The Aggregate Value of Urban Land in the Greater Los Angeles Region[1]

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November 20, 2013

This paper was written out of curiosity.

Henry George advocated a 'single tax' on land value to finance government goods and services. Henry George's single tax has often been dismissed, or at least criticized, on the grounds that a tax on land value could not raise nearly enough revenue to finance today's governments. Some, who are sympathetic to land taxation because of its neutrality, argue that perhaps the single tax could have raised sufficient revenue at the time George proposed it, in 1879 when agriculture was the largest sector in the US economy and when the role of government was considerably smaller than it now is, but would surely not today. One might also argue that George had in mind local goods and services. Interest in George's single tax outside the fraternity of Georgist scholars reemerged for a brief period of time in the 1970's when the "Henry George Theorem" was established independently by several mainstream economists (Serck-Hanssen, 1969; Starrett, 1974; Flatters, Henderson, and Mieszkowski, 1974) including most notably William Vickrey (1977), a 1996 Nobel Prize winner in economics. The variant of the Theorem that is closest in spirit to Henry George states that "when the only source of increasing returns to scale is a pure local public good, and when the only source of decreasing returns to scale is commuting costs, in a city of optimal population size, differential land rents (aggregate land rents in excess of the opportunity rent on land in non-urban use) exactly equal expenditure on the pure public good". (Arnott and Stiglitz, 1979). A more general statement of the Theorem is that "in a city of optimal population size, under marginal cost pricing differential land rents exactly cover the losses from decreasing returns to scale activities" (Arnott, 1979, 2004). Kanemoto *et al.* (1996) considered whether the Theorem could be used to determine whether Tokyo is too large, and, in response to the criticism that actual cities deviate significantly from marginal cost pricing (most notably, urban residents do not pay for the traffic congestion they impose on others), Behrens *et al.* (2010) adapted the Theorem to apply to such cities.

Aggregate urban land *rents* are not observable or estimable with a reasonable degree of accuracy. For one thing, most urban *properties* are not rented, so that it is difficult to

[1] We would like to thank the Multicampus Research Programs and Initiatives (MRPI), University of California, Office of the President, Grant Number 142934 for financial support for this research. The views and recommendations expressed in this report are those of the authors and do not necessarily represent those of the Regents of the University of California.

measure aggregate urban property rents, and the market rent on vacant urban land (perhaps as market garden, perhaps as parking lot) is typically considerably below its opportunity cost in its highest developed, urban use. For another, since most urban land (in rent terms) is developed, even if urban property rent were observable, it would be necessary to decompose urban property rent into urban land rent and urban structure rent. Urban land *values* may however be estimable to a reasonable degree of accuracy on the basis of recorded sales of vacant land.

This paper asks the empirical question: What is the aggregate *value* of urban land in the Greater Los Angeles Area? And how does it compare with aggregate regional income? The paper does not investigate the link between urban land value and urban land rent, and therefore does not derive an estimate of the aggregate (shadow) rent of urban land. Nevertheless, it provides some insight into the tax revenue potential of urban land. For reasons that will be explained, it would be futile to attempt a precise estimate; instead, we are interested in ballpark estimates, as proportions of gross domestic product and of overall wealth.

We know of no studies that address these particular questions. There are however related studies. First, there is a long tradition of studies that estimate the aggregate property rent for particular countries on the basis of national accounting data (e.g. Goldsmith, xxxx). Second, a recent study by the World Bank (2006) estimated the aggregate value of all land for xxx countries, as part of a broader comparative study of the wealth of nations. Third, Davis and Heathcote (2007) estimate the "price" (market value) and quantity of residential land in the United States from 1976 to 2006, from which the aggregate market value of residential land may be calculated. And fourth, Nicols *et al.* (2013) estimate separate land price indices for commercial and residential land in the United States over the period 1995-2009. We shall later describe the procedures each of these works followed.

Our approach is different from that of all the previous studies. We estimate the aggregate value of urban land from only *vacant* land sales transactions. We do this using the 2007 land parcel database assembled by the Southern California Association of Governments (SCAG) and for the five counties of the Greater Los Angeles Metropolitan Area (Los Angeles, Orange, Riverside, San Bernardino, and Ventura). We do not claim that our approach is superior to the alternative approaches that have been employed to estimate aggregate land values. All the approaches suffer from both data and conceptual problems of one sort or another. However, in contrast to the other works, our approach allows us to estimate what is of interest to us, the aggregate value of urban land, for a particular metropolitan area, Los Angeles. Furthermore, for those land use categories (commercial and residential) where our results can be compared with those of previous studies, discussion of the sources of differences between the alternative estimates should lead to improved estimation methods in the future.

Following the real estate crisis in the United States from 2008 to the present, there has been heightened interest in the role of fluctuations and cycles in land and property values in generating macroeconomic fluctuations and cycles. While that is not our focus, the estimates we generate of aggregate urban land value should prove useful in that context.

Section 2 discusses data problems, and estimates the value of land in the LA Metro Area that was vacant in 2008, without taking into account spatial autocorrelation. Section 3 imputes land value to parcels that were developed by 2008, and estimates the value of all developed land in the Greater LA Metro Area in 2008, as well as the proportion of the ratio of aggregate land value to aggregate property value for developed properties, without taking account of spatial autocorrelation. Section 4 draws together previous results, providing alternative estimates of the aggregate value of land in the Greater LA Metro Area. Section 5 develops a revised set of estimates accounting for spatial autocorrelation. Section 6 relates our work to that of previous studies, describing the methods they employed and attempting to reconcile their estimates with ours. As we proceed, we shall take up many methodological issues.

2. Estimating the Aggregate Value of Vacant Land

The core data for this study are taken from the 2007 Southern California Association of Governments (SCAG) parcel database. The data were assembled by SCAG from registry and assessment data provided by each of its constituent counties. The SCAG region covers six counties, Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura. The Greater Los Angeles Area, in contrast, is defined to include Los Angeles, Orange, Riverside, San Bernardino, and Ventura Counties. Imperial County is a relatively small, predominantly agricultural county, bordering on Mexico, centered about 200 miles southeast of Los Angeles. We have chosen to exclude Imperial County from this study, so that when we refer to LA Metro Area we mean the five counties of the Greater Los Angeles Area. Figure 1 provides a map of the LA Metro Area. The reader should keep in mind that much of the LA Metro Area, especially in Riverside and San Bernardino Counties, is desert and mountains, and that eastern edge of Riverside County is 225 miles away from downtown Los Angeles. Thus, one of the issues that will need to be addressed is the appropriate definition of urban land within the Metro Area.

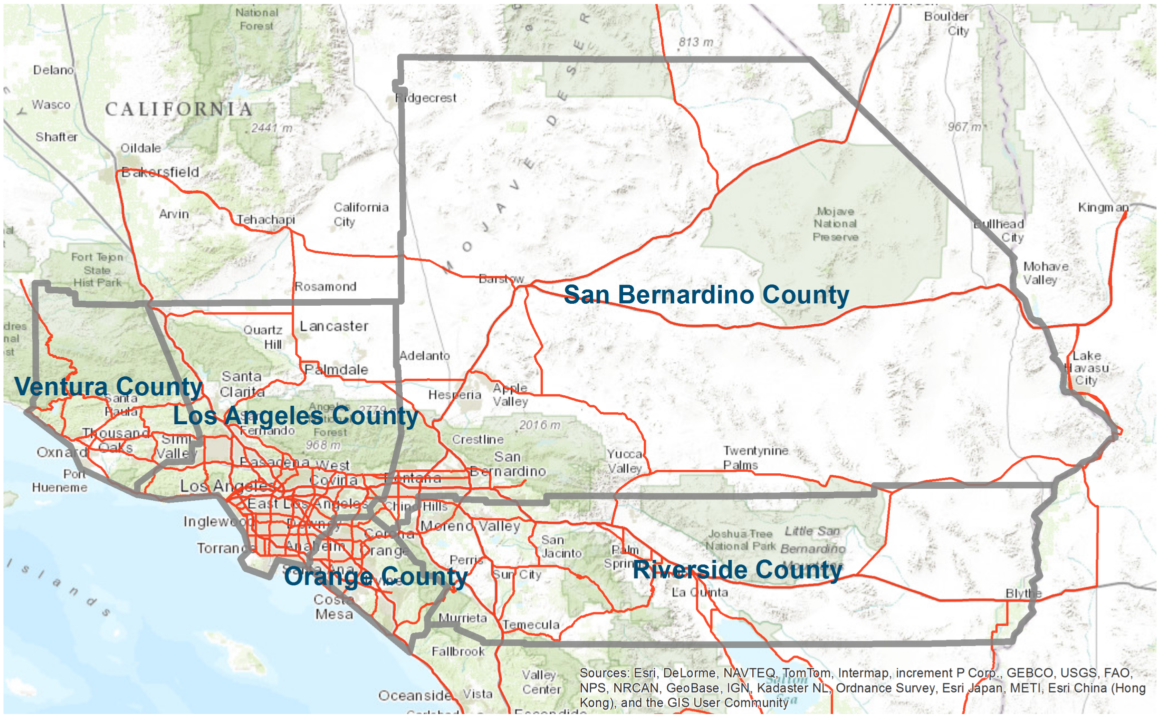

Figure 1: Map of LA metro area. Grey lines represent county boundaries, and red lines represent major road links.

Of the many fields in the 2008 SCAG parcel database, the main part of this study uses only year of most recent sale from the county registry data, the 2007 assessed value, current land use code from the assessment data, and for vacant parcels the plan land use code (which gives the planned land use from the relevant official Plan, as collected by SCAG). Under law, the county registry offices are required to have comprehensive registry data for all parcels of land within their jurisdictions, and the county assessment offices are required to have comprehensive assessment data for all parcels within their jurisdictions. Unfortunately, many cells for the relevant fields in the SCAG parcel database contain either a zero or a blank. Except for the fact that Ventura County had not got around to converting all their historical data to electronic form, we do not know the causes of the zeroes and blanks, nor whether the zeroes and blanks are random. Non-randomness in the zeroes and blanks might impart unknown bias into our estimates. Table 1 provides information on the zeroes and blanks, by county, for the three fields. Column 1 gives the percentage of parcels for which the current land use code is either zero or blank. Column 2 gives the number of parcels whose current land use code is "vacant". Column 3 gives the percentage of parcels, whose current land use code is "vacant", for which the year of last sale date is either zero or blank. Column 4 gives the percentage of parcels, whose current land use code is "vacant", for which the assessed value is either zero or blank. And column 5 gives the percentage of parcels, whose current land use code is "vacant", for which either the sales year or assessed value is either zero or blank.

	current land use, % zero or blank	# of parcels, current land use code = vacant	% zero or blank, sale year, vacant	% zero or blank assessed value, vacant	% zero or blank,either sale year or assessed value, vacant
Los Angeles		155184	23.4%	5.2%	23.7%
Orange		23631	79.5%	54.0%	88.5%
Riverside		59422	50.8%	18.8%	51.4%
San Bernardino		206867	86.4%	27.3%	88.5%
Ventura		30667	82.8%	40.5%	84.3%

Table 1: Zeroes and blanks in relevant fields of SCAG 2008 parcel database

Another potential source of error are mistakes in the data entered. Registry office data are normally very reliable, but assessment data are of variable reliability. In ground truth tracking, we did detect errors in the classification of parcels according to current land use. The ground truth tracking we undertook to uncover these and other potential sources of error is reported in Appendix A.

The concept of "vacant" land employed here is a broad one, and includes all land either without a completed structure or for which the structures are of secondary importance to the land use (notably open space and recreation, and agriculture). Table 2 gives the SCAG 2008 current land use categories that we took to be vacant. There are five main categories: under construction, open space and recreation, agriculture, vacant, and military (vacant).

Main categories	Detailed type	Developability
17** Under Construction	1700 Under Construction	Y
18** Open Space and Recreation	1800 Missing detailed type	?????
	1810 Golf Courses	Y
	1820 Local Parks and Recreation	N
	1821 Developed Local Parks and Recreation	N
	1822 Undeveloped Local Parks and Recreation	N
	1830 Regional Parks and Recreation	N
	1831 Developed Regional Parks and Recreation	N
	1832 Undeveloped Regional Parks and Recreation	N
	1840 Cemeteries	Y
	1850 Wildlife Preserves and Sanctuaries	N
	1860 Specimen Gardens and Arboreta	N

	1870 Beach Park	N
	1880 Other Open Space and Recreation	N
2*** Agriculture	2000 Missing detailed type	?????
	2100 Cropland and Improved Pasture Land	Y
	2110 Irrigated Cropland and Improved Pasture Land	Y
	2120 Non-Irrigated Cropland and Improved Pasture Land	Y
	2200 Orchards and Vineyards	Y
	2300 Nursery	Y
	2400 Dairy, Intensive Livestock, and Associated Facilities	Y
	2500 Poultry Operations	Y
	2600 Other Agriculture	Y
	2700 Horse Ranches	Y
3*** Vacant	3000 Missing detailed type	Y/N
	3100 Vacant Undifferentiated	Y/N
	3200 Abandoned Orchards and Vineyards	Y
	3300 Vacant with Limited Improvements	Y
	3400 Beaches (Vacant)	Y
127* Military (Vacant)	1274 Former Base (Built-up Area)	Y
	1275 Former Base (Vacant Area)	Y
	1276 Former Base Air Field	Y/N

Table 2: SCAG 2008 parcel database land use categories classified as "vacant".

Vacant land is least valuable in its raw state (unimproved), without having been graded and without services having been provided. Services include access to water, electricity, gas, telephone, and sewage. Sewage may be provided either via a septic system or via connection to the city sewage system. Water may be provided either from a well or from connection to the city water system. The SCAG parcel database provides no information on whether a particular vacant parcel has been graded and on what services it has. Thus, the value of vacant land that we measure is the value of land in its current state, whatever that may be.

Table 3 gives the estimated aggregate values, by county, for the year 2000 of all parcels that were vacant in 2008 for which both year of last sale and assessed value were available, and for which the year of last sale was 1980 or later. The 2007 assessed values were used, but were inflated or deflated to the year 2000. We shall explain shortly how we inflated or deflated assessed values to the year 2000. We excluded parcels whose date of last sale was 1980 or earlier since we doubted the accuracy of our inflation procedure when applied for a period of over twenty years.

Some vacant land uses are assessed at below market value in order to accord them preferential property tax treatment (for example, in California, agricultural land is assessed on the basis of its agricultural income and not on the basis of its market value). This underassessment will impart a downward bias to our estimates.

	number of vacant parcels	aggregate area of vacant parcels ($10^9 ft^2$)	2000 market value of vacant land per ft^2	aggregate 2000 market value of vacant land ($\$10^9$)
Los Angeles	98682	25.20	0.71	17.99
Orange	2402	1.34	0.92	1.23
Riverside	28813	6.09	1.01	6.14
San Bernardino	22588	5.49	0.63	3.45
Ventura	2978	4.46	0.45	2.01
Total	155463	42.58	0.72	30.83

Table 3: Estimated aggregate values for 2000 for all parcels that were vacant in 2008 for which both year of last sale and sales price were available, and for which the year of last sale was 1980 or later.
Note: 2000 market value per ft^2 was obtained by dividing aggregate 2000 market value by the aggregate area of parcels.

We now estimate the aggregate values, by county, for the year 2000 of all parcels that were vacant in 2008 and for which either year of last sale or assessed value or both were entered as either zero or blank, or for which the year of last sale is earlier than 1980. We do this by hedonic imputation, on the assumption that whether a parcel has data available on year of last sale and assessed value, and whether the year of last sale is earlier than 1980, is random. As the dependent variable, we could be either logarithm of sales price per unit area of vacant land or the logarithm of the sales price. We considered both, but present only the results when the dependent variable equals the logarithm of sales price since the fit was considerably better. The independent variables include city dummies, sale year dummies, and four accessibility measures (distance to the CBD, the coast, the nearest employment sub-center, and the nearest major road), and plan land use in 2008. The city dummies capture city-specific amenities and zoning policies. The sales year dummies capture cyclical fluctuations in vacant land value at the level of the metropolitan area, as well as the state formula used to compute assessed values on the basis of the sales price. The accessibility measures are standard. The plan use dummies capture the dependence of the value of a parcel of vacant land on its allowable developed land uses. No independent variables are including that reflect the residential sorting of income/race/demographic groups across the metropolitan area. In this section, we ignore spatial autocorrelation and assume simply that the errors are normally and independently distributed. Thus, the estimated regression equation is

$$ln(assessed\ land\ value) = constant + b_0\ ln(land\ area) + b_1X_1 + b_2X_2 + u \qquad (1)$$

where X_1 includes four accessibility measures: distance to the nearest major road, distance to the nearest sub-center, distance to the CBD, and distance to the nearest coast, all in miles. X_1 also includes quadratic terms of distance to the CBD and distance to the nearest coast. X_2 includes four dummy variables: city, (vacant) land use as of assessment date, planned (developed) land use as of assessment date, and year of most recent transaction.

On the basis of Arnott and Guo (2012), we classified all vacant parcels as either developable or undevelopable[2], and ran separate regressions for developable vacant parcels and undevelopable vacant parcels.

Below is part of the regression results. The full regression results are reported in Appendix C. The signs and magnitudes of all the dummy variables are "reasonable". The time dummies are omitted, and the constant term is the value of the time dummy for the year 2000.

	Developable	Undevelopable
ln(land area)	0.619***	0.574***
	(0.006)	(0.004)
fsub	-0.020***	0.041***
	(0.002)	(0.001)
cbd	-0.014***	-0.037***
	(0.003)	(0.003)
cbd2	0.000***	0.001***
	(0.000)	(0.000)
fwy	0.014***	0.002
	(0.004)	(0.002)
ocean	-0.038***	-0.007**
	(0.002)	(0.002)
ocean2	0.000***	-0.001***

[2] The procedure is described in detail in Arnott and Guo (2012). Previous work, such as Angel ( ) and Saiz ( ) categorizes parcels as developable or undevelopable primarily on the basis of topographical characteristics. Our general approach instead is to categorize parcels according to official land use and land value per ft^2, on the rationale that the market knows best what land is developable and what is not. Thus, for example, much of the land in the Santa Monica Mountains, though topographically expensive to develop, is nevertheless classified as developable since it has a high value per ft^2. Missing data, errors in coding, and anomalies were dealt with via a combination of econometric imputation, spatial smoothing, and ground truth tracking using satellite images.

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                         (0.000)        (0.000)
Constant                   6.823***      10.282***
                         (1.990)        (1.449)
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R-squared                  0.266          0.443
N                          84645          70818
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Standard deviation in parenthesis
* p<0.05, ** p<0.01, *** p<0.001
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Table 4 is the same as Table 3, but is for parcels for which either the sale price or the sales date is absent, and for which therefore 2000 sales price was imputed.

	number of vacant parcels	aggregate area of vacant parcels (10^9 ft^2)	2000 market value of vacant land per ft^2	aggregate 2000 market value of vacant land ($\$10^9$)
Los Angeles	56502	47.53	0.18	8.60
Orange	21229	7.98	2.09	16.71
Riverside	30609	39.45	0.11	4.19
San Bernardino	184279	450.19	0.02	7.14
Ventura	17040	39.72	0.15	6.01
Total	309659	584.87	0.07	42.66

Table 4: Estimated aggregate value for 2000 for all parcels that were vacant in 2008 for which either year of last sale or sales price or both were not available, or whose date of last sale is earlier than 1980.
Note: 2000 market value per ft^2 for a particular county was obtained by dividing that county's aggregate 2000 market value by its aggregate area of parcels.
Note: This excludes parcels whose sale year is earlier than 1980, as we think those assessed values are unreliable.

For each county, the difference between the 2000 market value of vacant land per ft^2 in Tables 3 and 4 presumably arise from assessment practices, which appear to differ markedly between counties. In aggregate, however, the value of vacant land per ft^2 for parcels in Table 3 are about ten times as high as those in Table 4.

Table 5 gives the estimated aggregate value for 2000 for all parcels, using (1) to impute missing values. Columns 1, 2, and 4 are obtained by summing the corresponding cells for Tables 2 and 3 and the entries in column 3 are obtained by dividing the corresponding cell in column 4 by the corresponding cell in column 2.

	number of	aggregate area	2000 market	aggregate 2000

	vacant parcels	of vacant parcels (10^9 ft^2)	value of vacant land per ft^2	market value of vacant land (\$$10^9$)
Los Angeles	155184	72.73	0.37	26.59
Orange	23631	9.32	1.93	17.95
Riverside	59422	45.54	0.23	10.33
San Bernardino	206867	455.68	0.02	10.59
Ventura	20018	44.18	0.18	8.02
Total	465122	627.45	0.12	73.48

Table 5: Estimated aggregate value for 2000 for all parcels that were vacant in 2008, using fitted values from (1).
Note: 2000 market value per ft^2 for a particular county was obtained by dividing that county's aggregate 2000 market value by its aggregate area of parcels.

Most economists believe that, in theory, land value provides a better tax base than property value, since, unlike property taxation, land value taxation is neutral with respect to (does not distort) the timing and density of urban development. The standard argument used to be that, while land value taxation is superior in principle, it is inferior in practice since there are few sales of vacant land, and many, if not most, of those are not arm's-length transactions, especially in heavily developed areas. During the era of urban renewal projects, many city governments assembled blighted properties using the right of eminent domain and sold them to a private developer for a nominal price, in return for the developer developing the assembled parcels according to an agreed-upon plan. This may still be the case for certain parts of the downtown area, and perhaps to other blighted areas, but most of the Los Angeles area is healthy. Also, it is claimed that many intra-family transfers of land and property are at below-market prices (though the assessments are based on market prices). Jifei Ban identified a field in the 2003 SCAG parcel database, giving the legal form of property sale, and found that only a small percentage of vacant land sales were classified as not being at arm's length. These problems therefore appear to be less quantitatively important than the conventional wisdom suggests. To the extent that these problems remain, they result in the *undervaluation* of vacant urban land.

Another problem is "undevelopable" land. The problem is particularly important in the Greater LA Region since much of the land area is either desert or mountains. The problem has several aspects. First, what is it that we want to measure? The formulation of the Henry George Theorem provides little guidance since it assumes all land to be developable. The simple variant of the Theorem relates differential land rents (the urban surplus) to current expenditure on local public goods. In discounted terms, the Theorem relates differential land value (the discounted urban surplus) to the discounted expenditure on local public goods. Henry George, however, had in mind all land rents/values, whether urban or rural. We could debate whether land in the Los Angeles National Forest or those parts of the Mojave Desert in Riverside and San Bernardino Counties, both parks and private land, should be included in measuring the aggregate value of land in the Greater LA Region. But since different measures of the aggregate value of land are relevant for different purposes, we have chosen to be agnostic, and report the aggregate value of developable land, the aggregate value of undevelopable land, and the total aggregate value of land. Since all developed land should, by definition, be developable, we have three categories of land: developed, vacant and developable, and vacant and undevelopable. Second, what criteria should be employed to determine whether a parcel of land is developable or undevelopable? Arnott and Guo (2012) addressed this question. Table 1 shows which land use categories are classified as unambiguously undevelopable (N) and unambiguously developable (Y). The developability of parcels in the remaining land use categories (3000, 3100, and 1275) are decided on a parcel-by-parcel basis using a method based on ground truth tracking. Details of the procedure are provided in Appendix D.

Table 6 corresponds to Table 5 exactly, but applies to parcels that were classified as "developable" according to the above procedure. Table 6 gives the estimated aggregate value for 2000 for all "developable" parcels, using (1) to impute missing values. Columns 1, 2, and 4 are obtained by summing the corresponding cells for the analogs of Tables 3 and 4 for developable parcels and the entries in column 3 are obtained by dividing the corresponding cell in column 4 by the corresponding cell in column 2.

	number of vacant parcels	aggregate area of vacant parcels (10^9 ft^2)	2000 market value of vacant land per ft^2	aggregate 2000 market value of vacant land (\$$10^9$)
Los Angeles	60916	11.31	1.32	14.89
Orange	13297	1.96	1.95	3.83
Riverside	51715	13.91	0.63	8.74
San Bernardino	53057	18.4	0.30	5.49
Ventura	13337	34.67	0.20	7.00
Total	192322	80.25	0.50	39.95

Table 6: Estimated aggregate value for 2000 for all parcels that were vacant and "developable" in 2008, using fitted values from (1).
Note: 2000 market value per ft^2 for a particular county was obtained by dividing that county's aggregate 2000 market value by its aggregate area of parcels.

Table 7 corresponds to Tables 5 exactly, but applies to parcels that were classified as "undevelopable" according to the Arnott-Guo procedure. Table 7 gives the estimated aggregate value for 2000 for all "undevelopable" parcels, using (1) to impute missing values. Columns 1, 2, and 4 are obtained by summing the corresponding cells for the analogs of Tables 3 and 4 for undevelopable parcels, and the entries in column 3 are obtained by dividing the corresponding cell in column 4 by the corresponding cell in column 2.

	number of vacant parcels	aggregate area of vacant	2000 market value of vacant	aggregate 2000 market value of

		parcels (10^9 ft^2)	land per ft^2	vacant parcels ($\$10^9$)
Los Angeles	94268	61.42	0.19	11.70
Orange	10334	7.35	1.92	14.11
Riverside	7707	31.63	0.05	1.60
San Bernardino	153810	437.29	0.01	5.10
Ventura	6681	9.51	0.11	1.02
Total	272800	547.20	0.06	33.54

Table 7: Estimated aggregate value for 2000 for all parcels that were vacant and "undevelopable" in 2008, using fitted values from (1).
Note: 2000 market value per ft^2 for a particular county was obtained by dividing that county's aggregate 2000 market value by its aggregate area of parcels.

In measuring the value of *urban land* within a metropolitan area, the distinction between developable and undevelopable land is important. In the context of the LA Metro Area, intuitively one does not want to include the hundreds of square miles of the Mojave Desert in San Bernardino County or national and state parks as urban land. But there is also a broad band of grey between developable and undevelopable land. For example, land in the Santa Monica Mountains, which includes the Malibu Hills, might be classified as undevelopable on the basis of its terrain and availability of water, but might nonetheless have considerable value as sites for the homes of the rich. Also, land that is currently undevelopable because of the unavailability of water might become developable if, due to technological improvements, the cost of drilling deep wells decreases significantly.

3. *Estimating the Aggregate Value of Developed Land*

All parcels classified as developed are classified as developable. Furthermore, the assessed value of all parcels classified as developed is the assessed *property* value, where a property includes both land and structures. We estimate the market value of the land of a developed parcel through imputation, using (1). We distinguish between parcels whose land use is given in the SCAG parcel database from those who land use is given there as a zero or blank.

	current land use, % zero or blank	# of parcels, current land use code = developed	% zero or blank,sale year, developed	% zero or blank, assessed property value, developed	% zero or blank, either sale year or assessed value, developed

Los Angeles		1893741	10%	1%	10%
Orange		680062	67%	9%	68%
Riverside		632804	47%	8%	49%
San Bernardino		645595	74%	5%	75%
Ventura		246680	75%	5%	75%

Table 8: Zeroes and blanks in relevant fields of SCAG 2008 parcel database

Table 8 above is similar to Table 1. Column 1 is exactly the same as Table 1's, giving the proportion of parcels without a land use code. The other columns are the same as the corresponding columns in Table 1, except that they apply to developed rather than to vacant parcels. It should be noted, however, that the subsequent estimates of land value for developed parcels do not use the property value assessment. Columns 3, 4, and 5 will instead be of interest later, when we estimate, for developed properties with both assessed value and sales date, the proportion of property value attributable to land and the proportion attributable to structures.

Table 11 gives the estimated land values of developed parcels. Table11 reports on the land values estimated using (1) but with the current land use replacing the planned land use. These estimates are based on the assumption that (1) provides unbiased estimates of the value of land of developed parcels, even though they were estimated from data on the assessed value of vacant land parcels. One reason to doubt this assumption is spatial autocorrelation, which we shall address in section 5. Another reason is omitted variable bias. Intuition suggests that, holding the value of the regressors in (1) fixed (and setting the plan land use code applicable to vacant parcels equal to the actual land use code for a developed parcel), the average parcel of developed land is more attractive than the average parcel of vacant land. If this intuition is correct, then land value for a developed parcel should be higher than that of a vacant parcel with the same value for the regressors, in which case the values in Table 11 are downward biased.

Table 9 gives the estimated land values of developed other than single-family residential (SFR) parcels. Table 9 gives the estimated land values of single-family residential parcels. Table 11 aggregates cells from Tables 9 and 10. Throughout the paper, values are expressed in \$2000.

	number of developed parcels	aggregate land area of developed parcels (10^9 ft^2)	2000 market value of land per ft^2	aggregate 2000 market value of land (\$$10^9$)
Los Angeles	625342	27.45	2.49	68.43
Orange	172772	9.08	3.84	34.86
Riverside	154654	22.72	0.60	13.72
San Bernardino	178123	180.52	0.09	16.80
Ventura	72105	6.56	1.87	12.23

Total	1202996	246.33	0.59	146.05

Table 9: Estimate aggregate land values for developed other than single-family residential properties in 2000.
Note: The aggregate land area of developed other than single-family residential parcels for San Bernardino County is so high because it includes XXXXX.

	number of developed parcels	aggregate land area of developed parcels (10^9 ft^2)	2000 market value of land per ft^2	aggregate 2000 market value of land ($\$10^9$)
Los Angeles	1268399	11.18	9.86	110.21
Orange	507290	4.27	15.63	66.76
Riverside	478150	5.52	4.99	27.53
San Bernardino	467472	6.15	5.14	31.63
Ventura	174575	1.91	11.53	22.06
Total	2895886	29.03	8.89	258.19

Table 10: Estimate aggregate land values for single-family residential (SFR) properties in 2000.

It is reassuring that the ratio of aggregate land values for developed other than SFR to SFR is similar across the counties, ranging from a high of 0.62 for Los Angeles County to a low of 0.50 for Riverside County. Furthermore, it is highest for the least residential of the counties and lowest for the most residential of the counties.

	number of developed parcels	aggregate land area of developed parcels (10^9 ft^2)	2000 market value of land per ft^2	aggregate 2000 market value of land ($\$10^9$)
Los Angeles	1893741	38.63	4.62	178.65
Orange	680062	13.35	7.61	101.62
Riverside	632804	28.23	1.46	41.25
San Bernardino	645595	186.68	0.26	48.43
Ventura	246680	8.47	4.05	34.29
Total	4098882	275.36	1.47	404.24

Table 11: Estimate aggregate land values for developed properties in 2000.

It is of interest to compare the results for the aggregate 2000 market value of land in Figures 6 and 11. In Los Angeles County, for example, the 2000 aggregate market value of vacant, developable land is $14.89 billion, while that of developed land is $178.65, a ratio of 0.083. As would be expected, the ratio is higher for the less developed counties

(Riverside, Ventura, and San Bernardino) than for the more developed counties (Los Angeles and Orange).

For developed properties, there is considerable debate over the proportion of property value that is attributable to land and the proportion that is attributable to structures. One theoretical issue relates to whether land should be valued according to its unimproved or improved state. Another theoretical issue relates to how structures should be valued. There is also a host of practical issues related to assessment practice (Gaffney, 2013), including the preferential treatment of certain land uses and the use of accelerated depreciation for structures. Here we largely sidestep the issues, simply investigating the ratio of the aggregate value of land in 2000 computed as described above to the aggregate property value in 2000, whose estimation we now describe.

Elsewhere (Zhang and Arnott, 2012) we describe the procedure employed to estimate the aggregate property value of single-family residential property. Since the proportion of parcels with sales price and sales date were considerably more complete than for other land uses, we used sales price rather than assessed value. In that paper, a hedonic regression was used to impute 2000 sales price to single-family residential parcels without sales price/sale date information. For other classes of property, we impute property value using the following regression equation.

$$ln(price\ per\ unit\ floor\ area) = constant + b_1X_1 + b_2X_2 + u \qquad (2)$$

where X_1 includes four accessibility measures: distance to the nearest major road, distance to the nearest sub-center, distance to the CBD, and distance to the nearest coast, and X_2 includes three dummy variables: city, land use as of assessment date, year of most recent transaction.

The regression is similar to (1), except that: i) (3) uses current land use as the land use dummy variable, in contrast to (1) which uses plan land use as the land use dummy variable, and ii) (3) estimates property value per unit floor area, in contrast to (1) which estimates land value per unit land area. The regression results are presented in Appendix C.

The results are recorded in Tables 12 and 13. Table 12 gives the results for single-family residential parcels. Table 13 gives the results for developed parcels, other than single-family residential.

	Aggregate 2000 SFR property value, APV_{SFR} (\$$10^9$)	Aggregate 2000 land value, SFR parcels, per (2), ALV_{SFR} (\$$10^9$)	ALV_{SFR}/APV_{SFR}
Los Angeles	402	113.39	0.27
Orange	132	57.42	0.51
Riverside	86.5	27.65	0.32
San		30.76	

Bernardino	56.9		0.56
Ventura	59.9	22.14	0.37
Total	737.3	251.37	0.35

Table 12: The ratio of aggregate land value to aggregate property value for single-family residential (SFR) parcels.

The results are puzzling. As a property ages, the land typically becomes more valuable due to the metropolitan area having become more developed while the structure typically becomes less valuable due to depreciation and style obsolescence. Thus, one expects the ratio of aggregate land value to aggregate property value to be higher for older properties. Instead, one observes the ratio to be lowest for Los Angeles, which was the first county to be extensively developed.

COMMENTS ON TABLE 13.

	Aggregate 2000 property value, developed non-SFR, APV_{NSFR} ($\$10^9$)	Aggregate 2000 land value, developed non-SFR, per (1), ALV_{NSFR} ($\$10^9$)	ALV_{NSFR}/APV_{NSFR}
Los Angeles		68.43	
Orange		34.86	
Riverside		13.72	
San Bernardino		16.80	
Ventura		12.23	
Total		146.05	

Table 13: The ratio of aggregate land value to aggregate property value for developed parcels other than single-family residential.
Note: Subscript NSFR denotes not single family residential.

There are parcels without a land use code. Also, only very little of the land used for city streets and freeways is part of a parcel in the SCAG database. We shall simply exclude such land from our calculations, which introduces a further downward bias in our estimation of the aggregate value of urban land in the Greater Metro LA Area. For each of the five counties, as well as for the Greater Metro LA Area, Table 14 reports on the amounts and proportions of land that is vacant, developed, and unclassified (lacking a land use code or being a street or being a body of water). Unclassified land area is calculated as total land area minus developed and vacant land areas

	Vacant land area (10^9 ft^2)	Developed land area (10^9 ft^2)	Unclassified land area (10^9 ft^2)	Prop of land vacant	Prop of land developed	Prop of land unclassified
Los Angeles	64.6	73.1	8.4	44.2%	50.0%	5.8%
Orange	8.5	12.6	2.6	35.8%	53.2%	11.0%
Riverside	169.4	25.8	4.5	84.7%	12.9%	2.4%
San Bernardino	439.6	101.8	4.1	80.6%	18.7%	0.7%
Ventura	44.1	6.7	0.1	86.7%	13.2%	0.1%
Total	726.2	220.0	19.7	75.2%	22.8%	2.0%

Table 14: Vacant, developed, and unclassified land area, by county, total and proportions.
Note: Unlike the other counties, Ventura County assigns parcel numbers to streets.

One expects the proportion of land that is unclassified to be higher in counties with a higher population density since most of the unclassified land is land that is used in roads. The results in Table 14 are consistent with this expectation, except for Ventura County. The explanation for the anomaly is that Ventura County, in contrast to the other counties, treats city streets as parcels, with a transportation, communications, and utilities land use code.

4. *The Aggregate Value of Vacant and Developed Land*

This section collects results from the previous two sections. Table 16 repeats the estimates presently previously of aggregate land values for: i) single-family residential parcels; (ii) developed, non-SFR parcels; (iii) developable vacant land; and (iv) total vacant land, when land values are imputed per regression (1).

	ALV_{SFR} ($\$10^9$)	ALV_{NSFR} ($\$10^9$)	ALV_{DV} ($\$10^9$)	ALV_{NDV} ($\$10^9$)	Total ALV ($\$10^9$)

Los Angeles	110.21	68.43	15.72	10.84	215.38
Orange	66.76	34.86	3.66	2.31	95.8
Riverside	27.53	13.72	8.77	0.54	53.66
San Bernardino	31.63	16.80	5.52	5.14	60.39
Ventura	22.06	12.23	7.53	1.04	43.32
Total	258.19	146.05	41.2	19.87	468.55

Table 16: Aggregate land values in 2000 imputed per regression (2).
Notes: ALV denotes aggregate land value, R single family residential, NR developed, non-SFR, DV developable vacant, and NDV undevelopable vacant.

Is $469 billion dollars large or small? We advise our students to convert all such large dollar sums into an intuitive metric. On several occasions, Arnott has heard claims that, across time and space, the value of land is about equal to GNP. This is a natural metric that one can relate to. Table 17 gives aggregate land value, aggregate income (measured on a residency basis, as county income in the 2000 Census), and the ratio of aggregate land value to aggregate income, for the Greater Los Angeles Area, as well as for its constituent counties. The ratio of aggregate land value to aggregate income, 1.132, is remarkably close to the rule-of-thumb conventional wisdom.

From the time dummy variables in the regressions, one can compute the annual rate of nominal land value appreciation. Subtracting off the inflation rates (measured as the CPI), one can compute the annual rate of real land value appreciation, as well as a time index of real land value. It can be shown that the index was about at its minimum over the time period of the regression in 2000. Since we have consistently made assumptions that lead to more conservative estimates of aggregate land values, it is reasonable to say that 1.132 is a lower bound estimate of the average ratio of aggregate land value to aggregate income over time in the Greater Los Angeles, at least until the property market crash in 2008.

	Total ALV ($\$10^9$)	Aggregate Income ($\$10^9$)	Ratio
Los Angeles	215.38	260.30	0.828
Orange	95.8	73.51	1.303
Riverside	53.66	28.89	1.857
San Bernardino	60.39	28.81	2.096
Ventura	43.32	22.32	1.941
Total	468.55	413.83	1.132

Table 17: The ratio of aggregate land value to aggregate income, 2000.

It is interesting to speculate on why the ratio differs in the way it does across counties. The most obvious explanation is that the ratio of aggregate land value to aggregate income is highest for agricultural and other vacant land, including undeveloped land, which is highest in the least developed counties. But also microeconomic theory indicates that, in the production of a particular good, the land share of income depends on the elasticity of substitution between land and other factors in production. If the elasticity of substitution is less than one, then in locations where the factor rent on land is relatively high, the land value share is relatively high too.

Another way of expressing aggregate numbers in intuitive terms is in per capita terms. Table 18 gives aggregate land value, population, and land value per capita, for each of the five counties and then for the Greater Los Angeles Region. In 2000 land value per capita for the Region was $28,620, was lowest in Los Angeles County at $22,630, and was highest in Ventura County at $57,530.

	Total ALV ($\$10^9$)	Population (10^6)	Ratio (per capita LV -- $\$10^3$)
Los Angeles	215.38	9.519	22.63
Orange	95.8	2.846	33.66
Riverside	53.66	1.545	34.69
San Bernardino	60.39	1.709	35.33
Ventura	43.32	0.753	57.53
Total	468.55	16.372	28.62

Table 18: Aggregate land value, population, and land value per capita in 2000

5 *Estimates Accounting for Spatial Autocorrelation*

WHY SHOULD WE BE CONCERNED ABOUT SPATIAL CORRELATION?

1) Add literature on the spatial hedonic regression of land or property values. Did they find spatial approach significantly improve the results?
2) Check if the OLS residuals display a spatial clustering pattern?
3) Perform a test to choose among the three models.
4) Explain why spatial approach does not change the results much.

There are typically three models accounting for spatial autocorrelation: one is spatial error model (SEM), one is spatial autoregressive model (SAR), and the other is spatial Durbin model (SD).

SEM assumes that spatial dependence is caused by correlated unobservable variables. For example neighborhood crime rate is local and unobservable to econometricians, but it may affect land value in the neighborhood.

SAR assumes that land value of a vacant parcel is affected directly by the land value of other vacant parcels nearby.

SD is a combination of the two, assuming that not only there are correlated unobservable variables, but also the land value of one parcel is directly affected by the land value of other parcels nearby.

In the hedonic land value model of this paper, differences in land values of parcels are fully explained by physical and location amenities. Increase in the land value of a vacant parcel nearby should not affect a parcel's value, given all physical and location amenities unchanged. Therefore, we believe spatial error model (SEM) is more reasonable in our setting.

We chose the nearest ten parcels as the relevant neighbors of a parcel, and put an equal weight on the ten parcels in constructing the weight matrix. The regression was done in R, and code can be found here. As spatial regressions are computationally intensive and our data is huge, we did the comparison for some model zones. These model zones have large proportion of vacant land being mountains or deserts.

It turns out that the results from spatial error model regression are not quite different from that of OLS with the same regression formula.

COMPARE THE REGRESSION COEFFICIENTS

Victorville	Parcels missing either sale year or assessed value ($/ft^2))		Parcels whose sale year and assessed value are both available ($/ft^2)	
	developable	undevelopable	developable	undevelopable
OLS	0.194	0.068	0.432	0.142
SEM	0.196	0.054	0.436	0.136
# of parcels	9369	31574	6823	7941

Table: Value per unit land area of vacant parcels by developability and by regression method for Victorville model zone.

Santa Monica Mountains	Parcels missing either sale year or assessed value ($/ft^2))		Parcels whose sale year and assessed value are both available ($/ft^2)	
	developable	undevelopable	developable	undevelopable
OLS	88.22	7.04	19.17	4.64
SEM	95.29	3.31	21.96	4.27
# of parcels	776	285	3019	1112

Table: Value per unit land area of vacant parcels by developability and by regression method for Santa Monica Mountains model zone.

San Bernardino Mountains	Parcels missing either sale year or assessed value ($/ft^2))		Parcels whose sale year and assessed value are both available ($/ft^2)	
	developable	undevelopable	developable	undevelopable
OLS	0.59	0.43	1.88	0.89
SEM	0.55	0.54	1.97	1.07
# of parcels	1773	6598	1321	312

Table: Value per unit land area of vacant parcels by developability and by regression method for San Bernardino Mountains model zone.

6. *Comparison to Estimates of Aggregate Land Values Using Alternative Approaches*

There are two general approaches to estimating aggregate land values. The first is the approach that we have taken, to estimate aggregate land values from vacant land sales. The second draws on information in the national accounts.

The first approach is employed in a pair of companion papers, Nicols, Oliner, and Muhall (2010, 2012) and is applied to 23 MSA's. The aim of these papers is to develop indexes of commercial and residential land prices from 1995 to 2009. Average land values are not given. These papers' method is very similar to that employed in this paper, but draws on a different database, source parcel data vacant land sales obtained from the CoStar Group, Inc. For each MSA and for both land use types, and with single parcel sales as observations, a separate regression is run, with the log of land value per ft^2 regressed against property and transactions characteristics: the log of land area of the property, type of property, condition of the property, intended use of the property, characteristics of the transaction, grid vertex, distance from the population-weighted center of the MSA, and semi-annual time dummies. The indexes are obtained from the time dummies, and are very similar to those implied by the time dummies in our regression analysis.

The second approach draws on the national accounts. Davis and Heathcote (2007) and Davis and Palumbo (2008) focus on residential land at the national level. The aggregate value of land is determined as a residual, equaling the aggregate market value of residential real estate minus the aggregate replacement cost of residential structures, which are derived from the Flow of Funds accounts published by the Federal Reserve Board. To estimate the aggregate replacement cost of residential structures, they employ a Census Bureau estimate that residential land accounts for 12.6% of the National Income and Product Accounts gross investment in new residential structures, and then apply a perpetual inventory method, with assumed depreciation rates, to estimate the aggregate replacement cost of residential structures. For the aggregate market value of housing, they employ Census estimates along with the Residential Finance Survey. For 2000, they estimate that the land share of the market value of residential real estate (Davis and Heathcote, Table 1) is 36.4%. This is remarkably similar to the corresponding figure that we obtain for the Los Angeles Metropolitan Area for the same year, of 35% (Table 12). Having obtained value time series, they decompose these into price and quantity series. For structures, they employ a price index for gross investment in new residential structures produced by the Bureau of Economic Analysis, and for residential real property, they employ the repeat-sales-based index produced by the Office of Federal Housing Enterprise Oversight. This provides them with the information they need to estimate a land price index.

The World Bank (2006) estimates per capita wealth, as well as its components, in 2000 for a broad range of countries. This study too draws on the countries' national accounts, but because of data limitations in many countries' national accounting, the estimates are obtained by cruder methods. They treat land as "natural capital", decomposing it into energy resources, mineral resources, timber resources, non-timber forest resources, cropland, pastureland, protected areas, and urban land. Their urban land is comparable to our developed urban land. They estimate the value of urban land as 24% of the value of physical capital, which applied to the United States gives an estimate of $15,460 (Appendix 2). In our paper, the aggregate land value for developed properties in the LA Metro Area was $404.24 trillion. With a population of 16.372 million, this translates into a per capita value of $24,690.

In conclusion, our results are broadly consistent with others in the literature, both those that draw on sales transactions in vacant land, and those that draw on the national accounts.

7 Concluding Comments

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Appendix A
Results of Ground Truth Tracking
in Riverside County

Appendix B

Results with Sales Price rather than Assessed Value

Orange and Riverside counties are the two that have data on both sales price and assessed value. So here are the estimated land value results of the two counties using sales price data.

County	dvlp	v2000_p	v2000	shape_area	nparcel_p	nparcel_v	nparcel	pvratio
OR	0	4.05E+09	1.48E+10	1.17E+07	64	443	679	0.27
OR	1	2.99E+09	1.32E+09	4.07E+07	1390	2739	4327	2.26
RV	0	9.22E+10	1.64E+10	1.45E+10	15625	57041	71748	5.63
RV	1	1.06E+11	2.49E+10	1.81E+09	27513	74855	88598	4.27

Table B1: Aggregate vacant land value in 2000 estimated from sales price and aggregate vacant land value estimated from assessed value.

Table B1 gives the imputed aggregate land value in 2000 for the two counties by developability. Predicted aggregate vacant land values using sales prices are higher than using assessed value in three out of four cases.

But sales price suffers more severe missing data problem than assessed value. Sales price data is missing for 69% of developable vacant parcels in Riverside County, while assessed value is missing for only 15%. If the missing of sales price data is correlated with some variables that are unobservable to econometrician and therefore not controlled of in the hedonic regressions in this paper, then the imputed sales prices are biased. For example, if missing is caused by a parcel having fewer transactions in the past, and assume qualitatively inferior lands are less likely to be traded, then the parcels missing sales price is generally of lower quality, and the aggregate land value imputed from sales price is going to be biased upward.

In fact, we can check this. Table B2 gives the mean of accessibility measures, imputed land values using sales price data, imputed land values using assessed value data, and land area of two samples in Riverside County. One sample includes only parcels that have sales price data available, while the other sample includes only parcels whose sales price data is missing. The first sample on average has better accessibilities (in terms of shorter distances to the nearest sub-center, CBD, major roads, and coast), higher land values, and smaller land area than the second sample.

Imputed land value using sales price is 4.5 times as high as the imputed land value using assessed value, on the sample that has sales price data. But the ratio is only 2.8 for the sample missing sales price.

Variables	Variable mean of parcels whose sales price data is available	Variable mean of parcels whose sales price data is missing
Distance to the nearest sub-center	8.76	10.25
Distance to the CBD	94.39	98.67
Distance to the nearest major road	1.68	2.25
Distance to the nearest coast	48.22	52.65
Imputed land value at year 2000, using assessed value data	395751	310898
Imputed land value at year 2000, using sales price data	1768432	858536
Land area	31607	148183
Number of parcels	69718	95634
Imputed land value per sq. ft using assessed value data	12.52	2.10
Imputed land value per sq. ft using sales price data	55.95	5.79

Table B2: Comparison of mean statistics of parcels that have sales price data available to parcels whose sales price data is missing. The two samples include all vacant parcels in Riverside County.

Table B3 gives imputed aggregate land value by detailed land use code.

Land use code	ALV-- sales price (1e6$)	ALV -- assessed value (1e6$)	Land area (1e6 sq. ft)	# of parcels with sales price	# of parcels with assessed value	Total # of parcels	Land value per sq. ft, using sales price	Land value per sq. ft, using assessed value
1274	147.11	49.96	12.43	0	2	61	11.84	4.02
1275	118.32	113.14	26.10	0	17	45	4.53	4.33
1276	91.43	9.73	11.82	0	10	41	7.73	0.82
1700	1040.62	462.39	28.63	423	752	1645	36.35	16.15
1810	245.65	99.26	58.69	9	62	121	4.19	1.69
1840	31.55	27.95	6.53	1	7	26	4.83	4.28

2100	1.38	1.15	0.02	1	3	3	57.86	48.20
2110	51.35	4.49	4.36	1	12	18	11.79	1.03
2200	15.27	23.86	4.76	0	5	7	3.21	5.01
2300	41.34	9.14	5.00	9	28	40	8.26	1.83
2400	1.92	0.68	0.03	4	4	4	55.14	19.53
2600	6.78	3.19	0.17	4	10	11	39.07	18.36
2700	8.76	0.84	0.94	4	9	10	9.36	0.90
3000	1.52	1.76	0.92	0	1	1	1.64	1.91
3100	1158.14	504.72	275.41	895	1774	2243	4.21	1.83
3300	12.80	6.11	1.92	39	42	46	6.66	3.18
3400	19.11	4.72	0.76	0	1	5	25.07	6.20

Table B3: Imputed aggregate land value in 2000 by detailed land use code for "developable" vacant parcels in Orange County.

Table B4 gives the detailed land-use-type-level comparison of imputed aggregate land value using sales price to imputed aggregate land value using assessed value. The last column records the ratio of the two aggregate land values. Land use type "Irrigated Cropland and Improved Pasture Land" has the highest sales price to assessed value ratio being 11.18. Considering only the land use types that have sufficient number of parcels, land use type "Under Construction" has the lowest sales price to assessed value ratio being 2.44, and land use type "Vacant Undifferentiated" has the second lowest sales price to assessed value ratio being 2.74.

Note Table B4-2 takes three major columns from Table B4-1 and has a column of land use description added.

Land use code	ALV -- sales price (1e9 $)	ALV -- assessed value (1e9 $)	Land area (1e9 sq.ft)	N_{SP}	N_{AV}	N_{total}	ALV_{SP}/ALV_{AV}
1274	0.041	0.025	0.013	3	15	20	1.62
1275	0.111	0.075	0.120	5	36	77	1.47
1700	24.174	9.917	0.553	13926	22985	24058	2.44
1800	0.063	0.008	0.475	7	138	291	7.60
1810	5.935	0.892	0.968	401	2249	2724	6.66
1840	0.044	0.032	0.024	6	32	62	1.35

2000	9.332	1.381	1.082	1142	4357	6015	6.76
2100	0.003	0.007	0.001	1	6	6	0.42
2110	15.899	1.423	6.251	1179	5925	7894	11.18
2120	7.053	1.081	1.338	706	3221	4750	6.53
2200	6.914	1.030	2.755	903	3376	3539	6.72
2300	0.313	0.113	0.159	85	358	376	2.77
2400	0.239	0.084	0.085	12	170	282	2.84
2500	0.101	0.014	0.019	10	36	38	7.42
2600	0.464	0.181	0.279	151	701	814	2.57
2700	1.070	0.500	0.400	330	1052	1157	2.14
3000	21.754	3.821	1.289	3518	12755	15274	5.69
3100	10.150	3.706	3.516	3942	14601	17799	2.74
3200	0.083	0.028	0.043	15	100	112	2.92
3300	2.408	0.550	0.156	1171	2742	3310	4.38

Table B4-1: Imputed aggregate land value in 2000 by detailed land use code for “developable” vacant parcels in Riverside County.

Land use code	Land use description	ALV -- sales price (1e9 $)	ALV -- assessed value (1e9 $)	ALV_{SP}/ALV_{AV}
1274	Former Base Built-up Area	0.041	0.025	1.62
1275	Former Base Vacant Area	0.111	0.075	1.47
1700	Under Construction	24.174	9.917	2.44
1800	Open Space and Recreation	0.063	0.008	7.60
1810	Golf Courses	5.935	0.892	6.66
1840	Cemeteries	0.044	0.032	1.35
2000	Agricultural	9.332	1.381	6.76
2100	Croplands and Improved Pasture Land	0.003	0.007	0.42
2110	Irrigated Croplands and Improved Pasture Land	15.899	1.423	11.18
2120	Non-irrigated Croplands and Improved Pasture Land	7.053	1.081	6.53
2200	Orchards and Vineyards	6.914	1.030	6.72
2300	Nurseries	0.313	0.113	2.77
2400	Dairy	0.239	0.084	2.84
2500	Poultry Operations	0.101	0.014	7.42
2600	Other Agricultural	0.464	0.181	2.57
2700	Horse Ranches	1.070	0.500	2.14
3000	Vacant	21.754	3.821	5.69

3100	Vacant Undifferentiated	10.150	3.706	2.74
3200	Abandoned Orchards and Vineyards	0.083	0.028	2.92
3300	Vacant with Limited Improvements	2.408	0.550	4.38
	Total	106.151	24.868	4.27

Table B4-2: Imputed aggregate land value in 2000 by detailed land use code for "developable" vacant parcels in Riverside County.

Land use code		ALV -- sales price (1e9 $)	ALV -- assessed value (1e9 $)	Land area (1e9 sq.ft)	N_{SP}	N_{AV}	N_{total}	ALV_{SP}/ALV_{AV}
1821	OR	2.559	0.197	0.042	25	238	406	13.00
1831	OR	0.044	0.004	0.006	0	2	9	11.82
1850	OR	0.000	14.197	0.006	0	6	6	0.00
1870	OR	1.134	0.285	0.008	9	98	124	3.98
1880	OR	0.032	0.080	0.003	2	16	27	0.39
3100	OR	0.283	0.007	0.062	28	83	107	40.93
1820	RV	1.515	0.101	0.227	41	402	861	15.05
1821	RV	0.932	0.034	0.069	32	207	394	27.31
1822	RV	0.002	0.060	0.000	1	1	7	0.03
1830	RV	0.056	0.008	0.060	2	34	70	7.22
1831	RV	0.009	0.001	0.034	0	13	23	8.88
1832	RV	0.234	0.041	29.800	75	1048	3753	5.76
1850	RV	1.636	6.987	0.623	38	210	292	0.23
1860	RV	0.000	0.000	0.000	0	4	6	24.35
1880	RV	2.935	0.256	0.339	590	1764	2010	11.48
3000	RV	51.056	2.130	3.941	2299	9203	10509	23.97
3100	RV	33.826	6.746	121.07	12547	44155	53823	5.01

Table B5: Imputed aggregate land value in 2000 by detailed land use code for "Undevelopable" vacant parcels in Orange County and Riverside County.

Appendix C
Regression Results

Here are the regression results comparison of developable vacant land and undevelopable vacant land. The regression formula is

$ln(assessed\ value) = constant + b_0 ln(land\ area) + b_1 X_1 + b_2 X_2 + u$

Where X_1 includes four accessibility measures (all measured in miles): distance to the nearest major road (fwy), distance to the nearest sub-center (fsub), distance to the CBD (cbd), and distance to the nearest coast (ocean). X_1 also includes the quadratic terms of fsub and cbd.

X_2 includes four dummy variables: city, land use as of assessment date (lu_08), planned land use as of assessment date (scag_gp_co), year of most recent transaction.

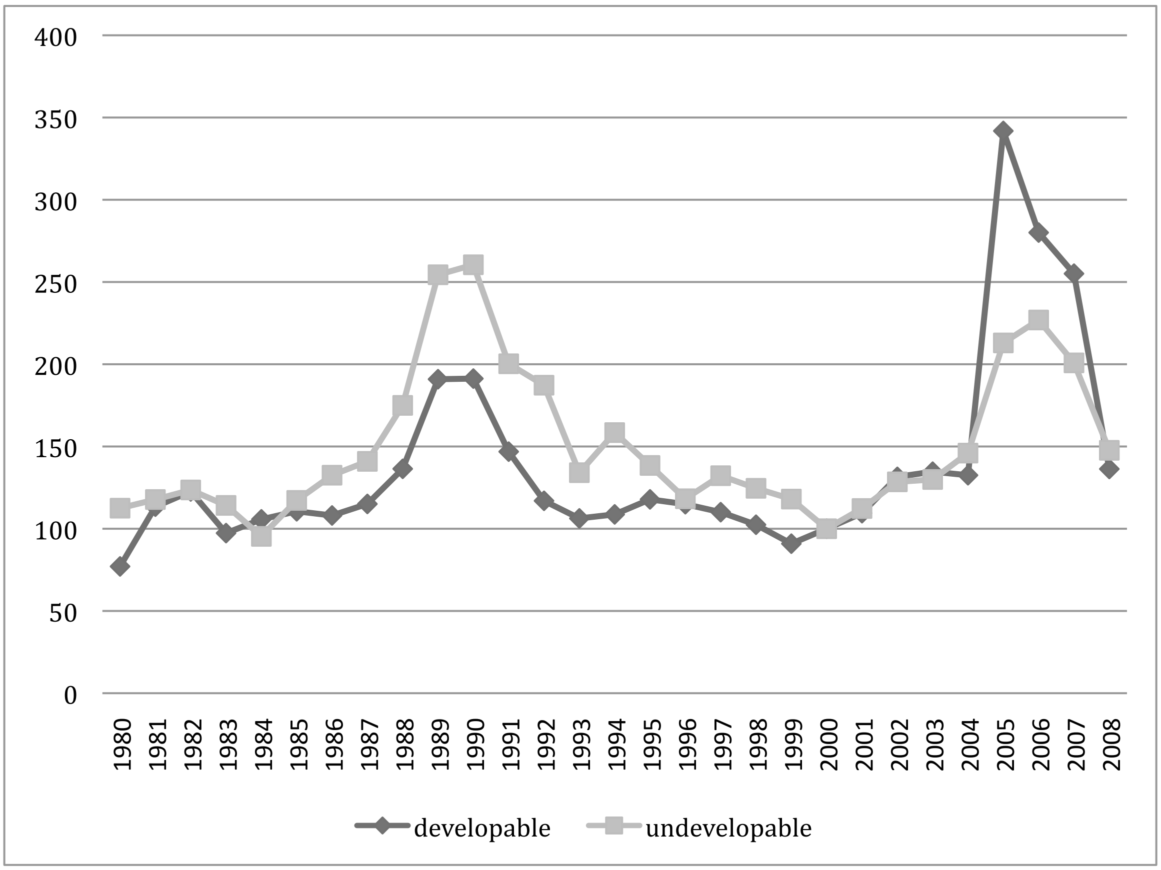

Figure: Land value index for developable and undevelopable land. Year 2000 is the reference year with both developable and undevelopable land value indexes being 100. Note the land value index is only valid for comparing land value of the same develpablility in different years, and the comparison between developable and undevelopable land value index is meaningless.

	Developable vacant land	Undevelopable vacant land
constant	6.823***	10.282***
ln(land area)	0.619***	0.574***
fsub	-0.020***	0.041***
cbd	-0.014***	-0.037***
cbd^2	0.000***	0.001***
fwy	0.014***	0.002
ocean	-0.038***	-0.007**
$ocean^2$	0.000***	-0.001***
city==Adelanto	0.502	-3.204*
city==Agoura Hills	-0.254	-4.566**
city==Alhambra	1.401	2.283
city==Aliso Viejo		-4.384*
city==Anaheim		-3.042
city==Apple Valley	1.253	-3.557*
city==Artesia		0.101
city==Avalon		-3.911**
city==Azusa	-3.482	-6.841***
city==Baldwin Park	1.443	0.538
city==Banning	0.98	-1.729
city==Barstow	2.243	
city==Beaumont	-1.281	-12.115***
city==Bell Gardens	1.338	-1.963
city==Bellflower		-1.384
city==Beverly Hills	1.806	
city==Big Bear Lake	2.809	-0.718
city==Blythe	-0.339	
city==Bradbury	0.523	-2.761
city==Brea	0.313	-3.954**
city==Burbank		-2.573
city==Calabasas	-4.645*	-3.970**
city==Calimesa	1.297	
city==Camarillo	1.025	
city==Canyon Lake		-9.040***
city==Carson	0.601	-5.921***
city==Cathedral City	0.898	
city==Cerritos	-0.266	-8.112***
city==Chino	1.871	-3.522*
city==Chino Hills	-0.127	-3.665**
city==Claremont	0.999	-2.975*
city==Coachella	1.299	

city==Colton	-1.218	-1.32
city==Commerce	1.914	-0.319
city==Compton	-0.846	
city==Corona	0.146	-10.141***
city==Costa Mesa	0.671	-1.345
city==Covina	1.684	-0.678
city==Cudahy	0.243	1.153
city==Culver City	1.09	0.44
city==Cypress	-0.027	
city==Dana Point	1.822	-0.931
city==Desert Hot Springs	1.258	-2.043
city==Diamond Bar	1.372	-0.401
city==Downey	0.587	
city==Duarte	2.085	-4.049**
city==El Monte	0.341	-8.523***
city==El Segundo	0.794	
city==Fillmore	0.673	-4.172**
city==Fontana	1.314	-2.901*
city==Fullerton	1.219	
city==Garden Grove	1.117	
city==Gardena	-1.217	-3.007
city==Glendale	-0.093	-3.684**
city==Glendora	-0.468	-3.520*
city==Grand Terrace	0.421	-0.677
city==Hawthorne	-1.279	-4.418**
city==Hemet	0.249	-5.128***
city==Hermosa Beach		-0.376
city==Hesperia	0.034	-1.858
city==Hidden Hills	-0.746	-7.140***
city==Highland	0.734	-1.911
city==Huntington Beach	0.526	
city==Huntington Park		-1.915
city==Indian Wells	1.652	-4.352**
city==Indio	0.504	-3.438*
city==Industry	0.714	
city==Inglewood	-0.007	-4.068*
city==Irvine	-0.076	-2.282
city==Irwindale	2.162	-0.536
city==La Canada Flintringe	-1.73	-4.012**
city==La Habra	-0.211	-1.81
city==La Habra Heights	0.111	-3.397*
city==La Mirada	-1.321	-7.832***

city==La Puente	0.832	-9.516***
city==La Quinta	-0.258	-6.194***
city==La Verne	-0.989	-3.895**
city==Laguna Beach	1.079	-5.160***
city==Laguna Hills	1.754	-3.721**
city==Laguna Woods	1.239	0.283
city==Lake Elsinore	-0.71	-2.627
city==Lake Forest	0.697	-3.936**
city==Lakewood	0.592	
city==Lancaster	1.64	-3.699**
city==Loma Linda	1.768	-2.526
city==Lomita	0.807	-2.158
city==Long Beach	0.797	-0.25
city==Los Alamitos		-3.321
city==Los Angeles	-0.008	-3.772**
city==Lynwood	0.27	
city==Malibu	1.159	-1.842
city==Manhattan Beach	1.601	-4.393**
city==Maywood	2.696	-4.943**
city==Menifee	0.333	-6.281***
city==Mission Viejo	0.692	-4.753***
city==Monrovia	0.748	-2.742
city==Montclair	1.251	
city==Montebello	1.239	-1.235
city==Monterey Park	1.591	-1.926
city==Moorpark	2.063	-2.929*
city==Moreno Valley	0.233	-4.522**
city==Murrieta	0.682	-8.025***
city==Needles		1.893
city==Newport Beach	0.839	-3.055*
city==Norco	0.458	-3.7
city==Norwalk	1.131	
city==Ojai	1.773	
city==Ontario	0.365	
city==Orange	0.114	-4.467**
city==Oxnard	1.516	
city==Palm Desert	1.472	-3.734*
city==Palm Springs	0.532	-1.828
city==Palmdale	1.197	-3.655**
city==Palos Verdes Estates		1.573
city==Paramount	0.172	-3.050*
city==Pasadena	0.456	-2.3
city==Perris	0.695	-2.899*

city==Pico Rivera	0.244	-13.071***
city==Pomona	0.286	-1.969
city==Port Hueneme	1.036	
city==Rancho Cucamonga	1.437	-0.378
city==Rancho Mirage	1.257	-5.695***
city==Rancho Palos Verdes	-1.231	-8.679***
city==Rancho Santa Margarita	-0.025	-4.815***
city==Redlands	1.494	-3.647*
city==Redondo Beach	1.485	-2.244
city==Rialto	1.943	-3.488*
city==Riverside	0.582	-8.261***
city==Rolling Hill Estates	0.557	-2.878
city==Rosemead	1.401	-3.347
city==San Bernardino	1.1	-3.427*
city==San Buenaventura	1.372	-2.246
city==San Clemente	1.014	-3.819*
city==San Dimas	0.035	-10.041***
city==San Fernando	1.881	
city==San Gabriel	1.12	-4.481**
city==San Jacinto	0.788	-3.876**
city==San Juan Capistrano	1.511	-5.211**
city==Santa Ana		-4.308*
city==Santa Clarita	-0.089	-2.377
city==Santa Fe Springs	0.404	
city==Santa Monica	0.993	-2.441
city==Santa Paula	0.904	
city==Seal Beach	0.979	-3.881*
city==Sierra Madre		-3.385*
city==Signal Hill	-1.332	-3.127*
city==Simi Valley	0.39	-5.055***
city==South El Monte	0.355	-1.688
city==South Gate	0.957	
city==South Pasadena	-0.293	-0.559
city==Stanton	1.454	
city==Temecula	-0.017	-9.958***
city==Thousand Oaks	0.518	-3.776*
city==Torrance	-0.091	-1.011
city==Tustin	0.895	0.94
city==Twentynine Palms	1.173	-5.055**

city==Upland	1.315	-2.446
city==Victorville	1.783	-1.49
city==Walnut	0.23	-4.232**
city==West Covina	0.319	-3.754**
city==West Hollywood	3.021	-2.283
city==Westlake Village	-1.597	-4.513**
city==Westminster	-0.006	
city==Whittier	1.295	-4.024**
city==Wildomar	0.415	
city==Yorba Linda	-1.111	
city==Yucaipa	1.416	-2.761
city==Yucca Valley	1.625	-3.728*
city==unincorporated_la	0.545	-3.060*
city==unincorporated_or	0.017	-4.608***
city==unincorporated_rv	0.574	-5.296***
city==unincorporated_sb	0.712	-2.528
city==unincorporated_vn	0.843	-4.102**
saleyr==1981	0.386***	0.046
saleyr==1982	0.465***	0.094
saleyr==1983	0.233*	0.015
saleyr==1984	0.316**	-0.165**
saleyr==1985	0.361***	0.041
saleyr==1986	0.338***	0.164***
saleyr==1987	0.401***	0.226***
saleyr==1988	0.571***	0.442***
saleyr==1989	0.907***	0.816***
saleyr==1990	0.909***	0.840***
saleyr==1991	0.645***	0.577***
saleyr==1992	0.417***	0.510***
saleyr==1993	0.321**	0.175***
saleyr==1994	0.344***	0.342***
saleyr==1995	0.425***	0.208***
saleyr==1996	0.399***	0.05
saleyr==1997	0.356***	0.162**
saleyr==1998	0.284**	0.102
saleyr==1999	0.165	0.048
saleyr==2000	0.260**	-0.118*
saleyr==2001	0.351***	-0.002
saleyr==2002	0.535***	0.133**
saleyr==2003	0.558***	0.144**
saleyr==2004	0.542***	0.261***
saleyr==2005	1.490***	0.638***
saleyr==2006	1.290***	0.702***

saleyr==2007	1.197***	0.580***
saleyr==2008	0.570***	0.272**
lu_08==1700	1.435***	
lu_08==1800		-1.255**
lu_08==1810	0.388**	
lu_08==1820		1.241**
lu_08==1821		-1.319**
lu_08==1830		0.899
lu_08==1832		-1.601***
lu_08==1840	0.294	
lu_08==1850		0.863
lu_08==1860		2.982**
lu_08==1870		0.718
lu_08==1880		0.889*
lu_08==2000	0.107	
lu_08==2100	0.935	
lu_08==2110	-0.146	
lu_08==2120	-0.139	
lu_08==2200	-0.044	
lu_08==2300	0.335*	
lu_08==2400	0.096	
lu_08==2500	0.849**	
lu_08==2600	0.615***	
lu_08==2700	0.661***	
lu_08==3000	0.143	0.501
lu_08==3100	-0.147	-0.612
lu_08==3200	-0.031	
lu_08==3300	0.425**	
lu_08==3400	0.967***	
scag_gp_co==1100	0.687	0.761*
scag_gp_co==1110	0.178***	0.190***
scag_gp_co==1120	-0.170***	0.123
scag_gp_co==1130	-0.404***	-0.564***
scag_gp_co==1200	0.504***	0.805***
scag_gp_co==1210	0.671***	1.417***
scag_gp_co==1220	0.210*	-0.067
scag_gp_co==1230	0.458***	0.754***
scag_gp_co==1233	0.436	0.476
scag_gp_co==1240	-1.607**	
scag_gp_co==1250	-0.003	-1.334***
scag_gp_co==1260	-0.151	-0.244
scag_gp_co==1270	-0.558	-2.040***
scag_gp_co==1280	-0.106	

scag_gp_co==1290	-1.654	
scag_gp_co==1300	0.231*	0.622***
scag_gp_co==1310	0.302**	-0.316**
scag_gp_co==1320	0.136	-0.561***
scag_gp_co==1330	-0.371*	1.767***
scag_gp_co==1340	-0.418**	-0.455***
scag_gp_co==1350	2.095	
scag_gp_co==1400	-1.778	
scag_gp_co==1410	1.093***	0.024
scag_gp_co==1420	-1.418***	-0.625***
scag_gp_co==1430	-0.255	-2.766**
scag_gp_co==1500	-0.071	-0.873***
scag_gp_co==1600	0.235***	0.381***
scag_gp_co==1800	-1.327***	-1.034***
scag_gp_co==1810	0.586***	-2.106***
scag_gp_co==1820	-1.169***	-0.403***
scag_gp_co==1830	-1.388**	-0.564
scag_gp_co==1840	1.086	0.746
scag_gp_co==1850	-1.148***	-0.890***
scag_gp_co==1870		-1.088**
scag_gp_co==1880	-1.152***	-1.301***
scag_gp_co==2000	-0.498***	-1.268***
scag_gp_co==3000	-0.863	
scag_gp_co==4000	-2.886***	-3.014***

Appendix D

Land Values
Disaggregation by Land Use Category

This appendix presents various statistics related to land values, disaggregated by land use category. Of particular interest is the proportion of aggregate land value, as well as the proportion of aggregate land areas, associated with the twelve land use categories. Table D1 reports the numbers for *developed* land, Table D2 the corresponding numbers for all land.

	Land use	Number	Aggregate	Percentage	Aggregate	Percentage

		of Parcels	Land Value (1e9 $)	of Total Developed Land Value	Land Area (1e9 sq. ft)	of Total Developed Land Area
1	Single Family Residential	2895886	258.19	63.87%	29.03	10.54%
2	Multi Family Residential	290809	20.88	5.16%	3.32	1.21%
3	Mixed Residential	266383	16.31	4.03%	8.67	3.15%
4	Office	47510	12.95	3.20%	3.19	1.16%
5	Retail	249836	31.46	7.78%	8.19	2.97%
6	Other Commercial	13872	3.32	0.82%	1.48	0.54%
7	Public	88092	9.78	2.42%	185.11	67.22%
8	Warehousing	6450	1.04	0.26%	1.49	0.54%
9	Other Industrial	166780	29.79	7.37%	16.02	5.82%
10	Transportation, Communication, and Utilities	58012	19.00	4.70%	18.52	6.73%
11	Mixed	15252	1.51	0.37%	0.33	0.12%
	Total Developed	4098882	404.24	100.00%	275.36	100.00%

Table D1: Aggregate land value and land area of developed parcels by major land use categories.

About 73% of aggregate land value is associated with residential land use, 4% office and other commercial, 8% with warehousing and other industrial, 8% in retail, and somewhat over 7% in public and transportation, communication, and utility. In terms of total developed land area, the corresponding percentages are 15%, 2%, 6%, 3% and 75%. That 75% of the developed land area is either public, or transportation communication, and utilities is the result of much of it being classified as developed even though it is largely vacant. Also of interest is the average land value per sq. ft. for land in different uses: single-family residential ($8.89), multi-family residential ($6.29), mixed residential ($1.88), office ($4.06), retail ($3.84), other commercial ($2.24), public ($0.01), warehousing ($0.70), other industrial ($1.86), TCU ($1.03), and mixed ($4.58). These figures confound differences in the value of land at a particular location and different locations for different land use. Differences in the value of land at a particular location, controlling for location and city, can be inferred from the magnitude of the regressions' land use dummy variables.

Table D2 is the same as Table D1 except that it includes vacant land. Vacant land constitutes 15.38% of aggregate land value and 69.50% of all land area. Developable vacant parcels have an average value per sq. ft of $0.50, and undevelopable vacant parcels an average value per sq. ft. of $0.06.

	Land use	Number of Parcels	Aggregate Land Value (1e9 $)	Percentage of Total Land Value	Aggregate Land Area (1e9 sq. ft)	Percentage of Total Land Area
1	Single Family Residential	2895886	258.19	54.05%	29.03	3.22%
2	Multi Family Residential	290809	20.88	4.37%	3.32	0.37%
3	Mixed Residential	266383	16.31	3.41%	8.67	0.96%
4	Office	47510	12.95	2.71%	3.19	0.35%
5	Retail	249836	31.46	6.59%	8.19	0.91%
6	Other Commercial	13872	3.32	0.70%	1.48	0.16%
7	Public	88092	9.78	2.05%	185.11	20.50%
8	Warehousing	6450	1.04	0.22%	1.49	0.16%
9	Other Industrial	166780	29.79	6.24%	16.02	1.77%
10	Transportation, Communication, and Utilities	58012	19.00	3.98%	18.52	2.05%
11	Mixed	15252	1.51	0.32%	0.33	0.04%
12	Developable Vacant	192322	39.95	8.36%	80.25	8.89%
12	Undevelopable Vacant	272800	33.54	7.02%	547.20	60.61%
	Total parcels	4564004	477.72	100.00%	902.81	100.00%

Table D2: Aggregate land value and land area of all parcels by major land use categories.

Appendix E
Major Land Use Categories

LA project land use code			SCAG 1993 code		
	Alphabetic	Name	3-digit	Name	Note
1	RS-SF	Single-family residential	111	Single family residential	
2	RS-MF	Multi-family residential	112	Multi-family residential	
3	RS-MX	Mixed residential	110	Residential	Missing more detailed land use
			113	Mobile homes and trailer parks	
			114	Mixed residential	
			115	Rural residential	
4	OF	Office	121	General office use	
5	RF	Retail	122	Retail stores and commercial stores	
6	OC	Other commercial	120	Commercial and Services	Missing more detailed land use
			123	Other commercial	
7	P	Public	124	Public facilities	
			125	Special Use Facilities	
			126	Educational institutions	
			127	Military installations	
8	W	Warehousing	134	Wholesaling and warehousing	
9	OI	Other industrial	130	Industrial	Missing more detailed land use

			131	Light industrial	
			132	Heavy industrial	
			133	Extraction	
10	TCU	Transportation/communication /utilities	14x	Transportation, communications, and utilities	Including 140, 141, 142, 143, 144, 145, 146
11	M	Mixed	150	Mixed commercial and industrial	
			160	Mixed urban	
12	V	Vacant	170	Under construction	
			18x	Open space and recreation	Including 180, 181, 182, 183, 184, 185, 186, 187, 188
			2x0	Agriculture	Including 200, 210, 220, 230, 240, 250, 260, 270
			3x0	Vacant	Including 300, 310, 320
13	W	Water	4x0	Water	Including 400, 410, 420, 430, 440, 450
14	O	Other	0, 8888, 9999, or missing		Not in SCAG code

Appendix F
Imputing the Land Value of Developed Parcels on the Basis of the Value of Vacant Land Imparts a Downward Bias

Casual experience suggests that, controlling for accessibility, if two parcels of equal accessibility are converted to urban use at different times, the one that is converted earlier is of higher quality. If this is correct, then the procedure we follow of imputing land value to developed properties on the basis of the value of vacant land, controlling for location, imparts a systematic downward bias to our estimates of aggregate land values. This appendix investigates whether casual experience is supported by theory.

The simplest model in which to address this question is the Arnott and Lewis (1979) model of the transition of land to urban use. The model assumes that a landowner/developer chooses when and at what density to convert his parcel of vacant land to urban use under perfect foresight so as to maximize discounted profit. Once developed, a parcel remains at the same density forever. Let R(t,A) be the rent per unit area of floor space at time t on a site has exogenous amenity level A, T be the time of development, K be the capital per unit area of land in developing the property in monetary units, $\mu(K)$ be the floor-area ratio with $\mu' > 0$ and $\mu'' < 0$, r be the interest rate, and V(A) be the market value of the vacant land today. The question of interest is whether $dT/dA < 0$, i.e. whether a site will a higher amenity level is developed earlier. The landowner/developer's maximization problem is

$$\max_{T,K} \int_T^\infty \mu(K)R(t,A)\, e^{-rt}\, dt - Ke^{-rT} - V(A). \tag{1}$$

The first-order profit-maximization conditions with respect to development timing and density are:

$$T: \quad [- \mu(K)R(T,A) + rK]e^{-rT} = 0 \tag{2}$$

$$K: \quad \int_T^\infty \mu'(K)R(t,A)\, e^{-r(t - T)}dt - 1]e^{-rT} = 0. \tag{3}$$

The timing condition states that land is developed at a time when the marginal benefit from postponing development, the cost of capital, rK, equals the marginal cost, the rent foregone. The density condition states that land is developed when the marginal benefit from spending an extra unit of capital at development time, the increase in the present value of rents from doing so, equals the unit cost. If the second-order conditions hold as strict inequalities, then $R_T(T,A) > 0$ and $\mu''(K) < 0$.

Total differentiation of the pair of equations with respect to A yields

$$- \mu(K)R_T(T,A)\, dT/dA + \quad [- \mu'(K)R(T,A) + r]\, dK/dA \quad = \mu(K)R_A(T,A) \tag{4}$$

$$[-\mu'(K)R(T,A) + r]\, dT/dA + [\textstyle\int_T^\infty \mu''(K)R(t,A)\, e^{-r(t-T)}dt]\, dK/dA = -\textstyle\int_T^\infty \mu'(K)R_A(t,A)\, e^{-r(t-T)}dt \quad (5)$$

Thus,

$$[-\mu'(K)R(T,A) + r]\, dK/dA = \mu(K)R_A(T,A) + \mu(K)R_T(T,A)\, dT/dA \quad (6)$$

Substituting this into the second equation gives

$$[-\mu'(K)R(T,A) + r]^2\, dT/dA = [-\textstyle\int_T^\infty \mu'(K)R_A(t,A)\, e^{-r(t-T)}dt][-\mu'(K)R(T,A) + r] - \{[\textstyle\int_T^\infty \mu''(K)R(t,A)\, e^{-r(t-T)}dt](\mu(K)R_A(T,A) + \mu(K)R_T(T,A)\, dT/dA\} \quad (7)$$

or

$$\{[-\mu'(K)R(T,A) + r]^2 + [\textstyle\int_T^\infty \mu''(K)R(t,A)\, e^{-r(t-T)}dt]\mu(K)R_T(T,A)\}\, dT/dA = [-\textstyle\int_T^\infty \mu'(K)R_A(t,A)\, e^{-r(t-T)}dt][-\mu'(K)R(T,A) + r] - [\textstyle\int_T^\infty \mu''(K)R(t,A)\, e^{-r(t-T)}dt]\mu(K)R_A(T,A). \quad (8)$$

Now, the expression in curly brackets preceding dT/dA is negative via the second-order conditions for a maximum. Thus, the sign of dT/dA depends on the sign of the terms on the RHS; specifically

$$\text{sgn}\,(dT/dA) = \text{sgn}\,\{[\textstyle\int_T^\infty \mu'(K)R_A(t,A)\, e^{-r(t-T)}dt][-\mu'(K)R(T,A) + r] + [\textstyle\int_T^\infty \mu''(K)R(t,A)\, e^{-r(t-T)}dt]\mu(K)R_A(T,A)\}. \quad (9)$$

Using (3), this can be simplified to

$$\text{sgn}\,(dT/dA) = \text{sgn}\,\{[\textstyle\int_T^\infty \mu'(K)R_A(t,A)\, e^{-r(t-T)}dt][-\mu'(K)R(T,A) + r] + [\mu''(K)/\mu'(K)]\mu(K)R_A(T,A)\}. \quad (10)$$

Thus far, we have placed no restrictions on how an increase in the amenity level affects the time path of rents. To simplify, where A_0 is an arbitrary amenity level, I shall assume that

A-1: $R(t, A) = AR(t, A_0)$ for all A and all t;

that is, a given change in the amenity level results in a proportional change in the rent function over time. Under **A-1**:

$$\text{sgn}\,(dT/dA) = \text{sgn}\,\{[\textstyle\int_T^\infty \mu'(K)R_A(t,A)\, e^{-r(t-T)}dt][-\mu'(K)R(T,A) + r] + [\mu''(K)/\mu'(K)]\mu(K)R_A(T,A)\} \quad (11)$$

$$= \text{sgn}\,\{[\textstyle\int_T^\infty \mu'(K)R(t,A)\, e^{-r(t-T)}dt][-\mu'(K)R(T,A) + r] + [\mu''(K)/\mu'(K)]\mu(K)R(T,A)\}.$$

Using (2) and (3), this reduces to

$$\text{sgn}\,(dT/dA) = \text{sgn}\,\{[-\,\mu'(K)R(T,A) + r] + [\mu''(K)/\mu'(K)]rK\}. \quad (12)$$

Recall that the elasticity of substitution in intensive form under CRS is

$$\sigma = -\,\mu'(K)(\mu(K) - \mu'(K)K)/[\mu(K)\mu''(K)K]. \quad (13)$$

Using $\mu(K)R(T,A) = rK$ from (2), $-\,\mu'(K)R(T,A) + r = r(-\,\mu'(K)K/\mu(K) +1)$. Substituting this into (12) yields

$$\text{sgn}\,(dT/dA) = \text{sgn}\,\{[-\,\mu'(K)K +\mu(K)] + [\mu''(K)K\mu(K)/\mu'(K)]\}$$

$$= \text{sgn}\,\{(-\,\sigma +1)[\mu(K)\mu''(K)K/\mu'(K)\} < 0 \text{ when } \sigma < 1. \quad (14)$$

Consider the case where $\sigma = 0$. Then K is essentially constant. Thus, comparing two properties that differ in A, both have the same marginal benefit from postponing development, rK, but the property with the higher amenity level has the higher marginal cost, which is the rent foregone. When $\sigma \in (0,1)$, the landowner/developer responds to a higher amenity level by both bringing forward development and increasing development density. When $\sigma > 1$, the landlord-development will respond by constructing later at much higher density. Only under exceptional rental growth conditions is $\sigma > 1$ consistent with the second-order conditions, and all the empirical evidence indicate that σ is less than one.

Thus, casual experience is supported by theory. Controlling for accessibility, locations with higher amenities are developed earlier. Thus, controlling for accessibility but not for amenities, ascribing land values to parcels that have already been developed on the basis of the market value of vacant land imparts a downward bias to those estimates.