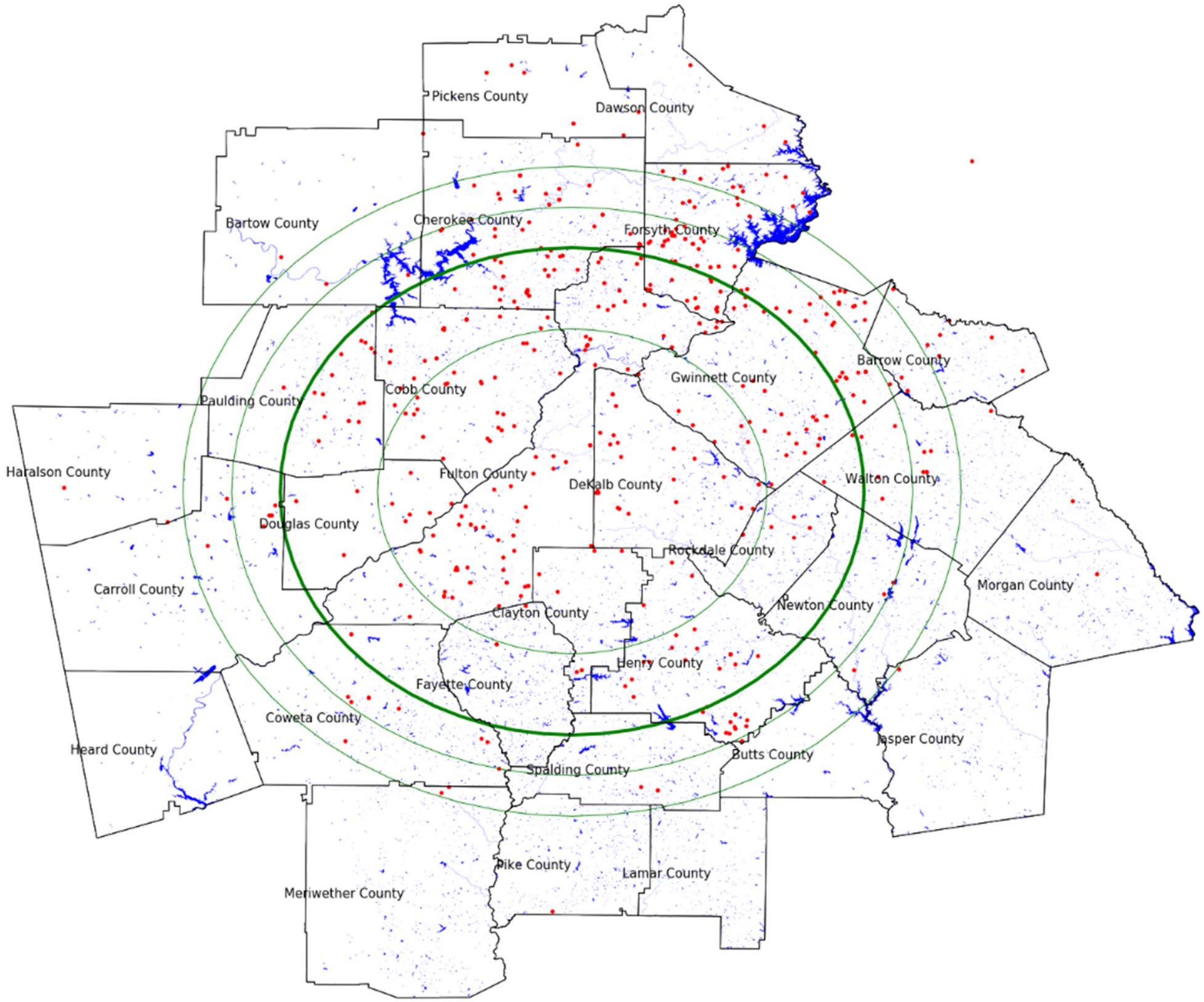
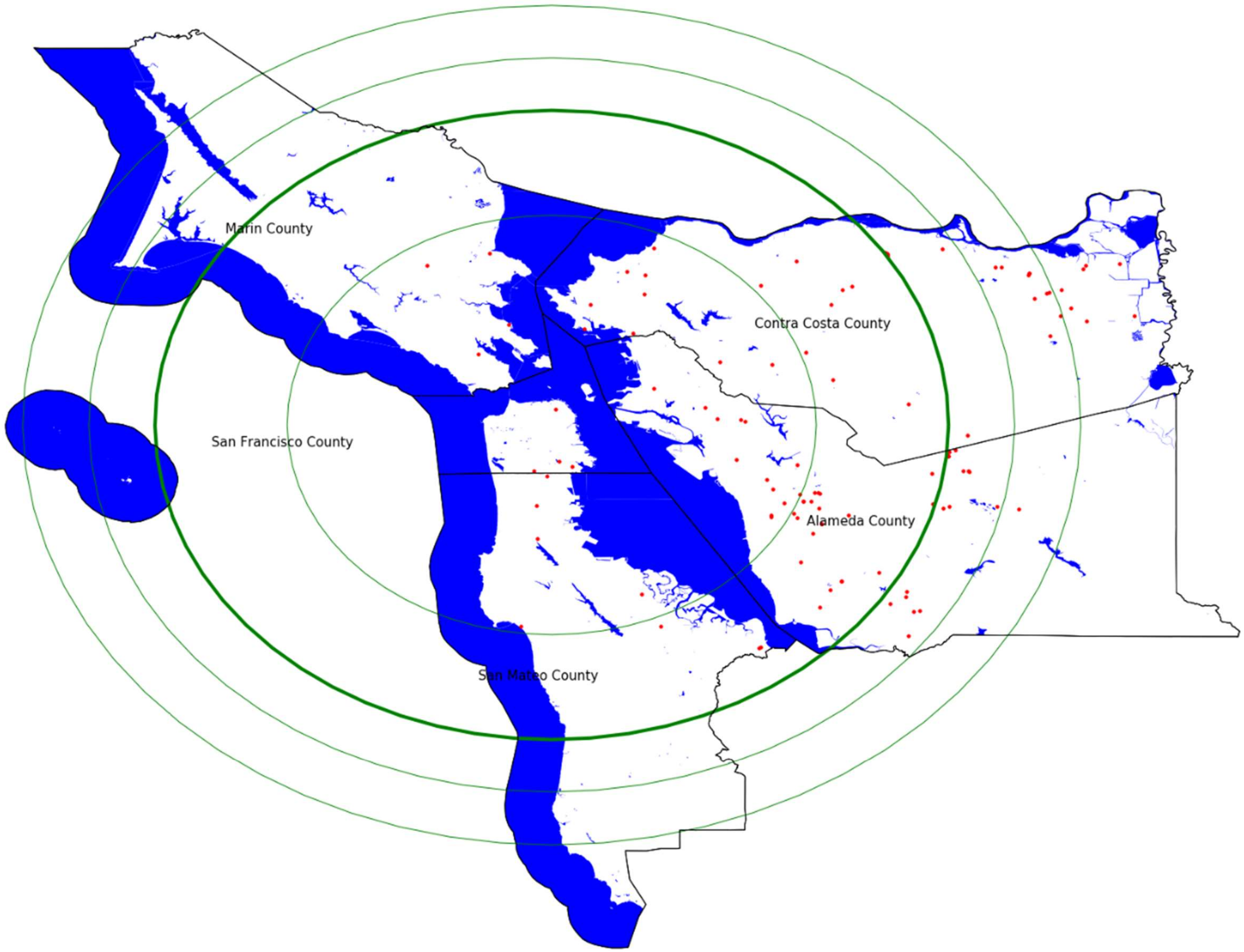
Online Appendix

Appendix 1:

Atlanta CBSA: 20, 30, 35 and 40 Mile Radii Boundaries



San Francisco CBSA: 20, 30, 35 and 40 Mile Radii Boundaries



New York CBSA: 20, 30, 35, and 40 Mile Radii Boundaries

Appendix 2: Summary Statistics on Vacant Land Purchases Intended for Single Family Home Development, 2013 - 2018 (within 30 miles)
CoStar Data

		Parcel Size (ft^2)			
CBSA Name	*Number of Observations*	*Median*	*Mean*	*Mean P(L) / ft^2 (Std. Dev.)*	*Total SF Vacant Land Area Transacted (acres)*
Atlanta	301	435,600	1,077,105	\$3.80 (\$6.36)	7,443
Boston	23	653,400	1,120,446	\$8.01 (\$10.70)	592
Charlotte	279	522,720	2,010,451	\$3.73 (\$7.33)	12,877
Chicago	70	139,233	753,787	\$22.08 (\$55.43)	1,211
Cincinnati, OH	20	2,178,000	2,602,309	\$0.83 (\$1.03)	1,195
Columbus, OH	49	594,158	948,952	\$3.18 (\$7.41)	1,067
Dallas	36	612,018	2,001,506	\$3.75 (\$6.16)	1,654
Deltona	37	1,047,618	5,370,782	\$8.70 (\$36.44)	4,562

Appendix 2 Continued

CBSA Name	Number of Observations	Parcel Size (ft^2) Median	Mean	Mean P(L) / ft^2 (Std. Dev.)	Total SF Vacant Land Area Transacted (acres)
Denver	253	195,149	1,850,655	$14.67 ($45.50)	10,749
Detroit	43	170,280	673,733	$3.75 ($7.99)	665
Los Angeles	157	75,489	725,481	$49.64 ($87.48)	2,615
Miami	112	266,587	6,467,220	$15.24 ($40.78)	16,628
Minneapolis	41	914,760	1,585,248	$5.90 ($13.27)	1,492
Nashville	45	1,237,104	2,567,597	$2.59 ($4.02)	2,652
New York	58	113,691	718,918	$56.98 ($117.92)	957
Orlando	249	187,000	1,122,591	$5.32 ($8.26)	6,417
Philadelphia	73	304,920	975,765	$25.92 ($51.92)	1,635

Appendix 2 Continued

CBSA Name	Number of Observations	Parcel Size (ft^2) Median	Parcel Size (ft^2) Mean	Mean P(L) / ft^2 (Std. Dev.)	Total SF Vacant Land Area Transacted (acres)
Phoenix	788	435,600	1,020,967	\$7.78 (\$8.03)	18,469
Portland	256	88,032	310,189	\$12.01 (\$12.69)	1,823
Riverside	286	463,479	1,452,707	\$9.09 (\$15.33)	9,538
San Francisco	69	119,354	597,764	\$61.95 (\$192.16)	947
San Jose	44	306,227	1,200,930	\$32.69 (\$48.66)	1,213
Seattle	232	181,428	455,279	\$24.08 (\$37.00)	2,425
Washington	119	114,837	2,488,874	\$26.65 (\$50.57)	6,799

Appendix 3: Median Number of Housing Units (N) per Acre, by CBSA

CBSA	*Median Housing Units Per Acre*
Atlanta	2.89
Boston	0.91
Charlotte	2.12
Chicago	3.56
Cincinnati, OH	1.63
Columbus, OH	2.23
Dallas	3.14
Deltona	3.34
Denver	4.25
Detroit	1.68
Los Angeles	4.79
Miami	4.77
Minneapolis	2.16
Nashville	2.29
New York	2.88
Orlando	4.00
Philadelphia	3.66
Phoenix	3.94
Portland	6.53
Riverside	3.53
San Francisco	4.45
San Jose	5.17
Seattle	4.85
Washington	4.13

Appendix 4: Summary Statistics on Intensive Margin Valuations and their Components: Interquartile Ranges

CBSA	*Panel*	*p25*	*p50*	*p75*
Atlanta	Panel (a) q	$0.10*	$0.54	$1.38
	Panel (b) A	7,363	10,019	13,558
	Panel (c) qA	$1,132	$5,539	$15,822
Boston	Panel (a) q	$0.25	$0.62	$1.32
	Panel (b) A	26,262	35,987	42,315
	Panel (c) qA	$9,739	$27,226	$35,993
Charlotte	Panel (a) q	$0.28	$1.02	$2.79
	Panel (b) A	10,623	15,131	22,498
	Panel (c) qA	$4,377	$18,887	$40,298
Chicago	Panel (a) q	$1.21	$3.74	$5.53
	Panel (b) A	6,326	7,854	10,417
	Panel (c) qA	$11,717	$31,214	$54,989
Cincinnati, OH	Panel (a) q	$0.62	$0.85	$1.57
	Panel (b) A	15,318	17,658	23,328
	Panel (c) qA	$11,444	$18,719	$27,578
Columbus, OH	Panel (a) q	$0.49	$0.94	$2.02
	Panel (b) A	8,370	12,234	19,595
	Panel (c) qA	$6,682	$13,873	$21,072
Dallas	Panel (a) q	$0.88	$1.66	$2.89
	Panel (b) A	7,802	9,161	11,323
	Panel (c) qA	$10,546	$17,628	$27,870

Appendix 4 Continued

CBSA	*Panel*	*p25*	*p50*	*p75*
Deltona	Panel (a) q	$0.77	$1.46	$2.45
	Panel (b) A	7,620	8,690	11,082
	Panel (c) qA	$7,447	$12,528	$24,176
Denver	Panel (a) q	$3.74	$7.43	$10.84
	Panel (b) A	5,683	7,184	8,715
	Panel (c) qA	$28,893	$49,904	$89,026
Detroit	Panel (a) q	$0.10*	$0.31	$1.63
	Panel (b) A	14,493	17,494	21,073
	Panel (c) qA	$1,746	$5,024	$29,497
Los Angeles	Panel (a) q	$7.07	$12.24	$20.13
	Panel (b) A	5,084	6,267	8,439
	Panel (c) qA	$47,896	$84,119	$153,781
Miami	Panel (a) q	$1.80	$4.30	$10.35
	Panel (b) A	4,782	6,513	9,697
	Panel (c) qA	$8,638	$36,477	$81,642
Minneapolis	Panel (a) q	$1.53	$2.11	$3.25
	Panel (b) A	10,356	13,372	15,665
	Panel (c) qA	$20,541	$27,916	$43,818
Nashville	Panel (a) q	$0.10*	$0.28	$0.85
	Panel (b) A	10,010	12,378	17,685
	Panel (c) qA	$1,542	$4,345	$15,416

Appendix 4 Continued

CBSA	*Panel*	*p25*	*p50*	*p75*
New York	Panel (a) q	$2.25	$5.80	$17.92
	Panel (b) A	5,995	11,928	19,715
	Panel (c) qA	$40,330	$65,829	$142,743
Orlando	Panel (a) q	$0.99	$2.77	$5.30
	Panel (b) A	6,632	8,379	10,691
	Panel (c) qA	$7,790	$21,096	$45,313
Philadelphia	Panel (a) q	$0.53	$1.36	$3.47
	Panel (b) A	1,160	7,995	14,118
	Panel (c) qA	$4,609	$12,005	$25,342
Phoenix	Panel (a) q	$3.24	$5.77	$9.74
	Panel (b) A	6,194	7,554	10,208
	Panel (c) qA	$24,070	$46,671	$80,360
Portland	Panel (a) q	$2.98	$5.00	$7.66
	Panel (b) A	4,190	5,369	7,574
	Panel (c) qA	$15,788	$23,900	$39,577
Riverside	Panel (a) q	$1.83	$3.54	$5.90
	Panel (b) A	6,905	8,224	9,548
	Panel (c) qA	$15,843	$31,425	$50,159
San Francisco	Panel (a) q	$4.63	$7.46	$12.05
	Panel (b) A	4,328	7,828	9,573
	Panel (c) qA	$29,846	$53,190	$92,286

Appendix 4 Continued

CBSA	*Panel*	*p25*	*p50*	*p75*
San Jose	Panel (a) q	$7.32	$11.46	$15.37
	Panel (b) A	5,149	6,170	8,352
	Panel (c) qA	$50,142	$62,231	$105,194
Seattle	Panel (a) q	$2.36	$3.98	$6.49
	Panel (b) A	4,845	6,361	8,330
	Panel (c) qA	$15,892	$26,593	$42,783
Washington	Panel (a) q	$1.23	$2.80	$6.66
	Panel (b) A	4,796	8,669	14,444
	Panel (c) qA	$10,064	$28,896	$65,368

Notes:

1. Each row reflects the interquartile range of our estimates or calculations of q, A or $q*A$ for each CBSA. Within CBSA, the underlying observation can and does change across rows.
   A * indicates an allocated value for q, the intensive margin value of a square foot of extra land. This was done in the few cases when we estimated a negative value for this parameter. When this happened, we allocated a value of $0.10 (10 cents) per square foot. While we have no trouble believing an existing owner might not pay much at all for extra land in a market with low land prices in general and large lot sizes, we thought it unlikely that they would actually be willing to pay to reduce their lot size. Hence, this allocation decision. This outcome occurred most frequently in Atlanta. That is the only CBSA for which at least 25% of the cases generated estimated values of $q<0$ (although these cases were not statistically significant in general). Implementing this procedure does not change any result in any meaningful way. The largest absolute impact is in Philadelphia, where if we take the negative q's literally, the median parcel zoning tax increases to $84,857 from $76,672 in Table 1. Other markets change by much smaller amounts ranging from $0 to $6,767 with half of markets experiencing no change. Atlanta is in the middle, as its median parcel would have a zoning tax value of $18,269 (versus $15,111 in Table 1) were we to leave the negative q's unchanged.

Appendix 5 - Mathematical Appendix:

Proof: If the homeowner is able to subdivide, the gap between the extensive and intensive margin will equal the zoning tax.[1]

The primary reason is that the equality of extensive and margin prices relies on the ability to subdivide without constraint on the intensive margin by existing owners, not on any factor that might be pushing up land value on the extensive margin. No matter how high a price developers are willing to pay on the extensive margin, existing owners are incented to subdivide and sell until their value of an extra square foot of lot equals the value of land on the extensive margin. There must be a constraint on the ability to subdivide for equality not to result. We illustrate this below.

Assume the homeowner's value function increasing in structure and land Cobb-Douglas:

$$U(S, L) = AS^{\theta\psi}L^{(1-\theta)\psi}$$

where S is square footage and L is lot size, with $\psi < 1$.

The elasticity on lot size is then $(1-\theta)\psi$, so the market price of homebuyers adding an additional unit of land to an existing house is $(1-\theta)\psi(\frac{p^H}{L})$ and therefore the market price for a particular lot is $(1-\theta)\psi(p^H)$.

On the homebuilders' side, assuming a competitive bidding process, the market price of that lot should be $(1-\theta\psi)p^H$. To see this, note the following:

Once a lot is acquired, a builder's revenue less costs are $AS^{\theta\psi}L^{(1-\theta)\psi} - p^S S$

where $p^S S$ is the price per unit to install an additional square foot of home space. The optimal square footage is then $\theta\psi p^H = p^S S$, which will yield profits of $(1-\theta\psi)p^H$ before considering land costs.

Now, note that if the homeowner is able to subdivide, then the homeowner is able to sell at the prevailing price builders are willing to pay, $(1-\theta\psi)p^H$. Then the homeowner solves the arbitrage condition where they can either consume an additional unit according to $AS^{\theta\psi}L^{(1-\theta)\psi}$ or sell at the builders' price.

$$\frac{\partial U}{\partial L} = AS^{\theta\psi}(1-\theta)\psi(L)^{(1-\theta)\psi-1} = (1-\theta\psi)p^H$$

[1] Referees and readers have raised potential confounders, such as the prospect of decreasing returns to scale at the parcel level, the plattage effect of land assembly, or option value. Regardless of the specific factor, we remain convinced that our interpretation of the gap between extensive and intensive margin price is theoretically correct. Decreasing returns to scale in housing production/land assembly or high house prices may be consistent with gaps between extensive and intensive margin prices, but they are neither necessary nor sufficient conditions.

$$L^a = \left(\frac{(1-\theta\psi)p^H}{AS^{\theta\psi}(1-\theta)\psi}\right)^{\frac{1}{(1-\theta)\psi - 1}}$$

At lot size L^a, the intensive margin of the homeowner is equal to the extensive margin and the homeowner is indifferent between consuming an additional unit of land or selling out to the builder.

$$\frac{\partial U}{\partial L}(L^a) = (1-\theta\psi)p^H$$

The Cobb-Douglas functional form implies for any $L > L^a$ the intensive margin to the homeowner at that lot size will be less than the extensive margin price.

To show: So long as intensive margin value is less than extensive margin price and infinite subdivision is allowed homeowners will subdivide until the intensive margin equals the extensive margin.

Let the homeowner choose to subdivide some amount of land $\hat{L}$ from their plot and sell at the prevailing price builders are willing to pay from the referee's solution, $(1-\theta\psi)p^H$, then the homeowner faces the following maximization problem:

$$\max_{\hat{L}} U(\hat{L}) = AS^{\theta\psi}(L-\hat{L})^{(1-\theta)\psi} + (1-\theta\psi)p^H\hat{L}$$

Taking the derivative with respect to $\hat{L}$

$$\frac{\partial U}{\partial \hat{L}} = -AS^{\theta\psi}(1-\theta)\psi(L-\hat{L})^{(1-\theta)\psi - 1} + (1-\theta\psi)p^H = 0$$

$$AS^{\theta\psi}(1-\theta)\psi(L-\hat{L})^{(1-\theta)\psi - 1} = (1-\theta\psi)p^H$$

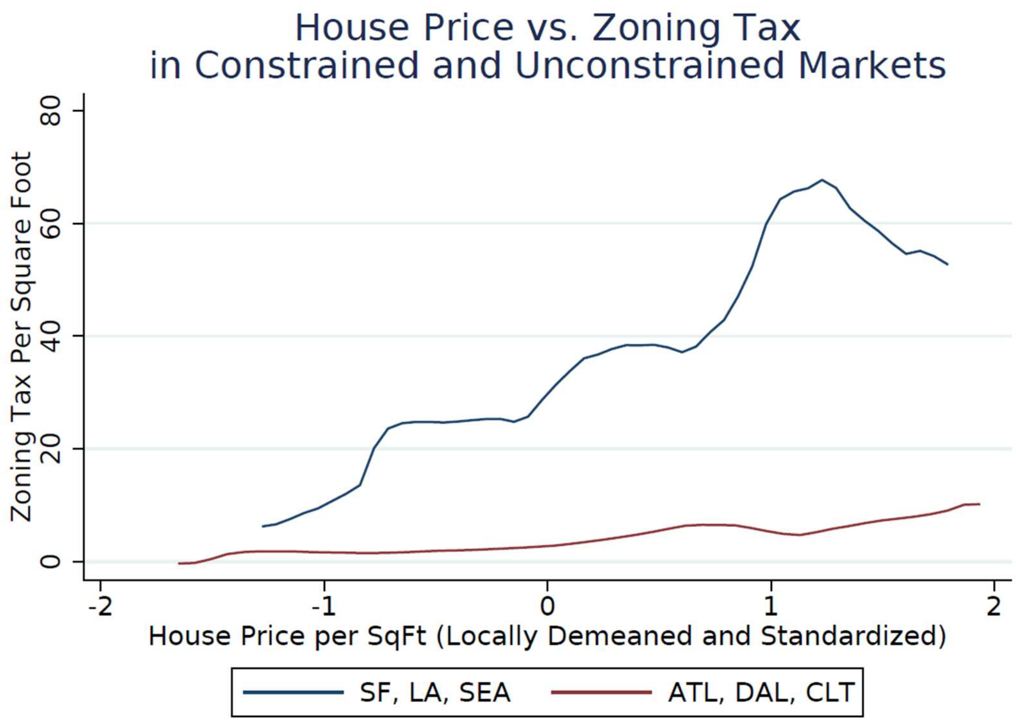
$$(L-\hat{L})^{(1-\theta)\psi - 1} = \frac{(1-\theta\psi)p^H}{AS^{\theta\psi}(1-\theta)\psi}$$

$$\hat{L} = L - \left(\frac{(1-\theta\psi)p^H}{AS^{\theta\psi}(1-\theta)\psi}\right)^{\frac{1}{(1-\theta)\psi - 1}} = L - L^a$$

From this, we can see that the homeowner will choose to subdivide until $L - \hat{L} = L^a$. Since $\frac{1}{(1-\theta)\psi - 1} < 0$ and $\psi < 1$, the optimal quantity of land to subdivide is decreasing in ψ and increasing in p^H and θ. However, if $\hat{L} > 0$, the owner still wants to subdivide.

Decreasing returns to scale and high house prices could be the reason why subdivision is desirable, but they do not imply an extensive – intensive margin gap if unconstrained subdivision by existing owners is allowed at extensive market prices.

Appendix 6



Notes: This figure plots zoning tax per square foot by house price per square foot in three constrained markets (San Francisco, Los Angeles, and Seattle) versus three unconstrained markets (Atlanta, Dallas, and Charlotte). Because there is substantial nominal variation in price levels across markets, we locally demean and standardize house price per square foot, such that we are comparing the zoning taxes in areas priced 1 standard deviation above the mean in Los Angeles to observations 1 standard deviation above the mean in Dallas. The lines are local polynomial regressions from microdata and are pooled across CBSA type (i.e. SF, LA, and SEA observations pooled together). The advantage of this standardization is that it allows us to compare the zoning taxes of parcels in different markets that are on similar points on their local house price distribution.

Microdata observations are vacant land sale transactions from CoStar data. Zoning taxes per square foot are calculated as they are in the paper. House price per square foot is the median price per square foot of the 100 closest newly-constructed homes in CoreLogic. Newly constructed and transacted homes in CoreLogic represent the most likely outcomes for vacant land transacted in the CoStar data in terms of house prices and density.

Examining the figure, several facts stand out. First, there is no evidence that higher house prices mechanically raise zoning taxes to economically meaningful levels. There are extremely low zoning taxes even in high house price areas in Atlanta, Dallas, and Charlotte. Moving up the local house price distributions in these places increases the zoning tax from about \$3/sqft to \$5/sqft to \$10/sqft at the mean, 1 sd, and 2 sd, respectively. Even at the very top, these zoning taxes are not economically large. Second, any strong positive relationship between prices and zoning taxes seems to be driven entirely by the high zoning tax markets. At the far left tail of the figure, the zoning taxes in constrained and unconstrained markets are of a similar level and economically very small. There is wide divergence above the median, and then especially above 1 standard deviation, where zoning taxes exceed $50/sqft (almost $550,000 per quarter acre) in the high zoning tax markets. Third, these divergent distributions underscore the differences in housing affordability across markets. For instance, parcels 2 standard deviations above the mean price in Atlanta, Dallas, Charlotte have about the same zoning tax per square foot as a parcel 1 standard deviation below the mean in San Francisco, Los Angeles, Seattle.