The Unequal Effects of Upzoning: Evidence from Cook County

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Housing affordability crisis has reached new heights

Affordable housing policy now on the national stage

- **Harris**: "Cut Red Tape and Needless Bureaucracy"
- **Trump**: "Use federal land for large-scale housing construction, areas will be ultra-low tax, ultra-low regulation"

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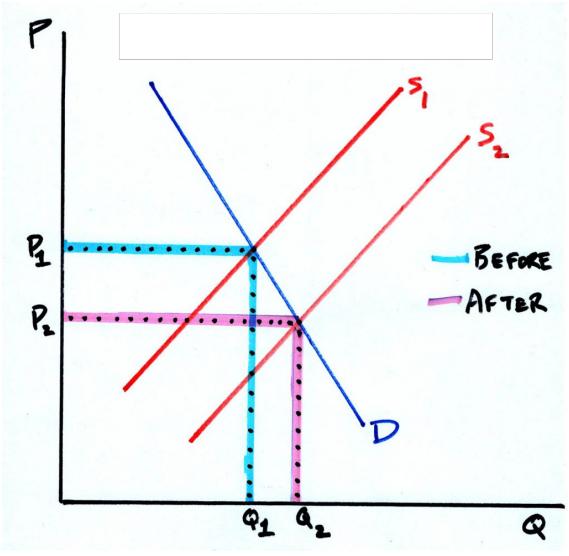
States actively experimenting with reform:

- Ban single family zoning: California, Oregon, Washington
- Allow residential in commercially zoned lots (California)
- Minimal zoning rules override local rules when cities do not satisfy state-set housing targets (California, Massachusetts)

Econ 101: Increase supply $\rightarrow$ lower prices



Not all zoning reforms are created equal

California "banned single family zoning" (2021) Allowed up to 2 units per lot and enables lot splits on current single family lots

- Calmatters, 2021: "Duplexes and small apartment buildings would spring up from single-family lots."
- Reality in 2024: Less than 100 total units built.

Why did it fail?

- Local jurisdictions found ways to not approve (the few) applications
- Fine print made it essentially impossible to use: lot splits must be no more unequal than 60%/40%, application must be from owner occupant
  - Owner-occupied houses tend to be higher end, not worth demolishing (plus where would the owner live?)
  - Existing houses tend to be built in the center of the lot. No way to add housing/lot splits
  - Most homeowners not in business of redevelopment

Need framework to map zoning reform details to supply response

Building on the shoulders of giants

Importance of Supply Constraints in Affordability

Glaeser, Gyourko and Saks (2005); Glaeser, Gyourko, and Saiz (2008); Saiz (2010); Gyourko and Mallory (2015); Glaeser and Gyourko (2018); Hseih and Moretti (2019); Gyourko, Hartley, and Krimmel (2021); Baum-Snow and Han (2024)

Reduced form effects of zoning reform

Brueckner and Sridhar (2012); Ding (2013); Ganong and Shoag (2017); Song (2024)

Structural Models of zoning and developer behavior

Epple, Gordon, and Sieg (2010); Turner, Haughwout, and Van Der Klaauw (2014); Murphy (2018); Anagol, Ferreira, and Rexer (2021), Combes, Duranton, and Gobillon (2021); Soltas (2024)

Zoning Reform: A Solution to the Affordability Crisis?

Zoning reform is the solution: Quantity ↑

"Ordinances routinely ban the construction of multifamily housing and require homes to be built on very large lots, artificially boosting the price of shelter" (WSJ, 2024)

Zoning reform builds very expensive housing: Quality ↑

"Upzoning gives developers a free pass to demolish good, modest-priced houses and replace them with much more expensive homes that will do nothing to ease the affordability crisis." (Restore Oregon, 2017)

Zoning reform increase property values, developer profits

"Real estate interests in favor of a large-scale upzoning of SoHo and NoHo... would line the pockets of the developers behind the effort." (CityLimits, 2020)

This paper: Structural model of developer behavior, quantify these forces in *partial* equilibrium.

- Parcel-level, supply-side model
- Leave demand-side estimation to future work. No GE effects.

This paper: Micro-model of housing developer decisions

1. **New data:** Linked parcel-level transactions, zoning, redevelopment, and historical parcel characteristics from Cook County

2. **Structural model:** Revealed preference estimation of developer behavior:
   - Non-developer hedonic price surface $\rightarrow$ Potential net revenue from redevelopment
   - Parcel zoning data + current structure $\rightarrow$ Observe development opportunities
   - Construction costs: fixed + variable costs, IDed by developer revealed preference
   - Prices paid by developers IDs share of redevelopment surplus going to property owners

3. **Counterfactuals:** Quantify impacts of proposed zoning reform, e.g. lower fixed costs vs. ban single-family zoning
   - Housing quantity vs. quality effects
   - Surplus from rezoning: Who benefits? Developers vs. property owners
   - Heterogeneity by neighborhood and property type

4. **Housing supply elasticities**: New parcel-level measure, heterogeneous supply response to multi-dimensional price shocks (e.g. single family demand shock in low-income neighborhoods vs. multi-family demand shock in city center) [No time for today]

Preview of Results

- Parcel characteristics play key role in prob. of redevelopment:
  - Only 52% of variance in Pr(redevelopment) explained by block-group FEs
  - Developers target low-end properties in high-end neighborhoods
- Avg lot built only to 52% zoned sqft capacity (96% in units), current prices/zoning support little development
  - Most lots with spare capacity located in lower-income areas, redevelopment not profitable
  - Lots that do redevelop mostly add quality (either new housing or sqft expansion)
- Redevelopment surplus split: 25% property owners, 75% developer profits

Counterfactuals:

- 3-flat zoning reform: Avg lot could more than double units built
  - 3% increase in units, 7% drop is average unit price
  - Generates largest windfall returns in low-income neighborhoods
- 25% reduction in fixed construction costs:
  - No increase in housing supply, 1% increase in avg unit price
  - Generates largest windfall returns in high-income neighborhoods

Administrative data from Cook County Assessor's Office

Property transactions:

- Property deed records: 1999-2023
- Use arm's length residential transactions

Residential property characteristics:

- Property tax rolls: 1999-2023
- Building square feet, year built, number of bedrooms, etc.

Property boundaries:

- Parcel maps: 1999-2023

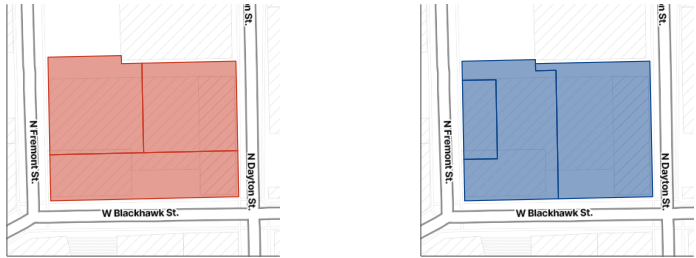
Severe data issue in commercially provided data:

- Corelogic, ATTOM **delete** deeds + assessor records for APNs that change
- These are exactly the properties where redevelopment is happening!

Identifying residential redevelopments

- Link together parcels over time, accounting for changes in parcels
  - Spatial overlay of historical parcel maps in GIS: ID prior properties on parcels

Boundaries in 2000 $\Longrightarrow$ Boundaries in 2020



- Classify a parcel as having undergone redevelopment if:
  1. Observe new residential building with year built between 2000 and 2023 (new construction)
  2. Residential building square footage increases by more than 10% (renovation)

Summary statistics

Transactions	Count
Arms-length	1,802,578
Single-family or multiplex	1,003,906
Redevelopment	61,706

Redevelopment	Share
New construction	32.7%
Merge via APN	71.7%
Merge via parcel boundaries	28.3%
Renovation	67.3%
Merge via APN	95.9%
Merge via parcel boundaries	4.1%

Land use restrictions

Spatially merge in 2023 municipal zoning maps from Zoneomics:

Variable	Mean	Std. dev.	Min.	Max.
Permitted use				
Missing	2.1%			
Single-family	37.2%			
Duplex	15.2%			
Multi-family	26.4%			
Min. lot size (sq. ft.)	8,458	39,403	1,650	1,742,000
Min. lot size per unit (sq. ft.)	4,870	9,076	100	217,800
Max. floor area ratio (FAR)	1.51	2.20	0.01	16.00

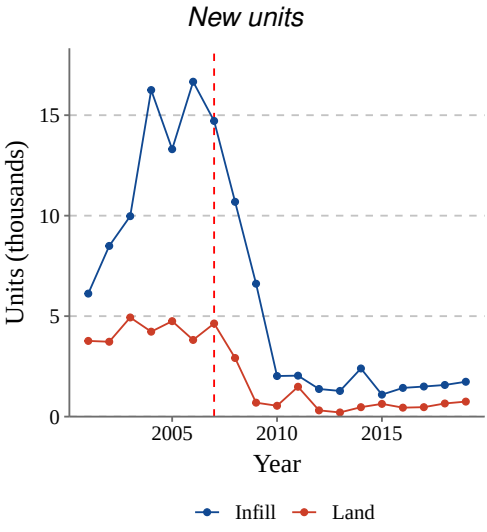
Very few zoning changes in sample over our time period.

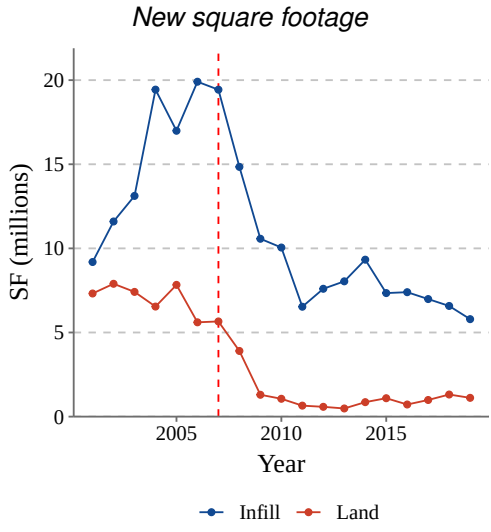
Developers redevelop low-quality housing in richer neighborhoods

LPM: Binary Indicator of Parcel Redevelopment within 5 years

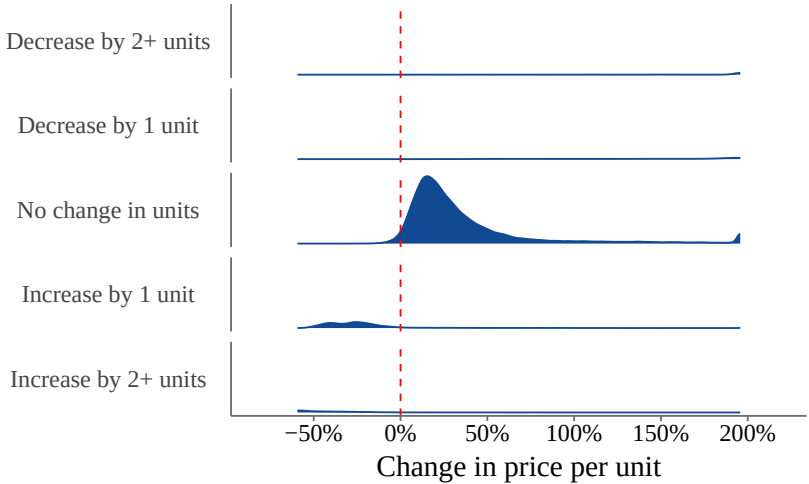
Redeveloped (2017)	(1)	Pairwise regression Estimate	SE	(2) Estimate	SE	(3) Estimate	SE
Census block group							
Population		−0.221	(0.258)				
Median income		1.927	(0.187)				
% white		1.666	(0.164)				
% college		2.462	(0.168)				
Median home value		2.696	(0.177)				
Distance to CBD		−25.503	(2.587)				
Parcel							
Lot SF				0.695	(0.336)	0.932	(0.397)
House SF				−3.237	(0.378)	−3.276	(0.377)
House age				3.456	(0.212)	3.563	(0.217)
# bedrooms / 1,000 SF				1.095	(0.213)	1.113	(0.212)
# bathrooms / 1,000 SF				0.288	(0.169)	0.255	(0.169)
# units				0.974	(0.287)	0.875	(0.288)
Zoning covariates						X	
Block group FE	X			X		X	
R^2	0.142			0.175		0.176	

Majority of by-right development is infill redevelopment



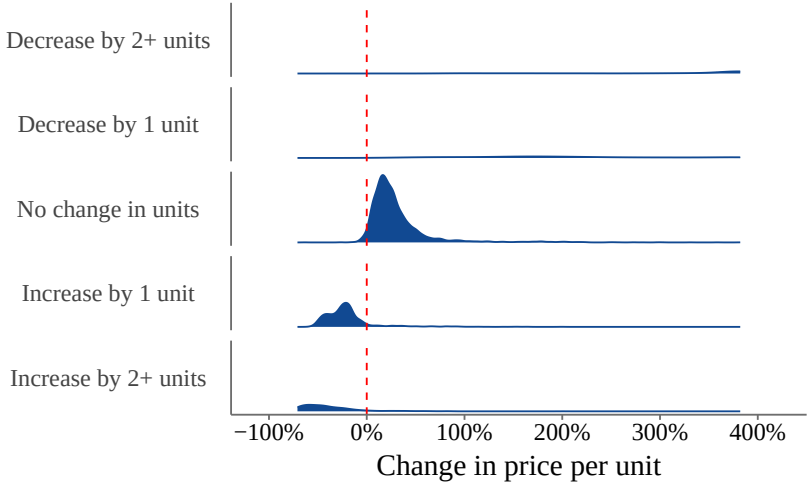


Large share of observed redevelopments only increase quality



True even for properties where zoning is not a binding constraint

Restrict data to lots where zoning allows for more units than currently built



Goal: quantify the development potential of each parcel

- Intuitively, a parcel's development potential should depend on:
  1. What currently exists on the lot
  2. What could be built on the lot
  3. The cost of construction

- The more underbuilt a lot is, relative to zoning, the more potential for redevelopment

- Begin with a model-free measure of development potential:

$$(1): \textbf{ SF development intensity } = \frac{\text{Existing SF}}{\text{Max. allowed SF}}$$

$$(2): \textbf{ Unit development intensity } = \frac{\text{Existing units}}{\text{Max. allowed units}}$$

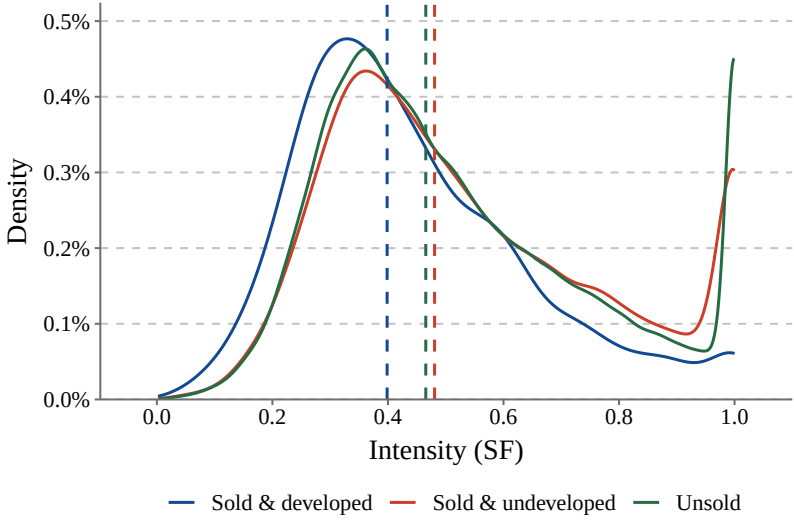
Determine maximum units/SF under current zoning

- Consider a 12,000 sqft. lot. With zoning rules:

Land use restriction	Value	Binding constraint
Min. lot size	5,000 sq. ft.	$\lfloor 12,000 \div 5,000 \rfloor =$ **2 lots, each 6,000 sq. ft.**
Max. FAR	0.4	$0.4 \times 6,000 =$ **2,400 sq. ft. building per lot**
Permitted use	Single-family	**1 unit per lot**
Min. lot size per unit	N/A	

- Assume developers lot split whenever possible and split evenly

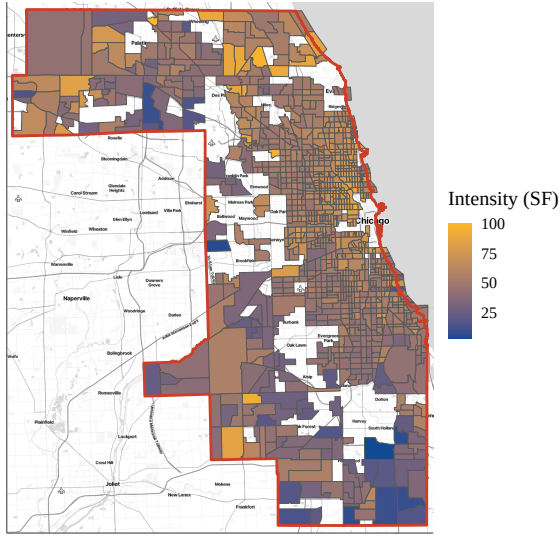
Developers buy properties that are less built up (SF Intensity)



Higher dev. intensity in high-end areas, lots with large/new homes

Development intensity (2017)	(1)	Pairwise regression Estimate	SE	(2) Estimate	SE	(3) Estimate	SE
Census block group							
Population		1.757	(0.719)				
Median income		2.504	(0.534)				
% white		2.052	(0.471)				
% college		5.745	(0.473)				
Median home value		6.650	(0.478)				
Distance to CBD		−95.141	(7.012)				
Parcel							
Lot SF				−6.529	(2.062)	−6.118	(2.171)
House SF				15.152	(0.695)	15.601	(0.593)
House age				−3.794	(0.291)	−3.857	(0.236)
# bedrooms / 1,000 SF				−3.865	(0.231)	−3.696	(0.191)
# bathrooms / 1,000 SF				0.050	(0.127)	0.010	(0.116)
# units				5.220	(0.482)	4.932	(0.388)
Zoning covariates						X	
Block group FE	X			X		X	
R^2	0.294			0.516		0.539	

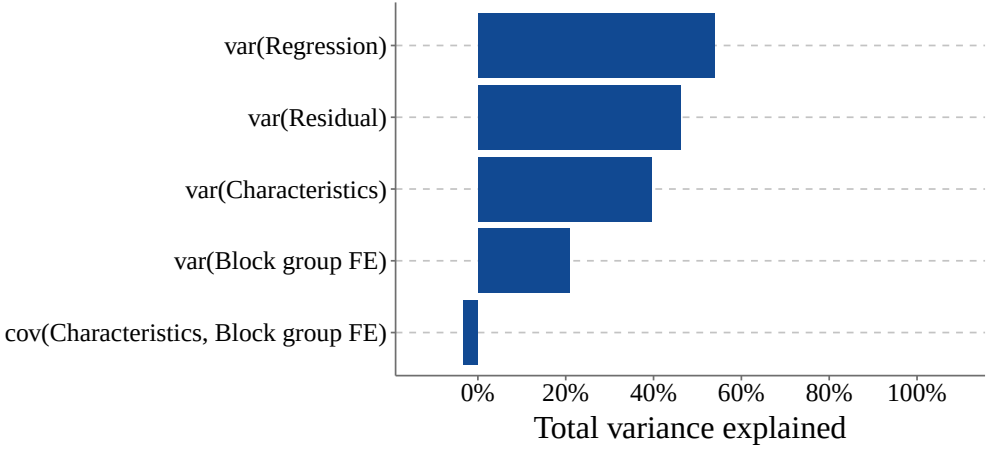
Higher development intensity closer to CBD



Block-group FEs only explain 20% of dev. intensity variation

Within-neighborhood parcel heterogeneity is key

$$y_i = \underbrace{\beta X_i}_{\text{Parcel characteristics}} + \underbrace{\lambda_{c(i)}}_{\text{Block group FE}} + \varepsilon_i$$



Structural Model of Housing Redevelopment

Set-up: Households

- Parcel i has existing housing with characteristics z_i^0
- Households exogenously put parcels up for sale
  - Households may sell to another household at $p\left(z_i^0\right)$ (hedonic price surface)
  - Alternatively, households may sell to a representative developer at p_i^*
- Households will sell to the developer whenever $p_i^* > p\left(z_i^0\right)$

Set-up: Developer

- The developer may buy parcel i and develop with intensity $j \in \{1, \ldots, J\}$
  - The new housing has characteristics $z_i^j = f\left(j, z_i^0\right)$
- After redevelopment, the developer can sell to a household and earn:

$$\underbrace{\pi_i^j}_{\text{Profit}} = \underbrace{p\left(z_i^j\right) - p_i^*}_{\text{Net revenue}} - \underbrace{C\left(j, z_i^j\right)}_{\text{Cost}} + \underbrace{\sigma\left(z_i^j\right)\varepsilon_i^j}_{\text{Cost shock}}$$

- If the developer passes on buying, they receive outside option: $\pi_i^{OO} = 0 + \varepsilon_i^{OO}$
- The developer buys if $\max_j \left\{\pi_i^j\right\} > \pi_i^{OO}$ and develops at intensity $j^* = \operatorname{argmax}_j \left\{\pi_i^j\right\}$

Nash bargaining equilibrium

- Suppose developer has bargaining power $1-\beta$ and households have bargaining power β
- Given development at intensity j, total surplus is:

$$S_i^H + S_i^D = p\left(z_i^j\right) - p\left(z_i^0\right) - C\left(z_i^j\right) + \sigma\left(z_i^j\right)\varepsilon_i^j - \varepsilon_i^{OO}$$

Nash bargaining $\Longrightarrow$

- In equiibrium, developer earns:

$$\pi_i^j = (1-\beta)\left[p\left(z_i^j\right) - p\left(z_i^0\right) - C\left(z_i^j\right) + \sigma\left(z_i^j\right)\varepsilon_i^j\right] + \beta\varepsilon_i^{OO}$$

- Key result: total surplus is a *sufficient statistic* for developer choice probabilities

Model-implied measure of parcel development potential

$$\textbf{Net revenue} = p\left(z^{max}\right) - p\left(z^{0}\right)$$

$p(\cdot)$: Hedonic price surface

z^0 : Existing property characteristics

z^{max} : Property characteristics of new construction, built to the maximum

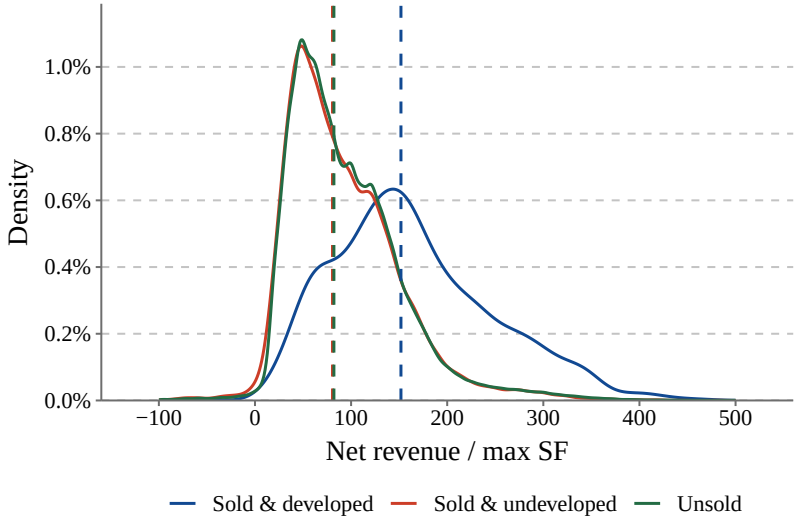
$\Longrightarrow$ Need hedonic price surface

Estimate hedonic model on non-redevelopment transactions

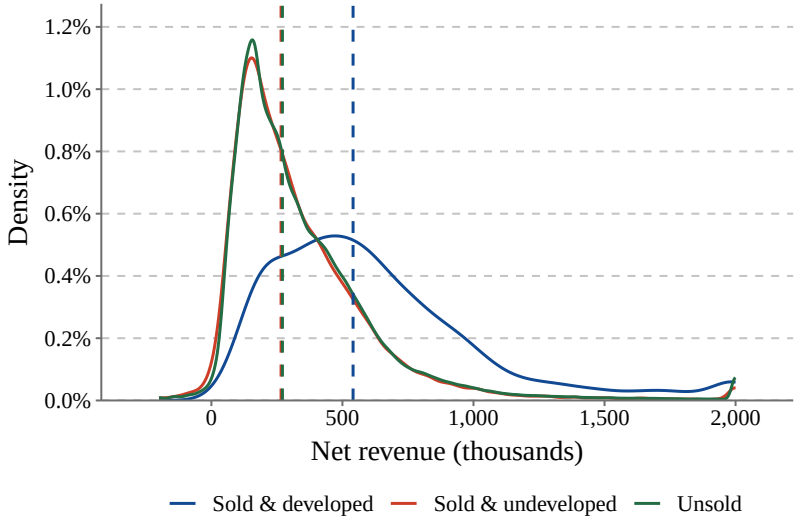
$$\underbrace{\log(p_{it})}_{\text{Price}} = \underbrace{\beta^t \mathbf{X}_{it}}_{\text{Year-varying covariates}} + \underbrace{\beta^d \mathbf{X}_{it}}_{\text{District-varying covariates}} + \underbrace{\lambda_{ct}}_{\text{Tract-year FE}} + \varepsilon_{it}$$

- i : transaction, t : year, d : commissioner district (n = 17), c : census tract
- Covariates:
  - Lot size, building size, building age, # units
  - # bedrooms, # bathrooms, # stories
  - Type of garage, attic, basement, porch, and HVAC
- Correct for Jensen's inequality when converting prices into levels (assume log-normality)

Developers buy properties that have higher net revenue



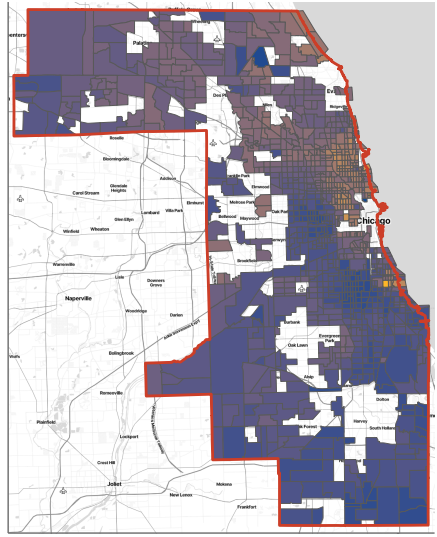
Developers buy properties that have higher net revenue



Low-quality housing in richer neighborhoods have highest net revenue

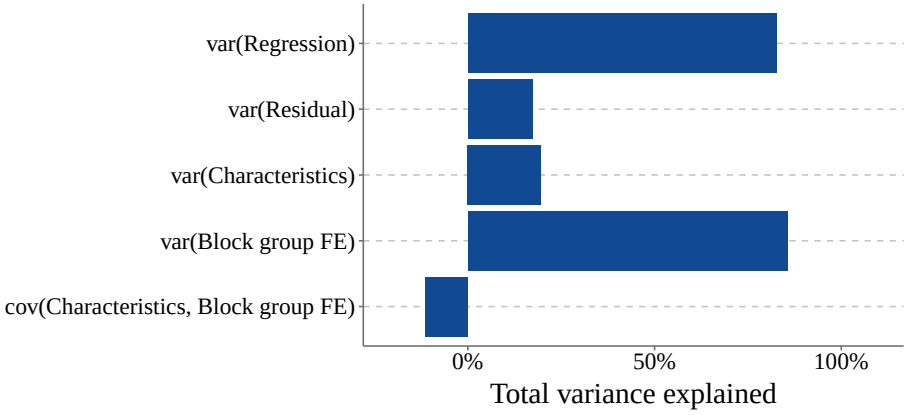
Net revenue / max SF (2017)	(1)	Pairwise regression Estimate	SE	(3) Estimate	SE	(4) Estimate	SE
Census block group							
Population		6.020	(1.626)				
Median income		32.518	(1.008)				
% white		33.437	(0.860)				
% college		43.221	(0.738)				
Median home value		38.829	(0.860)				
Distance to CBD		−206.653	(15.874)				
Parcel							
Lot SF				1.735	(0.655)	2.233	(0.864)
House SF				−15.297	(0.465)	−15.182	(0.461)
House age				16.682	(0.426)	16.459	(0.415)
# bedrooms / 1,000 SF				3.490	(0.131)	3.469	(0.129)
# bathrooms / 1,000 SF				−3.253	(0.101)	−3.213	(0.100)
# units				11.541	(0.379)	11.702	(0.381)
Zoning covariates						X	
Block group FE	X			X		X	
R^2	0.785			0.869		0.871	

Tracts closest to CBD have highest net revenue



Block-group FEs now explain 80% of variation in net-revenue

$$y_i = \underbrace{\beta X_i}_{\text{Parcel characteristics}} + \underbrace{\lambda_{c(i)}}_{\text{Block group FE}} + \varepsilon_i$$



Developer's construction costs

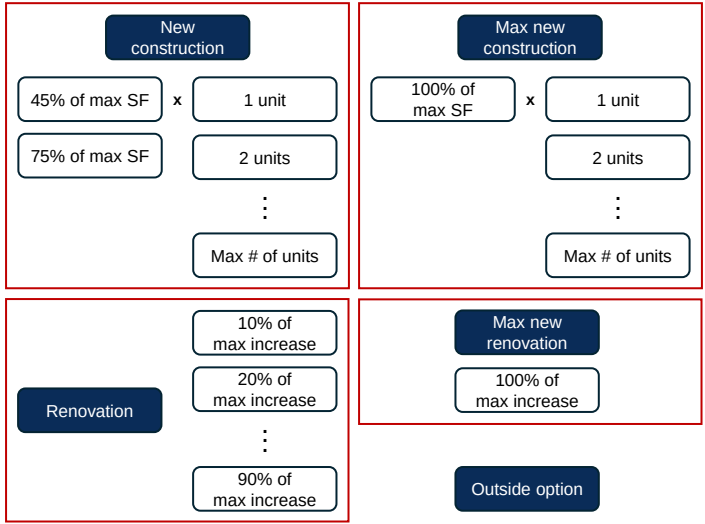
- **New construction:**
  - Developer lot splits and build new units up to the maximum
  - Housing age $= 0$

$$\underbrace{C^{NC}(S)}_{\text{Cost}} = \underbrace{\alpha^{NC}}_{\text{Variable cost}} \cdot \underbrace{S}_{\text{Building SF}} + \underbrace{FC^{NC}}_{\text{Fixed cost}} + \underbrace{\alpha^{split} 1(\#\text{ lots} > 1)}_{\text{Lot split cost}}$$

- **Renovation:**
  - Developer can increase building size up to the maximum
  - Housing age stays the same

$$\underbrace{C^{R}(S)}_{\text{Cost}} = \underbrace{\alpha^{R}}_{\text{Variable cost}} \cdot \underbrace{S}_{\text{Building SF}} + \underbrace{F^{R}}_{\text{Fixed cost}}$$

Developer's (nested) choice set



Estimation: construction costs

- **Data:** arms-length transactions from 2001-2019
  - Parcel is redeveloped if we observe redevelopment within 5 years of transaction
  - Use property characterics to classify redevelopment type (and intensity if renovation)

- Normalize profits by maximum building square feet (heteroskedastic cost shocks):

$$\widetilde{\pi}_{ij}^{NC} = \frac{\sigma^{-1}}{\text{Max FAR}_i \times \text{Lot SF}_i}\left[p\left(z_{ij}\right) - p\left(z_i^0\right)\right] - \frac{\sigma^{-1}}{\text{Max FAR}_i \times \text{Lot SF}_i} C^{NC}\left(z_{ij}\right) + \varepsilon_{iB(j)} + \varepsilon_{ij}$$

$$\widetilde{\pi}_{ij}^{R} = \frac{\sigma^{-1}}{\text{Max FAR}_i \times \text{Lot SF}_i}\left[p\left(z_{ij}\right) - p\left(z_i^0\right)\right] - \frac{\sigma^{-1}}{\text{Max FAR}_i \times \text{Lot SF}_i} C^{R}\left(z_{ij}\right) + \varepsilon_{iB(j)} + \varepsilon_{ij}$$

$$\widetilde{\pi}_{i}^{OO} = \varepsilon_i$$

- Assume ε_{ij} distributed EV type I and $\varepsilon_{iB(j)}$ distributed normal (nest-specific cost shock)

- Maximum simulated likelihood, bag of little bootstraps standard errors

Estimation: construction costs

- Assume following multivariate normal distribution for $\varepsilon_{iB(j)}$:

$B(j)$	Nest
1	Outside option
2	New construction
3	Max new construction
4	Renovation
5	Max renovation

$$\mu = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} ; \ \sigma = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma_2{}' & 0 & 0 \\ 0 & 0 & 0 & \sigma_3 & 0 \\ 0 & 0 & 0 & 0 & \sigma_4 \end{bmatrix}$$

Identification: construction costs

- **Intuition:** developer revealed preferences identify construction costs
  - e.g., fixed costs are large if developers only redevelop when increase in square footage is large
- Explicitly modeling shadow costs due to zoning and land availability
- **Key assumption:** $p\left(z_{ij}\right) - p\left(z_i^0\right) \perp \varepsilon_{iB(j)}, \varepsilon_{ij}$
  - i.e., net revenue cannot be correlated with unobserved cost shocks

Identification: endogeneity

- When might net revenue be correlated with unobserved cost shocks?
  - E.g., parcels with sloped land are more underbuilt
- Control for selection by allowing for heterogeneous construction costs
  - Single-family vs. multiplex, Chicago city vs. suburbs, pre vs. post-2007
- Ideally, only use variation in development potential from *side by side* parcels
  - Expect construction costs to be similar for such parcels
- Too underpowered to estimate heterogeneous construction costs by census tract
  - Robustness: interact construction costs by average net revenue of census tract

Cost estimates: single-family

$ 2021	All county		City		Suburbs	
	2001-07	2008-19	2001-07	2008-19	2001-07	2008-19
New construction						
Variable cost	216.2	278.4	198.2	241.3	224.5	279.2
	(8.0)	(9.0)	(10.6)	(10.7)	(11.6)	(13.5)
Fixed cost (000s)	334.2	356.8	348.2	404.3	258.2	307.4
	(20.3)	(21.6)	(24.2)	(26.0)	(29.0)	(30.3)
Lot split (000s)	491.3	394.7	450.9	395.2	504.3	504.0
	(47.4)	(47.3)	(53.1)	(51.8)	(81.9)	(92.7)
Renovation						
Variable cost	331.1	360.9	250.68	281.9	369.1	387.8
	(10.9)	(12.0)	(11.2)	(11.5)	(17.0)	(18.8)
Fixed cost (000s)	−37.5	−36.1	31.7	40.3	−90.5	−89.8
	(7.9)	(8.3)	(8.6)	(9.6)	(17.2)	(19.3)

2021 RS Means: $227.75 / sq. ft. for single-family homes

Cost estimates: multiplex

$ 2021	All county			All county	
	2001-07	2008-19		2001-07	2008-19
New construction			Renovation		
Variable cost	346.6	440.0	Variable cost	284.5	383.6
	(19.1)	(19.6)		(18.5)	(33.0)
Unit cost (000s)	37.1	51.1	Fixed cost (000s)	12.6	−3.3
	(29.6)	(23.3)		(23.9)	(41.0)
Fixed cost (000s)	221.3	328.1			
	(40.9)	(34.3)			
Lot split (000s)	556.3	603.7			
	(66.8)	(67.0)			

2021 RS Means: $345.16 / sq. ft. for apartments

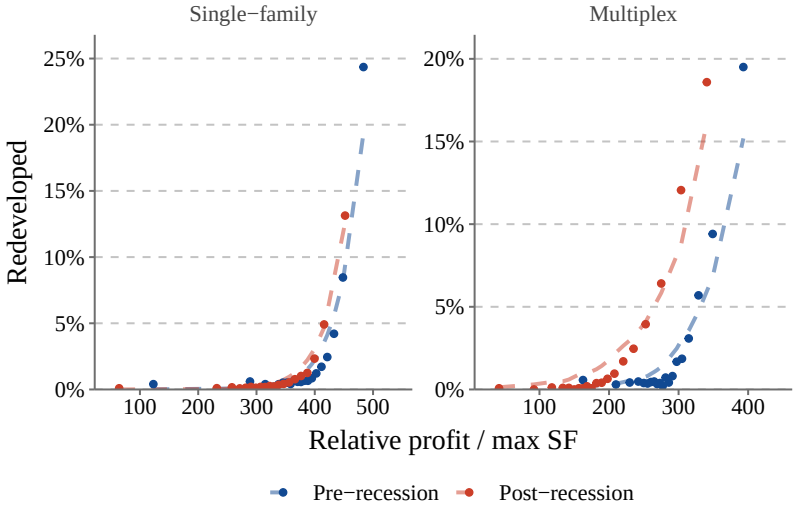
Cost estimates: single-family

$ 2021	All county	
	2001-07	2008-19
New construction		
Variable cost	240.7	277.4
Variable cost × interaction	−17.2	−4.3
Fixed cost (000s)	319.4	320.7
Fixed cost (000s) × interaction	0.7	25.4
Lot split (000s)	448.2	387.8
Renovation		
Variable cost	321.8	339.4
Variable cost × interaction	11.8	0.2
Fixed cost (000s)	−19.9	−39.3
Fixed cost (000s) × standardized tract net revenue	7.0	14.7

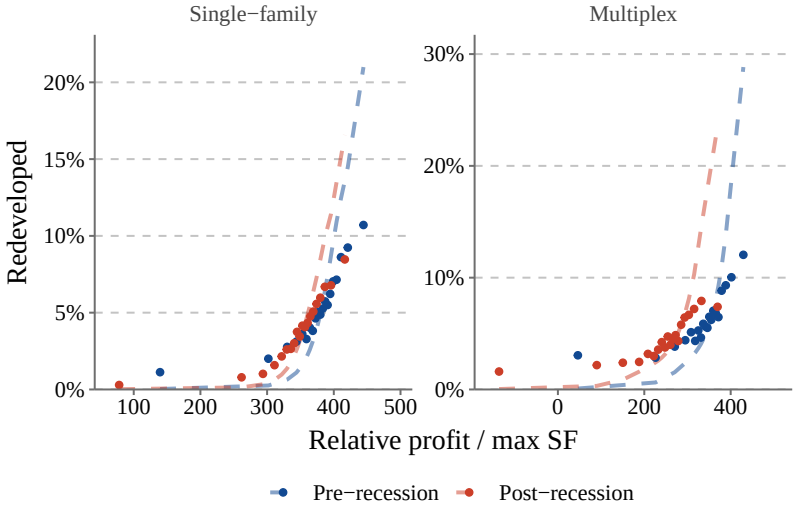
Cost estimates: multiplex

$ 2021	All county	
	2001-07	2008-19
New construction		
Variable cost	357.8	432.2
Variable cost × interaction	−3.8	−8.7
Unit cost (000s)	38.7	54.8
Unit cost× standardized tract net revenue	−10.6	−20.0
Fixed cost (000s)	213.4	288.6
Fixed cost (000s) × interaction	−11.4	72.6
Lot split (000s)	562.0	577.7
Renovation		
Variable cost	285.6	363.5
Variable cost × interaction	6.7	11.9
Fixed cost (000s)	24.5	−1.8
Fixed cost (000s) × standardized tract net revenue	9.9	−24.5

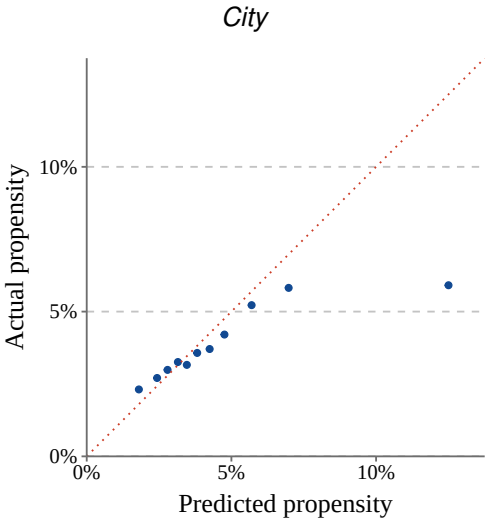
Model fit: new construction

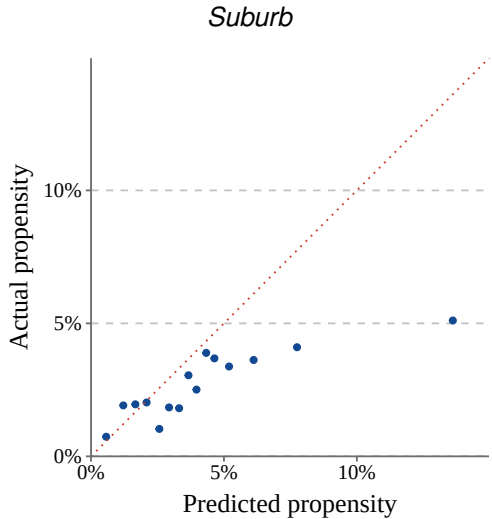


Model fit: renovation

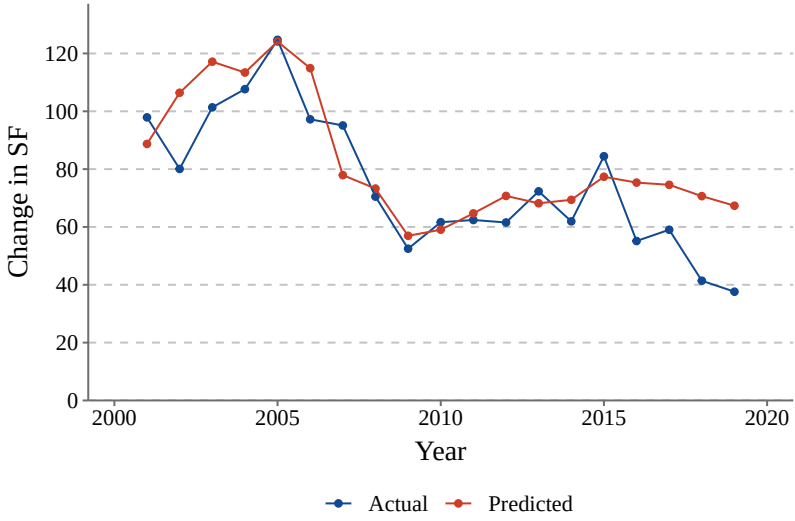


Tract-level model fit

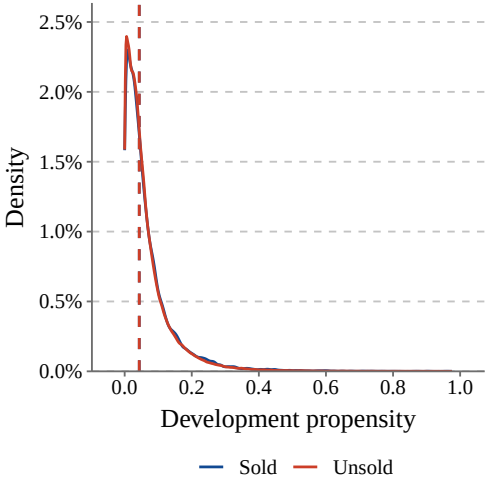


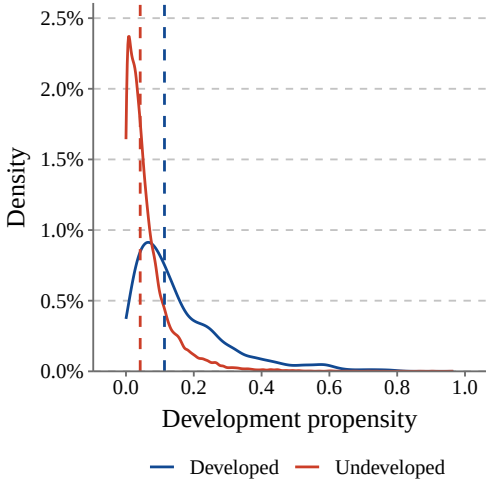


Annual model fit



Unsold parcels have similar redevelopment propensity as sold



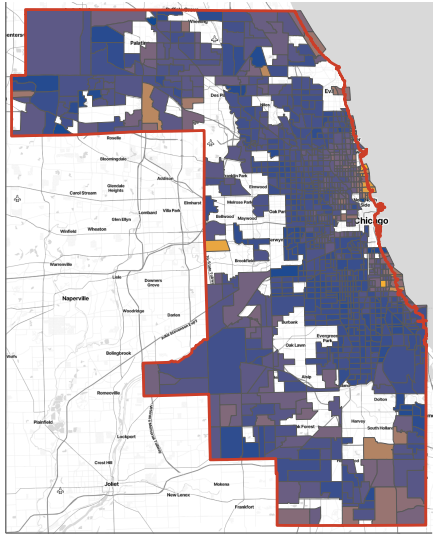


- No selection into what transacts

Developers prefer low-quality housing in richer neighborhoods

Development propensity (2017)	(1)	Pairwise regression Estimate	SE	(3) Estimate	SE	(4) Estimate	SE
Census block group							
Population		0.585	(0.166)				
Median income		1.839	(0.116)				
% white		2.072	(0.101)				
% college		3.262	(0.094)				
Median home value		2.584	(0.105)				
Distance to CBD		−12.430	(1.649)				
Parcel							
Lot SF				1.850	(0.555)	1.892	(0.639)
House SF				−3.512	(0.112)	−3.504	(0.107)
House age				1.704	(0.063)	1.869	(0.062)
# bedrooms / 1,000 SF				0.652	(0.029)	0.687	(0.028)
# bathrooms / 1,000 SF				−0.148	(0.021)	−0.178	(0.020)
# units				1.394	(0.079)	1.217	(0.073)
Zoning covariates						X	
Block group FE	X			X		X	
R^2	0.378			0.557		0.574	

Redevelopments most likely in central city and periphery

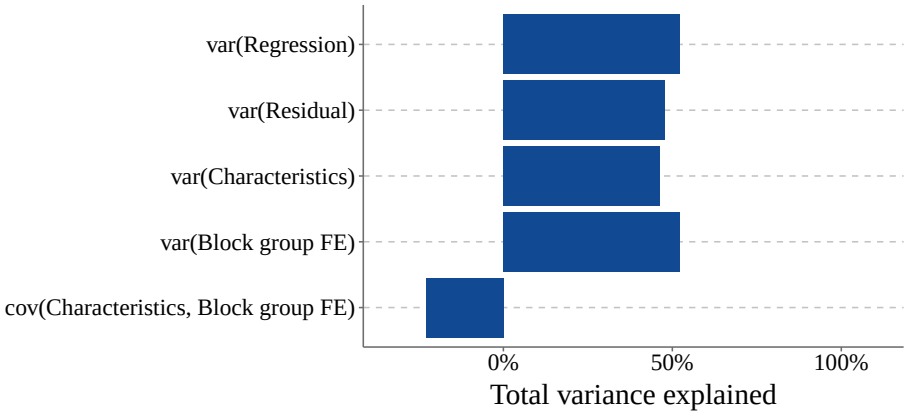


Development propensity

50
40
30
20
10

Block group FEs explain 50% of variation in development probability

$$y_i = \underbrace{\beta X_i}_{\text{Parcel characteristics}} + \underbrace{\lambda_{c(i)}}_{\text{Block group FE}} + \varepsilon_i$$



Identification: bargaining parameter

- **Intuition:** how much developers outbid households identifies bargaining parameter
- Nash bargaining $\implies$ developer pays mark-up:

$$\underbrace{p_i^* - p\left(z_i^0\right)}_{\text{Mark-up}} = \beta \cdot \underbrace{\left(p\left(z_i^j\right) - p\left(z_0^i\right) - C\left(z_i^j\right) + \sigma\left(z_i^j\right)\varepsilon_i^j - \varepsilon_i^{OO}\right)}_{\text{Total surplus}}$$

- Use estimated cost estimates to infer total surplus
- Take expectations on both size, use model-implied expected ε
- Estimated surplus split: 26% to property owners, 74% to developers

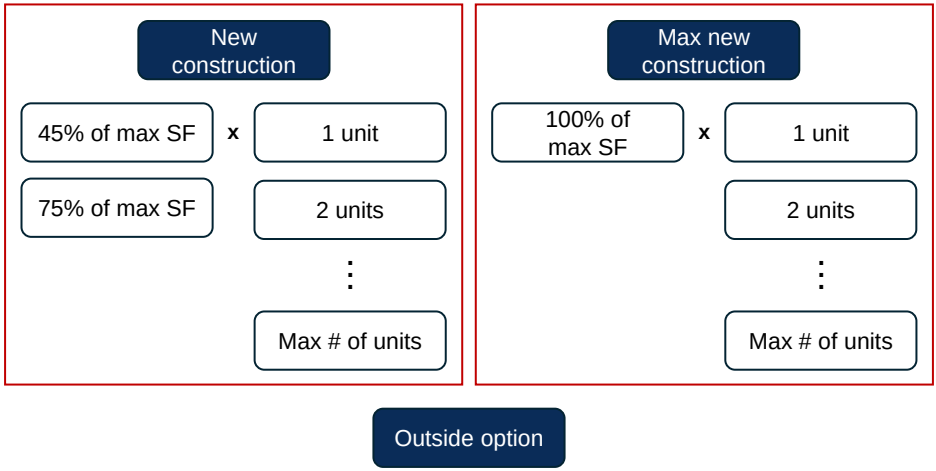
Model: vacant land

- Vacant land i with characteristics X_{it} is owned by a representative developer
  - The developer can choose to develop with intensity $j \in \{1, \ldots, J\}$
  - The new housing has quality $z_i^j = f(j, X_i)$
- After redevelopment, the developer can sell to a household and earn:

$$\underbrace{\pi_i^j}_{\text{Net profit}} = \overbrace{\underbrace{p\left(z_i^j\right)}_{\text{Hedonic price surface}} - \underbrace{c\left(z_i^j\right)}_{\text{Building costs}}}^{\text{Gross profit}} - \underbrace{f(X_i)}_{\text{Other costs}} + \underbrace{\sigma(X_i)\,\varepsilon_i^j}_{\text{Cost shock}}$$

- If the developer passes on redeveloping, they receive outside option: $\pi_i^{OO} = g(X_i) + \varepsilon_i^{OO}$
- The developer develops if $\max_j \left\{\pi_i^j\right\} > \pi_i^{OO}$ at intensity $j^* = \operatorname{argmax}_j \left\{\pi_i^j\right\}$

Developer's (nested) choice set



Estimation: outside option

- **Data:** arms-length transactions from 2001-2019
  - Parcel is redeveloped if we observe redevelopment within 5 years of transaction
  - Use property characterics to classify redevelopment type

- Normalize profits by maximum building square feet (heteroskedastic cost shocks):

$$\widetilde{\pi}_{ij} = \frac{\sigma^{-1}}{\text{Max FAR}_i \times \text{Lot SF}_i}\left[p\left(z_i^j\right) - c\left(z_i^j\right)\right] + \varepsilon_{iB(j)} + \varepsilon_{ij}$$

$$\widetilde{\pi}_i^{OO} = \frac{\sigma^{-1}}{\text{Max FAR}_i \times \text{Lot SF}_i}\left[f\left(X_i\right) + g\left(X_i\right)\right] + \varepsilon_i$$

- Assume ε_{ij} distributed EV type I and $\varepsilon_{iB(j)}$ distributed normal (nest-specific cost shock)

- Maximum simulated likelihood, bag of little bootstraps standard errors

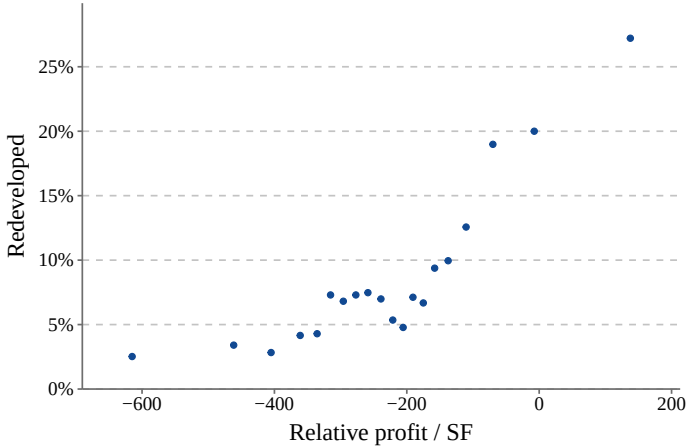
Estimation: outside option

- Assume following multivariate normal distribution for $\varepsilon_{iB(j)}$:

$B(j)$	Nest
1	Outside option
2	New construction
3	Max new construction

$$\mu = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}; \ \sigma = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & \sigma_3{}' \end{bmatrix}$$

Descriptive evidence: gross profit



- Normalized by maximum building SF

Estimates: outside option (sales)

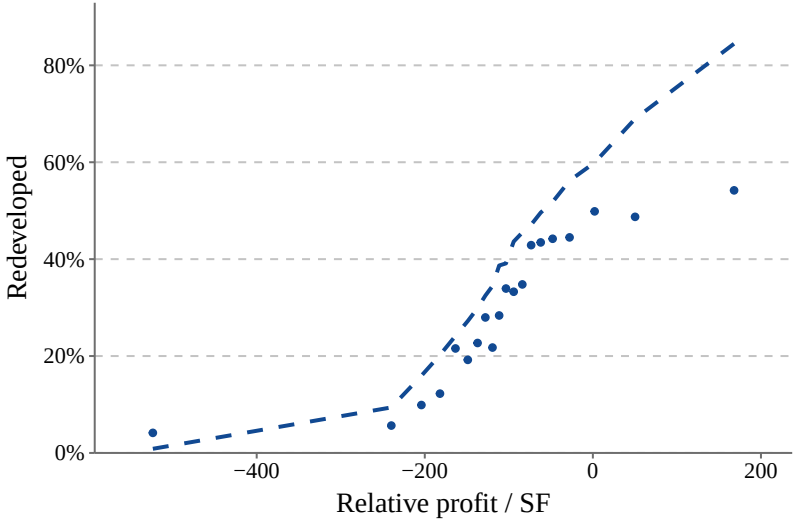
- Parametrize:

$$f(X_{it}) + g(X_{it}) = \underbrace{\alpha}_{\text{Fixed cost}} + \underbrace{\beta \times \text{Lot SF}_{it}}_{\text{Variable cost}}$$

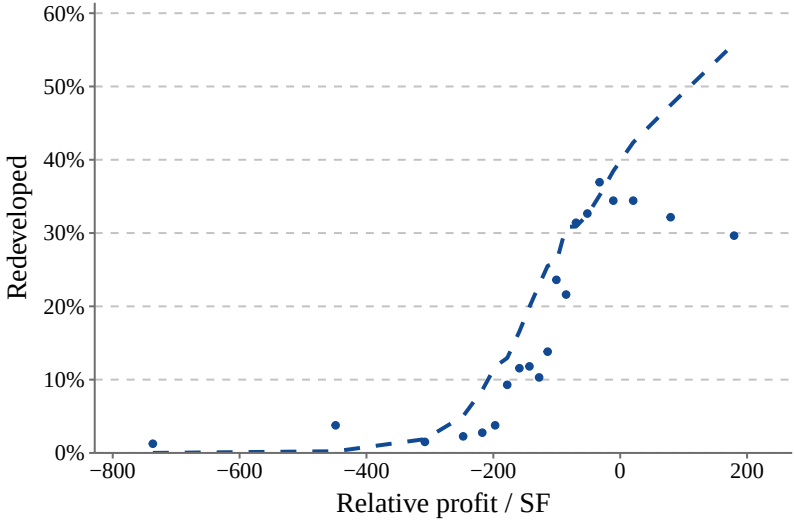
- Estimates:

$ 2021	Vacant		Other	
	Pre	Post	Pre	Post
VC	4.1	21.4	65.7	117.1
	(X)	(X)	(X)	(X)
FC (thousands)	479.3	351.4	576.1	615.7
	(X)	(X)	(X)	(X)

Model fit: vacant land (sales)



Model fit: other (sales)



Counterfactuals

Evaluate counterfactual welfare of currently proposed policies in Chicago in partial equilibrium:

1. **Triplex:** set min. lot size per unit to 1/3 of min. lot size (i.e., allow for triplexes everywhere)
2. **Triplex + FAR:** above + scale FAR for change in units allowed (e.g., triple FAR for single-family lots)
3. **Fixed cost:** reduce fixed costs by 25%

Compare relative to expected construction: e.g. assume all parcels first come to market and developers build under current zoning rules.

Triplex: Housing stock similarly affordable, more units

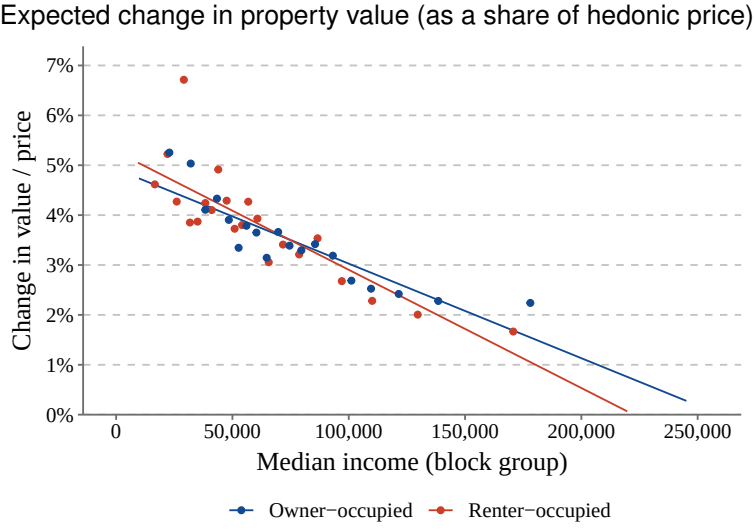
	City			
	Status quo	**Expected**	**Triplex**	**Δ**
Price per unit	$197,216	$239,785	$236,618	−1.32%
Price per sq. ft.	$172.6	$167.5	$171.2	2.20%
Sq. ft. per unit	1,218	1,373	1,378	0.36%
Units	1.351	1.394	1.435	2.91%

	Suburb			
	Status quo	**Expected**	**Triplex**	**Δ**
Price per unit	$310,647	$347,085	$349,096	0.58%
Price per sq. ft.	$183.6	$176.0	$178.2	1.20%
Sq. ft. per unit	1,686	1,898	1,961	3.85%
Units	1.011	1.072	1.142	6.51%

Triplex: richer neighborhoods benefit more in level terms

Expected Property value $= Pr(Develop)(\beta * Surplus + \text{Hedonic Price}) + (1 - Pr(Develop)) * \text{Hedonic Price}$

Triplex: poorer neighborhoods benefit more in log terms



Expected Property value $= Pr(Develop)(\beta * Surplus + \text{Hedonic Price}) + (1 - Pr(Develop)) * \text{Hedonic Price}$

Triplex + FAR: Housing stock less affordable, even more units

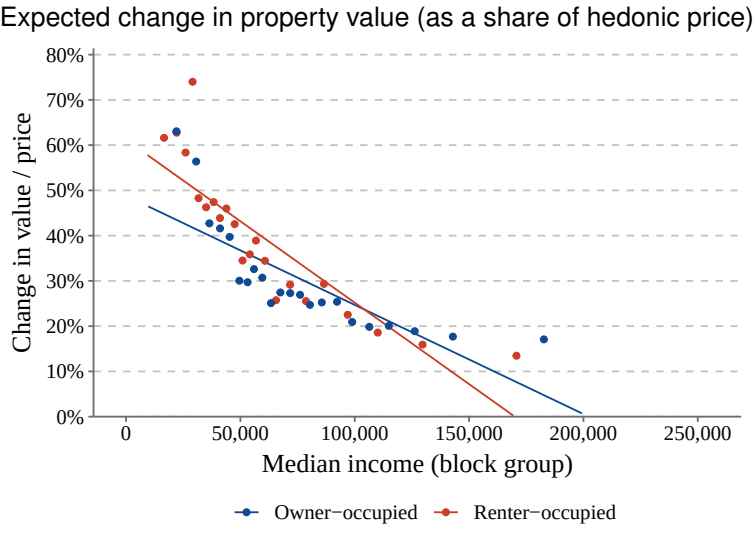
	City			
	Status quo	**Expected**	**Triplex + FAR**	**Δ**
Price per unit	$197,216	$239,785	$292,627	22.08%
Price per sq. ft.	$172.6	$167.5	$156.2	−6.76%
Sq. ft. per unit	1,218	1,373	1,938	41.12%
Units	1.351	1.394	1.468	5.29%

	Suburb			
	Status quo	**Expected**	**Triplex + FAR**	**Δ**
Price per unit	$310,647	$347,085	$429,182	23.65%
Price per sq. ft.	$183.6	$176.0	$161.3	−8.35%
Sq. ft. per unit	1,686	1,898	2,907	53.94%
Units	1.011	1.072	1.167	8.88%

Triplex + FAR: richer neighborhoods benefit more in level terms

Expected Property value $= Pr(Develop)(\beta * Surplus + \text{Hedonic Price}) + (1 - Pr(Develop)) * \text{Hedonic Price}$

Triplex + FAR: poorer neighborhoods benefit more in log terms



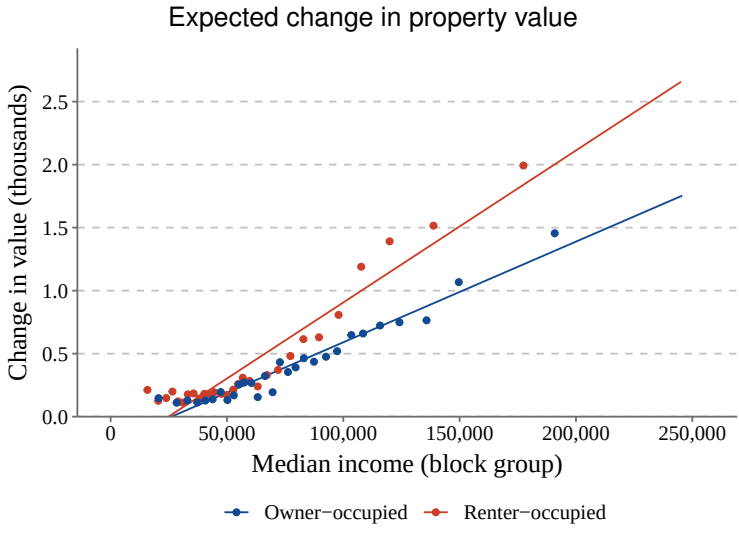
Expected Property value $= Pr(Develop)(\beta * Surplus + \text{Hedonic Price}) + (1 - Pr(Develop)) * \text{Hedonic Price}$

Cut fixed costs: no units produced, 1% increase in avg price

	City			
	Status quo	**Expected**	**Fixed cost**	**Δ**
Price per unit	$197,216	$239,785	$246,535	2.82%
Price per sq. ft.	$172.6	$167.5	$170.1	1.50%
Sq. ft. per unit	1,218	1,373	1,395	0.50%
Units	1.351	1.394	1.395	0.04%

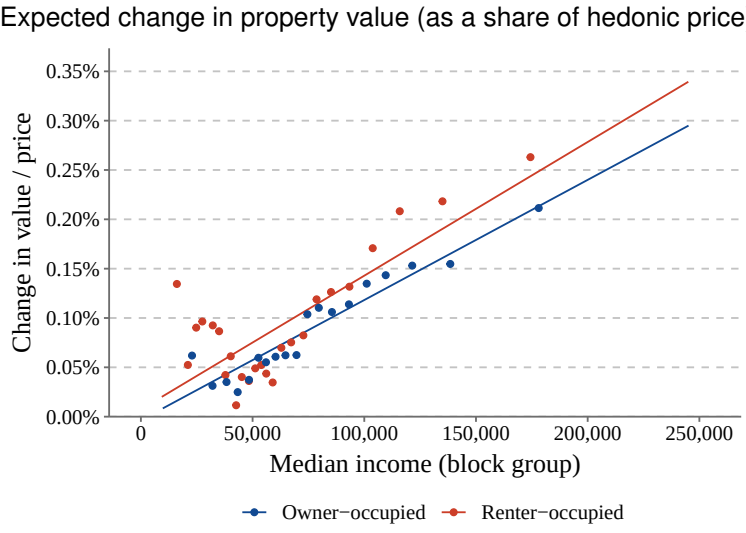
	Suburb			
	Status quo	**Expected**	**Fixed cost**	**Δ**
Price per unit	$309,882	$348,507	$352,808	1.23%
Price per sq. ft.	$183.5	$174.6	$175.8	0.69%
Sq. ft. per unit	1,681	1,897	1,908	0.57%
Units	1.011	1.085	1.088	0.25%

Fixed costs: richer neighborhoods benefit more in dollars



Expected Property value $= Pr(Develop)(\beta * Surplus + \text{Hedonic Price}) + (1 - Pr(Develop)) * \text{Hedonic Price}$

Fixed costs: richer neighborhoods benefit more in percent terms

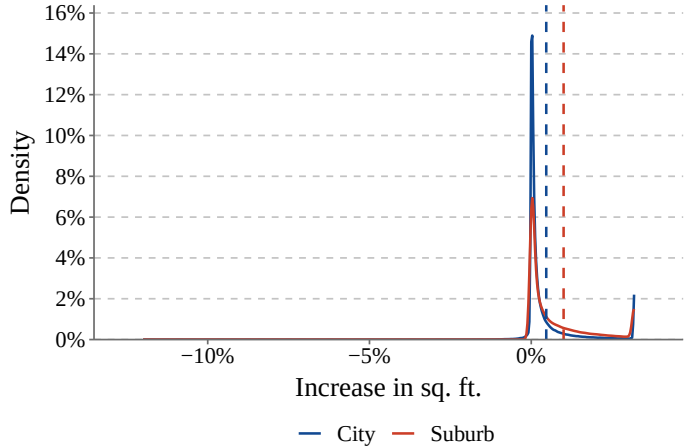


Expected Property value $= Pr(Develop)(\beta * Surplus + \text{Hedonic Price}) + (1 - Pr(Develop)) * \text{Hedonic Price}$

Aggregate change in housing stock

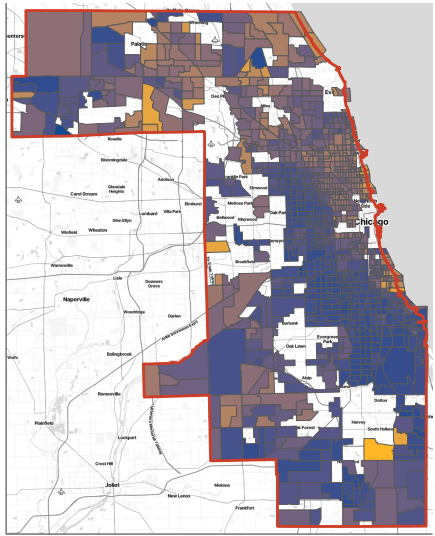
	Infill			Land		
	Expected	**Policy**	Δ	**Expected**	**Policy**	Δ
Triplex	812,092	826,301	14,209	34,862	51,006	16,144
Triplex + FAR	812,092	842,626	30,534	34,862	54,745	19,883
FC	812,900	812,112	−788	34,862	36,537	1,675

Price increase: suburbs are relatively more supply elastic



10% increase in price $\Longrightarrow$ 1% increase in floor space for infill developments

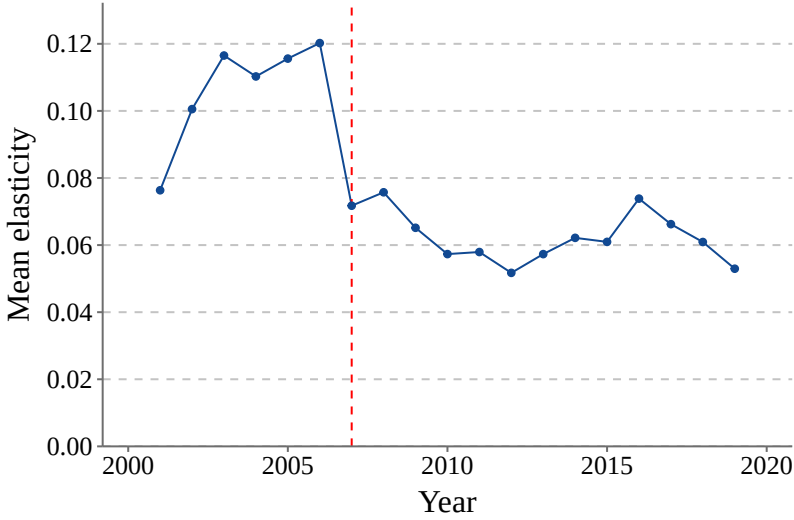
Price increase: suburbs are relatively more supply elastic



% increase in sq. ft.

2.5
2.0
1.5
1.0

Price increase: supply elasticities are higher pre-2007 financial crisis



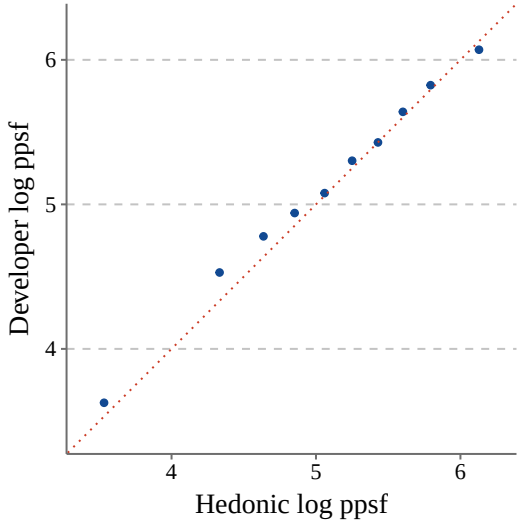
Conclusion

- New supply-side model of micro developer behavior
  - Observing lot-level zoning + before and after redevelopment lot characteristics enables data to directly reveal developer preferences
  - Lot characteristics are as important as neighborhood in determining Pr(development)
  - Current Cook County zoning likely only to produce quality upgrading in the future

- Evaluate currently proposed Cook County Zoning Reforms
  - Rezoning to allow triplexes everywhere produces 3% more units, lowers avg prices 7%, despite lot capacity doubling
  - Lowering fixed construction costs (cutting redtape, streamlining permitting): No effect on unit supply, increases unit prices, makes inframarginal units cheaper to build, property owners in low-income areas barely benefit

- Future work: Framework can be used as laboratory for many types of evaluation
  - Policy effects: Inclusionary zoning, other zoning reforms
  - Cross-county comparisons: Collect data and redo in many other counties (big data lift)
  - Parcel-level housing supply elasticities to predict how specific type of price shocks effect supply

Developers outbid households, suggesting some surplus split



Estimation: bargaining parameter

- Observe mark-ups for redeveloped parcel, but not cost shocks

$$\underbrace{p_i^* - p\left(z_i^0\right)}_{\text{Mark-up}} = \beta \cdot \underbrace{\left(p\left(z_i^j\right) - p\left(z_0^i\right) - C\left(z_i^j\right) + \sigma\left(z_i^j\right)\varepsilon_i^j - \varepsilon_i^{OO}\right)}_{\text{Total surplus}}$$

- However, know cost shocks in expectation; denote $d_i = 1$ if a parcel is redeveloped:

$$\mathrm{E}_{i,\varepsilon}\left[\underbrace{p_i^* - p\left(z_i^0\right)}_{\text{Mark-up}} \mid d_i = 1\right] = \beta \cdot \mathrm{E}_i\left[\underbrace{\mathrm{E}_\varepsilon\left[\left(p\left(z_i^j\right) - p\left(z_0^i\right) - C\left(z_i^j\right) + \sigma\varepsilon_i^j - \varepsilon_i^{OO}\right)\right]}_{\text{Expected total surplus}} \mid d_i = 1\right]$$

- Estimate via method of moments: $\beta = 0.26$