Supply Constraints and Housing Prices

Saku Aura*   Thomas Davidoff†‡

March 31, 2006

Regulatory supply constraints are sometimes blamed for high housing prices in the coastal United States.[1] This paper analyzes the effects of land use constraints in a world in which people are mobile, but preferences over different locations are heterogeneous. Loosening regulations within individual regions would have little effect on prices for plausible parameterizations. For example, if the median American would be induced to move to Manhattan in the long run if the price of apartment space fell by seventy percent, and if the threshold price were distributed normally in the US population, then even if every building in Manhattan were 100 stories tall, prices would fall by less than 15 percent, ignoring amenity loss. Under the same assumptions on demand for land in metropolitan New York, halving land prices would require multiplying developable land supply in existing locations by 15.

It is difficult to assess the role of land use constraints empirically because we do not observe the same city at the same time with and without these regulations.[2] A believable theoretical model of regulations' effects on prices can thus help inform important policy de-

*University of Missouri and CESifo, auras@missouri.edu

†Haas School of Business, UC Berkeley, davidoff@haas.berkeley.edu

‡We thank Barry Dinerstein of the New York Department of City Planning; Robert Johnson of Bowman, Barrett & Associates; and Johan Walden for helpful suggestions.

[1]See, e.g. Glaeser et al. (forthcoming, 2006, 2005).

[2]Glaeser et al. (2005) argue that apartment prices in Manhattan would fall to observed (regulated) marginal cost if height restrictions were lifted. This assumes marginal cost is independent of building height. If marginal cost is increasing in building height, the resulting equilibrium price would be above the observed current marginal cost.

bates. Classical urban economic theory provides two contradictory models to asses impacts, and both rely on unrealistic assumptions. If cities have fixed populations, then land use constraints lower the welfare of the regulated city and may have large price effects if demand for space is inelastic. If there is unfettered mobility across regions, then land use constraints have equal welfare effects across cities and can only raise prices in the regulated city relative to other cities through increased amenity.

In this paper, we consider the effects of land use constraints in a more realistic world in which mobility is free, but consumers balance housing cost against wage differentials or taste for living in one city or another.[3] The effects of supply constraints on prices depend on the extent of heterogeneity in willingness to pay for space in the regulated city. With very diverse valuations, we approach the closed city model with fixed population. When tastes are almost homogeneous, we approach the open city model.

We assume that the consumer price of a square foot of structure is exogenously given, but land is in limited supply and has an endogenous price. We ask what effect a small increase in the supply of land has on the price of land, ignoring amenity or wage consequences. A direct application of this analysis would be to ask what effect removal of land for critical habitat protection has on land prices (assuming the habitat has no amenity value).

Our model applies equally well to a city where all land is covered by a limited number of stories of apartments. In that case, land prices become irrelevant to consumers of apartments and what we call a unit of "land" can be interpreted as a square foot of apartment space.

The model does not precisely describe height restrictions or minimum lot size requirements in a world in which some people would prefer to live in apartments and others prefer to live in detached homes. We suspect that our results are instructive in those widely applicable cases, but leave more nuanced analysis to future work.[4] We ignore the amenity

[3]Our economy is similar to that described by Gyourko et al. (2004).

[4]In those cases, consumer valuation of both structure and land may deviate from their marginal cost. In the case of apartments, the price of residential land is different from opportunity cost in the next best use, but this matters only to developers and land owners, not apartment consumers, who see only a price per square foot of structure.

and wage effects of additional supply and abstract away from within-market heterogeneity of land quality.

We consider a static world, meant to represent a long run equilibrium. We assume for simplicity that profits from land development are distributed to an absentee landlord. We justify this simplification on the grounds that the effect of residents' wealth at the time of zoning on a long-run equilibrium is plausibly small.

N consumers in a nation may live in any of a number of locations. In one of these locations, an island, there are only L units of land. Because the entire island is assumed to be occupied in equilibrium, there is an endogenous price per unit, which we denote q. The island is meant to approximate a region where the quantity of desirable land is limited by transportation costs and perhaps regulation.

There are a continuum of consumers whose preferences give rise to the price per acre of land θ at which they are indifferent between living on the island and living at their next preferred location, at which the price of land is q_{oi} and wealth would be y_{oi}. For an individual i with wealth y_i on the island:

$$v(\theta_i, 1, y_i, \text{live on island}) = v(q_{oi}, 1, y_{oi}, \text{live in next preferred location}). \tag{1}$$

Specification (1) assumes that taste for living on the island is not associated with demand for land relative to all other goods for island residents. All other goods, including structures in the majority of markets where land consumption matters, are subsumed into a numeraire. This setup would arise if, for example, direct utility over consumption of land and the numeraire while living on the island were a monotonic transformation of direct utility over the same quantities while living on the mainland. The same structure could arise if preferences were different across locations. Land demand is assumed constant conditional on wealth only for notational convenience.

For all wealth levels, the minimum value of θ that lives on the island when land costs q per acre is q, since indirect utility is decreasing in consumer prices. We thus have the following land clearing condition:

$$Z \equiv N \int_0^\infty \int_q^\infty l(q,1,y) f(y,\theta) d\theta dy - L = 0. \tag{2}$$

$l(q,1,y)$ represents marshallian demand for island land. We drop the price arguments from here forward. The bivariate probability density function $f(y,\theta)$ is the density of consumers with wealth y if on the island and indifferent between the island and their next preferred location if the island's price is θ. We assume that the island is sufficiently small relative to other locations that entry or exit from other locations to the island has negligible effects on their prices, so that θ_i can be thought of as a constant.

We are interested in the change in prices induced by a change in land supply. Using the implicit function theorem, $\frac{dq}{dL} = -(\frac{\partial Z}{\partial q})^{-1} \frac{\partial Z}{\partial L}$. Differentiating, we find:

$$-\frac{\partial Z}{\partial L} = 1. \tag{3}$$

$$\frac{\partial Z}{\partial q} = N \left(\int_0^\infty -l(y) f(y,q) dy + \int_0^\infty \int_q^\infty \frac{\partial l(y)}{\partial q} f(y,\theta) d\theta dy \right). \tag{4}$$

Combining equations (3) and (4) we obtain:

$$\frac{dq}{dL} = \left(N \int_0^\infty \frac{l(y)}{q} \left(-q f(q,y) + \int_q^\infty \eta_{lq}(y) f(\theta,y) d\theta \right) dy \right)^{-1}. \tag{5}$$

$\eta_{lq}(y)$ is the elasticity of land demand with respect to price for consumers of wealth y, $\frac{\partial l}{\partial q}\frac{q}{l}$.

Multiplying both sides of equation (5) by $\frac{L}{q}$, we find that the elasticity of land price with respect to supply is:

$$\eta_{qL} = \left(N \int_0^\infty \frac{l(y)}{L} \left(-q f(q,y) + \int_q^\infty \eta_{lq}(y) f(\theta,y) d\theta \right) dy \right)^{-1} \tag{6}$$

$$= \left(-\frac{E(l(q)|\theta = q)}{E(l(q)|\theta \geq q)} \frac{q f(q)}{1 - F(q)} + \bar{\eta}_{qL} \right)^{-1} \tag{7}$$

This elasticity is composed of two terms. The first term is a product of two parts. The first part is the ratio of average land demand of people living on the island to the average land demand of marginal entrants. We assume in the following analysis that this ratio is equal to one.[5] The second part of the first term is the marginal hazard ratio of living in the

[5]New entrants' lower willingness to pay might signal lower incomes and hence lower land demand, but could also signal *greater* land demand holding income constant.

island at evaluated at q multiplied by q.[6] The second term is the elasticity of demand for land of people already living on the island that is weighted by their respective land consumption. We note that η_{qL} is negative unless land is a Giffen good.

Gyourko and Voith (2000) summarize empirical estimates for $\bar{\eta}_{lq}$ in the population ranging from -.5 to -1.0. Taking the lowest magnitude of -.5, we find that the maximum elasticity of land price with respect to quantity is -2. It is unrealistic to think that no one would move in or out of coastal cities if prices change, however, so elasticities must be closer to zero than 2.

Table 1 summarizes the elasticity of land price with respect to quantity that arises under different distributions of θ in the population. We consider four distributions: the uniform, the Pareto, the normal and the lognormal. We offer no opinion on which distribution is the most reasonable, except to note that there is no guarantee that this distribution need not look like the income distribution. We recognize that identifying distributional parameters empirically would be quite challenging. Under the normal and in some cases uniform distributions, there are some negative valuations; our results are unchanged if negative values are replaced with valuations of zero (or any valuation less than q.)[7]

For each of these four distributions, by specifying the fraction of national population that lives in a region as well as the median valuation θ in the population as a fraction of the price q, we have sufficient information to obtain the elasticity of interest η_{qL}. The demand elasticity η_{lq} and the probability density $f(q)$ should be interpreted as a land-share weighted averages, following the discussion above.

We consider valuations of 10, 30, and 60 percent of current price as population medians. These reflect consumers' maximum willingness to pay for space on the island in the long run, so these valuations should be considerably larger than the price levels that would induce

[6] The marginal hazard ratio $f(q)/(1-F(q))$ corresponds to the marginal distribution of θ that has been derived from the joint distribution of θ and y integrated over all values of y.

[7] The choice of analyzing willingness to live in a metropolitan area as a function of price per unit of land (or floor space) implies that the relevant population for housing market equilibrium is everyone who would be willing to move to metropolitan area if housing was free. Negative threshold price for moving into metropolitan area leads to paradoxical consumer's choices.

mobility in the short run. The lower the population median, the greater the magnitude of η_{Lq}. This is because as the median falls relative to current price, the fraction of the population that is indifferent between living in the city or not living in the city falls, since this value is moving into the right tail of the distribution and because the variance of the distribution rises, leaving all densities $f(x)$ smaller. When population in the city is large enough, low population medians are not feasible under the Pareto distribution.

In Table 1, we consider the effect of price changes in islands with varying shares of national population and mention real world areas with similar populations. For the cases of Manhattan and Hanover, we recognize that the assumption that the prices of nearby areas might adjust if there were a population shift into the central district. In those cases, though, the density of the population at q would likely spike due to the equilibrium condition of indifference among locations within a metropolitan area for similar households.

We find generally small elasticities. For apartments in Manhattan, a demand elasticity for apartment space of -.4 would be moderate based on Hanushek and Quigley (1980). Under the normal distribution, this implies that the elasticity of interest η_{qL} is not far from -0.1, whatever the median threshold price θ. With a constant elasticity, this implies that multiplying quantity by eight would reduce price by less than 15 percent. Multiplying quantity by eight in Manhattan would imply uniform heights of 100 stories, which would be devastating for amenity and generate high marginal construction cost. Hence constant amenity simply could not be achieved in Manhattan at much lower prices than under existing regulations, under that demand scenario.

The Manhattan analysis ignores offsetting effects of reduced demand in other New York metropolitan locations and the likely large density near current Manhattan prices that arises from equilibrium indifference among different locations within the market. It is more plausible that the entire New York metropolitan area, with between five and ten percent of national population, is a single market. Thinking of land as the scarce commodity for most of the metropolitan area, Gyourko and Voith (2000) suggests that -.7 is a moderate demand elasticity. Table 1 implies that under the normal distribution, if the median American would be induced to move to metropolitan New York by a 70 percent reduction in price, halving land prices would require a 15-fold increase in available land. This follows from the listed elasticity of -.26: ($15^{-.26\approx}$ .5).

It has become fashionable to discuss "two Americas": one comprised of large coastal metropolitan areas, where land use constraints are common, and the other comprised of largely unregulated exurban or rural interior regions. Land supply is generally thought to be quite elastic in the second region. If we bundle the ten largest metropolitan areas (mostly coastal) into a single "island" region and the remainder of the country into another, then the assumption that outside prices do not change when island land supply changes may not be too far off. In Table 1, we find that with approximately 30% of US population, the price elasticity with respect to land supply in the meta coastal region would be approximately .5 if the median American would move into the coastal region if land prices fell by forty percent. In this case, prices would fall by approximately thirty percent if land supply doubled in the largest coastal cities. By contrast, if the median American would be induced to move into the largest regions with a 10 percent reduction in price, then the elasticity falls to .15, and a doubling of supply would lead to a price decrease of just ten percent. Further, the assumption of a single market is suspect given easily available data. According to the 2000 US Census, residents of the Northeast were likelier to move to the South than to the West. Residents of the West were more likely to move to the South or Midwest than the Northeast.

We conclude that individual metropolitan areas are unlikely to increase "affordability" by encouraging more supply. Smaller metropolitan areas are likely to meet even less success than larger ones. If all regulated regions simultaneously lifted supply constraints, the price consequences might be somewhat larger. The price consequences of supply regulations depend on the distribution of threshold prices that induce mobility into different regions across the entire national population, and we recommend that empirical research focus on ways of identifying parameters of these distributions.

Table 1: Elasticity of land price with respect to land quantity η_{qL} under different distributions of willingness to pay θ and different land demand elasticities η_{lq}

Top panel: land demand elasticity $\eta_{lq} = .4$

$\frac{\text{Market size}}{\text{National Population}}$	Analog	$\frac{\text{Median valuation } \theta}{\text{price } q}$	Elasticity η_{qL} under distribution... Pareto	Lognormal	Normal	Uniform
0.0020%	Hanover, NH	.1	-0.2084	-0.1231	-0.0496	0.0000
0.0020%	Hanover, NH	.3	-0.1135	-0.0659	-0.0388	-0.0000
0.0020%	Hanover, NH	.6	-0.0494	-0.0284	-0.0223	-0.0000
0.7%	Manhattan	.1	-0.4437	-0.2969	-0.1251	-0.0127
0.7%	Manhattan	.3	-0.2535	-0.1646	-0.0984	-0.0099
0.7%	Manhattan	.6	-0.1142	-0.0726	-0.0572	-0.0057
10.0%	Metro New York	.1	N/A	-0.7264	-0.3450	-0.2064
10.0%	Metro New York	.3	-0.5758	-0.4409	-0.2768	-0.1636
10.0%	Metro New York	.6	-0.2816	-0.2082	-0.1661	-0.0962
30.0%	Top 10 Metro	.1	N/A	-1.5065	-0.9303	-0.8766
30.0%	Top 10 Metro	.3	N/A	-1.1056	-0.7888	-0.7394
30.0%	Top 10 Metro	.6	N/A	-0.6293	-0.5212	-0.4839

Bottom panel: land demand elasticity $\eta_{lq} = .7$

$\frac{\text{Market size}}{\text{National Population}}$	Analog	$\frac{\text{Median valuation } \theta}{\text{price } q}$	Elasticity η_{qL} under distribution... Pareto	Lognormal	Normal	Uniform
0.0020%	Hanover, NH	.1	-0.1962	-0.1188	-0.0489	0.0000
0.0020%	Hanover, NH	.3	-0.1098	-0.0647	-0.0383	0.0000
0.0020%	Hanover, NH	.6	-0.0487	-0.0282	-0.0222	0.0000
0.7%	Manhattan	.1	-0.3916	-0.2726	-0.1206	-0.0127
0.7%	Manhattan	.3	-0.2355	-0.1568	-0.0956	-0.0099
0.7%	Manhattan	.6	-0.1104	-0.0710	-0.0562	-0.0057
10.0%	Metro New York	.1	N/A	-0.5964	-0.3126	-0.1944
10.0%	Metro New York	.3	-0.4910	-0.3894	-0.2556	-0.1559
10.0%	Metro New York	.6	-0.2597	-0.1960	-0.1582	-0.0935
30.0%	Top 10 Metro	.1	N/A	-1.0376	-0.7273	-0.6941
30.0%	Top 10 Metro	.3	N/A	-0.8302	-0.6379	-0.6052
30.0%	Top 10 Metro	.6	N/A	-0.5293	-0.4507	-0.4225

References

Glaeser, Edward, Joseph Gyourko, and Raven Saks, "Why is Manhattan So Expensive?: Regulation and the Rise in House Prices," *Journal of Law and Economics*, 2005, *48* (2), 331–370.

_ , _ , and _ , "Urban Growth and Housing Supply," *Journal of Economic Geography*, 2006, *6*, 71–89.

_ , _ , and _ , "Why Have Housing Prices Gone Up," *American American Economic Review Papers and Proceedings*, forthcoming.

Gyourko, Joseph and Richard Voith, "The Price Elasticity of Demand for Residential Land," Real Estate Working Paper 329, Wharton 2000.

_ , Christopher J. Mayer, and Todd Sinai, "Superstar Cities," 2004. Working Paper, Wharton.

Hanushek, Eric A. and John M. Quigley, "What is the Price Elasticity of Housing Demand?," *The Review of Economics and Statistics*, August 1980, *62*, 449–454.