Saiz (2010)
"The Geographic Determinants of Housing Supply"

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Introduction

- So far we have used housing supply elasticities extensively in quantitative spatial models.
- In quantification of spatial models, we have always used Saiz's housing supply elasticities.
- Now we study how Saiz estimated housing supply elasticities.

Literature

- This paper, Saiz (2010), is the best-known source of housing supply elasticities.
- Later on, Baum-Snow and Han (2024) estimated housing supply elaticities for finer geographc units: neighberhoods.

Outline

- This paper processes satellite-generated data on
  1. terrain elevation (height and slope of land),
  2. presence of water bodies (rivers, ponds, sea (coasts)),

  to estimate the amount of developable land in U.S. metropolitan areas.
- Residential development is effectively curtailed by the presence of steep-sloped terrain.
- The author finds that most areas in which housing supply is regarded as inelastic are severely land-constrained by their geography.
- Econometrically, housing supply elasticities can be well characterized by functions of both physical and regulatory constraints.
  - But, regulatory constraints are, in turn, endogenous to prices and demographic growth.
- Geography is a key factor in the contemporaneous urban development of the Unites States.

Data

Constructing data on undevelopable land areas

- Saiz develops a comprehensive measure of the area that is unavailable for residential or commercial real estate development in MSAs.
- Three reasons for undevelopable lands:
  1. Steep slopes,
  2. Internal water bodies (like rivers),
  3. Oceans and lakes.

Steep terrains

- Architectural development guidelines typically deem areas with slopes above 15% severely contrained for residential construction.
  - Saiz himself does not refer to sources.
  - But ChatGPT finds that some U.S. states indicate that construction on 15% or steeper lots require special treatment or permission.
- USGS Digital Elevation Model (DEM) has data on elevation at 90-m resolution.
- Using these data, Saiz generated slop maps for the continental United States.
  - I guess he excluded Alaska and Hawaii.
- GIS software was used to calculate the exact share of the area corresponding to land with slope above 15% within 50-km radius of each metropolitan central city.

How steep land deters development

An example from Los Angeles

- LA's median housing values are among the highest in the U.S.
- So, the incentives to build on undeveloped land are very strong.
- There were 6,456 census block groups that lie within a 50-km radius of LA's city centroid in 2000.
  - The city centroid means the geometric center of the city area.
  - "Jushin" in Japanese high school math.
- The author calculated the share of the area in each block group with slope above 15%.
- He defines steep-slope block groups as those with a share of steep-sloped terrain of more than 50%.
- Steep-slope block groups emcompassed 47.62% of the land area within 50 km of LA's centroid in 2000.
- However, only 3.65% of the population within this 50-km radius lived in them.
- This illustrates the deterrent effect of steep slopes on housing development.

Water bodies

- The next step is to calculate the area within the cities' 50-km radii that corresponds to wetlands, lakes, rivers, and other internal water bodies.
- The 1992 USGS National Land Cover Dataset is a satellite GIS source about land cover characteristics at 30 by 30-m cell resolutions.
- The Wharton GIS lab processed (aggregated) this to the cencus tract levels.
- The distance from each city centroid to the centroid of all census tracts was calculated.
- Then, census tracts within 50 km were used to compute water cover shares.

Oceans and the Great Lakes

- The last step is to calculate the areas within 50-km radii that are lost to oceans and the Great Lakes.
  - Usual lakes are classified to "water bodies." The Great Lakes are classified to "Oceans and the Great Lakes."

Table 1

Physical and Regulatory Development Constraints (Metro Areas with Population > 500,000)

Rank	MSA/NECMA name	Undevelopable area (%)	WRI	Rank	MSA/NECMA name	Undevelopable area (%)	WRI
1	Ventura, CA	79.64	1.21	26	Portland–Vancouver, OR–WA	37.54	0.27
2	Miami, FL	76.63	0.94	27	Tacoma, WA	36.69	1.34
3	Fort Lauderdale, FL	75.71	0.72	28	Orlando, FL	36.13	0.32
4	New Orleans, LA	74.89	−1.24	29	Boston–Worcester–Lawrence, MA–NH	33.90	1.70
5	San Francisco, CA	73.14	0.72	30	Jersey City, NJ	33.80	0.29
6	Salt Lake City–Ogden, UT	71.99	−0.03	31	Baton Rouge, LA	33.52	−0.81
7	Sarasota–Bradenton, FL	66.63	0.92	32	Las Vegas, NV–AZ	32.07	−0.69
8	West Palm Beach–Boca Raton, FL	64.01	0.31	33	Gary, IN	31.53	−0.69
9	San Jose, CA	63.80	0.21	34	Newark, NJ	30.50	0.68
10	San Diego, CA	63.41	0.46	35	Rochester, NY	30.46	−0.06
11	Oakland, CA	61.67	0.62	36	Pittsburgh, PA	30.02	0.10
12	Charleston–North Charleston, SC	60.45	−0.81	37	Mobile, AL	29.32	−1.00
13	Norfolk–Virginia Beach–Newport News, VA–NC	59.77	0.12	38	Scranton–Wilkes-Barre–Hazleton, PA	28.78	0.01
14	Los Angeles–Long Beach, CA	52.47	0.49	39	Springfield, MA	27.08	0.72
15	Vallejo–Fairfield–Napa, CA	49.16	0.96	40	Detroit, MI	24.52	0.05
16	Jacksonville, FL	47.33	−0.02	41	Bakersfield, CA	24.21	0.40
17	New Haven–Bridgeport–Stamford, CT	45.01	0.19	42	Harrisburg–Lebanon–Carlisle, PA	24.02	0.54
18	Seattle–Bellevue–Everett, WA	43.63	0.92	43	Albany–Schenectady–Troy, NY	23.33	−0.09
19	Milwaukee–Waukesha, WI	41.78	0.46	44	Hartford, CT	23.29	0.49
20	Tampa–St. Petersburg–Clearwater, FL	41.64	−0.22	45	Tucson, AZ	23.07	1.52
21	Cleveland–Lorain–Elyria, OH	40.50	−0.16	46	Colorado Springs, CO	22.27	0.87
22	New York, NY	40.42	0.65	47	Baltimore, MD	21.87	1.60
23	Chicago, IL	40.01	0.02	48	Allentown–Bethlehem–Easton, PA	20.86	0.02
24	Knoxville, TN	38.53	−0.37	49	Minneapolis–St. Paul, MN–WI	19.23	0.38
25	Riverside–San Bernardino, CA	37.90	0.53	50	Buffalo–Niagara Falls, NY	19.05	−0.23

Table 1 [continued]

Rank	MSA/NECMA name	Undevelopable area (%)	WRI	Rank	MSA/NECMA name	Undevelopable area (%)	WRI
51	Toledo, OH	18.96	−0.57	74	Dallas, TX	9.16	−0.23
52	Syracuse, NY	17.85	−0.59	75	Richmond–Petersburg, VA	8.81	−0.38
53	Denver, CO	16.72	0.84	76	Houston, TX	8.40	−0.40
54	Columbia, SC	15.23	−0.76	77	Raleigh–Durham–Chapel Hill, NC	8.11	0.64
55	Wilmington–Newark, DE–MD	14.67	0.47	78	Akron, OH	6.45	0.07
56	Birmingham, AL	14.35	−0.23	79	Tulsa, OK	6.29	−0.78
57	Phoenix–Mesa, AZ	13.95	0.61	80	Kansas City, MO–KS	5.82	−0.79
58	Washington, DC–MD–VA–WV	13.95	0.31	81	El Paso, TX	5.13	0.73
59	Providence–Warwick–Pawtucket, RI	13.87	1.89	82	Fort Worth–Arlington, TX	4.91	−0.27
60	Little Rock–North Little Rock, AR	13.71	−0.85	83	Charlotte–Gastonia–Rock Hill, NC–SC	4.69	−0.53
61	Fresno, CA	12.88	0.91	84	Atlanta, GA	4.08	0.03
62	Greenville–Spartanburg–Anderson, SC	12.87	−0.94	85	Austin–San Marcos, TX	3.76	−0.28
63	Nashville, TN	12.83	−0.41	86	Omaha, NE–IA	3.34	−0.56
64	Louisville, KY–IN	12.69	−0.47	87	San Antonio, TX	3.17	−0.21
65	Memphis, TN–AR–MS	12.18	1.18	88	Greensboro–Winston–Salem–High Point, NC	3.12	−0.29
66	Stockton–Lodi, CA	12.05	0.59	89	Fort Wayne, IN	2.56	−1.22
67	Albuquerque, NM	11.63	0.37	90	Columbus, OH	2.50	0.26
68	St. Louis, MO–IL	11.08	−0.73	91	Oklahoma City, OK	2.46	−0.37
69	Youngstown–Warren, OH	10.52	−0.38	92	Wichita, KS	1.66	−1.19
70	Cincinnati, OH–KY–IN	10.30	−0.58	93	Indianapolis, IN	1.44	−0.74
71	Philadelphia, PA–NJ	10.16	1.13	94	Dayton–Springfield, OH	1.04	−0.50
72	Ann Arbor, MI	9.71	0.31	95	McAllen–Edinburg–Mission, TX	0.93	−0.45
73	Grand Rapids–Muskegon–Holland, MI	9.28	−0.15				

Table 2

	Share of area unavailable for development	
	OLS-regional FE β	Adds coastal dummy β
	(1)	(2)
Log population in 2000	0.443	−0.01
	(0.336)	(0.364)
Log median house value in 2000	0.592	0.41
	(0.081)***	(0.085)***
ΔLog median house value (1970–2000)	0.240	0.122
	(0.054)***	(0.057)**
Log income in 2000	0.233	0.164
	(0.056)***	(0.060)***
ΔLog income (1990–2000)	−0.002	0.006
	(0.020)	(0.022)
ΔLog population (1990–2000)	−0.027	−0.043
	(0.027)	(0.029)
Immigrants (1990–2000)/population (1990)	0.009	−0.007
	(0.011)	(0.012)
Share with bachelor's degree (2000)	0.006	−0.004
	(0.020)	(0.022)
Share workers in manufacturing (2000)	−0.01	0.005
	(0.021)	(0.023)
Log(patents/population) (2000)	0.762	0.771
	(0.260)***	(0.287)***
January monthly hours of sun (average 1941–1970)	−3.812	−12.047
	(11.252)	(12.318)
Log tourist visits per person (2000)	0.493	0.719
	(0.261)*	(0.286)**

Coastal dummies identify metropolitan areas that are within 100 km of the ocean or Great Lakes.

Model

Setup

- Saiz develops a model to illustrate how physical and man-made land availability constraints affect housing supply elasticities.
- He presents a variant of the Alonso–Muth–Mills model.
- It's basically a monocentric and circular model of a city's internal structure.
- Everyone in city k commutes to and works at the central business district (CBD).
- All jobs are located there.

Preferences

- If an individual lives at distance d from the CBD, her indirect utility is

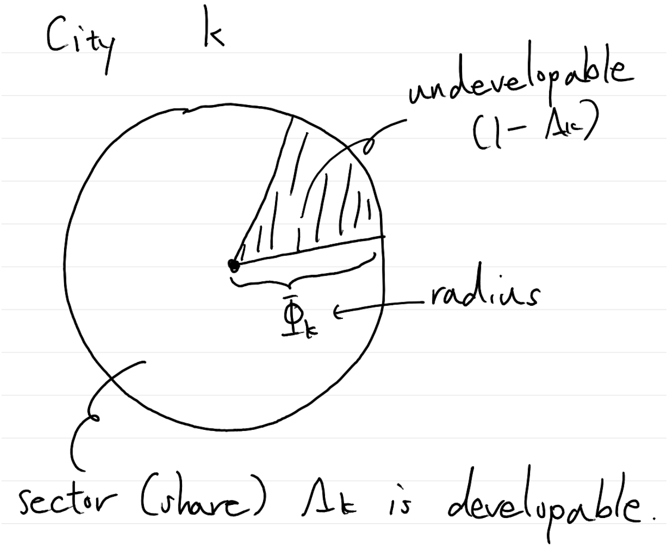
$$U_k(d) = (A_k + w_k - \gamma r' - td)^{\rho},$$

  where
  - A_k: amenities in city k,
  - w_k: wages in city k,
  - γ: the units of land/housing-space consumption,
  - r': the rent per unit of housing-space consumption,
  - t: the monetary cost per distance commuted,
  - d: the distance from the consumer's residence to the CBD.
- All city inhabitants attain utility $\bar{U}_k$.
- Therefore, the toral rent paid by an individual ($r = \gamma r'$) takes the functional form

$$r_k(d) = r_{k,0} - td, \qquad (1)$$

  where $r_{k,0}$ is just a constant.

The radius and the population (1)



The radius and the population (2)

- Suppose that k is a circular city with radius Φ_k.
- Because of geographi or regulatory land constraints, only a sector (share) Λ_k of the circle is developable.
- Let H_k be the population in city k.
- Then the livable land area is $\Lambda_k \pi \Phi_k^2$, and the demand for housing space is γH_k.
- Equating these: $\Lambda_k \pi \Phi_k^2 = \gamma H_k$.
- Solving this for Φ_k, the radius is

$$\Phi_k = \sqrt{\frac{\gamma H_k}{\Lambda_k \pi}}.$$

Developers and the construction sector

- Developers are price takers and buy land at market prices.
- They build and sell homes at price $P(d)$.
- The construction sector is competitive.
- Houses are sold at the cost of land, $LC_k(d)$, plus construction costs, CC_k

$$P_k(d) = CC_k + LC_k(d).$$

- In the asset market steady state equilibrium, prices equal to the discounted value of rents: $P_k(d) = r_k(d)/i$.
- This implies $r_k(d) = i \cdot CC_k + i \cdot LC_k(d)$.
- "At the city's edge, there is no alternative use for land."
- Without loss of generality, $LC_k(\Phi_k) = 0$.
- Therefore,

$$r_k(\Phi_k) = r_{k,0} - t\Phi_k = i \cdot CC_k.$$

- Solving the second equality for $r_{k,0}$,

$$r_{k,0} = i \cdot CC_k + t\Phi_k = i \cdot CC_k + t\sqrt{\frac{\gamma H_k}{\Lambda_k \pi}}. \qquad (2)$$

Average rents and housing values

- In this setup, the average rent, $\tilde{r}_k$, can be shown to be

$$\begin{aligned}\tilde{r}_k &= r_k\left(\frac{2}{3}\Phi_k\right)\\ &= i\cdot CC_k + t\Phi_k - t\frac{2}{3}\Phi_k\\ &= i\cdot CC_k + \frac{1}{3}t\Phi_k\\ &= i\cdot CC_k + \frac{1}{3}t\sqrt{\frac{\gamma H_k}{\Lambda_k\pi}}.\end{aligned}$$

  where the first equality is from the properties of circles, and the second equality is from (1) and (2).

- Now we can express the average housing value ($\tilde{P}_k^S$) as a function of the number of households

$$\tilde{P}_k^S = CC_k + \frac{1}{3i}t\cdot\sqrt{\frac{\gamma H_k}{\Lambda_k\pi}}. \tag{3}$$

Aggregate demand for housing in cities (1)

- Consumers can freely move across cities.
- As in the Rosen-Roback model, the spatial indifference condition is

$$\bar{U}_k = 0$$

  for any city k.
- In all cities, A_k and w_k are functions of population.
- Saiz specifies amenities and wages as

$$A_k = \tilde{A}_k - \alpha\sqrt{H_k},$$

$$w_k = \tilde{w}_k - \psi\sqrt{H_k}.$$

  - Saiz said these formulations can be microfounded.
  - But I think they are ultimately ad hoc.

Aggregate demand for housing in cities (2)

- We apply the spatial indifference condition to consumers living in the CBD

$$U_k(0) = (A_k + w_k - \gamma r_{k,0})^\rho$$
$$= (\tilde{A}_k - \alpha\sqrt{H_k} + \tilde{w}_k - \psi\sqrt{H_k} - \gamma i P_k(0))^\rho = 0.$$

- Then we must have

$$\tilde{A}_k - \alpha\sqrt{H_k} + \tilde{w}_k - \psi\sqrt{H_k} - \gamma i P_k(0) = 0.$$

- Rearranging this,

$$(\alpha + \psi)\sqrt{H_k} = \tilde{A}_k + \tilde{w}_k - \gamma i P_k(0).$$

- We get the demand schedule for housing in the city

$$\sqrt{H_k} = \frac{\tilde{A}_k + \tilde{w}_k}{\psi + \alpha} - \frac{\gamma i}{\psi + \alpha} P_k(0). \tag{4}$$

  - In the original paper, γ is missing in the second term on the right-hand side.
- Note that $\tilde{A}_k + \tilde{w}_k$ shifts housing demand, which can be used to identify housing supply elasticities.

Equilibrium numbers of households in cities

- Given (2), the housing value in the CBD is

$$P_k(0) = CC_k + \frac{t}{i}\sqrt{\frac{\gamma H_k}{\Lambda_k \pi}}.$$

- Plugging this into (4), based on my calculation, we get the equilibrium number of households in each city

$$H_k = \left(\frac{\tilde{A}_k + \tilde{w}_k - i\gamma \cdot CC_k}{(\psi + \alpha) + \gamma t \cdot \sqrt{\frac{\gamma}{\Lambda_k \pi}}} \right)^2 .$$

  - But the original paper says

$$H_k = \left(\frac{\tilde{A}_k + \tilde{w}_k - i \cdot CC_k}{(\psi + \alpha) + t \cdot \sqrt{\frac{\gamma}{\Lambda_k \pi}}} \right)^2 .$$

- Amenities and wages have to at least cover the annualized physical cost of construction.

City-specific supply inverse elasticity of average housing prices

- It's obvious that land unavailability affects the level of housing prices.
- How about supply elasticities?
- We focus on "city-specic supply inverse elasticity of average housing prices"

$$\beta_k^S \equiv \frac{\partial \ln \tilde{P}_k^S}{\partial \ln H_k}.$$

On contruction costs

- So far we have assumed city-specific construction costs CC_k.
- Actually Saiz assumes the same construction costs CC across all cities.
- I have not checked whether his proofs for the following propositions hold for heterogeneous construction costs.

Proposition 1

- The inverse elasticity of supply (that is, the price sensitivity to demand shocks) is decreasing in land availability.
- Conversely, as land constraints increase, positive demand shocks imply stronger positive impacts on the the growth of housing values.

Additional assumptions

- So far we have not specified the distributions of $\tilde{A}_k$, $\tilde{w}_k$, and Λ_k.
- Now we assume that the covariance between productivity, amenities, and land availability is zero across all locales.
- Assume further that the relevant upper tail of productivity-amenity shocks is drawn from a Pareto distribution.

Proposition 2

- Metropolitan areas with low land availability tend to be more productive or to have higher amenities.
- In the observable distribution of metro areas the covariance between land availability and productivity–amenity shocks is negative.

Intuition:

- "land-constrained cities *that thrived ex post* must be more productive or attractive than comparable locales."

Proposition 3

- Population levels in the existing distribution of metropolitan areas should be independent of the degree of land availability.

Propositions and Table 2

- Basically,
  1. geography constrained metropolitan areas *that we observe in the data* to be more productive or have high amenities,
  2. the correlation between land availability and population size is zero.
- Saiz asserts that Table 2 precisely shows this pattern.
- I guess he refers to
  - Log population in 2000 (Prop 3),
  - Log income in 2000 (Prop 2),
  - Log (patents/population) (2000) (Prop 2).

Geography and Housing Price Elasticities

Housing price elasticities (1)

- Rewrite (3) as
$$\tilde{P}_k = CC_k + LC_k(H_k).$$
- Totally differentiating the log of this yields
$$d \ln \tilde{P}_k = \frac{dCC_k}{\tilde{P}_k} + \frac{dLC_k(H_k)}{dH_k} \cdot \frac{H_k}{\tilde{P}_k} \cdot \frac{dH_k}{H_k}. \tag{5}$$
- We assume that changes in local construction costs to be exogenous to local changes in housing demand
$$\frac{d\tilde{P}_k}{dH_k} = \frac{dLC_k(H_k)}{dH_k}.$$
- Let $\sigma_k = \frac{CC_k}{\tilde{P}_k}$, the initial share of construction costs on housing prices.
- Then we can rewrite (5) as follows
$$d \ln \tilde{P}_k = \underbrace{\frac{CC_k}{\tilde{P}_k}}_{\sigma_k} d \ln CC_k + \underbrace{\frac{dLC_k(H_k)}{dH_k} \frac{H_k}{\tilde{P}_k}}_{\beta_k^S} \frac{dH_k}{H_k}.$$

Housing price elasticities (2)

- We got

$$d \ln \tilde{P}_k = \sigma_k d \ln CC_k + \beta_k^S \frac{dH_k}{H_k}.$$

- We can reexpress this as

$$d \ln \tilde{P}_k = \sigma_k d \ln CC_k + \beta_k^S d \ln H_k.$$

- The empirical specification also includes region fixed effects (R_k^j for $j = 1, 2, 3$) and an error term (ϵ_k)

$$\Delta \ln \tilde{P}_k = \sigma_k \Delta \ln CC_k + \beta_k^S \cdot \Delta \ln H_k + \sum R_k^j + \epsilon_k.$$

Data for estimation

$$\Delta \ln \tilde{P}_k = \sigma_k \Delta \ln CC_k + \beta_k^S \cdot \Delta \ln H_k + \sum R_k^j + \epsilon_k. \qquad (6)$$

- The construction cost relative to the housing price, σ_k, is from Davis and Heathcote (2007) and Davis and Palumbo (2008).
- This is combined with data on the growth of construction costs in each city from publishes sources, $\Delta \ln CC_k$.
- To identify the housing suply elasticity, Saiz need the housing demand shocks.
- So he instruments $\Delta \ln H_k$ with
  - a shift share of the 1974 metropolitan industrial composition: initial employment shares at the two-digit SIC level interacted with national growth rates in each industry,
  - the log of average hours of sun in January; to capture a secular trend of increasing demand for high-amenity areas,
  - the number of new immigrants (1970 to 2000) divided by the population in 1970.

Column 1 in Table 3

- As a first attempt, Saiz assumes that a common supply inverse-elasticity parameter for all cities, that is, $\beta_k^S = \beta^S$ for all k.
- Somehow $\Delta \ln H_k$ in the main body of the paper is $\Delta \log(Q)$ in the table.

Table 3

	$\Delta\log(P)$ (supply): 1970–2000					
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\log(Q)$	0.650	0.336	0.305	0.060		
	(0.107)***	(0.116)***	(0.146)***	(0.215)		
Unavailable land $\times\Delta\log(Q)$		0.560	0.449	0.511	0.516	−5.329
		(0.118)***	(0.140)***	(0.214)***	(0.116)***	(0.904)***
Log(1970 population) $\times$						0.481
unavailable land $\times\Delta\log(Q)$						(0.117)***
log(WRI)$\times\Delta\log(Q)$				0.237	0.268	0.301
				(0.130)*	(0.068)***	(0.066)***
$\Delta\log(Q)\times$ ocean			0.106			
			(0.065)			
Midwest	−0.099	−0.041	−0.022	−0.015	−0.009	0.002
	(0.054)*	(0.052)	(0.054)	(0.055)	(0.050)	(0.049)
South	−0.236	−0.170	−0.163	−0.129	−0.116	−0.115
	(0.065)***	(0.062)***	(0.062)***	(0.069)*	(0.050)**	(0.048)**
West	0.016	0.057	−0.022	0.059	0.069	0.035
	(0.076)	(0.072)	(0.054)	(0.072)	(0.063)	(0.046)
Constant	0.550	0.594	0.594	0.528	0.601	0.061
	(0.055)***	(0.052)***	(0.052)***	(0.058)***	(0.046)***	(0.045)***

Column 2 in Table 3

- Now Saiz gradually complicated his specification.
- We know that the inverse elasticity of housing supply should be a function of land availability.
- Break down β_k^S in (6) into two parts: the common constant $\tilde{\beta}^S$ and the linear function of land (un)availability $\beta^{LAND}(1 - \Lambda_k)$

$$\beta_k^S = \tilde{\beta}^S + \beta^{LAND} \cdot (1 - \Lambda_k).$$

- Then the full specification is

$$\begin{aligned}\Delta \ln \tilde{P}_k =& \sigma_k \cdot \Delta \ln CC_k + \tilde{\beta}^S \cdot \Delta \ln H_k \\ &+ \beta^{LAND} \cdot (1 - \Lambda_k) \cdot \Delta \ln H_k + \sum R_k^j + \epsilon_k.\end{aligned}$$

Column 3 in Table 3

Is it just coastal?

- New York, Boston, San Francisco, and San Diego are all coastal cities.
- So the effect of land unavailability is just the effect of coastal areas?
- Now the inverse housing elasticity is specified as

$$\beta_k^S = \tilde{\beta}^S + (1 - \Lambda_k) \cdot \beta^{LAND} + COAST_k \cdot \beta^{COAST},$$

  where $COAST$ is a coastal status dummy.
- But, somehow, $COAST$ in the main body is ocean in the table.

Column 4 and 5 in Table 3

- The inverse housing supply elasticity is now a function of land use regulations and geographic constraints

$$\beta_k^S = \tilde{\beta}^S + \beta^{LAND} \cdot (1 - \Lambda_k) + \ln WRI_k \cdot \beta^{REG}.$$

- Then the full specification is

$$\begin{aligned} \Delta \ln \tilde{P}_k = & \sigma_k \cdot \Delta \ln CC_k + \tilde{\beta}^S \cdot \Delta \ln H_k + \beta^{LAND} \cdot (1 - \Lambda_k) \cdot \Delta \ln H_k \\ & + \beta^{REG} \cdot \ln WRI_k \cdot \Delta \ln H_k + \sum R_k^j + \epsilon_k. \end{aligned} \quad (7)$$

- And because we cannot reject $\tilde{\beta}^S = 0$, Saiz run a regression with $\tilde{\beta}^S = 0$ and shows the result in column 5.

Column 6 in Table 3 (1)

- If a city has a big portion of unavailable land but also large empty land, its housing supply should be elastic.
- This means that the portion of unavailable land becomes gradually important for the housing supply elasticity as the city gets more crowded.
- Building on this idea, the inverse supply elasticity is specified as

$$\beta_k^S = (1-\Lambda_k)\cdot\beta^{LAND} + (1-\Lambda_k)\cdot\ln(POP_{T-1})\cdot\beta^{LAND,POP} + \ln WRI\cdot\beta^{REG}.$$

- Then the full specification is

$$\Delta\ln\tilde{P}_k = [\beta^{LAND} + \beta^{LAND,POP}\cdot\ln(POP_{T-1})]\cdot(1-\Lambda_k)\cdot\Delta\ln H_k + \sigma_k\cdot\Delta\ln CC_k + \beta^{REG}\cdot\ln WRI_k\cdot\Delta\ln H_k + \sum R_k^j + \epsilon_k.$$

Column 6 in Table 3 (2)

- The result confirms this theory.
- The author does not provide an explation for the negative coefficient for $(1 - \Lambda_k) \cdot \Delta \ln H_k$, though.

Endogeneity of land use regulations

- But, land use regulations represented by the WRI are endogenous to housing prices or quantities.
- That is, $\ln WRI_k$ may be correlated to ϵ_k in (7).
- Saiz regressed the WRI on many variables.
- He found that the WRI (as of 2005 or 2000, which is not clear) is
  - positively correlated to the log of inspection expenditres/local tax revenues as of 1982,
  - negatively correlated to the share of Christian "nontraditional" denominations as of 1970.
- "Protective inspection and regulation" includes
  - building inspections,
  - weights and measures,
  - regulation of financial institutions,
  - taxicabs,
  - public service corporations,
  - etc...
- The point is that it is not limited to building inspections. Expenditures on government inspections in general.

IVs for $\ln WRI_k \cdot \Delta \ln H_k$

- So Saiz's IVs for $\ln WRI_k \cdot \Delta \ln H_k$ are
  - the local public expenditure share in protective inspection,
  - the nontraditional Christian share,
  - the interactions of the above two with the instruments for $\Delta \ln H_k$ in p. 34.
- Then Saiz runs two-step least squares.

Table 5

	$\Delta\log(P)$ (supply)	
	(1)	(2)
Unavailable land $\times\Delta\log(Q)$	0.581	–5.260
	(0.119)***	(1.396)***
Log(1970 population) × unavailable land $\times\Delta\log(Q)$		0.475
		(0.119)***
Log(WRI) $\times\Delta\log(Q)$	0.109	0.280
	(0.078)*	(0.077)***
Midwest	–0.009	0.002
	(0.049)	(0.048)
South	–0.075	–0.109
	(0.049)	(0.049)**
West	0.149	0.059
	(0.063)	(0.065)
Constant	0.659	0.577
	(0.048)***	(0.048)***

Finally, housing supply elasticity

- Using Column 2 in Table 5, Saiz constructs housing supply elasticities for U.S. MSAs.
- The population-weighted average elasticity is 1.75 in metropolitan areas.

Table 6 (1)

Rank	MSA/NECMA name	Supply elasticity	Rank	MSA/NECMA name	Supply elasticity
1	Miami, FL	0.60	26	Vallejo–Fairfield–Napa, CA	1.14
2	Los Angeles–Long Beach, CA	0.63	27	Newark, NJ	1.16
3	Fort Lauderdale, FL	0.65	28	Charleston–North Charleston, SC	1.20
4	San Francisco, CA	0.66	29	Pittsburgh, PA	1.20
5	San Diego, CA	0.67	30	Tacoma, WA	1.21
6	Oakland, CA	0.70	31	Baltimore, MD	1.23
7	Salt Lake City–Ogden, UT	0.75	32	Detroit, MI	1.24
8	Ventura, CA	0.75	33	Las Vegas, NV–AZ	1.39
9	New York, NY	0.76	34	Rochester, NY	1.40
10	San Jose, CA	0.76	35	Tucson, AZ	1.42
11	New Orleans, LA	0.81	36	Knoxville, TN	1.42
12	Chicago, IL	0.81	37	Jersey City, NJ	1.44
13	Norfolk–Virginia Beach–Newport News, VA–NC	0.82	38	Minneapolis–St. Paul, MN–WI	1.45
14	West Palm Beach–Boca Raton, FL	0.83	39	Hartford, CT	1.50
15	Boston–Worcester–Lawrence–Lowell–Brockton, MA–NH	0.86	40	Springfield, MA	1.52
16	Seattle–Bellevue–Everett, WA	0.88	41	Denver, CO	1.53
17	Sarasota–Bradenton, FL	0.92	42	Providence–Warwick–Pawtucket, RI	1.61
18	Riverside–San Bernardino, CA	0.94	43	Washington, DC–MD–VA–WV	1.61
19	New Haven–Bridgeport–Stamford–Danbury–Waterbury, CT	0.98	44	Phoenix–Mesa, AZ	1.61
20	Tampa–St. Petersburg–Clearwater, FL	1.00	45	Scranton–Wilkes-Barre–Hazleton, PA	1.62
21	Cleveland–Lorain–Elyria, OH	1.02	46	Harrisburg–Lebanon–Carlisle, PA	1.63
22	Milwaukee–Waukesha, WI	1.03	47	Bakersfield, CA	1.64
23	Jacksonville, FL	1.06	48	Philadelphia, PA–NJ	1.65
24	Portland–Vancouver, OR–WA	1.07	49	Colorado Springs, CO	1.67
25	Orlando, FL	1.12	50	Albany–Schenectady–Troy, NY	1.70

Table 6 (2)

Rank	MSA/NECMA name	Supply elasticity	Rank	MSA/NECMA name	Supply elasticity
51	Gary, IN	1.74	74	Atlanta, GA	2.55
52	Baton Rouge, LA	1.74	75	Akron, OH	2.59
53	Memphis, TN–AR–MS	1.76	76	Richmond–Petersburg, VA	2.60
54	Buffalo–Niagara Falls, NY	1.83	77	Youngstown–Warren, OH	2.63
55	Fresno, CA	1.84	78	Columbia, SC	2.64
56	Allentown–Bethlehem–Easton, PA	1.86	79	Columbus, OH	2.71
57	Wilmington–Newark, DE–MD	1.99	80	Greenville–Spartanburg–Anderson, SC	2.71
58	Mobile, AL	2.04	81	Little Rock–North Little Rock, AR	2.79
59	Stockton–Lodi, CA	2.07	82	Fort Worth–Arlington, TX	2.80
60	Raleigh–Durham–Chapel Hill, NC	2.11	83	San Antonio, TX	2.98
61	Albuquerque, NM	2.11	84	Austin–San Marcos, TX	3.00
62	Birmingham, AL	2.14	85	Charlotte–Gastonia–Rock Hill, NC–SC	3.09
63	Dallas, TX	2.18	86	Greensboro–Winston–Salem–High Point, NC	3.10
64	Syracuse, NY	2.21	87	Kansas City, MO–KS	3.19
65	Toledo, OH	2.21	88	Oklahoma City, OK	3.29
66	Nashville, TN	2.24	89	Tulsa, OK	3.35
67	Ann Arbor, MI	2.29	90	Omaha, NE–IA	3.47
68	Houston, TX	2.30	91	McAllen–Edinburg–Mission, TX	3.68
69	Louisville, KY–IN	2.34	92	Dayton–Springfield, OH	3.71
70	El Paso, TX	2.35	93	Indianapolis, IN	4.00
71	St. Louis, MO–IL	2.36	94	Fort Wayne, IN	5.36
72	Grand Rapids–Muskegon–Holland, MI	2.39	95	Wichita, KS	5.45
73	Cincinnati, OH–KY–IN	2.46			

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