The Impact of Commercial Real Estate Regulations on U.S. Output

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How do commercial land use regulations affect output and welfare?

- Motivation.
  - Several studies of US *residential* land use regulations find substantial effects on U.S. economy (Herkenhoff Ohanian Prescott 2018, Hsieh Moretti 2019)
  - *Commercial* regulation is conceptually similar, yet little known about impact on U.S. economy
  - Challenge is commercial regulation is multi-dimensional, local & allows exemptions
  - Infeasible to consistently codify across cities or measure bite without model

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  - Challenge is commercial regulation is multi-dimensional, local & allows exemptions
  - Infeasible to consistently codify across cities or measure bite without model
- **This paper.**
  - Quantify effects of commercial regulation using CoreLogic's *address-level tax valuations*
  - Develop GE model with commercial construction sector to estimate *address-level regulatory distortion* for all U.S. buildings

How do commercial land use regulations affect output and welfare?

- Economic logic.
  - When land is costly, substitute towards construction (build taller)
  - Model infers regulatory distortion whenever valuable land has small building
  - We show model distortions correlate strongly with hand-collected zoning features

How do commercial land use regulations affect output and welfare?

- Economic logic.
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  - Model infers regulatory distortion whenever valuable land has small building
  - We show model distortions correlate strongly with hand-collected zoning features
- Results.
  - Moving all cities to *least strict regulations in US* yields 3% GDP & 1.5% CEV gain
  - Highly regulated CA cities (LA, SF) benefit vs. less regulated TX cities (Dallas, Houston)
  - Still large gains with 40% remote work share & doubling negative congestion externality

General equilibrium model

- One-sector optimal growth model w/ regions (j) & commercial buildings in production
- Regions are MSAs that differ by TFP and amenities with negative congestion externality
- One region is remote work sector which does not use buildings in production

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Household:

$$\max_{c_t, i_t, K_{j,t}, L_{j,t}} \sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\sigma}}{1-\sigma} - \frac{1}{1+\frac{1}{\eta}} \sum_{j=1}^{N} \left(\frac{L_{j,t}}{a_j(L_{j,t}/X_j)} \right)^{1+\frac{1}{\eta}} \right)$$

$$s.t. \quad c_t + i_t = \sum_j \left(\pi_{j,b,t} + \pi_{j,f,t} + w_{j,t} L_{j,t} + r_{k,t} K_{j,t} \right)$$

Firm j:

$$\max_{K_{j,t}, L_{j,t}, B_{j,t}} A_j L_{j,t}^{\alpha} B_{j,t}^{\chi_j} K_{j,t}^{1-\alpha-\chi_j} - w_{j,t} L_{j,t} - r_{k,t} K_{j,t} - r_{b,j,t} B_{j,t}$$

Developer j:

$$\max_{m_{j,t}} p_{j,t} \cdot T_{j,t} \cdot B_{j,t}(D_{j,t}, m_{j,t}) - m_{j,t}$$

Modeling Commercial Building Regulation

- Developer's problem.

  Developer owns commercial property i defined by

  x_i: Land square-footage
  p_i: Price per-building-square-foot
  q_i: Cost of construction ("improvements") m_i
  τ_i: Regulatory distortion ("virtual" wedge – distorts choices but no resource transfer, height limit)

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- No regulation: use land & improvements m_i to create building square footage (BSF_i)

$$\max_{m_i} p_i \underbrace{m_i^{\gamma} x_i^{1-\gamma}}_{BSF_i} - q_i m_i$$

  FOC implies $\gamma = \frac{q_i m_i}{p_i BSF_i}$ (marginal benefit=marginal cost)

  Regulatory limits imply marginal benefit $>$ marginal cost, attribute gap to regulations τ_i

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- Example of a regulation: floor-area ratio limit

$$\max_{m_i} p_i \underbrace{m_i^{\gamma} x_i^{1-\gamma}}_{BSF_i} - q_i m_i$$

$$\text{such that} \quad \frac{BSF_i}{x_i} \leq \bar{H}$$

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- Example of a regulation: floor-area ratio limit

$$\max_{m_i} \tau_i p_i \underbrace{m_i^{\gamma} x_i^{1-\gamma}}_{BSF_i} - \underbrace{q_i m_i}_{MV_i} \quad , \qquad \text{e.g. Floor Area Ratio: } \tau_i = \begin{cases} 1 & \text{if } \frac{BSF_i}{x_i} \leq \bar{H} \\ 0 & \text{otherwise} \end{cases}$$

- Assumption: τ_i is address-level constant, to capture multi-faceted zoning

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- FOC implies $\tau_i \gamma = \frac{q_i m_i}{p_i BSF_i}$
- Note τ_i distorts m_i^* but doesn't enter profit (e.g. zoning): $\pi = 1 \cdot \beta p_i (m_i^*)^{\gamma} x_i^{1-\gamma} - q_i m_i^*$

Modeling Commercial Building Regulation

Construction ban: $\tau_i = 0$

Sandhill road

Menlo Park

Interpretation of regulatory distortion τ_i

Developer's problem: $\max_{m_i} \tau_i p_i m_i^{\gamma} x_i^{1-\gamma} - q_i m_i$

- What τ_i is.

  Anything that restricts building size, conditional on factor prices p_i, q_i

  - Floor area ratios, setbacks, height limits, environmental review boards
  - Non-zoning restrictions: local ordinances, deed restrictions, etc.

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- What τ_i is **not**.

  Not anything that enters building prices p_i (e.g. local building demand, property taxes)

  Not anything that enters construction cost q_i

  - Restrictions on building techniques (Schmitz (2020): prefab)
  - Difficulty of building

Combining Model and Data

- **Data.**
  - Address-level tax assessments compiled by CoreLogic
  - Divides total property value into improvements & land (e.g., using replacement cost of building):

$$\text{Total Value of Property (TV)} = \underbrace{\text{Improvement Value (MV)}}_{q_i m_i = \text{cost of structures}} + \text{Land Value (LV)}$$

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- **Identifying τ using CoreLogic Data:**
  - Model's closed-form solution for regulatory distortion (τ_i) depends on *improvement share* $\frac{MV}{TV}$:

$$\tau_i = F\left(\frac{MV_i}{TV_i}\right), \quad F'(\cdot) > 0$$

  - **Low** improvement share implies **low** τ_i, **more** distorted

    (e.g. small building on valuable land $\rightarrow$ strict regulation)

Identification of τ_i

- Regulatory distortion (τ_i) is increasing in *improvement share* $\frac{MV_i}{TV_i}$:

$$\tau_i = \frac{\left(\frac{1-\beta(1-\delta_b)}{1-\beta}\frac{MV_i}{TV_i}\right)}{\gamma\beta\left(1+\frac{\delta_b}{1-\beta}\frac{MV_i}{TV_i}\right)}$$

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- For example, a small building on valuable land $\rightarrow$ strict regulation

Empirically Validating Model Distortions

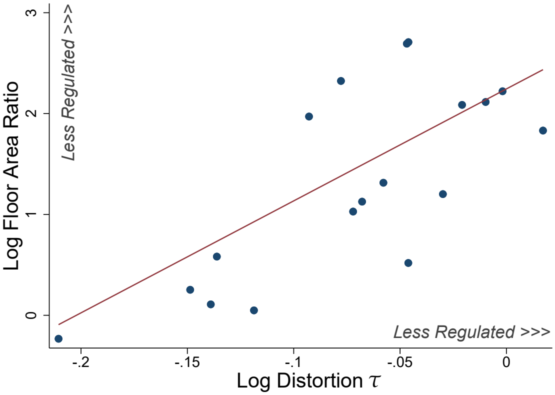
- Key zoning code features.
  - Two prominent components of zoning codes include
    - Height limits: caps building height
    - Floor-area-ratio limits: caps building size relative to land size

Empirically Validating Model Distortions

- **Key zoning code features.**
  - Two prominent components of zoning codes include
    - Height limits: caps building height
    - Floor-area-ratio limits: caps building size relative to land size
- **Comparing model distortion (τ) to data.**
  - Hand-collect height limits and floor-area-ratios for several cities and compare to τ
  - If these regulations are important, expect *positive but imperfect* correlation with τ
  - Model τ includes non-zoning features (*deed restrictions*), & zoning exemptions (*variances*)

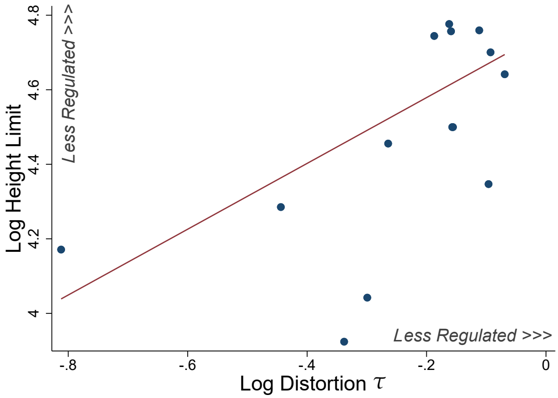
Comparing τ to actual zoning codes

1. Distortions align with hand-collected floor-area-ratios (FARs) in NYC



Comparing τ to actual zoning codes

1. Distortions align with hand-collected floor-area-ratios (FARs) in NYC
2. And hand-collected height limits in DC



Aggregation

- Aggregate address-level (i) distortions to city-level (j) for policy reforms
- Aggregation has average τ_i component (T_j) & dispersion in τ_i component (D_j)

$$\max_{m_j} p_j \cdot T_j \cdot BSF_j(D_j, m_j) - m_j$$

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$$\max_{m_j} p_j \cdot T_j \cdot BSF_j(D_j, m_j) - m_j$$

$$T_j = \frac{\sum_{i \in j} MV_i}{\sum_{i \in j} MV_i / \tau_i}$$

- Reflects **average** *city-wide* distortion
- Takes value $\overline{\tau}$ if all $\tau_i = \overline{\tau}$
- **Focus of counterfactuals**

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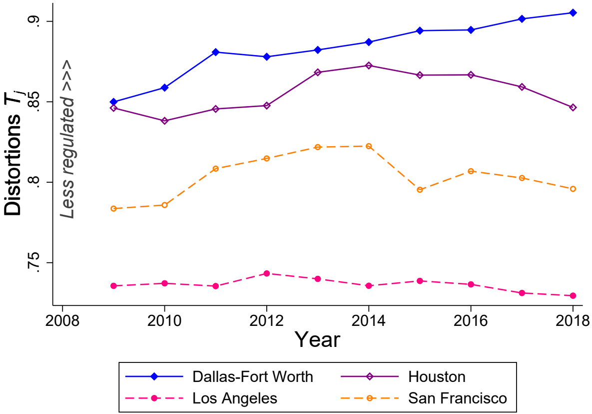
$$D_j = \left(\frac{\sum_{i \in j} MV_i / \tau_i}{\sum_{i \in j} MV_i / \tau_i^{\frac{1}{1-\gamma}}} \right) \Big/ \left(\frac{\sum_{i \in j} MV_i}{\sum_{i \in j} MV_i / \tau_i^{\frac{1}{1-\gamma}}} \right)^{\gamma}$$

- Reflects **average** *city-wide* distortion
- Takes value $\overline{\tau}$ if all $\tau_i = \overline{\tau}$
- **Focus of counterfactuals**

- Reflects τ_i **dispersion** *within* city
- Part regulation, part measurement error
- **Hold fixed today** [*paper alters* D_j]

Which cities are most and least regulated?

- Major California cities (LA, SF) more regulated than Texas (Dallas, Houston)



Which cities are most and least regulated?

- Major California cities (LA, SF) more regulated than Texas (Dallas, Houston)
- Least-regulated city is Midland TX; developers in strict zoned cities build 20% less, c.p.

	Name	T_j
	Average regulatory distortion	0.85
Least Regulated City:	Midland, TX ("The Tall City")	1 (Normalized)
Major MSAs:	San Diego	0.79
	San Jose	0.80
	Miami	0.80
	New York	0.86
	Chicago	0.88
	Phoenix	0.89

Counterfactuals

- Baseline: All distortions T_j set to loosest U.S. level (Midland, TX), fix dispersion D_j
  - More buildings drive output gain, & **Developer profits fall** suggesting τ reflects rent-seeking
  - Results robust to three available divisions of MV and LV, doubling or removing congestion

%Δ from 2018 steady state	**Baseline**
Output	3.0%
Employment	-0.8%
Building Stock	17%
Developer Profits	-2.8%
Output, holding building allocation fixed	0.2%
Consumption Equivalent Gain	1.6%

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- **40% remote work:** Output gains scale down linearly with remote work

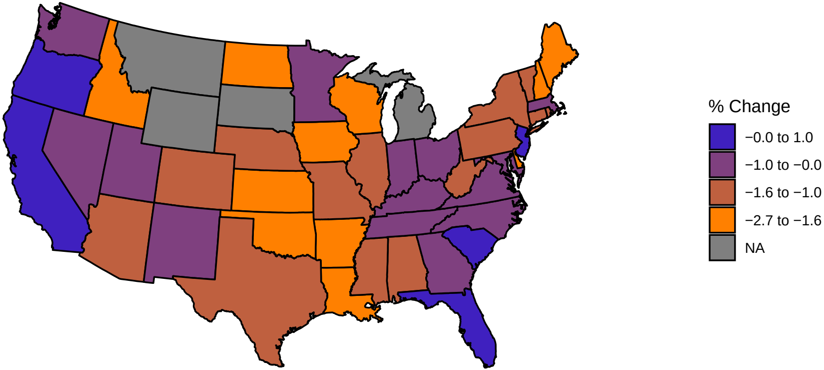
%Δ from 2018 steady state	**Baseline**	**Remote Work**
Output	3.0%	1.5%
Employment	-0.8%	-0.8%
Building Stock	17%	19%
Developer Profits	-2.8%	-1.1%
Output, holding building allocation fixed	0.2%	-0.4%
Consumption Equivalent Gain	1.6%	0.8%

Counterfactuals

- Baseline: All distortions T_j set to loosest U.S. level (Midland, TX), fix dispersion D_j
  - More buildings drive output gain, & **Developer profits fall** suggesting τ reflects rent-seeking
  - Results robust to three available divisions of MV and LV, doubling or removing congestion
- 40% remote work: Output gains scale down linearly with remote work
- Only use young buildings $\leq$ 10 years old: similar gains, avoids outdated regulations

%Δ from 2018 steady state	**Baseline**	**Remote Work**	**New Buildings**
Output	3.0%	1.5%	1.4%
Employment	-0.8%	-0.8%	-0.3%
Building Stock	17%	19%	8.4%
Developer Profits	-2.8%	-1.1%	-1.5%
Output, holding building allocation fixed	0.2%	-0.4%	0.1%
Consumption Equivalent Gain	1.6%	0.8%	0.8%

Baseline deregulation: Change in labor relative to 2018 steady state



- People leave already-deregulated Texas and South
- Largest population gain in major metro (LA) $< 2.5\%$

Local Deregulation: Relax Floor Area Ratio (FAR) in NYC

- Project model distortions onto **actual** floor area ratios (FAR): $\log \tau_z = \rho \log(FAR_z) + \epsilon_z$

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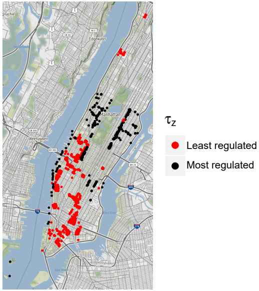

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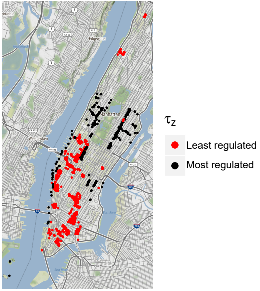

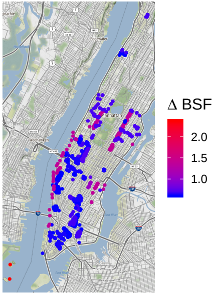

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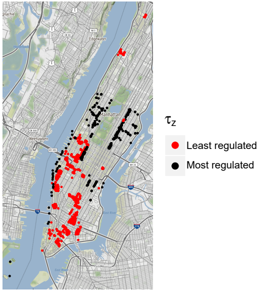

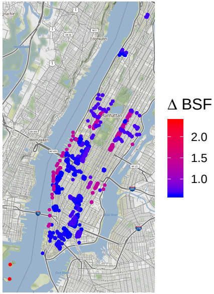

$$\Delta Y_{NYC} = +1.8\%$$

$$\Delta B_{NYC} = +6.1\%$$

Conclusion

Contributions:

- Develop spatial model of commercial land use regulations
- Identify distortions for each commercial property
- Validate against hand-collected zoning code features
- Moving all cities to least stringent regulations in U.S. yields large welfare/output gains

In progress:

- Quantifying impact of regulations on low income households and homelessness

Thank you!

Parcel i Developer's Problem

- Parcel i defined by

  x_i: Land square-footage
  p_i: Price per building square-foot (e.g. distance to interstate)
  q_i: Improvement cost (e.g. bedrock vs. mud)
  τ_i: Regulatory distortion (virtual wedge $\rightarrow$ does not result in payment/transfer of resources)

- Rent building, buildings depreciate fully at rate δ_b ("one-hoss-shay")

- If building depreciates, rebuild by investing in improvements $m_{i,t}$ subject to zoning τ_i:

$$\max_{m_{i,t}} \tau_i p_i \underbrace{m_i^\gamma x_i^{1-\gamma}}_{BSF_{i,t}} - \underbrace{q_i m_{i,t}}_{MV_{i,t}}$$

e.g. FAR: $\tau_i = \begin{cases} 1 & \text{if } BSF_i / x_i \leq \bar{H} \\ 0 & \text{otherwise} \end{cases} \rightarrow \tau_i$ parcel-level constant to capture multi-faceted zoning

- τ_i distorts m_i^*, but no τ_i in profits: $1 \cdot \beta p_i m_i^{*\gamma} x_i^{1-\gamma} - q_i m_i^*$ [≈*Lagrange multiplier*]

CoreLogic Dataset

- Overview
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$$\text{Total Value of Property } (TV_i) = \text{Improvement Value } (MV_i) + \text{Land Value } (LV_i)$$

  - Land square footage x_i
  - Alphanumeric zoning codes (“C8”, “M5”) that reflect local regulations
  - Building square footage BSF_i for subset of properties & age a_i

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  - Building square footage BSF_i for subset of properties & age a_i
- Challenge
  - Map local regulations into quantitative measure of distortions
  - Our approach: write down builder's problem for parcel *i* to structurally identify distortions
  - Model regulatory distortions as a *wedge* in the builder's problem

Sample Selection

Robustness

- We crucially rely on Corelogic's split of property value into land and improvements:

$$TotalValue(TV) = LandValue(LV) + ImprovementValue(IV)$$

- Our dataset includes 3 methods: assessed, market, CoreLogic calculated
- Each valuation relies on different methods
  - Replacement cost method often used to value structures
  - Land values based on vacant lots of redevelopments
- Our baseline output gain under each of these three methods are remarkably similar

Valuation method:	Assessed	Market	CoreLogic Calculated (*Benchmark*)
Output gain from Midland, TX zoning	+2.9%	+3.2%	+3.0%

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- "One-hoss shay" depreciation rate δ_b, developer then uses m_i to build new structure

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- τ_i is wedge between unconstrained marginal product of improvements m_i & marginal cost
- FOC implies $\tau_i = \frac{q_i m_i}{\gamma \beta p_j z_i BSF_i}$

Interpretation of regulatory distortion τ_i

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  Not anything that enters building prices p_j (e.g. local building demand)

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  - Restrictions on building techniques (Schmitz (2020): prefab)
  - Difficulty of building

Identification of τ_i

Developer's problem: $\max_{m_i} \tau_i \beta p_j z_i \underbrace{m_i^{\gamma} x_i^{1-\gamma}}_{BSF_i} - q_i m_i \rightarrow$ FOC: $\tau_i = \frac{q_i m_i}{\gamma \beta p_j z_i BSF_i}$

- Numerator of τ_i is improvement value (cost of structures), $MV_i = q_i m_i$, observed in CL
- Challenge is building square feet (BSF_i) not observed for all parcels, z_i unobserved

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- Proceed by defining denominator of τ_i as building value, $BV_i = p_j z_i BSF_i$
- Model then relates BV_i to observed total (TV_i) & improvement value (MV_i)
- This insight allows us to identify τ_i for all buildings in U.S.

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$$TV_i = \frac{1-\beta(1-\delta_b)}{1-\beta} BV_i - \delta_b \frac{MV_i}{1-\beta}$$

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- Solve for building value $BV_i = g(TV_i, MV_i)$ & substitute into denominator of τ_i

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- Solve for building value $BV_i = g(TV_i, MV_i)$ & substitute into denominator of τ_i
- Closed-form regulatory distortion (τ_i) depends on *improvement share* $\frac{MV_i}{TV_i}$:

$$\tau_i = F\left(\frac{MV_i}{TV_i}\right), \quad F'(\cdot) > 0$$

Identification of τ_i

- Regulatory distortion (τ_i) is increasing in *improvement share* $\frac{MV_i}{TV_i}$:

$$\tau_i \quad = \quad \frac{\left(\frac{1-\beta(1-\delta_b)}{1-\beta}\frac{MV_i}{TV_i}\right)}{\gamma\beta\left(1+\frac{\delta_b}{1-\beta}\frac{MV_i}{TV_i}\right)}$$

- **Low** improvement share implies **low** τ_i, **more** distorted

- For example, a small building on valuable land $\rightarrow$ strict regulation

Aggregation

- Aggregate address-level (i) distortions to city-level (j) for policy reforms
- Aggregation has average τ_i component (T_j) & dispersion in τ_i component (D_j)

$$\max_{m_j} p_j \cdot T_j \cdot BSF_j(D_j, m_j) - m_j$$

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$$T_j = \frac{\sum_{i \in j} MV_i}{\sum_{i \in j} MV_i / \tau_i}$$

- Reflects **average** *city-wide* distortion
- $T_j = \overline{\tau}$ if common $\tau_i = \overline{\tau}$
- **Focus of counterfactuals**

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$$D_j = \left(\frac{\sum_{i \in j} MV_i / \tau_i}{\sum_{i \in j} MV_i / \tau_i^{\frac{1}{1-\gamma}}} \right) \Bigg/ \left(\frac{\sum_{i \in j} MV_i}{\sum_{i \in j} MV_i / \tau_i^{\frac{1}{1-\gamma}}} \right)^{\gamma}$$

- Reflects **average** *city-wide* distortion
- $T_j = \overline{\tau}$ if common $\tau_i = \overline{\tau}$
- **Focus of counterfactuals**

- Reflects τ_i **dispersion** *within* city
- Part regulation, part noise
- **Hold <u>fixed</u> today** [*paper alters* D_j]

Identification of production technology ($BSF_i = m_i^{\gamma} x_i^{1-\gamma}$)

- Challenge: improvement exponent γ always multiplies distortion
  - At parcel-level, recover *product* of $\tau_i \cdot \gamma$
  - At city-level, recover *product* of $T_j \cdot \gamma$

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  - High γ, Cobb-Douglas both in line with building production literature

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- Given γ recover $\tau_i = \frac{MV_i}{\gamma \beta BV_i}$ at parcel level $\rightarrow$ next, many litmus tests of τ_i & T_j

Sample Selection

- Keep Parcels Where:
  - MV_i, TV_i, and x_i all recorded
  - $MV_i\,/\,TV_i \in (0.01, 0.99)$
- Outcome of Filtering:
  - End up with parcels worth 72% of aggregate TV_i

Back

What is τ ?

- Distortion: Anything that causes a landlord to build less than they want to, conditional on factor prices
  - Floor Area Ratios
  - Setbacks
  - Height limits
  - Environmental review boards
  - Threat of lawsuits
- Regulatory “tax”: Any cost that doesn’t act as a building improvement
  - Payments for local improvements (sewers, schools)
  - Litigation

Back

What is τ not?

- Prices: Anything that enters z_i or $r_{b,j,t}$
  - Restrictions on what you can build (factories vs office towers)
  - Property taxes
- Costs: Anything that enters q_i
  - Restrictions on building techniques (Schmitz (2020): prefab)
  - Difficulty of building (bedrock)

Back

Household Problem

- Chooses labor $L_{j,t}$ and capital $K_{j,t}$ across cities $j \in J$, capital investment $i_{k,t}$
- Earns wages $w_{j,t}$, rents $r_{k,t}$, and profits from final-good firms $\pi_{j,f,t}$ and landlords $\pi_{j,b,t}$
- Maximizes utility:

$$\max_{c_t, i_{k,j,t}, L_{j,t}} \sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\sigma}}{1-\sigma} - \frac{1}{1+\frac{1}{\eta}} \sum_j \left(\frac{L_{j,t}}{a_j(L_{j,t}, X_{j,t})} \right)^{1+\frac{1}{\eta}} \right)$$

subject to:

$$c_t + i_{k,t} = \sum_j \left(\pi_{j,b,t} + \pi_{j,f,t} + w_{j,t} L_{j,t} + r_{k,t} K_{j,t} \right)$$

$$K_{t+1} = i_{k,t} + (1 - \delta_k) K_t$$

$$K_t = \sum K_{j,t}$$

Back

Final Goods

- Combine labor L_j, buildings B_j, capital K_j at city level to produce final good
- Pay a national rental rate for capital r_k and city-specific wages w_j and building rents $r_{b,j}$

$$\pi_{j,f} = \max_{K_{j,t}, L_{j,t}, B_{j,t}} \underbrace{A_j L_{j,t}^{\alpha} B_{j,t}^{\chi_j} K_{j,t}^{1-\alpha-\chi_j}}_{Y_{j,t}} - w_{j,t} L_{j,t} - r_{k,j,t} K_{j,t} - r_{b,j,t} B_{j,t}$$

- Building share $\chi_j = 0$ in remote work “region” and constant elsewhere

Back

Identifying Improvement Share γ and Zoning Distortions

- CoreLogic: total value TV_i, improvement value MV_i, building age $\Rightarrow \delta_b$, and $\beta = \frac{1}{1+r}$
  - Can recover improvement share γ multiplied by zoning distortion T_j....
  - ... but cannot separate returns to scale γ and distortion T_j without more assumptions
  - Intuition: low T_j lowers improvements, pushes MV / TV away from optimum implied by improvement share
- Our approach:
  - Treat city with the highest $T_j \gamma$ (Midland TX) as a "deregulated benchmark" Details
  - Assume undistorted developer's problem in that city, thus T_j=1
  - Recover conservative lower bound for γ (i.e. $T_j < 1$ implies a higher γ)
- Identifying Parcel Distortions:
  - Can use T_j, γ, and parcel-level MV, TV to get τ_i

Identification of γ: Part 1

- Steady state: landlord will expend same MV each time building falls

$$V_f(\tau, z, q, x) = \beta V(B, \tau, z, q, x) - \underbrace{qm}_{MV}$$

- TV is therefore NPV of payments minus NPV of costs

$$TV = \frac{r_{b,j}B}{1-\beta} - \frac{\delta_b qm}{1-\beta}$$

- BV is NPV of payments to building before it depreciates:

$$BV = \frac{r_{b,j}B}{1-\beta(1-\delta_b)}$$

- MV:

$$MV = \beta\gamma\tau BV$$

Back

Identification of γ: Part 2

- Combine to get:

$$TV = \frac{r_{b,j}B}{1-\beta} - \frac{\delta_b MV}{1-\beta}$$

$$BV = \frac{r_{b,j}B}{1-\beta(1-\delta_b)}$$

$$TV = \left(\frac{1-\beta(1-\delta_b) - \delta_b\beta\gamma\tau}{1-\beta}\right)\frac{MV}{\tau\beta\gamma}$$

$$\gamma\tau = \frac{\left(\frac{1-\beta(1-\delta_b)}{1-\beta}\right)\frac{MV}{TV}}{\left(\beta + \frac{\delta_b\beta}{1-\beta}\frac{MV}{TV}\right)}$$

Back

Identification of γ: Part 3

- Use $C_i \propto MV_i / \tau_i^{\frac{1}{1-\gamma}}$ and get:

$$T_j = \frac{\sum_{i\in j} MV_i}{\sum_{i\in j} MV_i/\tau_i}$$

$$T_j = \frac{\sum_{i\in j} MV_i}{\sum_{i\in j} MV_i \gamma \big(\beta + \frac{\delta_b \beta}{1-\beta}\frac{MV_i}{TV_i}\big) \Big/ \Big(\big(\frac{1-\beta(1-\delta_b)}{1-\beta}\big)\frac{MV_i}{TV_i}\Big)}$$

$$= \frac{\big(\frac{1-\beta(1-\delta_b)}{1-\beta}\big)\sum_{i\in j} MV_i}{\beta\gamma\big(\sum_{i\in j} TV_i + \frac{\delta_b}{1-\beta}\sum_{i\in j} MV_i\big)}$$

- Finally:

$$T_j = T_j \frac{\sum_{i\in j} TV}{\sum_{i\in j} TV} = \frac{\big(\frac{1-\beta(1-\delta_b)}{1-\beta}\big)\sum_{i\in j} MV}{\beta\gamma\big(\sum_{i\in j} TV + \frac{\delta_b}{1-\beta}\sum_{i\in j} MV\big)} \frac{\sum_{i\in j} TV}{\sum_{i\in j} TV} = \frac{\big(\frac{1-\beta(1-\delta_b)}{1-\beta}\big)\frac{\sum_{i\in j} MV}{\sum_{i\in j} TV}}{\beta\gamma\big(1 + \frac{\delta_b}{1-\beta}\frac{\sum_{i\in j} MV}{\sum_{i\in j} TV}\big)}$$

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GE Model: Standard Parameters

Parameter	Description	Value	Source
β	Discounting	0.96	Standard
σ	CRRA	2	Standard
η	Labor Curvature	2	Keane and Rogerson (2012)
δ_k	Depreciation	0.032	McGrattan (2020)
α	Labor Share	0.594	Penn World Table (US, 2018)

Back

GE Model: Key Variables

Variable	Description	Source
Y	Aggregate GDP	NIPA Table 1.1.6
Y_j	MSA GDP	BEA
$\sum_j i_{k,j}$	Equipment+IP Investment	NIPA Table 1.1.6
L_j	MSA Labor Supply	ACS
$L_r / \sum_j L_j$	Remote Labor Supply Share	ACS
$w_r L_r / \sum_j w_j L_j$	Remote Wage Bill Share	ACS

Back

GE Model: Identification

- Remote Work:
  - Allocate labor L_r based on ACS labor share $\rho_L = L_r / \sum_j L_j$
  - Allocate GDP Y_r based on ACS wage share $\rho_W = w_r L_r / \sum_j w_j L_j$
  - Scale L_j and Y_j in other regions by $(1 - \rho_L)$, $(1 - \rho_W)$
- Factor Shares:
  - Back out χ in non-remote regions by subtracting inferred payments to other factors:

$$\chi_n = \frac{(1-\alpha)\sum_j Y_j - r_k \sum_j i_{k,j}/\delta_k}{\sum_{j \neq r} Y_j} \sim 0.15$$

Back

GE Model: Identification

- **Supply**:
  - Building supply in each period can be expressed as a supply shifter Ψ_j:

$$\Psi_j = T^{\frac{\gamma}{1-\gamma}} D^{\frac{1}{1-\gamma}} \delta_b C_j (\beta\gamma)^{\frac{\gamma}{1-\gamma}}$$

  - Use GE model, not CoreLogic, to back out level of supply shifter Ψ_j (property taxes, Prop 13 mean CoreLogic building values will be lower than true factor payments)

$$\underbrace{p_j^{\frac{1}{1-\gamma}} \Psi_j}_{p_j B_j^N} = \frac{\chi_j Y_j}{1 - \beta(1-\delta_b)}$$

- **Demand**:
  - Demand for improvements is as follows:

$$q_j m_j = T_j \gamma \beta p_j B_j^N$$

Back

Identifying Building Parameters: δ_b, p_j

- δ_b: Depreciation identified from average age of buildings $\bar{a}$:

$$\delta_b = \frac{1}{\bar{a}}$$

- p_j: Normalized to average price per building square foot identified from buildings with BSF:

$$p_j = \frac{\sum_{i \in j} BV_i}{\sum_{i \in j} BSF_i}$$

Back

Validation: NYC FAR

- First Test: NYC Floor Area Ratios (FAR)
  - Aggregate τ_i into zoning codes z (e.g. $z \in \{C1, C2, \ldots\}$ in NYC):

$$\tau_z = \frac{\sum_{i \in z} MV_i}{\sum_{i \in z} MV_i / \tau_i}$$

  - Test theory by comparing floor area ratios ($\log FAR_z$) vs. our model distortion $\log \tau_z$
  - Expectation: higher (less-regulating) FAR should have higher (less-regulating) τ
  - Result: positive correlation between statutory and model-based regulation Regression

Back

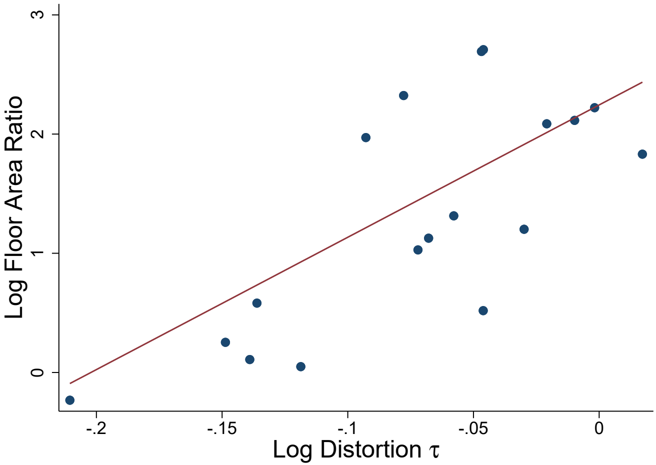
FAR Regression

Variables	(1) log τ_z
log FAR_z	0.0341***
	(1.19e-07)
R^2	0.365
N	104

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Weighted by Building Value

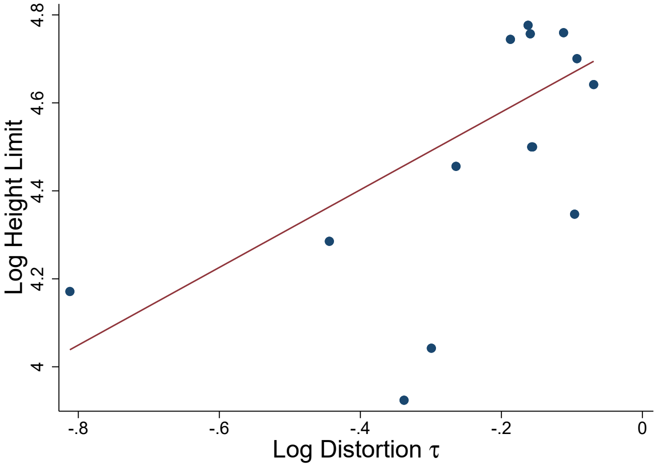
Back to Validation

NYC: Log Model Distortion τ_z vs Log Statutory *FAR*



Back to Validation

DC: Log Model Distortion τ_z vs Log Statutory Height Limits



Back to Validation

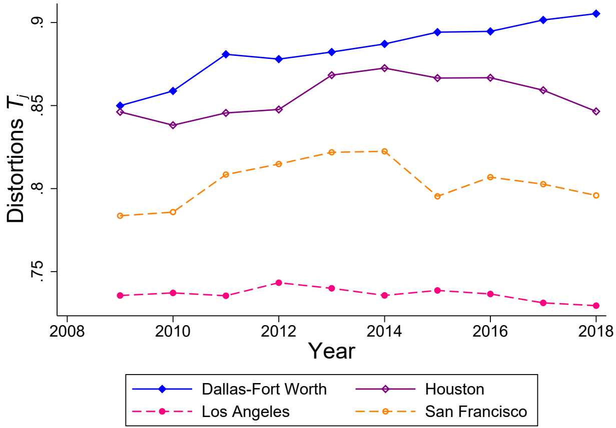
Validation: Cities

- Second Test: Maps and Time Series
  - Does T_j align with our priors about which cities are more regulated?
  - Expectation: cities in California should be highly regulated; cities in Texas should be less so
    - e.g. Houston, TX has no "zoning"

      ...but still has other deed restrictions, historic districts, ordinances that limit building development
  - Result: Houston and Dallas less regulated than SF and LA

Back

Time Series of Aggregate Distortion T_j in Major MSAs



Map of T Histogram of T

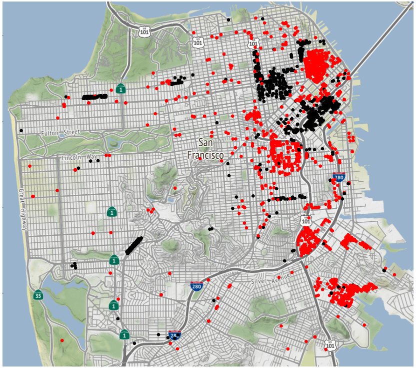
Validation: FAR

- Third Test: Business Districts
  - Plot τ_z in two well-known regions: San Francisco, Manhattan
  - Litmus test/prior expectation: Center business districts should be less regulated
  - Result: Parcels in business districts generally have higher τ_z

Back

San Francisco Distortions

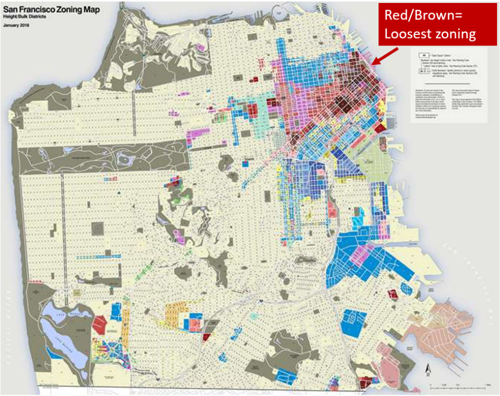
Model distortion



τ_z

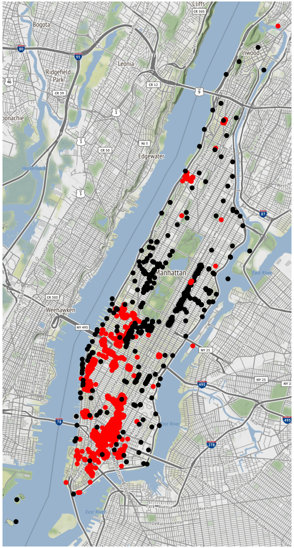
- Top 10%
- Bottom 10%

SF Height Limit Zoning Map, 2021



Back

Manhattan Distortions



τ_z

- Top 10%
- Bottom 10%

Equilibrium

- An equilibrium in this economy is:
  - Prices $\{\{r_{b,j,t}, w_{j,t}\}_{j\in J}, r_{k,t}\}_{t=0}^{\infty}$
  - Quantities $\{\{Y_{j,t}, K_{j,t}, L_{j,t}, B_{j,t}, i_{k,j,t}\{m_{i,t}, B_{i,t}^{N}\}_{i\in j_{\delta,t}}\}_{j\in J}, c_t\}_{t=0}^{\infty}$
  - Decision rules

- Such that:
  - Given prices, the stand-in household maximizes utility
  - Given prices, firms maximize profits
  - Markets clear and the laws of motion and resource constraint hold:

$$B_{j,t+1} = (1-\delta_b)B_{j,t} + \sum_{i\in j_{\delta,t}} B_{i,t}^{N}$$

$$c_t - \sum_{j}\left(i_{k,j,t} + \sum_{i\in j_{\delta,t}} q_i m_{j,t}\right) = \sum_{j} Y_j$$

Back

Aggregation Back

- Landlord problems aggregate to a city-level landlord problem:

$$\max_{m_j} \beta T_j p_j \underbrace{D_j (\delta_b C_j)^{1-\gamma} m_j^{\gamma}}_{B_j^N} - \underbrace{m_j}_{MV_j}$$

- Where:

Aggregation Back

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- Where:

$$\text{(Parcel Efficiency) } C_i = z_i^{\frac{1}{1-\gamma}} x_i q_i^{\frac{\gamma}{1-\gamma}} \propto MV_i / \tau_i^{\frac{1}{1-\gamma}}$$

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$$\text{(Dispersion) } D_j = \left(\frac{\sum_{i \in j} \tau_i^{\frac{\gamma}{1-\gamma}} C_i}{\sum_{i \in j} C_i} \right) \Big/ \left(\frac{\sum_{i \in j} \tau_i^{\frac{1}{1-\gamma}} C_i}{\sum_{i \in j} C_i} \right)^{\gamma}$$

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$$\text{(Aggregate Distortion)} \quad T_j = \sum_{i \in j} \tau_i^{\frac{1}{1-\gamma}} C_i \Big/ \sum_{i \in j} \tau_i^{\frac{\gamma}{1-\gamma}} C_i$$

Identifying Improvement Share γ and Distortions τ_i

- Deregulated benchmark: Midland, TX *(oil producing MSA)*
- Implied improvement share $\gamma \sim 0.92$, i.e. near linear
- Arguments for near-linear production function:
  - Glaeser, Gyourko, and Saks (2005): average cost per *BSF* very flat for different building sizes
  - Intuition: can always add more floors
- With γ identified, can recover τ_i at parcel level:

$$\tau_i = \frac{\left(\frac{1-\beta(1-\delta_b)}{1-\beta}\right)\frac{MV_i}{TV_i}}{\gamma\left(\beta + \frac{\delta_b \beta}{1-\beta}\frac{MV_i}{TV_i}\right)}$$

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Identifying Amenities

- Internal IV
  - Re-solve model setting TFP and amenities equal in all regions
  - Use counterfactual congestion $\widehat{L/X}$ as IV for real congestion
  - Recover impact of congestion on amenities
- Results:

$$\log a_j = \underbrace{\mu}_{\substack{-0.53^{***} \\ [0.07]}} \log(L_j/X_j) + e_j \tag{1}$$

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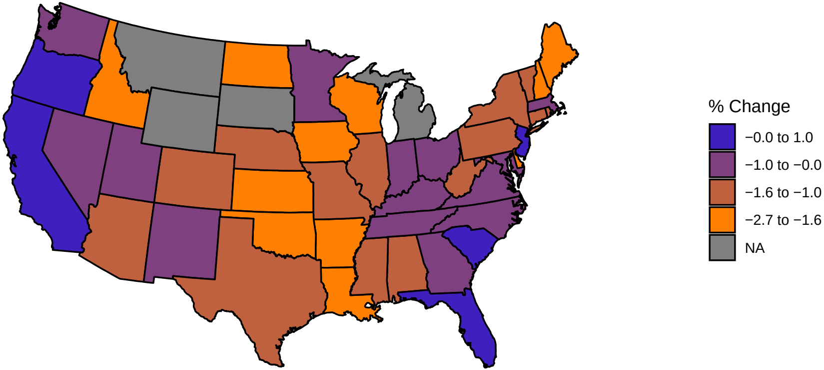
Baseline: Change in Labor L_j Relative to Initial SS



Losers are already-deregulated Texas and South; Winners are highly regulated coast

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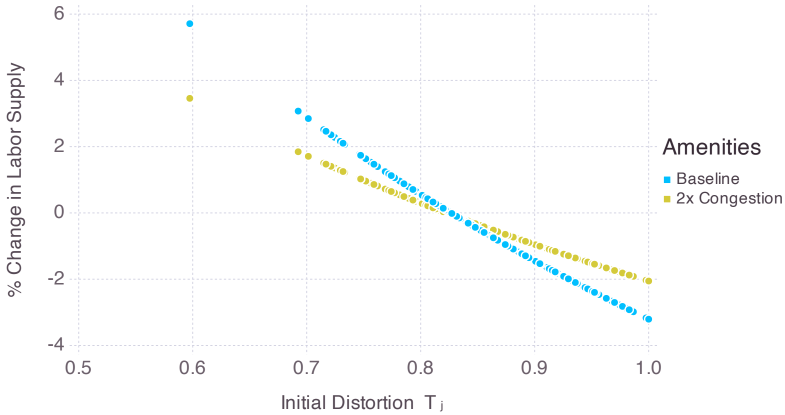
Exogenous Amenities



As congestion *worsens* in some cities, it *improves* in others

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Commercial Developers

- Owns plot of land i with square footage x_i, zoning distortion τ_i
  - $\tau_i = 1$ means no regulation, $\tau_i = 0$ means construction ban
- Construction:
  - Buy improvements (concrete, glass, labor) m_i at price q_i
  - Combine w/ land to make building square footage BSF
  - Sell at price per square foot p_i

Developer's problem: $\max_{m_i} \tau_i p_i \underbrace{m_i^{\gamma} x_i^{1-\gamma}}_{BSF_i} - \underbrace{q_i m_i}_{MV_i}$ Developers' profits: $\pi = 1 p_i m_i^{\gamma} x_i^{1-\gamma} - q_i r$

- τ_i only distorts FOC (e.g. height limit $\bar{B}$ alters investment, but creates no revenue)

Interpreting Distortions