To estimate s, we must recover the land value of both types of parcels. $V(p)$, the land value of an unassembled parcel, can be recovered using the technique pioneered by Rosenthal and Helsley (1994) and refined by Dye and McMillen (2007). This technique recovers the value of land using the sales of homes to be torn down. The value of such a teardown sale reflects only the value of the underlying land, since the capital is discarded.

A similar logic can be applied to valuing the land used in assemblies. Most assemblies discard the existing capital and place new capital on the assembled site to take advantage of the larger building area. Intuitively, if the capital on the initial parcels were retained, there would be no gain from assembly.[9] As a result, parcels that are to be assembled can themselves be considered teardowns and their sales price used as a measure of the value of the land. We therefore recover the value of assembled land, $V(2p) - \delta$, and estimate the incremental value that to-be-assembled parcels command relative to teardown parcels.

[8]We view this as very suggestive evidence of private market failures, but acknowledge that there are also public market frictions (zoning changes, regulatory hurdles) that could be dampened by assembling fewer parcels.

[9]Gains from assembly come from placing capital on the new site that was not viable on the old site.

The larger this incremental value, the larger the surplus earned by landowners selling to an assembler and the greater the implied frictions in the market for assembly.

One possible objection to the strategy of comparing to-be-assembled parcels to unassembled parcels is that many plots are constrained from assembly. For instance, physical barriers such as steep slopes may prevent assembly. Public capital, such as roads, may separate parcels and prevent assembly. A parcel ready for redevelopment may be next to a parcel with a lot of capital, making redevelopment as part of an assembly economically infeasible. These factors are reasonably viewed as materially different from factors such as zoning and holdouts which may also prevent assembly. It would be unreasonable to label the failure to assemble two parcels separated by a road as "inefficient." However, arbitrage opportunities should cause the price of assembled and unassembled teardown parcels to converge as long as a corner solution is not reached in which no feasible assemblies exist. In other words, as long as there are available assembly opportunities, arbitrage should drive the assembly surplus to zero. At least in Los Angeles it seems clear that ample assembly opportunities remain and that a corner solution has not been reached.

We estimate the first test with a panel specification

$$\begin{aligned} \log(\frac{\mathit{real\ sale\ price}}{\mathit{lot\ square\ footage}})_{i,g,t} &= \beta_{10} + \beta_{11} \mathit{assembly}_i + \mathit{year}{*}\mathit{quarter}_t \\ &+ \mathit{neighborhood}_g + \beta_{12} \mathit{amenities}_i + \varepsilon_{i,g,t}. \end{aligned} \tag{4}$$

where $\frac{\mathit{real\ sale\ price}}{\mathit{lot\ square\ footage}}_{i,g,t}$ is the per-square foot price of land for parcel i in neighborhood g at time t and $\mathit{assembly}_i$ equals one for an assembly and zero for a teardown. β_{11} captures the surplus to assembly versus redeveloping within the existing boundaries of the parcel and is the coefficient of interest. The estimation sample includes only teardown and assembly sales.

Assembly may be correlated with the unobservable determinants of price, $\varepsilon_{i,g,t}$, for at least two reasons. First, rising land values often dictate increasing the capital-to-land ratio and assembly may be required to increase this ratio. Thus, land with a particularly high value may be more likely to assemble than less valuable land. Second, some of the very frictions we are attempting to quantify, such as zoning, may make high value land less likely to assemble. For instance, more stringent zoning in Malibu may make assembly less likely there than in Watts. Because land is more valuable in Malibu than in Watts for reasons having nothing to do with the likelihood of assembly, this may introduce bias.

We tackle the above endogeneity concerns by observing that the value of land, virtually by definition, is a function of location. We therefore include a very fine set of geographic fixed-effects, either census tract indicators or census block group indicators, $neighborhood_g$. The comparison of land price between assemblies and teardowns is therefore made only within very small areas, either a census tract or census block group. There are 2,054 census tracts and 6,346 block groups in Los Angeles County. The median tract contains 985 parcels, and the median block group 290.

Of course, some elements of location vary even within small geographic areas. For instance, access to a highway may differ within a neighborhood. We therefore control for distance to a major highway and distance to urban and commuter rail with the $amenities_i$ vector. Finally, to control for market-wide evolution in price over time we include a full set of indicators for each quarter in our sample, $year*quarter_t$ (i.e., indicators for 1999Q1, 1999Q2, etc, are included).

Our approach departs from the teardown literature in one important regard. The teardown literature controls for selection into redevelopment using a standard Heckman two-stage procedure. Accordingly, coefficient estimates yield marginal effects for the untruncated, latent dependent variable. As the goal of the teardown literature is to recover the value of all land, whether redeveloped or not, this is clearly the correct empirical approach. Because our aim differs, we estimate equation (4) using OLS. Two points bear emphasis. First, the

OLS coefficients recover marginal effects for the truncated, observed dependent variable. These effects are precisely those required for the first test. Specifically, the OLS estimate of β_{11} answers the question: among redeveloped parcels (i.e. in the observed portion of the distribution), is there excess value to assembly? The arbitrage argument underlying the test is only valid for parcels actually undergoing redevelopment. Arbitrage should not eliminate the surplus to assembly for parcels containing capital too valuable for redevelopment. Second, although the conditional expectation function is non-linear, OLS provides a well-defined minimum mean squared error linear approximation.[10]

For the second test – in a competitive market, smaller parcels should be more likely to be assembled – we use the full cross-section of *all* county parcels from the first year of the sample (1999). Specifically, we estimate

$$\begin{aligned} assembly_{i,g} &= \beta_{20} + \beta_{21}\log(lot\ square\ footage_i) + neighborhood_g \\ &+ \beta_{22} amenities_i + K\ vintage_i * K\ quantity_i + \beta_{23}\frac{K\ value_i}{land_i} + \varepsilon_{i,g}, \end{aligned} \quad (5)$$

where $assembly_{i,g}$ equals one if the parcel is involved in an assembly over the following 11 years of the sample and zero otherwise, and $lot\ square\ footage_i$ is the size of the parcel. β_{21} captures the marginal effect of lot size on the probability of assembly and is the coefficient of interest.

β_{21} is identified under the assumption that lot size is uncorrelated with unobserved determinants of assembly, $\varepsilon_{i,g}$. There are at least three possible reasons to be concerned that this may not be the case. First, the likelihood of assembly may vary by location, and location may be correlated with parcel size. For example, parcels near the urban center may be ripe for redevelopment and assembly due to increased commute times. These parcels may also be smaller, but it is their lower commute time, not their size, driving the assembly decision.

[10]Angrist and Pischke (2009, page 102-3) and Cameron and Travedi (2005, page 542) discuss using OLS to fit the conditional expectation function of a left-truncated distribution.

As in the first test, we net out such neighborhood-specific factors with tract or block group fixed effects, so that all our comparisons are made within a given, limited geographic area.

The second threat to the credibility of the identifying assumption is the possibility that large plots tend to have more valuable capital per square foot of land than smaller parcels. All else equal, the more valuable the capital on a parcel, the less likely the capital is scrapped to allow for redevelopment and the less likely is assembly. Larger lots may very well have more valuable capital. For instance, if small lots tend to contain two-story single family homes, whereas large lots tend to contain multi-story buildings, larger lots will have systematically more capital. We therefore control for the presence of capital in a flexible, relatively non-parametric manner by including a full set of interaction terms between indicator variables for the vintage of the existing capital, $K\ vintage_i$, and indicator variables for the size or quantity of the capital per square foot of land, $K\ quantity_i$. This approach fails to account for both differences in depreciation across properties and differences in the initial quality of the capital given its size. We therefore also control for the ratio of the value of improvements (i.e. capital) to the value of land, $\frac{K\ value_i}{land_i}$. Unfortunately, as discussed below, this variable suffers from measurement error concerns.

A third reason lot size may be correlated with the error term is because not all lots are "assemble-able," and "assemble-ability" may be correlated with lot size. To be assembled, a parcel needs a contiguous neighbor, one not separated by an existing road or other physical barrier. The most extreme example of an "un-assemble-able" parcel would be one that takes up an entire city block. Such a parcel cannot be assembled given the existing structure of roads. In general, larger parcels should be more likely to be unable to assemble for such reasons. However, this possibility will tend to bias our estimation toward *failing* to reject the hypothesis that smaller parcels are more likely to be assembled (and hence make it less likely we will conclude the market for assembly is inefficient).

We implement the third test – in an efficient market, small parcels should not sell into assembly at a premium – with a panel specification

$$\log(\frac{\textit{real sale price}}{\textit{lot square footage}})_{i,g,t} = \beta_{30} + \beta_{31}\log(\textit{lot square feet}_i) + \textit{year*quarter}_t + \textit{assembly group}_g + \beta_{32}\textit{amenities}_i + \varepsilon_{i,g,t}, \quad (6)$$

where *assembly group*$_g$ is an indicator variable for a set of contiguous parcels which are assembled together. (We provide a more precise definition below.) β_{31} captures the marginal effect of lot size on sales price and is the coefficient of interest. The sample is limited to only parcels involved in an assembly and the inclusion of the *assembly group*$_g$ term ensures the influence of lot size on sales price is measured solely *within* groups of parcels assembled together. The identifying assumption required for equation (2) – that lot size is uncorrelated with the unobserved determinants of price – is therefore extremely plausible. To-be-assembled parcels are sold only for their land value. Within an assembly group the parcels are contiguous to each other and thus have the same locational, or land, value.

3 Land Assembly Definition and Institutions

Before estimation, we discuss the institutions of land assembly and our data. This section presents our empirical definition of land assembly and then discusses the institutions for assembly in Los Angeles County.

To explain how we define land assembly in our dataset, we first define a "parcel change group." A parcel is part of a parcel change group if it or its ancestor or descendant parcel(s) ever changes. However, parcels combine and disaggregate in a number of different ways, so membership in a a parcel group does not alone indicate assembly. The list below presents three examples of possible parcel changes.

A. $3 \rightarrow 1 \rightarrow 7$

B. $1 \rightarrow 5$

C. $8 \rightarrow 1 \rightarrow 2$

We define a change group to have land assembly if any part of the parcel change group goes from $n > 1$ properties to one. In the example above, this includes cases A and C, but excludes case B. Case C involves land assembly (8 parcel into 1 parcel) followed by disassembly (1 parcel into 2 parcels). We use this definition, despite the fact that it encompasses episodes of net disassembly, because we wish to consider any development that includes any land assembly as a redevelopment that would not occur without the assembly step.

In addition, this definition is a good match with our data. Parcel identification numbers change only when the physical boundaries of a parcel change. We observe all changes in parcel numbers and thus measure all assemblies as defined above.

When is the type of land assembly we have defined required? A developer may purchase adjoining land with the intent of building new structures but not go through the formal process of "assembling" in legal terms.[11] It is this legal assembly which we observe in the data. For the purposes of our estimation, this type of underreporting likely biases our estimates of the inefficiency of land assembly downward, by mistakenly putting some assembled parcels in the competitive market comparison group.

There are two circumstances under which formal assembly is required, and these regulations are the province of the city (or the county for unincorporated areas). To the best of our knowledge, these two circumstances do not vary across regulatory jurisdictions in the county. In general, cities do not require developers to assemble parcels, even when a new structure spans more than one parcel.[12] The first of two exceptions to this laissez-faire policy is when the new land use will be condominiums. Each unit in a condominium must have a

[11] In such cases, with multiple owners, owners usually write legally binding easement agreements across properties.

[12] Information in this section comes primarily from an interview with Wolfgang Krause, Chief Planner, City of Glendale, May 2010. We plan to improve this section through additional interviews.

separate parcel, as each unit may have a unique legal owner. Therefore, any land combined for condos must be assembled.

The second exception from the laissez-faire policy is a function of the use of the property. Suppose that a city's zoning requires two parking spaces for each multi-family unit, and that the developer has purchased two parcels upon which to build a new multi-family development. If the developer builds the parking on one parcel and the structure on the other, he is required to legally assemble the parcels. Cities make such a requirement to ensure that all future sales keep parcels in compliance with zoning regulations. The developer can avoid the requirement to legally assemble by building a structure that spans both parcels.

Even if it is not legally required, a developer may still wish to assemble parcels. Selling an assembled parcel, rather than multiple unassembled parcels reduces uncertainty in future transactions. Assembly also yields a reduction in legal paperwork.

It is important to note that the legal land assembly process does not trigger a reassessment under California's Proposition 13. Proposition 13 limits the increase of a property's assessed value to two percent per year, and the assessed value raises to market value at sale. Thus, a developer may face a increase assessment due to property purchase, but does not face an increased assessment due to the legal act of assembly.[13]

4 Data

Our project relies on multiple sources of data. We summarize the data here, and refer interested readers to our lengthy Data Appendix for full details on all data inputs and data construction details. The three key components of our data are the annual property-level data for Los Angeles County, sales data for properties, and census neighborhood measures.

Our annual property data consist of three key parts: (i) ten annual cross-sectional obser-

[13]This information comes from the Special Investigations Section, Los Angeles County Assessor.

vations of the 2.2 million parcels in the County of Los Angeles, (ii) a dataset listing all parcels that change, and the number of the parcel(s) to which they change, and (iii) electronic maps with geographic information on all properties.

The annual cross-sections are the heart of the dataset. In each year from 1999 to 2010 (except for 2003[14]) we observe attributes about each individual piece of property in the 88 cities and the large unincorporated area of Los Angeles County. We observe too many attributes to list here, but briefly the data include attributes about the property itself (e.g., size and location); attributes about the building on the property (e.g., building size); and attributes about the legal regime that governs the property (i.e., the use and zoning rules for each property). Thus, this part of the dataset includes somewhat more than 24 million observations with many descriptive variables.

The second part of the data is a file that allows us to take the 11 cross-sections and make them into a true panel by linking property identification numbers over time. Though most properties retain a constant identification number throughout the sample, some properties split or merge. Our dataset of all property identification number changes allows us to follow each initial piece of land to its current, perhaps aggregated or disaggregated, form. While this task is conceptually simple, it has mechanically been quite difficult, and the bulk of our data assembly has been devoted to making sure that we have built these linkages correctly.

The third and final part of the annual property data is electronic maps of all parcels. These maps, which we have from 2006 onward, allow us to pinpoint the exact location of each individual property and calculate distances from one property to another, or from a given property to key urban amenities, such as light rail stops or freeways. These maps also allow us to assign each property to an unique census block group.[15]

We combine this panel of all properties in the county with all property transactions by

[14]We were never able to get access to this cross-section.

[15]On average, populated block groups in Los Angeles contain approximately 1,400 people.

property identifier. Specifically, we observe the last three sales on each property as of 2006, and sales in the last two years from 2009 and 2010. This leaves a small gap of sales in 2006. We limit the sample of transactions to include only arms' length transactions and make other small adjustments as defined in the Data Appendix.

We measure neighborhood economic and demographic factors with data from the 1990 and 2000 Decennial Censuses at the block group level. To use the 1990 block group data, we use GIS mapping to make a correspondence from 1990 to 2000 census block groups.

5 Results

We now turn to describing the results of each our three tests in turn.

5.1 First Test: Surplus Value of Assembly

We begin to motivate our comparison of assembled to teardown parcels by comparing their characteristics. Our sample is assembly and teardown parcels for which we observe a sale within four years of assembly or teardown, including the year of assembly.[16] We define a property as a teardown if the structure's age changes in our panel. Specifically, we require that the replacement structure be newer than the old structure, that the new structure is built after 1998, and that the old structure was built before 1990.

Columns (1) and (2) of Table 1 present summary statistics for our sample of assembly and teardown parcels, respectively, while column (3) displays the mean difference between these types of parcels. Assemblies and teardowns differ on all observable dimensions, a potential problem for our first test given its requirement that assemblies and teardowns be comparable on all unobserved determinants of price other than assembly status. While we could control for these covariates in equation (4), the systematic differences raise the

[16] Although we observe an exact date for the sale, we observe only the year for teardown or assembly.

possibility that assembly and teardown parcels differ on unobserved dimensions.

Column (4), however, presents regression-adjusted mean differences conditioned on census tract fixed effects.[17] In this and all following regressions, we report standard errors clustered at the tract level. With the comparison between the two parcel types made only within small neighborhoods, differences are very small and imprecise. The notable exception is the probability of being a single family parcel. Overall, we view the results of column (4) as supportive of our identification strategy which relies on geographic fixed effects to control for unobservable differences between the two types of parcels. The right half of the table repeats this exercise for neighborhood demographic variables which are expressed as the level difference between 1990 and 2000 values. The same pattern of no difference conditional on tract-level fixed effects holds.

Given the results in Table 1, we take care below to address the difference in single family status. Most specifications include a control for use type. We also present specifications that restrict the sample to only single family parcels or non-residential parcels to make the teardowns and assemblies as comparable as possible.

Table (2) presents the results for our first test (in a competitive equilibrium, the price of teardowns and assembly parels should equate), implemented by estimating equation (4) on the panel of teardowns and assemblies. The coefficient estimate in column (1) indicates that being in an assembly is associated with an almost 65 percent sales price premium relative to being sold for redevelopment without a change in parcel boundaries. The extremely large magnitude of the assembly surplus suggests substantial frictions in the market for assembly.

Columns (2) - (4) present alternative specifications. Column (2) addresses within neighborhood variation by adding neighborhood demographic controls at the block group level and controls for local amenities. Column (3) further addresses intra-neighborhood variation

[17]The demographic characteristics, such as the poverty rate, are from the census and are measured at the block group level. The census tracts in the sample on Table 1 have an average of 2.5 block groups within them.

by controlling for very finely grained neighborhood effects. Instead of tract fixed effects, we use block group fixed effects. Column (4) controls for the evolution in price specific to each tract by using tract fixed effects and tract-level linear trend terms. Regardless of specification, the magnitude of the surplus estimate falls only slightly.

The remaining columns use different subsets of the sample. Column (5) includes assemblies only if we observe that the existing capital is torn down and replaced with new capital following assembly. It is possible that assemblies may occur with the aim of redeveloping at some point in the future, not immediately. If so, the sales price of the to-be-assembled parcels reflects the return to any existing capital over the period before redevelopment. Such a scenario would bias our surplus estimates upward. In this case, estimates in Columns (1) to (4) should be interpreted as upper bounds.

However, we can identify assemblies that lead to immediate new construction. Due to the nature of our data, we under-identify these parcels. For a given assembly, pre-assembly, we observe attributes for one structure per parcel, though a parcel may, in fact, contain more than one parcel. For each parcel change group before assembly, we find the minimum and maximum of the age of the structure on each parcel: $\max(age_{c,before})$ and $\min(age_{c,before})$ (c indicates a parcel change group). We observe similar ages post-assembly: $\max(age_{c,after})$ and $\min(age_{c,,after})$. We define parcels as being assembly teardowns only if $\max(age_{c,before}) < \min(age_{c,after})$. This is likely too restrictive, so we interpret results from this sample as lower bound estimates of the surplus. Though these results are smaller, the magnitude is similar to the unrestricted sample.

To address the concern that assembled parcels are systematically less likely to be single family than are teardowns, Columns (6) and (7) restrict the sample to single family parcels only. The results increase in magnitude somewhat. Columns (8) and (9) restrict the sample to non-residential properties only and report estimates similar to that produced by the full sample.

5.2 Second Test: The Influence of Lot Size on the Probability of Assembly

Our second test states that in an efficient market, developers should prefer to assemble larger parcels. Table 3 presents the results for this second test, implemented by estimating equation (5) on the 1999 cross-section of all parcels.[18] The coefficient in column (1) indicates that a 10 percent increase in the size of a parcel increases the probability of ever being assembled by 0.1 percent. This is a large effect, equal to 10 percent of the sample mean probability of ever assembling (see the bottom row of the table). The estimate can also be interpreted as indicating that the elasticity of the probability of assembly with respect to lot size is roughly 1.

Columns (2) - (4) present specification permutations which result in very little change in the lot size coefficient. In column (2), the estimates are robust to conditioning on the extremely finely grained block group fixed-effect. To better purge intra-neighborhood variation, Columns (3) and (4) add parcel- and neighborhood-specific covariates. Parcel-specific covariates are dummies for use type (four categories), the improvement to land ratio (from 1999 reported assessed values for each) and the distance to key amenities as above. The improvement to land ratio is measured with error, as Proposition 13 caps increases in assessed values to 2 percent per year until sale. Neighborhood demographics are as in the first test. As neighborhood demographics are observed at the block group level, we omit them in all specifications with block group fixed effects.

Across specifications, and despite the fact that the model argues that the surplus to assembly is largest for small parcels, large parcels are more likely to assemble. Thus, this evidence is consistent with the theory that holdouts and strategic delay impede the market for assembly.

[18]Summary statistics for this sample are in Appendix Table 1.

The $K\ vintage_i * K\ quantity_i$ terms (full interactions of decile dummies for structure size per lot square foot and structure age) are not included in columns (1) - (4). We are interested in results conditional on these variables, because they are a relatively non-parametric method of capturing the quantity and quality of capital per parcel. Including these terms, which are not available for all parcels, truncates the sample. For comparison purposes, columns (5) and (6) replicate columns (3) and (4) using the truncated sample without adding the $K\ vintage_i * K\ quantity_i$ terms. Although around one-third of the assemblies are lost from the sample – see the bottom row – the lot size coefficient is essentially unchanged. Columns (7) and (8) add in the $K\ vintage_i * K\ quantity_i$ terms and again the coefficient is little altered.

Table 4 presents robustness checks based on columns (7) and (8) of Table 3. To examine whether effects differ by initial use, consistent with the concern raised in Table 1, columns (1) and (2) restrict the sample to only single family parcels, while columns (3) and (4) restrict the sample to only non-residential parcels. The marginal effect of lot size on the likelihood of assembly is remarkable consistent across these use categories. The remaining columns exclude the least dense block groups in order to ensure our results are driven by outcomes in a dense urban setting. The parcels excluded are generally located in outlying areas of the county where land subdivision and new development, as opposed to assembly and redevelopment, are likely more prevalent. Again, the results are little changed.

5.3 Third Test: Influence of Lot Size on Price of To-Be-Assembled Parcels

Given our finding that the amount of land assembly is inefficiently low, we now move to our third test: in an efficient equilibrium, small parcels should not sell into assembly at a premium. Table 5 presents the results for this third test, implemented by estimating equation (6) on the panel of parcels ever involved in an assembly and for which we observe a sale either in the year of or in the three years prior to the assembly. Column (1) includes all use types, while columns (2) and (3) restrict the sample to single family and non-residential. The results indicate that a 10 percent increase in parcel size reduces the sales price of a to-be-assembled parcel by roughly 9 to 10 percent. Alternatively, the results suggest an elasticity of price with respect to lot size of around 1. The substantial premium to small parcels supports the hypothesis that owners of small parcels of land tend to hold out and demand higher than average prices for their land – behavior which works to reduce the number of successful assemblies.

6 Conclusion

In sum, the evidence offers a robust rejection of the conjecture that the market for land assembly functions efficiently. This rejection occurs despite the fact that land ownership is clearly defined, a precondition for an efficient transaction. Our evidence on the premium paid to small parcels suggests that at least part of this inefficiency is due to private market failures, and not to governmental regulation of land. These findings speak to the workings of land value taxation, the literature on the regulatory tax, and the historiography of urban renewal.

Rejecting the efficiency of land assembly means that the price of land sold for assembly is not the "true" competitive market price. This calls into question the literal base of land value taxation. Within a jurisdiction, this excess price for assembled land means that assembled land pays a larger share of the jurisdiction's tax revenue, further lowering the likelihood of land assembly. The excess price also means that the efficiency of land value taxation is also called into question.

Glaeser and Gyourko (2002) and Glaeser et al. (2005), and a following literature, defines the regulatory tax as the difference between the competitive market price for land and the observed price for land. It then attributes this difference to market failures due to government regulation. This paper points out that the wedge between the competitive and observed prices contains – at least in the case of parcels purchased for assembly, which we know to be a non-trivial amount of new construction – the effects of both public and private market failures. Thus, this methodology may overstate the impact of the regulatory tax. In future work, we hope to examine the role of public market constraints on the likelihood of assembly.

If land assembly indeed operates as inefficiently as we suggest in this work, it is natural to look to government for remediation. The most recent large-scale government action to assemble land is what is known as "urban renewal," a process in the United States, Canada and in some parts of Europe in the 1960s and 70s. Urban renewal used the government's power of eminent domain to assemble small parcels of land, predominantly in the urban core. While readers may associate renewal with tall towers of public housing, this was not its predominant output. Urban renewal generated substantial high and middle income housing, as well as non-residential construction. Copley Place in Boston, and the "new downtown" atop Bunker Hill in Los Angeles are both examples of urban renewal. Urban renewal ended amid charges of developer cronyism and racism, and has largely been judged harshly by historians (Cord, 1974). Our results suggest that urban renewal may have been a bad but best solution to a very difficult problem.

References

Angrist, Joshua and Pischke, Jorn-Steffen, 2009. *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton: Princeton University Press.

Asami, Y., 1988. "A game-theoretic approach to the division of profits from economic land development." *Regional Science and Urban Economics* 18: 233–246.

Bogart, Dan and Richardson, Gary, 2009. "Making property productive: reorganizing rights to real and equitable estates in Britain, 1660-1830." *European Review of Economic History* 13: 3–30.

Brownstone, David and DeVany, Arthur, 1991. "Zoning, Returns to Scale, and the Value of Undeveloped Land." *Review of Economics and Statistics* 73(4): 699–704.

Cadigan, John, Schmitt, Pamela, Shupp, Robert, and Swope, Kurtis, 2010. "The Holdout Problem and Urban Sprawl: Experimental Evidence."

Cameron, A. Colin and Travedi, Pravin K., 2005. *Microeconometrics: Methods and Applications*. Cambridge: Cambridge University Press.

Colwell, Peter and Sirmans, C. F., 1993. "A Comment on Zoning, Returns to Scale and the Value of Undeveloped Land." *Review of Economics and Statistics* 75(4): 783–786.

Colwell, Peter F. and Munneke, Henry J., 1997. "The structure of urban land prices." *Journal of Urban Economics* 14: 321–336.

Colwell, Peter F. and Munneke, Henry J., 1999. "Land Prices and Land Assembly in the CBD." *Journal of Real Estate Finance and Economics* 18(2): 163–180.

Cord, Steven, 1974. "Urban Renewal: Boon or Boondoggle?" *American Journal of Economics and Sociology* 33(2): 184–186.

Cunningham, Christopher, 2010. "Estimating the holdout problem in land assembly." Federal Reserve Bank of Atlanta Working Paper.

Dye, Richard F. and McMillen, Daniel P., 2007. "Teardowns and land values in the Chicago metropolitan area." *Journal of Urban Economics* 61: 45–63.

Eckart, Wolfgang, 1985. "On The land assembly problem." *Journal of Urban Economics* 18: 364–378.

Field, Alexander James, 1992. "Uncontrolled Land Development and the duration of the Depression in the United States." *Journal of Economic History* 52(4): 785–805.

Fu, Daniel P. McMillen, Yuming and Somerville, Tsur, 2002. "Land Assembly: Measuring Holdup." University of British Columbia Centre for Urban Economics Working Paper 02-08.

Glaeser, Edward and Gyourko, Joseph, 2002. "The Impact of Zoning on Housing Affordability." NBER Working Paper No. 8835.

Glaeser, Edward, Gyourko, Joseph, and Saks, Raven, 2005. "Why is Manhattan so Expensive? Regulation and the Rise in Housing Prices." *Journal of Law and Economics* XLVIII: 331–369.

Grossman, Zachary, Pincus, Jonathan, and Shapiro, Perry, 2010. "A Second-Best Mechanism for Land Assembly."

Harding, John P., Rosenthal, Stuart, and Sirmans, C. F., 2003. "Estimating Bargaining Power in the Market for Existing Homes." *Review of Economics and Statistics* 85(1): 178–188.

Henderson, J. Vernon, 1977. *Economic Theory and the Cities*. New York: Academic Press.

Jacobs, Jane, 1961. *The Death and Life of Great American Cities*. New York: Vintage Books.

Libecap, Gary D., Lueck, Dean, and O'Grady, Trevor, 2010. "Large Scale Institutional Changes: Land Demarcation Within the British Empire." NBER Working Paper No. 15820.

Menezes, Flavio and Pitchford, Rohan, 2004. "The land assembly problem revisited." *Regional Science and Urban Economics* 34: 155–162.

Miceli, Thomas and Segerson, Kathleen, 2007. "A bargaining model of holdouts and takings." *American Law and Economics Review* 9(1): 160–174.

Miceli, Thomas J and Sirmans, C. F., 2007. "The holdout problem, urban sprawl, and eminent Domain." *Journal of Housing Economics* 16: 209–219.

Munch, Patricia, 1976. "An Economic Analysis of Eminent Domain." *Journal of Political Economy* 84(3): 473–497.

Nelson, Arthur and Lang, Robert, 2007. "The Next 100 million." *Planning* 73(1): 4–6.

O'Flaherty, Brendan, 1994. "Land Assembly and Urban Renewal." *Regional Science and Urban Economics* 24: 284–300.

Rosenthal, Jean-Laurent, 1990. "The Development of Irrigation in Provence, 1700-1860: The French Revolution and Economic Growth." *Journal of Economic History* 50(3): 615–638.

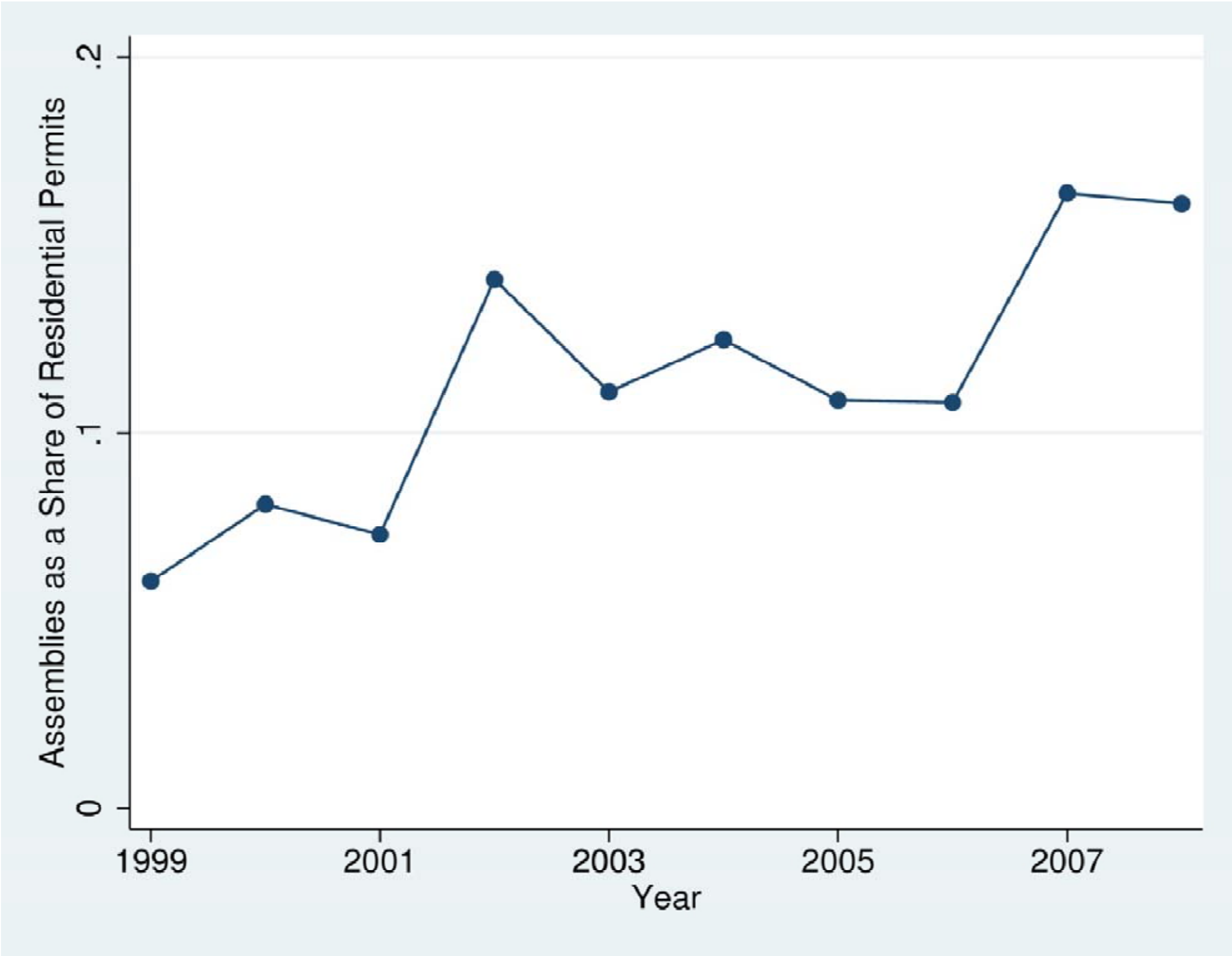
Rosenthal, Stuart and Helsley, Robert W., 1994. "Redevelopment and the Urban Land Price Gradient." *Journal of Urban Economics* 35: 182–200.

Shigley, Paul, 2007. "Round 3 for eminent domain." *Planning* 73(3): 11–15.

Shoup, Donald, 2008. "Graduated Density Zoning." *Journal of Planning Education and Research* 28(2): 161–179.

Strange, William C., 1995. "Information, Holdouts and Land Assembly." *Journal of Urban Economics* 38: 317–332.

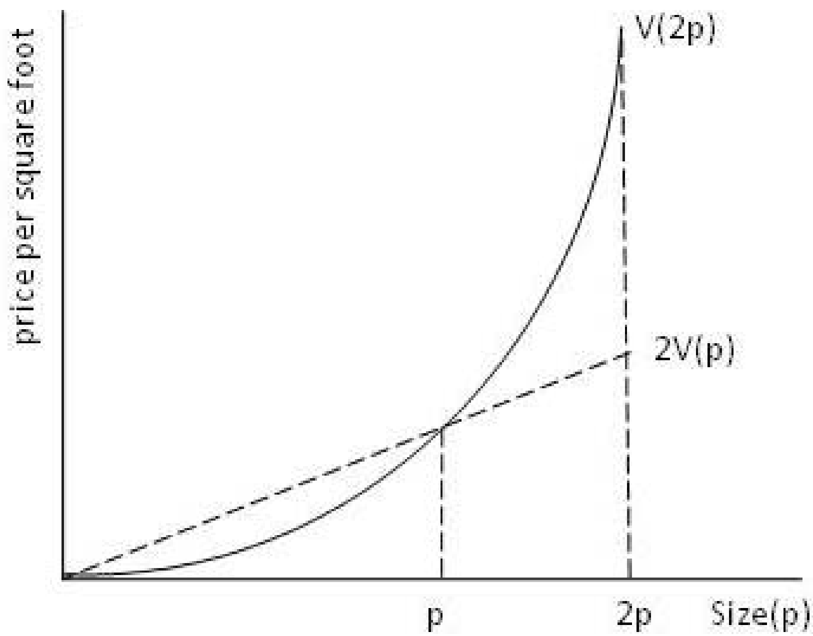
Figure 1: Ratio of Assemblies to Permits



Sources: Permit data from Census Bureau, assemblies calculated from authors' dataset. See Data Appendix for details.

Notes: While the Census Bureau counts one permit for each new unit, one assembly (in our terms) may result in more than one unit. This means that our measure in the chart understates the importance of assembly. However, the Census Bureau counts residential permits only, while our measure of assemblies includes assemblies that result in non-residential construction. This leads to this measure overstating the importance of assembly. Because we do not have a cross-section of properties from 2003, we all assemblies in 2002 and 2003 are attributed to 2002; for the purposes of this chart, we split the assemblies in 2002 evenly between 2002 and 2003. Though our assembly information continues through 2010, this chart ends in 2008 when our permit data ends.

Figure 2: Price Per Square Foot is Convex in Lot Size



Notes: This picture shows that the price per square foot of land increases with lot size at an increasing rate.

Table 1: Summary Statistics for Price Analysis

	Levels				Change from 1990 to 2000			
	Assembled	Teardown	Difference	Difference conditional on tract FE	Assembled	Teardown	Difference	Difference conditional on tract FE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Price per square foot	359.407	112.538	246.869	n/a	n/a	n/a	n/a	n/a
	[899.491]	[160.084]	(11.388)***					
Single family	0.279	0.647	-0.368	-0.241	n/a	n/a	n/a	n/a
	[0.449]	[0.478]	(0.012)***	(0.034)***				
Poverty rate	0.103	0.115	-0.012	0.004	0.736	0.584	0.152	0.075
	[0.124]	[0.119]	(0.003)***	(0.005)	[2.404]	[2.808]	(0.074)**	(0.119)
Neighborhood share	0.056	0.059	-0.004	0.004	0.971	0.393	0.578	0.025
Black	[0.089]	[0.120]	(0.003)***	(0.003)	[2.494]	[1.894]	(0.060)***	(0.092)
Neighborhood share	0.259	0.244	0.015	-0.002	0.599	0.354	0.246	0.019
Hispanic	[0.254]	[0.266]	(0.007)**	(0.008)	[1.623]	[1.117]	(0.033)***	(0.061)
Share housing units	0.050	0.046	0.004	0.003	-0.031	-0.121	0.091	0.069
vacant	[0.072]	[0.048]	(0.001)***	(0.004)	[1.260]	[1.173]	(0.033)***	(0.061)
Share housing units	0.715	0.621	0.094	-0.021	8.225	4.288	3.937	0.498
owner-occupied	[0.282]	[0.264]	(0.0070)***	(0.015)	[20.929]	[13.009]	(0.402)***	(0.662)
Observations	2,079	6,892	8,971	8,971	1,695	6,687	8,382	8,382

Sources: See Data Appendix for complete information.
Notes: Columns (1), (2), (5) and (6) present means. Columns (3) and (7) present equality of means test for the means presented in columns (1) and (2), and (5) and (6), respectively. Columns (4) and (8) present coefficient estimates from a regression of the variable in the row on an indicator variable for assembly and a set of census tract fixed-effects. [] denotes standard deviation and () denotes standard error. Significance levels are denoted by *** for significant at the 1% level, ** for significant at the 5% level, and * for significant at the 10% level.

Table 2: Excess Value of Land in Assembly

	Full Sample					Single Family		Non-Residential	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1 if Parcel is in an assembly	0.638	0.550	0.532	0.534	0.484	0.782	0.808	0.581	0.501
	(0.123)***	(0.115)***	(0.125)***	(0.134)***	(0.149)***	(0.132)***	(0.141)***	(0.208)***	(0.154)***
Observations	8,123	7,645	8,123	8,123	6,193	5,026	4,898	3,097	2,747
Geographic Fixed Effects									
Tract	X	X		X	X	X	X	X	X
Block Group			X						
Additional Covariates									
Year-Quarter of Sale	X	X	X	X	X	X	X	X	X
Use Classifications	X	X	X	X	X	X	X	X	X
Cubic in Lot Size	X	X	X	X	X	X	X	X	X
Neighborhood Demographics		X			X		X		X
Distance to Key Amenities		X			X		X		X
Linear Tract Trends				X					
Assembly Teardowns					X				

Sources: See Data Appendix for complete information.
Notes: The dependent variable in these regressions is log(real sales price per square foot). () denotes standard error. Significance levels are denoted by *** for significant at the 1% level, ** for significant at the 5% level, and * for significant at the 10% level. Neighborhood demographics, obtained from the census, include the following variables in both 2000 level form and as changes between 1990 and 2000 levels: poverty rate, neighborhood share black, neighborhood share hispanic, share of housing units vacant and share of housing units owner-occupied. Use classifications include indicator variables for: single family, non-condo multi-family, condo, vacant and other. Distance to key amenities include measures for the shortest distance from each parcel to three amenities: a highway entrance or exit, a metrolink stop (commuter rail), and a metrorail stop (subway or light rail).

Table 3: Impact of Lot Size on Likelihood of Assembly

	Biggest Possible Sample		Biggest Possible Sample		Sample with full information		Sample with full information	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(Lot Size)	0.0123	0.013	0.0109	0.0119	0.0108	0.0116	0.0097	0.0104
	(0.0012)***	(0.0012)***	(0.0016)***	(0.0016)***	(0.0013)***	(0.0013)***	(0.0012)***	(0.0012)***
Geographic Fixed Effects								
Tract	x		x		x		x	
Block Group		x		x		x		x
Additional Covariates								
Use Classification			x	x	x	x	x	x
Improvement/Land Ratio			x	x	x	x	x	x
Neighborhood Demographics			x		x		x	
Distance to key amenities			x	x	x	x	x	x
Full interaction of year built and structure/lot size decile dummies							x	x
R-squared	0.082	0.100	0.110	0.127	0.082	0.101	0.086	0.105
Observations	2,155,932	2,155,932	2,155,932	2,155,932	1,993,303	1,993,303	1,993,300	1,993,303
Share Ever Assembled	0.012	0.012	0.012	0.012	0.008	0.008	0.008	0.008

Sources: See Data Appendix for complete information.
Notes: The dependent variable is 1 if the parcel is every engaged in assembly from 1999 to 2010, and zero otherwise; results are estimated via OLS. The sample is all parcels that exist in 1999, and excludes public land as denoted by the parcel number. Use classification is as in Table 2. Improvement/land ratio is calculated with assessed values as of 1999. Census variables and amenities are as listed in the notes for Table 2. The “full interaction” is the interaction of indicators for decile of structure age with deciles of structure square feet divided by lot square feet.

Table 4: Robustness Results for Impact of Lot Size on Likelihood of Assembly

	By Use Type				Parcel is in a Block Group with Density is Greater Than			
	Single-Family Residential Only		Non-Residential Only		1st Percentile of Block Groups		10th Percentile of Block Groups	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(Lot Size)	0.0101	0.0109	0.014	0.0138	0.0097	0.0104	0.0077	0.0082
	(0.0016)***	(0.0016)***	(0.0019)***	(0.0016)***	(0.0012)***	(0.0012)***	(0.0009)***	(0.0009)***
Geographic Fixed Effects								
Tract	x		x		x		x	
Block Group		x		x		x		x
Additional Covariates	x	x	x	x	x	x	x	x
R-squared	0.057	0.078	0.203	0.265	0.086	0.105	0.079	0.093
Observations	1,389,272	1,389,272	148,411	148,414	1,993,300	1,993,303	1,759,088	1,759,091
Share Ever Assembled	0.005	0.005	0.052	0.052	0.008	0.008	0.006	0.006

Sources: See Data Appendix for complete information.
Notes: The dependent variable is 1 if the parcel is every engaged in assembly from 1999 to 2010, and zero otherwise; results are estimated via OLS. The sample is all parcels that exist in 1999, and excludes public land as denoted by the parcel number. All covariates are as in final column of the previous table. Results estimated when using the biggest possible sample and omitting controls for structure year built and structure square feet per lot square feet are very similar.

Table 5: Elasticity of Sales Prices with Respect to Lot Size

	Full Sample	Single Family	Non-Residential
	(1)	(2)	(3)
Log(lot size)	-0.865	-1.054	-0.910
	(0.093)***	(0.168)***	(0.085)***
Observations	2,042	568	1,474
Assembly Group FE	X	X	X
Year-Quarter of Sale	X	X	X
Use Classification	X		X

Sources: See Data Appendix for complete information.
Notes: The dependent variable in these regressions is log(real sales price per square foot). () denotes standard error. Significance levels are denoted by *** for significant at the 1% level, ** for significant at the 5% level, and * for significant at the 10% level.

Appendix Table 1: Summary Statistics for 1999 Cross-section

	Maximal Sample		Sample with full covariates	
	Ever Assembled	Never Assembled	Ever Assembled	Never Assembled
	(1)	(2)	(3)	(4)
Log(Lot Size)	9.728	8.912	9.667	8.783
	[1.569]	[1.093]	[1.393]	[0.848]
Improvement/Land Assessed Value	36.878	3.937	59.933	4.285
	[2156.9]	[864.9]	[2751]	[902.7]
1 if Single Family	0.257	0.643	0.400	0.699
	[0.437]	[0.479]	[0.49]	[0.459]
Structure Square Feet in 100,000s	0.080	0.027	0.121	0.029
	[0.421]	[0.149]	[0.514]	[0.155]
Year Structure Was Built	1960.0	1955.2	1960.4	1955.2
	[28.881]	[21.613]	[28.565]	[21.612]
Census 2000 Block Group Covariates				
Poverty Rate	0.128	0.135	0.133	0.134
	[0.124]	[0.113]	[0.129]	[0.113]
Share Black	0.068	0.086	0.072	0.088
	[0.119]	[0.162]	[0.122]	[0.166]
Share Hispanic	0.292	0.353	0.317	0.359
	[0.271]	[0.284]	[0.28]	[0.286]
Share Housing Units Vacant	0.050	0.043	0.046	0.038
	[0.062]	[0.053]	[0.053]	[0.037]
Share Housing Units	0.619	0.606	0.605	0.600
Owner-Occupied	[0.296]	[0.262]	[0.308]	[0.264]
Distances to Amenities				
Nearest Highway Entrance	1.741	1.637	1.342	1.272
or Exit	[2.907]	[2.683]	[1.771]	[1.573]
Nearest Subway or Light Rail	10.362	8.172	8.743	7.040
	[10.717]	[9.316]	[9.462]	[7.506]
Nearest Commuter Rail	5.919	6.195	5.552	5.929
	[4.891]	[4.982]	[4.414]	[4.703]
Observations	26,907	2,157,067	16,538	1,979,876

Sources: See Data Appendix.
Notes: [] denotes standard deviation. The "maximal sample" is the largest sample used for estimation in Table 3. The "sample with full covariates" is the sample where we observe structure square feet and age for all parcels.

Data Appendix

This appendix describes how we created the Los Angeles County parcel dataset. Section 1 describes the input datasets. Section 2 describes how we join these datasets, and reports statistics on the uncleaned data. Section 3 describes how we clean the joined dataset, and Section 4 reports statistics on the quality of the final dataset.

1 Data Sources

The basic unit of analysis is the parcel, which is an individual property as legally defined by the Los Angeles County Assessor and Recorder. In any year, there are roughly 2.3 million parcels in the County of Los Angeles. We rely on a number of different sources for information about parcels.

1.1 Parcel-Level Data

For detailed property information on parcels, we rely on data from three separate vendors: DataQuick, Applied Geodetics, and the Los Angeles County Assessor directly.

1.1.1 DataQuick: 1999 - 2002

Dataquick is a property information vendor. It purchases property information from the Los Angeles County Assessor to sell to real estate professionals. We rely on Dataquick data for 1999-2002, and data are reported as of January of each year.

As far as we can ascertain, the Dataquick data are a slightly modified version of the "Secured Basic File" that the Assessor prepares. Dataquick modifies the data from the original Los Angeles County format, and we re-modify it to be consistent with the two following datasets. We discuss modifications at length in Section 3. This data vendor is abbreviated in tables as DQ.

1.1.2 Applied Geodetics: 2004 - 2006

Applied Geodetics is a mapping firm in Los Angeles County. Applied Geodetics sold us data for 2004 (April), 2004 (February) and 2005 (May). To the best of our knowledge, these data are the unmodified Assessor's "Secured Basic File," which is the most complete record of property attributes available to the public from the Assessor. This data vendor is abbreviated in tables as AG.

1.1.3 Los Angeles County Assessor, Local Roll: 2007 - 2009

From 2007 through 2009, we have purchased data directly from the Assessor. Due to financial constraints we purchased the "Local Roll" database (roughly $400) instead of the "Secured Basic File" (roughly $13,000). The Local Roll has fewer parcel attributes than the Secured Basic File, and comes out annually in July. This data source is abbreviated in tables as LR.

1.1.4 Los Angeles County Assessor, Secured Basic File: 2010

In 2010, we purchased the Secured Basic File, which is the County's most complete publicly available dataset about properties. These data are from July 2010, and this data source is abbreviated in tables as SB.

1.2 Sales Data

1.2.1 Last Three Sales, 1980 to 2006

In 2006, Brooks purchased a file from the County Assessor that contains information on the last three transactions for each property in the county. For each transaction, we observe transaction type, sale amount (if applicable), and date of transaction.

1.2.2 Sales Within Two Years: 2008, 2009, and 2010 Files

In 2008, 2009, and 2010, we purchased additional lists of sales data from the County Assessor. These contain information on all transactions in the prior two years. For each transaction, we observe transaction type, sale amount (if applicable), and date of transaction.

These files leave a small gap from May through December 2006 which we have not been able to obtain.

1.3 Parcel Change Database

At our request, the Assessor made a special file that includes all parcel changes from July 1999 January 2009. Specifically, for each change, this file includes the old parcel number(s), the new parcel number(s), and the effective date of the change. The County has electronic records for parcel changes starting in July 1999 and continuing to the end of our data.

This change database allows us to isolate land assembly and disassembly. The California Assessor's Handbook mentions only one reason for a parcel number to change: if the physical boundaries of a parcel are modified (California State Board of Equalization, 1997, page 26).

We purchased this change database again in July 2009 and 2010 (covering all changes in the past two years) to allow us to link all later parcels with previous parcels.

1.4 Digital Parcel Maps

For each year since 2006, we have an electronic map of all parcels that exist in that year. These maps have a boundary (a polygon) for each individual parcel. For each parcel, we use ArcGIS to calculate the x- and y-coordinates (latitude and longitude) of the polygon's geographic center (centroid).

1.5 Census Tract and Block Group Indentification

The Census provides census tract and block group boundaries in shapefile format online.[1] We use ArcGIS to intersect the 2000 census boundaries and the 2006 parcel boundaries to assign each parcel to a census block group.

The majority – 96% – of ever-existing parcels have block group identifiers.

1.6 Block Group Data

We use block group level data from the 2000 Decennial Census (ICPSR file 13346, summary level 150), and from the 1990 Decennial Census (ICPSR 9782, summary level 150, but California file is damaged so we used a similar file downloaded from UCLA ATS).

We use ArcGIS and the Census's electronic maps to make a linkage between 1990 and 2000-based block groups, where relationships are based on land area overlap.

1.7 Assorted Non-Parcel Digital Maps

- Parks: Information from 2008 ESRI files of local and national parks for California
  - parks displayed on maps are only those more than 1.25 square miles
- Freeways: Data from State of California Cal-Atlas Geospatial Clearinghouse
  - website is http://www.atlas.ca.gov/download.html
  - transportation → Census 2000 → state_highways.* and us_highways.*
- Freeway Entrances and Exits
  - Tele-Atlas US Data, contains federal interstate highway entrances and exits
- Coastline
  - layer of points every 1000 feet along LA County coastline
  - created by taking Census 2000 county map and deleting non-coastline portions
  - used X-tools feature to points to convert coastline line to points

[1] Files are at http://www.census.gov/geo/www/cob/bdy_files.html.

- Metrolink Stations
  - Commuter rail stations
  - File received from Javier Minjares, Southern California Association of Governments, 2010
- Metro Rail Stations
  - Intra-urban rail stations
  - File received from Javier Minjares, Southern California Association of Governments, 2010
- Major Roads
  - Tele-Atlas US Data, version 9.3
  - Major roads only

2 Initial Data Linking

Each parcel is identified by a 10-digit number: MMMM-PPP-XXX. The first four digits are the "map book" number – literally the number of the "book" in which the parcel appears. The second three digits are the map book page. Each map book page contains a set of geographically contigious parcels. The last three digits identify individual parcels on the map book page.

We began the data assembly by attempting to link all the annual cross-sections described above (1999-2009, without the missing 2003) using the parcel change database. Panel A of Table 1 presents the results of this original linkage. Slightly fewer than 2 million parcels never change their number throughout the sample (column 2). Column 3 reports the number of ever-changing parcels; this number varies by year as a changer could be 3 parcels in 1999, but 12 (or 1) parcels in 2009. The number of changes in any given year varies from 28,996 to 58,557. Column 4 reports the number of parcels that exist in this year of the sample, but not in all years of the sample. Column 4 shows a striking number of parcels that exist after 2004, but not before. These missing, or "phantom," observations are due to DataQuick editing. We discuss how we deal with these discrepancies in the next section.

We also analyze the total amount of land area, measured in square feet, in each category as a check on our data assembly process. We report annual totals in Panel B of Table 1. Columns 2 through 4 report the total amount of parcel square footage in each of the parcel assembly categories by year. Sadly, for 2004 and 2005 we do not observe parcel size in the data. It is very clear that across all categories, but particularly in the "phantom" category, that the total land area is drastically smaller in the earlier data source (DataQuick). The California Department of Water Resources measures the total land area of Los Angeles County as 132,487,077,888 square feet, which is clearly much closer to the later data source (143 billion square feet) than the earlier one (22 billion square feet).[2]

Table 2 shows the total number of parcels (Panel A) and total land area (Panel B) by four categories of use types and by year. The Assessor assigns each property a "use code" that describes how the property is currently used (as distinct from how it is zoned). We use this code to make four major categories of use: single-family, multi-family, vacant, and other. The number of vacant parcels by year (column 4) shows a large break concomitant with the break in data sources, and similar to the break for the "phantom" parcels of the previous table.[3] The bottom panel of the table shows that this discrepancy appears across types.

3 Cleaning and Consistency Changes

This section details the work we did to make the property data consistent across data sources and time. The main issues in cleaning the data were how to give a measure of land area to

[2]Parcels cover all land and water area of the county with the exception of public roadways. We discuss later how the latter datasets "overcount" the county's land area.

[3]Vacant parcels may be coded vacant residential, vacant commercial, or simply vacant. "Vacant" appears to refer to habitation or use, and not to the presence of structures.

parcels in 2004 and 2005, how to count the land area of parcels that were vertically stacked, how to account for parcels present in later years and missing in the earlier years, how to account for lack of consistency between the change database and the cross-sectional data, how to deal with reported changes in lot size for parcels that do not change, how to deal with consistently reporting land area for parcels that make complicated changes, and how to impute geographic information for parcels pre-dating our electronic maps.

3.1 Defining the Parcel Group

For ease of analysis, we define a "parcel group" to include all parcels linked by a change. For example, consider a change where parcels A and B combine to C, parcel C splits to D and E, and E splits to F and G. All parcels A through G would have one parcel group. We create a unique identifer for each group.

3.2 No Observation of Land Area in 2004 and 2005

The data source we use for 2004 and 2005 does not contain information on parcel land area. We assume that all 2004 parcels existing in 2002 have the same land area that they did in 2002, and all 2005 parcels existing in 2006 have the same land area they will have in 2006. These are very reasonable assumptions, as lot size changes only when parcel number does. As we describe in greater detail below, we use a variety of methods to evaluate and clean lot size across time.

If a 2004 or 2005 parcel is also missing lot size information in 2002 or 2006, we take lot size from the closest year for which it is available.

3.3 Vertically Stacked Parcels

The assessor draws the boundary for a piece of land with multiple owners, such as a condominium, so that each owner's parcel has the land area of the entire lot. This type of separate ownership of the same piece of land is distinct from joint ownership of a single property. Condominium-type ownership parcels are "stacked" vertically on the Assessor's map, in the same way you would stack checkers. In this case, think of each checker as the condominium of an individual owner. A 100-unit condominium will consist of 100 parcels, one for each legally distinct unit of ownership. Stacked parcels are usually, but not always, condominiums.

In the DataQuick data, the land area of each condominium unit is the land area of the lot divided by the number of parcels covering that lot. In the remaining datasets, when units and parcels are co-terminous, each unit is assigned the land area of the entire lot. This leads to much of the discrepancy in land area between the 1999 to 2002 and 2003 to 2010 periods in Tables 1 and 2. We correct for this problem by modifying all parcels to have a land area consistent with the method in the DataQuick data (land area of a parcel = total land area of parcel / number of parcels occupying that lot). We prefer this method of measuring land area because the net land area remains unchanged even if one parcel becomes three condos. The method used in the later datasets suggests that the total land area of the county increases when condominiums are created.

We identify vertically stacked parcels by calculating the centroid of every parcel on each map we have (annual maps, 2006-2010). In any given year, all parcels that share the same x- and y-coordinates are "stacked," and their land area requires correction. On average, a map-year has 250,562 unique parcels that are stacked, 14,400 stacks, and a mean of 17 parcels per stack. Unfortunately, we do not have maps for years before 2006, so this correction is incomplete for 2004 and 2005. Specifically, we can correct all stacked parcels that exist in 2004 and 2005 and which continue to exist in 2006. We cannot correct stacked parcels that exist in 2004 or 2005 and not in 2006.

3.4 "Phantom" Parcels

The third data challenge we faced was the presence of parcels that did not appear in all years, and the disappearance of which could not be explained by any observation in the parcel change database. We call these appearing and disappearing parcels "phantoms."

Table 1 suggests that the DataQuick data do not include all parcels that exist in the county. We strongly suspect that, in an effort to satisfy customers primarily interested in residential (or at least tradeable property) property, DataQuick deletes parcels that will not be transacted.

Table 3 describes the appearance of phantoms across the years of the dataset. The horizontal axis has one column for each year of the dataset. The vertical axis has one row for each year of phantom non-appearance. The (1999,2000) cell says that 516 parcels that exist in the 1999 dataset do not exist in the 2000 dataset and are not accounted for by any parcel changes. The diagonal axis is by definition zero, since a parcel cannot be missing in the year in which it exists. The clear and striking pattern in this table is that the vast majority of phantom parcels are missing in in the years 1999 to 2002, and come from datasets in years 2004 to 2010.

To resolve this problem, we say that any parcel that ever exists in the dataset is a "true" parcel. Because these parcels are not in the change database, we assume that their shape is constant over the period of interest and that they exist in all years. Roughly 200,000 of these parcels truly exist from 2004 to 2010 and do not appear from 1999 to 2002. Only about 20,000 parcels appear from 1999 to 2002 and not from 2004 to 2010. Were we not to make this adjustment, we would have an severely unbalanced panel, and the early years of the panel would not account for a substantial amount of the land area of the County.

3.5 Relating Parcel Change to Parcel Cross-sectional Databases

We use the assessor's parcel change database to link parcels across years. The assessor reports on changes of four types: one to many, one to one, many to one, zero to one and one to zero. These last two changes (zero to one and one to zero) are the least frequent of all change types. They are used to move land in and out of the county. Land in use by roads does not have parcels, so the addition of a road from existing land could cause a zero to one change. A one to zero change could occur when a parcel becomes part of a road.

Table 4 reports on the quality of the match between the datasets. Across all years, we are able to match 89 percent of parcels in the change database with parcels in the cross-sectional databases (column 9). The table reports statistics for all changing parcels, and by change type. Columns 2 and 3 show that more parcels enter the county than leave over the period, according to the change database. Columns 4 and 5 report the number of parcels from the change database that find a match in the cross-sectional database, and shows whether these parcels are entering or leaving the county. Columns 7 through 10 report the share of parcels from the change database that find a match in the cross sectional databases.

Panel B reports these same statistics for a later year in the sample. In general, match rates between the parcel match dataset and the cross-sectional datasets improve over time, but fall off in the final year. In the final year, all new parcels may not yet have appeared in the cross-sectional dataset. This seems reasonable, as column 10 tells us that it takes an average of a year from the date of appearance in the change database for the new parcel to appear in the cross-sectional data.

To give a specific date to a parcel change, we must make a choice. We decided that in cases where the parcel change database and the cross-sectional databases did not agree, we would defer to the change database. The change database records an administrative, or policy change, while the cross-sectional data more likely reflects what is actually physically changing. Since we are most interested in policy choices regarding land use, the date of the decision to change a parcel seemed more relevant than the physical change itself.

3.6 Reported Changes in Land Area for Non-Changing Parcels

We check the internal consistency of the data by examining whether there are changes in land area for parcels that do not change identification number across the years of the sample. By construction, such parcels should have the same land area for all years of the sample. For each parcel, we calculate the percentage difference between the largest land area and the smallest land area reported (relative to the mean lot size of the entire period). The median change is 0.7 percent, but changes at the ninetieth percentile and above can be quite large.

Given this, we make two of adjustments to clean the land area variable. First, if a parcel's land area changes by less than 20 percent from 1999 to 2010, we give the parcel the 2010 land area value for each year. We rely on data from the later years of the sample because by all measures we describe here it is more reliable than the DataQuick data. This change modifies the values for virtually all of the parcels that remain in the dataset. Of the modified parcels, slightly more than 20 percent of them have very minor differences of less than 0.1 percent, which seem to be due to rounding differences between the different datasets. Another 61 percent have differences between 0.1 and 5 percent of land area over time, and the remaining 18 percent have differences of between 5 and 20 percent.

The second adjustment to clean the land area variable uses the same rule to clean parcels that are vertically stacked (if the percentage change in land area for the same parcel is less than 20 percent, replace the area for all years with the 2009 value).

Finally, we delete 109,923 unique parcels, between 2 and 4 percent of the observations in each cross-section, that have land area changes of more than 20 percent, or which have always-missing values for land area. These parcels account for roughly three percent of each cross-section

3.7 Land Area Adjustments for Parcel Changes

When parcels change, the total lot initial lot size of changing parcels should equal the final total lot size of the changing parcels. Unfortunately, this is not always the case.

For example, if one parcel changes number and becomes only one new parcel, the parcel's geographic area does not change by construction. However, due to dataset breaks and other inconsistencies, differences in lot size sometimes appear. These create inconsistencies in geographical areas over time that do not reflect actual changes to parcels.

We resolve this problem by inflating or deflating each parcel's lot size so that the total lot size for parcels that change is the same for each year of data. Let g be the parcel group, which is all parcels ever associated with a given change. The adjustment is

$$\text{lot size}_{i,g,t} = \text{reported lot size}_{i,t} * \frac{\text{average total lot size}_g}{\text{total lot size}_{g,t}}.$$

The final value for parcel i in year t ($\text{lot size}_{i,t}$) is equal to parcel i's reported square footage in year t ($\text{reported lot size}_{i,t}$) multiplied by the ratio of the average of the parcel group's total square feet ($\text{average total lot size}_g$) divided by the current year total square feet ($\text{total lot size}_{g,t}$). By adjusting at the parcel group level, this method allows us to account for both simple and very complex changes.

The result of this adjustment is that each parcel group has a constant lot square footage. This better reflects the reality of a parcel change. Square footage at the beginning should equal square footage at the end, regardless of how the land is parceled.

3.8 Missing Values for Parcel Attributes

In addition to the work with lot square feet that we do above, we fill in missing values for parcel attributes to a limited extent. For non-geographic information, we edit parcels that do not change number, and for which a later observation of the parcel exists. In these cases, we attribute the later parcel characteristics to the earlier parcel if the structure on the parcel was built before the year of the data. For example, imagine parcel A exists from 1999 to 2009, but we observe attributes starting only in 2005. If the structure on parcel A was built in 1995, we fill in the missing values for parcel A from 1999 through 2004 with the 2005 values. If the structure on parcel A was built built in 2005, we do not fill in missing values (save lot square footage as described above).

Geographic identifying information – tract and block group information, and latitude and longitude information – come from merging the panel data with information generated from electronic maps. We have these electronic maps starting only in 2006. For parcels that do not change, the physical border has not changed and therefore the 2006 geographic information is still valid.

For for parcels that existed before 2006 and not afterward we impute geographic information. This is relatively straightforward. For parcels that change, we assign old parcels to the same block group or tract as the later-existing parcels (no parcel change groups cross block groups). For the latitude and longitude, we give the old parcels the average of the latitude and longitude of the later-existing parcels. This should be a very close approximation to the actual location.

For parcels that do not have a block group through these methods (changing or not), we interpolate to find the block group. Specifically, if a parcel is missing a block group, we assign the parcel to have the block group of all other parcels on that map book page. A map book page is identifiable by the first seven digits of the parcel number. Map book pages have very few parcels and very rarely cross block group boundaries.

3.9 Preparing Sales Data

To prepare the sales data, we restrict our analysis to arms-length transactions. We drop sales with dates not on any calendar (e.g., day 45; this is a problem only for the 2006 dataset), sales with values of 10 or less (which the assessor uses as a special code for adjoining pools or structures), and sale amounts equal to 999,999,999. Because data appear to be collected electronically only from 1964 onward, we drop sales before 1964. We keep only one observation if the data report two sales on the same day of the same amount. A small share of observations have two sales on the same day of differing amounts. In this case, we drop both observations.

4 Cleaning and Consistency Results

Tables 5 and 6 present the results of the data cleaning. In the first of these tables, Panel A shows that the overall pattern of the number of parcels over time no longer exhibits any breaks when we change data sources. The number of phantom parcels and never-changing parcels is now consistent across all years. The number of changing parcels increases over time: there are roughly 30,000 of these parcels in 1999 and 55,000 of them in 2010. This means that, on net, more parcels have split than merged. Panel B shows that this increase is not driven by substantial changes in land area. This table no longer shows discontinuous patterns across dataset breaks.

Panel A of Table 6 shows that, from 1999 to 2009, the number of single- and multi-family parcels increased, while the number of vacant and "other" parcels decreased. This pattern holds for land area as well, as shown in Panel B, though the percentage changes are not as large. As in the previous table, these results no longer show sharp discontinuities related to dataset breaks. Total land area increases over time, since individually-owned properties in condominiums are separately parceled, and each parcel contains the lot size of the entire lot.

References

California State Board of Equalization, 1997. "Assessor's Handbook 215: Assessment Map Standards." Tech. rep., California State Board of Equalization.

Table 1: Original Dataset: By Type of Appearance in Dataset

		(1)	(2)	(3)	(4)
		Panel A: Parcels			
Year	Source	Total	Never-Changers	Changers	Phantoms
1999	DQ	2,054,630	1,974,322	28,996	6,118
2000	DQ	2,062,666	1,974,322	30,067	13,115
2001	DQ	2,087,854	1,974,322	32,516	33,727
2002	DQ	2,087,416	1,974,322	36,928	29,120
2004	AG	2,311,387	1,974,322	37,083	247,115
2005	AG	2,319,526	1,974,322	40,027	250,095
2006	AG	2,337,233	1,974,322	43,856	254,809
2007	LR	2,354,414	1,974,322	51,827	254,104
2008	LR	2,366,832	1,974,322	56,164	251,744
2009	LR	2,376,360	1,974,322	57,947	251,048
2010	SB	2,380,386	1,974,322	58,757	249,355
		Panel B: Land Area, Square Feet			
Year	Source	Total	Never-Changers	Changers	Phantoms
1999	DQ	27,764,230,819	19,645,546,954	977,750,276	448,460,263
2000	DQ	22,403,685,543	19,645,922,629	846,283,090	601,903,930
2001	DQ	23,929,788,784	19,645,923,464	854,822,086	1,931,672,544
2002	DQ	22,411,729,309	19,645,957,949	869,685,087	540,404,227
2004	AG	.	.	.	.
2005	AG	.	.	.	.
2006	AG	138,025,141,417	49,445,296,763	3,040,095,062	77,568,380,188
2007	LR	141,249,361,785	50,825,703,096	3,478,861,722	77,157,371,619
2008	LR	142,126,764,819	50,824,750,529	4,026,210,983	76,883,380,642
2009	LR	142,791,412,096	50,824,661,151	4,284,048,431	76,667,836,617
2010	SB	143,083,855,131	50,800,757,455	4,624,977,833	76,579,664,196

Note: Columns 2, 3 and 4 do not add up to the total in column 1, as we drop some parcels as described in this appendix. Because these parcels are dropped, they are not classified under this scheme.

Table 2: Original Dataset: Use Type By Year

		(1)	(2)	(3)	(4)	(5)
				Panel A: Parcels		
Year	Source	Total	Single-Family	Multi-Family	Vacant	Other
1999	DQ	2,054,630	1,659,917	243,386	135,153	16,069
2000	DQ	2,062,666	1,666,775	243,564	136,015	16,205
2001	DQ	2,087,854	1,675,331	243,991	139,845	28,354
2002	DQ	2,087,416	1,686,514	244,490	137,462	18,589
2004	AG	2,311,387	1,705,031	245,497	226,280	131,992
2005	AG	2,319,526	1,713,035	245,518	226,943	132,034
2006	AG	2,337,233	1,731,829	245,862	227,397	129,918
2007	LR	2,354,414	1,749,070	246,454	227,303	129,600
2008	LR	2,366,832	1,761,984	247,136	228,564	127,129
2009	LR	2,376,360	1,772,071	247,755	228,860	125,511
2010	SB	2,380,386	1,777,436	248,097	228,791	123,751
				Panel B: Land Area, Square Feet		
Year	Source	Total	Single-Family	Multi-Family	Vacant	Other
1999	DQ	27,764,230,819	16,456,132,388	3,164,288,059	7,314,122,805	809,916,239
2000	DQ	22,403,685,543	14,688,828,290	2,647,621,527	4,610,112,501	450,069,675
2001	DQ	23,929,788,784	14,754,694,550	2,662,660,428	5,242,808,095	1,258,558,401
2002	DQ	22,411,729,309	14,806,880,026	2,677,849,069	4,481,695,438	437,417,990
2004	AG					
2005	AG					
2006	AG	138,025,141,417	49,477,666,919	3,358,135,088	46,790,566,956	13,670,675,727
2007	LR	141,249,361,785	51,697,344,419	3,373,264,623	47,139,052,348	13,895,134,582
2008	LR	142,126,764,819	52,429,447,269	3,404,275,216	47,380,322,248	13,770,460,036
2009	LR	142,791,412,096	53,111,200,572	3,419,191,304	47,470,576,152	13,625,541,866
2010	SB	143,083,855,131	53,320,804,684	3,421,321,560	47,600,112,590	13,653,776,642

Note: Columns 2 through 5 do not add up to the total in column 1, as a very few parcels do not have an intelligible use code.

Table 3: Phantom Parcels Across Years

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
		Year of Data										
		1999	2000	2001	2002	2004	2005	2006	2007	2008	2009	2010
Parcel takes a value of 1 in this year if the parcel exists in the original data	1999	0	7,497	25,417	20,629	223,634	222,409	219,972	217,992	215,349	213,974	212,214
	2000	516	0	20,870	17,839	222,629	221,331	218,896	216,920	214,248	212,873	211,116
	2001	866	390	0	11,743	208,998	207,866	205,786	204,002	201,481	200,200	198,503
	2002	5,221	4,913	16,068	0	220,238	218,917	216,606	214,648	212,033	210,670	208,903
	2004	1,752	1,319	1,157	1,112	0	5,376	6,981	7,428	7,662	7,901	7,936
	2005	1,758	1,329	1,176	1,134	102	0	8,916	9,333	9,557	9,821	9,833
	2006	1,761	1,333	1,183	1,146	248	164	0	2,405	2,789	3,108	3,200
	2007	1,766	1,340	1,196	1,164	361	301	309	0	1,018	1,424	1,589
	2008	1,766	1,341	1,197	1,166	481	435	475	228	0	1,159	1,382
	2009	1,766	1,341	1,198	1,167	517	473	529	310	149	0	576
	2010	1,766	1,341	1,199	1,170	583	544	614	427	299	180	0

Notes: This table reports a count of only phantom parcels. Each cell reports the number of parcels in the year of the horizontal axis (year of data) that are "phantoms" that we have added in other years. For example, cell (20004,1999) has a value of 230,407, which means that 230,407 parcels that at some point started (or stopped appearing) without a matching change in the change database appear in the original data from year 2004. By construction, the diagonal is zero – a parcel that we add to the database because it does not appear (a phantom) cannot exist in the original data in that year.

Table 4: Cleaned Dataset: By Type of Appearance in Dataset

		(1)	(2)	(3)	(4)
		Panel A: Parcels			
Year	Source	Total	Never-Changers	Changers	Phantoms
1999	DQ	2,238,337	1,974,322	28,994	235,021
2000	DQ	2,245,080	1,974,322	29,276	241,482
2001	DQ	2,250,420	1,974,322	28,590	247,508
2002	DQ	2,257,824	1,974,322	29,944	253,558
2004	AG	2,266,664	1,974,322	35,541	256,801
2005	AG	2,272,612	1,974,322	37,851	260,439
2006	AG	2,275,776	1,974,322	42,504	258,950
2007	LR	2,281,750	1,974,322	50,702	256,726
2008	LR	2,283,392	1,974,322	54,832	254,238
2009	LR	2,284,011	1,974,322	56,554	253,135
2010	SB	2,281,702	1,974,322	56,778	250,602
		Panel B: Land Area, Square Feet			
Year	Source	Total	Never-Changers	Changers	Phantoms
1999	DQ	101,141,388,368	20,104,375,427	1,521,589,117	79,515,423,823
2000	DQ	101,139,463,687	20,104,375,427	1,409,035,164	79,626,053,096
2001	DQ	101,123,335,380	20,104,375,427	1,574,991,288	79,443,968,664
2002	DQ	101,087,643,094	20,104,375,427	1,678,513,494	79,304,754,172
2004	AG	101,106,061,329	20,104,375,427	2,012,482,403	78,989,203,498
2005	AG	101,094,721,056	20,104,375,427	2,122,474,399	78,867,871,230
2006	AG	101,092,256,000	20,104,375,427	2,888,466,390	78,099,414,183
2007	LR	101,091,124,053	20,104,375,427	3,341,035,624	77,645,713,001
2008	LR	101,090,900,770	20,104,375,427	3,846,494,494	77,140,030,848
2009	LR	101,092,046,083	20,104,375,427	4,087,266,349	76,900,404,307
2010	SB	101,091,736,639	20,104,375,427	4,413,714,704	76,573,646,507

Table 5: Cleaned Dataset: Use Type By Year

		(1)	(2)	(3)	(4)	(5)
			Panel A: Parcels			
Year	Source	Total	Single-Family	Multi-Family	Vacant	Other
1999	DQ	2,238,337	1,418,826	463,900	176,344	179,180
2000	DQ	2,245,080	1,422,936	466,436	177,197	178,392
2001	DQ	2,250,420	1,426,788	467,734	179,080	176,712
2002	DQ	2,257,824	1,432,413	469,829	178,679	176,788
2004	AG	2,266,664	1,439,064	473,384	188,326	165,885
2005	AG	2,272,612	1,443,011	475,036	188,302	166,255
2006	AG	2,275,776	1,449,644	475,649	184,932	165,548
2007	LR	2,281,750	1,455,515	477,137	183,788	165,307
2008	LR	2,283,392	1,457,763	478,612	181,672	165,345
2009	LR	2,284,011	1,459,218	479,000	180,202	165,591
2010	SB	2,281,702	1,459,232	478,676	178,400	165,394
			Panel B: Land Area, Square Feet			
Year	Source	Total	Single-Family	Multi-Family	Vacant	Other
1999	DQ	101,141,388,368	15,220,405,675	3,329,124,339	42,481,518,355	40,051,723,892
2000	DQ	101,139,463,687	15,738,700,778	3,357,013,177	42,288,988,008	39,701,786,975
2001	DQ	101,123,335,380	16,850,694,605	3,440,125,295	41,110,698,633	39,668,229,961
2002	DQ	101,087,643,094	16,561,419,196	3,739,242,848	41,034,330,369	39,706,498,431
2004	AG	101,106,061,329	16,802,756,545	3,767,608,880	41,408,767,780	39,125,157,636
2005	AG	101,094,721,056	16,870,449,564	3,758,195,623	41,314,648,352	39,148,160,367
2006	AG	101,092,256,000	16,864,368,220	3,811,098,267	41,264,820,826	39,148,716,613
2007	LR	101,091,124,053	16,975,553,582	3,922,783,968	41,010,639,560	39,178,894,869
2008	LR	101,090,900,770	17,046,810,448	3,933,788,985	40,895,764,867	39,214,536,470
2009	LR	101,092,046,083	17,072,064,613	3,961,136,451	40,779,823,552	39,279,021,466
2010	SB	101,091,736,639	17,082,857,623	3,972,777,866	40,760,459,053	39,275,642,097

Note: Columns 2 through 5 do not add up to the total in column 1, as a very few parcels do not have an intelligible use code.

Table 6: Parcels in Change Database by Type of Appearance

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Parcels in Change Database		Parcels in the Cross-Section with match in parcel change database		Share of all parcels in Change Database				
Change Type	Entering County	Leaving County	Entering County	Leaving County	Match in Cross-sectional database	Temporary parcels, not matched, but subsequent parcel in change sequence is	Successfully Matched Parcels	No match in Cross-sectional database	Matches: Average years for change to appear in cross-section
Panel A: Full Sample									
All types	184,860	87,339	149,800	51,268	0.74	0.15	0.89	0.11	1.00
Zero to One	2,205	1	637	0	0.29	0.60	0.89	0.11	1.51
One to Zero	1	860	0	425	0.49	0.00	0.49	0.51	
One to One	27,919	27,919	19,747	19,340	0.70	0.15	0.85	0.15	1.13
One to Many	139,814	16,230	119,523	8,026	0.82	0.10	0.92	0.08	0.96
Many to One	14,921	42,329	9,893	23,477	0.58	0.27	0.86	0.14	1.09
Panel B: Restricted sample: Cross-sectional years 2007-2008, same headings									
All types	35,262	14,129	31,514	10,953	0.86	0.10	0.96	0.04	0.94
Zero to One	265	1	86	0	0.32	0.62	0.94	0.06	1.00
One to Zero	1	52	0	44	0.83	0.00	0.83	0.17	
One to One	4,116	4,116	3,409	3,668	0.86	0.07	0.93	0.07	0.85
One to Many	28,548	2,811	26,185	1,845	0.89	0.07	0.96	0.04	0.95
Many to One	2,332	7,149	1,834	5,396	0.76	0.20	0.96	0.04	0.93