Green Commercial Development within Urban Environments: Theory & Evidence

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Additional Materials

Research Goal

The research objective is to explore and explain the spatial distribution of green commercial buildings within cities by first developing a spatial equilibrium model for commercial green development and then testing the model's prediction.

Motivation & Related Literature

Why Green Buildings?

- Buildings account for 30% of all greenhouse gas emissions in the US (Resources for the Future, 2021)
- Investment in energy-efficient buildings can be a win-win: firms reduce energy expenses and policy makers achieve lower greenhouse gas emissions
- Major policy proposals like the American Jobs Plan contain funding for investment in green infrastructure, particularly homes and commercial buildings
- There is a need for formal theory with empirical support to consider policy obstacles and strategy

The Adoption Decision

- Allcott and Greenstone (2012) utilize a simple model for the adoption of energy-efficient technologies and introduce issues of energy expense salience in adoption
- Bansal and Roth (2000) provide a qualitative analysis of firm attributes associated with greater ecological responsiveness, and thus greater adoption of green technologies

The Location Decision

- Glaeser (2008) refines and applies earlier spatial equilibrium models to describe how workers, firms, and developers interact to determine local wages, rents, and housing supply
- Gaubert (2018) builds heterogeneous firms and evaluates how these firms will choose to locate across different cities based on their sectoral agglomeration economies

The Model: Environment

- Consider one city with many neighborhoods
- Before firms locate, neighborhoods differ only in their number of workers N
- Firms can move/trade freely (an open world) and all decisions occur in the same period (static model)
- Two Actors: Firms and developers
- Want to determine (1) the adoption decision, (2) the location decision

The Model: Actors & Behavior

Firms

Firms differ along two dimensions: (1) ecological responsiveness, and (2) agglomeration economies. The firm is profit maximizing:

$$\max_{L,R,d,N}\left\{A\psi(\alpha_i,N)\lambda(\theta_j,d)L^{\beta}R^{\gamma}\overline{K}^{1-\beta-\gamma}-WL-p_dR-k_{ij}\right\}.$$

A	Raw productivity
α_i	Agglomeration ranking for industry i; high $\alpha_i \Rightarrow$ high agglomeration
$\psi(\alpha_i, N)$	Agglomeration effect for firm type i in neighborhood N (Gaubert, 2018)
θ_j	Ecological response ranking for type j; high $\theta_j \Rightarrow$ high ecological response
$\lambda(\theta_j, d)$	Ecological response for firm type j with building design d
L	Labor (in workers)
R	Commercial real estate (in square feet)
$\overline{K}$	Fixed capital inputs
W	Wage
p_d	Price per square foot of commercial real estate with design d
k_{ij}	Entrance costs to firm type ij

Developers

There is a single, profit-maximizing developer in each neighborhood.

$$\max_{h_g,h_b,\ell_g,\ell_b}\left\{\pi_g(h_g,\ell_g)+\pi_b(h_b,\ell_b)\right\} \quad \text{s.t.} \quad \bar{\ell}=\ell_g+\ell_b$$

where for building design $d \in \{green, brown\}$,

$$\pi_d(h_d,\ell_d)=p_dh_d\ell_d-c_dh_d^{\eta}\ell_d-p_\ell\ell_d.$$

h_d	Height of buildings with design d
ℓ_d	Land allocation for buildings with design d
$\bar{\ell}$	Total land available for commercial development
p_d	Price of commercial real estate with design d per square foot
c_d	Material cost per square foot (for single story) with design d; $c_g > c_b$
p_ℓ	Price of land per square foot
η	Upward friction parameter of building, $\eta > 1$

Agglomeration & Ecological Response

What drives agglomeration and ecological responsiveness?

- Importance of connections with similar firms (Bansal and Roth, 2000)
- Importance of human connections (Kok, McGraw, and Quigley, 2012)

Assume in higher agglomeration industries firms have higher ecological responsiveness types that induce them to adopt green buildings more frequently. Formally, for firms 1 and 2 with $\alpha_1 < \alpha_2$, then

$$\Pr\{\theta_1 > \theta^* \mid \alpha_1\} < \Pr\{\theta_2 > \theta^* \mid \alpha_2\}.$$

Equilibrium

Green Building Adoption

Firms will purchase and the developer will build green real estate if and only if the adoption condition holds:

$$\frac{\lambda(\theta_j,g)}{\lambda(\theta_j,b)} > \left(\frac{c_g}{c_b}\right)^{\frac{\gamma}{\eta}}.$$

With the assumptions we have made about λ, this implies there exists a threshold green benefit type θ^*.

Firm Sorting

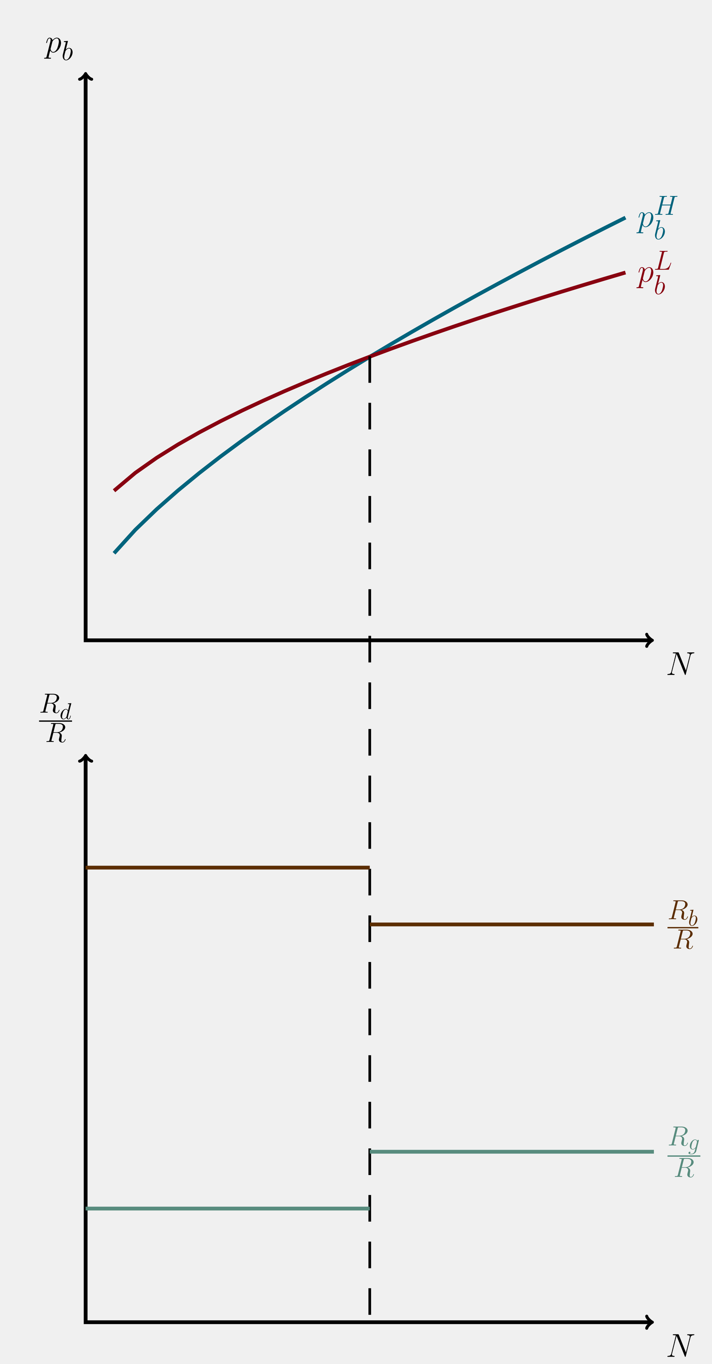
Type ij firms will locate in every neighborhood in the set of optimal neighborhoods defined by,

$$N^*(\alpha_i,\theta_j)=\left\{N\in\mathcal{N} \mid p_d^*(N,\alpha_i,\theta_j)\geq p_d^*(N,\alpha_k,\theta_j),\forall k\in\mathcal{I}\right\},$$

where $\mathcal{N}$ is the support of neighborhoods and $\mathcal{I}$ is the set of all agglomeration types. This brings us to the central claim.

Claim: *High agglomeration effect firms will locate in worker-dense neighborhoods and occupy green buildings more frequently.*

Figure 1: Example with Two Agglomeration Types



Data

- Data do not allow us to test the model precisely
- Instead, verify the claim that firms in worker-dense neighborhoods go green more often
- Green building data: Clean and merge data sets → geolocate addresses → match to Census tracts → calculate count of green buildings and total green space for each Census tract
  1. Energy Star Program
  2. Leadership in Energy and Environmental Design (LEED)
- Worker data: Use cellphone data from SafeGraph to proxy the number of workers in each neighborhood (from February 2019)
- Use 2019 Census tracts as the unit of analysis

Empirics

- For ease, restrict the sample to just those Census tracts with at least one green commercial building
- Estimate the following model for the log of green real estate R_g (in sq. ft.) in neighborhood i in city n,

$$\log(R_g)_{in}=\alpha+\beta N_i+\gamma\mathbf{X}_i+\sum_{n=1}^{N}\left[\delta_n\log\left(\frac{N_i}{\ell_i}\right)c_n\right]+\varepsilon_{in}$$

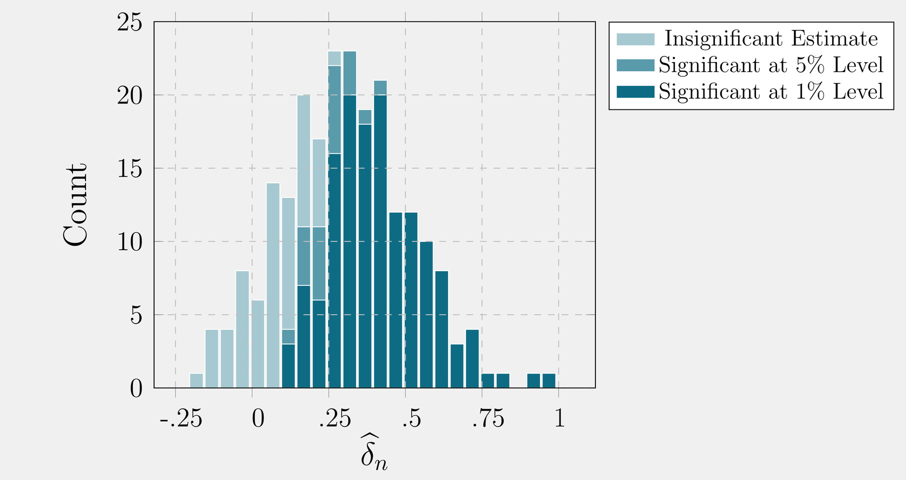
- N_i is the number of workers proxy, $\mathbf{X}_i$ is a vector of neighborhood characteristics, and c_n is a dummy variable for city n
- δ_n is the percent change in green real estate for a 1% increase in worker density
- Distribution of the $\widehat{\delta}_n$'s in Figure 2 provides evidence that within cities, worker-dense neighborhoods have more green commercial real estate

Table 1: Agglomeration & Green Space

	Log Green Real Estate (sq. ft.)	
	(1)	(2)
Log Number of Workers	3.213**	3.158**
	(0.038)	(0.039)
Log Median Housing Value		1.228**
		(0.051)
Log Median Resident Age		−0.889**
		(0.155)
Log Worker Density - City	✓	✓
Observations	34,285	33,332
R^2	0.263	0.277
Adjusted R^2	0.258	0.272
Notes:	*Sig. at 5% level; **Sig. at 1% level	

Estimates

Figure 2: Distribution of $\widehat{\delta}_n$ in (2)



Takeaways & Policy Implications

- Agglomeration effects and ecological responsiveness are driven by similar economic forces
- The model suggests green commercial development will be concentrated in worker-dense neighborhoods, and we demonstrate empirical support for this claim
- In the model, adoption is based on firm type, not location – this implies effective policy targets firms with low ecological responsiveness, not places with few green buildings

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References

Allcott, H., and M. Greenstone (2012): "Is there an energy efficiency gap?," *Journal of Economic Perspectives*, 26(1), 3–28.

Bansal, P., and K. Roth (2000): "Why companies go green: A model of ecological responsiveness," *Academy of management journal*, 43(4), 717–736.

Gaubert, C. (2018): "Firm sorting and agglomeration," *American Economic Review*, 108(11), 3117–53.

Glaeser, E. L. (2008): *Cities, agglomeration, and spatial equilibrium*. Oxford University Press.

Kok, N., M. McGraw, and J. M. Quigley (2012): "The diffusion over time and space of energy efficiency in building," *The Annals of Regional Science*, 48(2), 541–564.

Resources for the Future (2021): "US carbon emissions at a glance," *Federal Climate Policy Toolkit*.