Foto: Ana Paula Hirama

The Skyscraper Revolution:
Global Economic Development and Land Savings

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Outline

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  - Much in developing economies (previous photo: São Paulo)
  - 15 trillion dollars c. 2015. 10% of built volume in million+ cities

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- Main literature: (i) urban transportation infrastructure & city growth (railroads, roads, subways) (ii) technology & economic development

Our Analysis

- Global panel data analysis
  - Novel database: 12,877 world cities (90% world's urban pop) in 1975 and 2015. RHS: tall building stock. LHS: pop, area.
  - Emporis: data on all tall buildings ($\geq$ 55 m, 180 ft, 14 stories) ever built worldwide: height, construction year, some cost info

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- Identification from DiD: large cities 1975 x intermediate bedrock
  - "Clean slate" of tall buildings in developing countries in 1975

    Larger cities 1975 more likely to adopt tall buildings post-1975
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- Height elasticities: pop 13%, built area -16%, pop. density 29%
- Model: Economic benefits of tall buildings $\sim$6% of global welfare (ignore costs). 1/4 realized, likely due to height restrictions

Literature

1. Economics of skyscrapers [we study global economic effects]

   Barr '10, '12, Barr et al '11, Ahlfeldt & McMillen 2018, Liu et al '18, '20, Ahlfeldt & Barr '20, '22, Jedwab et al '20, '21, Jedwab & Barr '22, Jedwab '22

2. Causes of sprawl [we focus on the role of tall buildings]

   Bertaud & Brueckner '05, Burchfield et al '06, Baum-Snow '07, '22, Brueckner & Sridhar '12, Jedwab et al '20, '21, Ahlfeldt & Barr '22

3. Economics of density [we examine the effects of tall buildings]

   Combes & Gobillon '15, Ahlfeldt & Pietrostefani '19, Duranton & Puga '20 for surveys; Rosenthal & Strange '08 and Combes et al '11 for geological IVs

4. Global differences in urbanization [we find heterogeneous effects]

   Jedwab et al '17, '19, '21, Chauvin et al '16, Bryan & Morten '18

Outline

Data

- Sample: 12,877 50K+ agglomerations* today (*urban centres* from GHS)
- City-level outcomes:

  From GHS, pop, built-up area and land area 1975 (1990 2000) 2015

  Radiance calibrated version of the DMSP night lights 1996-2011**

  Global land use data 1982-2015 (deforestation, cropland, etc.)

- Main variable of interest:

  Tall building stocks (km) for each city 1975 (1990 2000) 2015

  Emporis: city, height ($\geq$ 55 m, 180 ft, 14 stories), year of construction

  Information provided by industry. "*Emporis collects information about the full life-cycle of each building, from idea to demolition*"

* Urban centres correspond to commuting zones. For example, New York UC includes "New York; Islip; Newark; Jersey City; Yonkers; Huntington; Paterson; Stamford; Elizabeth; New Brunswick"

** Radiance calibrated = NOT top coded at 63.


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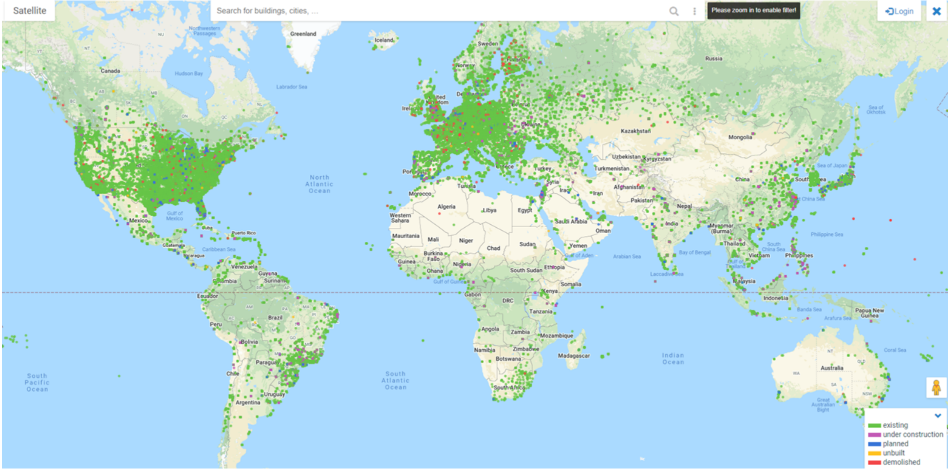
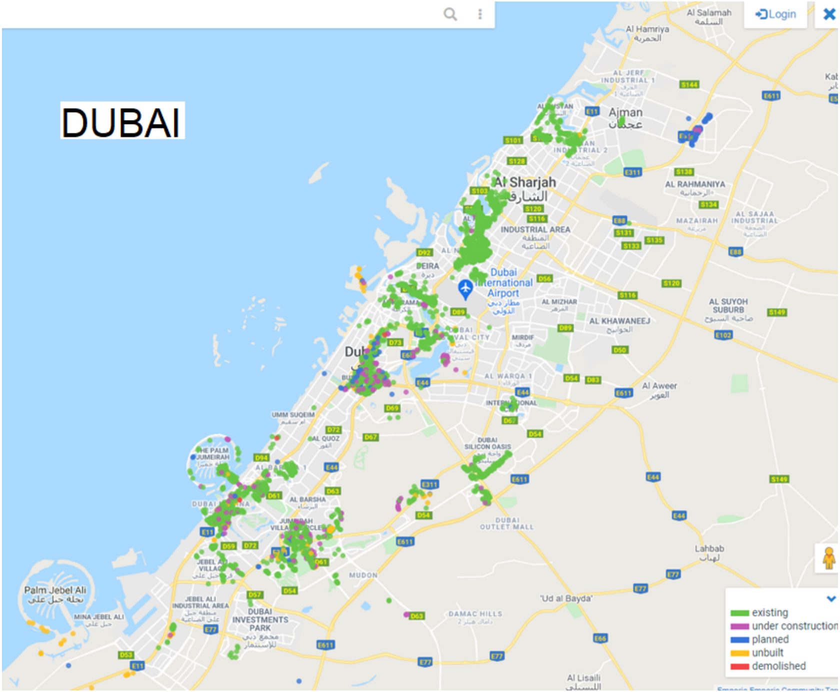


Data for 270K tall buildings (buildings $\geq$ 55 m $\approx$ 180 ft $\approx$ 14 stories)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AL QUOZ
THE PALM JUMEIRAH
AL BARSHA
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JUMEIRAH VILLAGE CIRCLE
JEBEL ALI VILLAGE
Palm Jebel Ali
MINA JEBEL ALI
JEBEL ALI INDUSTRIAL AREA
DUBAI INVESTMENTS PARK
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'Ud al Bayda'
Lahbab
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existing
under construction
planned
unbuilt
demolished

Examples of Concrete Tall Buildings ($\geq$ 55 m $\approx$ 180 ft)

Dubai (Burj Khalifa reaches 830 m = 2,722 ft)

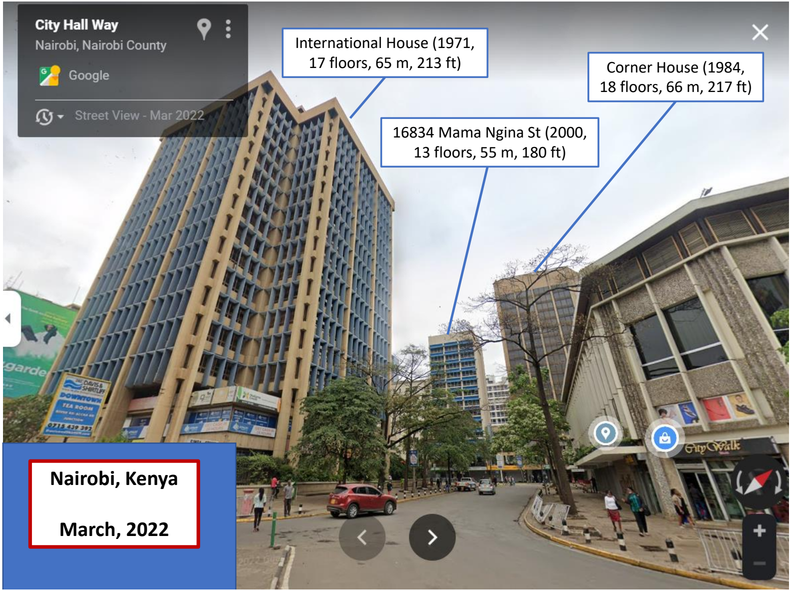
Examples of Concrete Tall Buildings ($\geq$ 55 m $\approx$ 180 ft)

Hong Kong (International Commerce Centre reaches 484 m = 1,588 ft)

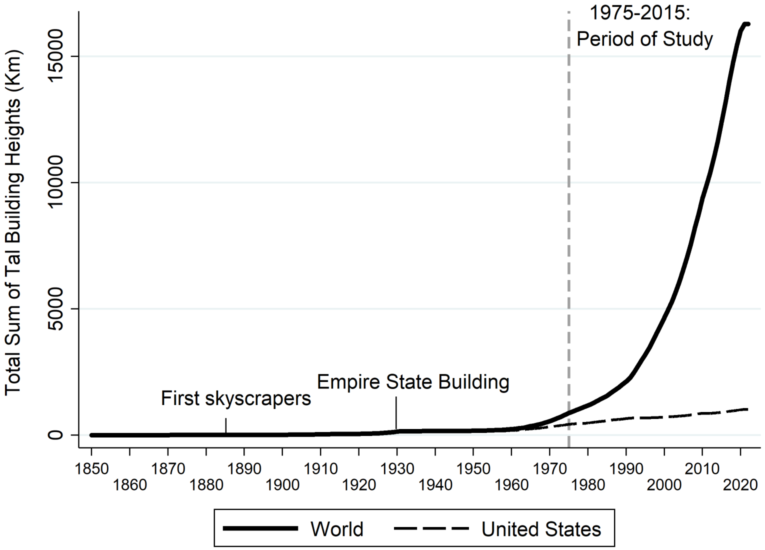
Examples of Concrete Tall Buildings ($\geq$ 55 m $\approx$ 180 ft)

Nairobi (Britam Tower reaches 200 m = 656 ft))

Examples of Concrete Tall Buildings ($\geq$ 55 m $\approx$ 180 ft)

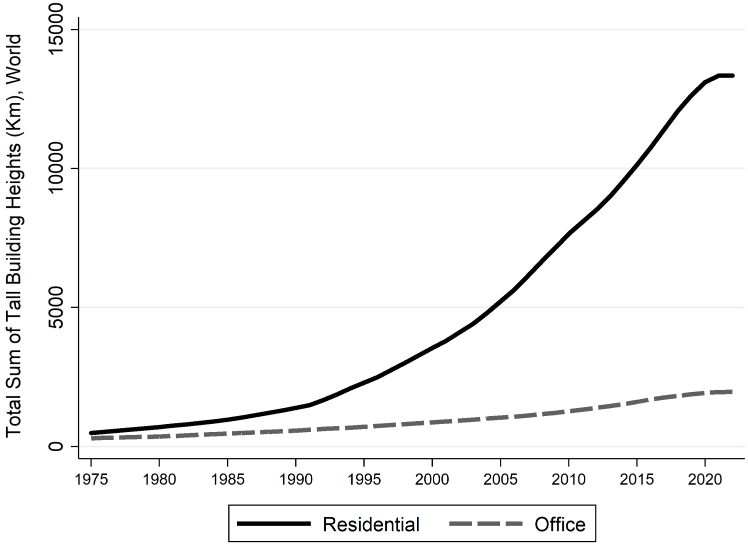


The Global Stock of Tall Buildings



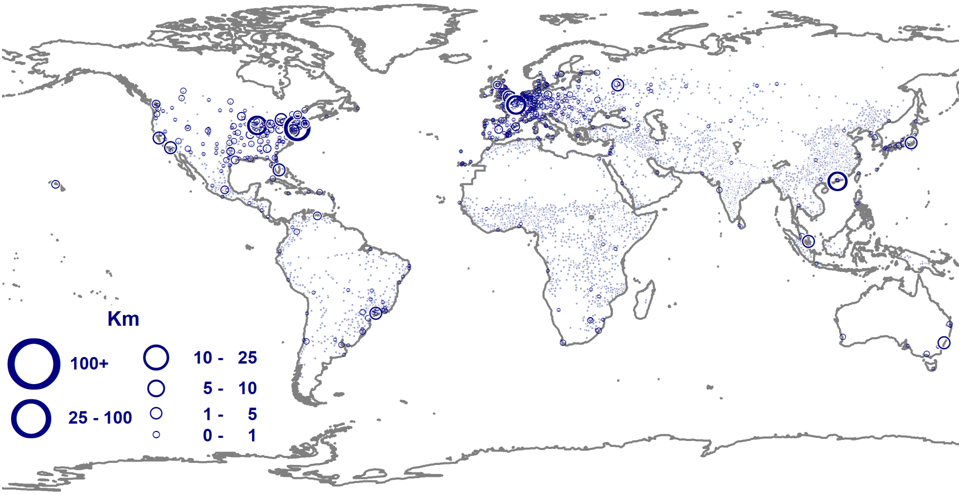
Includes all buildings $\geq$ 55 meters, $\approx$ 14 floors. 1975-2015: +11,500 km $\approx$ 26K Empire State Buildings $\approx$ 3x Euclidean distance between NYC and LA!

Most Recent Tall Building Construction is Residential



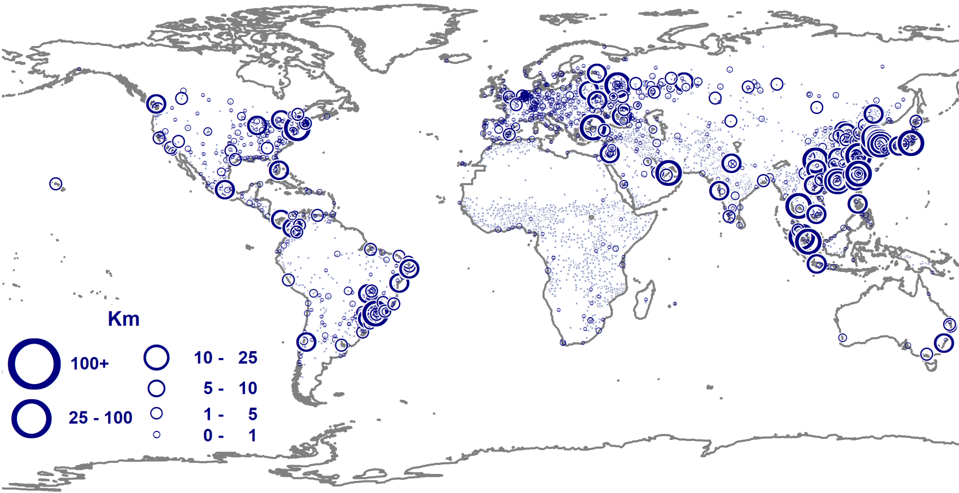
World of residential towers: Increased 7x more for residential buildings (typically in the 55-100 m range) than for commercial/office buildings (100 m+).

The Stock of Skyscraper Heights in 1975



Developing countries start with a clean slate of tall buildings circa 1975.

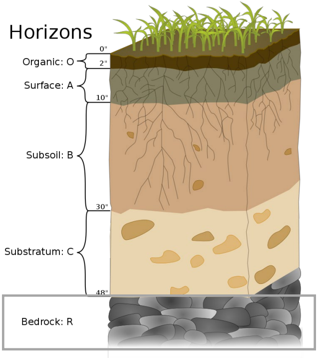
The Flow of Skyscraper Heights 1975-2015

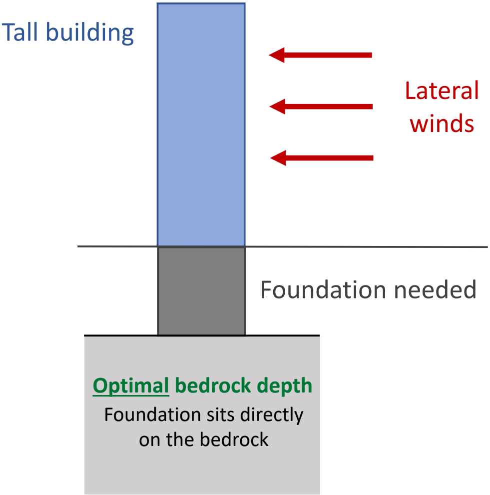


Skyscraper revolution in developing countries in 1975-2015

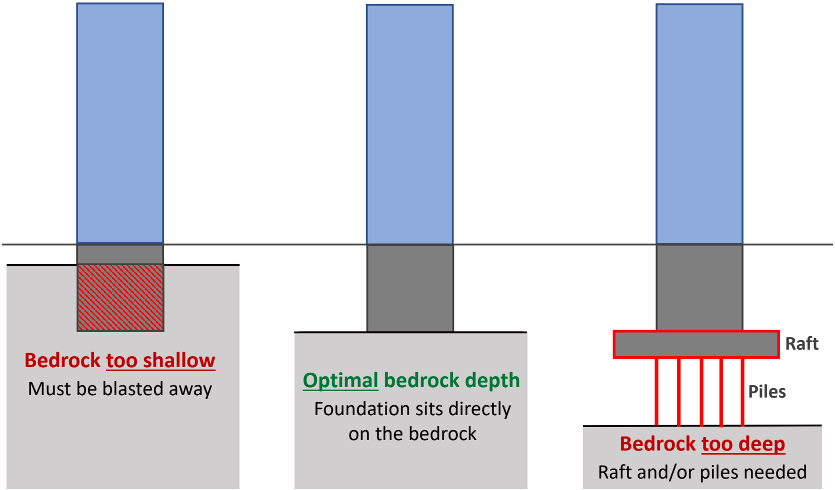
Due to falling “cost of height” (data for the U.S. and the World)

Role of Bedrock I (needed to build the identification strategy)





Role of Bedrock II (needed to build the identification strategy)



Construction cost per sq ft data for ∼1,000 tall buildings in 55 countries: intermediary bedrock depth saves 5-10% (vs. shallow or deep bedrock).

DiD

1. Developing countries start with clean slate of tall buildings in 1975:
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   - Should disproportionately benefit larger cities (demand shifter).

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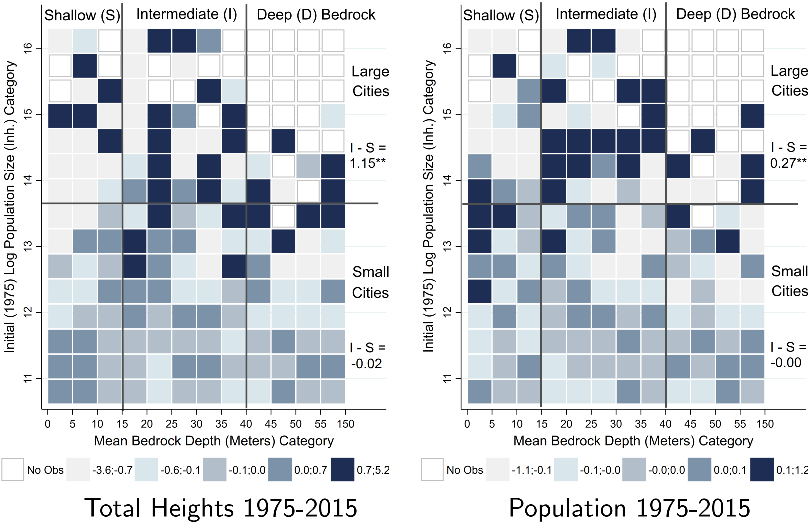
$\rightarrow$ DiD:

- (large vs. small cities in the initial year 1975) x (intermediate bedrock depth vs. shallow/deep bedrock depth) x (2015 vs. 1975)
- Use DiD directly or use it as IV for change in heights 1975-2015

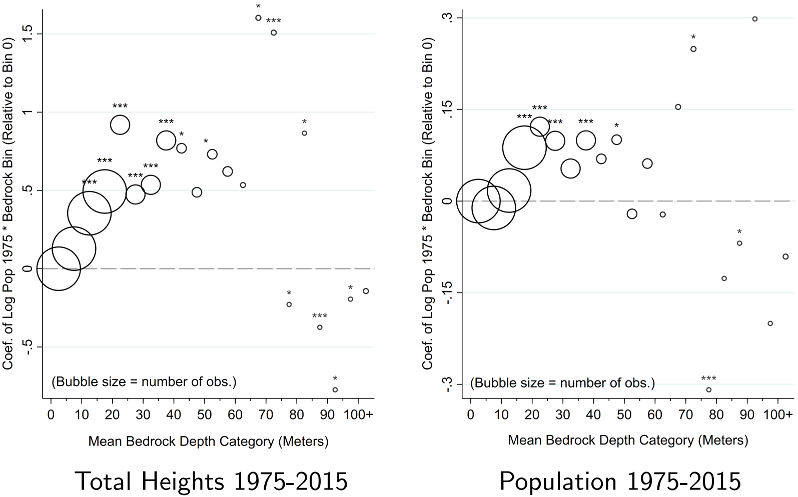
Figure: Residualized Log Changes in Heights and Pop., 1975-2015



12K developing country cities, pop category FE, bedrock category FE, country FE

Implied Wald estimate of the elasticity of population with respect to heights = 0.23**

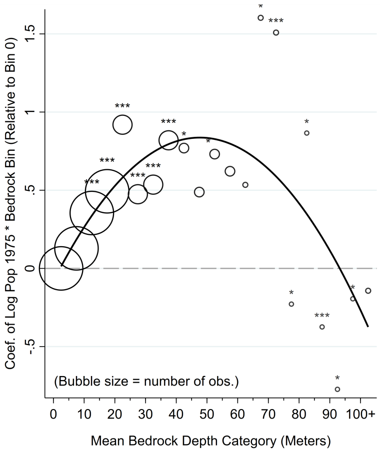
Figure: Log Changes in Heights and Population, 1975-2015



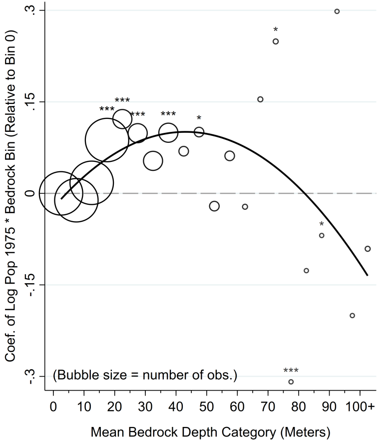
12K developing cntry cities, bedrock bin FE, log pop 1975 as control, cntry FE

We show for each bedrock depth bin the coefficient of log initial pop 1975.

Figure: Log Changes in Heights and Population, 1975-2015



Total Heights 1975-2015



Population 1975-2015

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First Stage Estimates (3rd Column)

	Δ ln Height 1975-2015		
ln Pop 1975	0.8730***	0.8741***	0.4753***
	[0.0351]	[0.0351]	[0.0653]
Bedrock Depth		-0.0028*	-0.3248***
		[0.0016]	[0.0612]
$(\text{Bedrock Depth})^2$		0.0000	0.0021**
		[0.0000]	[0.0009]
Bedrock Depth X ln Pop 1975			0.0276***
			[0.0054]
$(\text{Bedrock Depth})^2$ X ln Pop 1975			-0.0002**
			[0.0001]
Country FE	Y	Y	Y
R-squared	0.17	0.17	0.18
Observations	12,869	12,869	12,869

Faster height growth in initially larger cities*intermediate bedrock. 1st stage $F = 28.42$

The Change as a Final Level: Log Heights 1975 vs. 2015

	1975	2015	Δ 1975-2015
	Panel A: All Countries		
Bedrock Depth	0.0126***	0.0402***	0.0276***
× ln Pop 1975	[0.0032]	[0.0062]	[0.0054]
(Bedrock Depth)^2	-0.0002***	-0.0003***	-0.0002**
× ln Pop 1975	[0.0000]	[0.0001]	[0.0001]
R-Squared	0.18	0.33	0.18
	Panel B: Developing Economies		
Bedrock Depth	0.0030	0.0292***	0.0262***
× ln Pop 1975	[0.0028]	[0.0060]	[0.0056]
(Bedrock Depth)^2	-0.0000*	-0.0002**	-0.0002**
× ln Pop 1975	[0.0000]	[0.0001]	[0.0001]
R-squared	0.14	0.29	0.22

Developing economies: Little heights in 1975. g(bedrock,pop75) irrelevant

Outline

Main IV Results (1975-2015)

Period s-t:	Δ ln Population 1975-2015	Δ ln Built Area 1975-2015	Δ ln Urban Area 1975-2015	Δ ln Pop Dens. 1975-2015
	Panel A: All Countries (Observations = 12,849)			
Δ ln(Heights+1)	0.12***	-0.17***	-0.15**	0.27***
	[0.03]	[0.04]	[0.06]	[0.07]
First Stage F	28.42	28.42	28.42	28.42
	Panel B: Developing Economies (Observations = 11,257)			
Δ ln(Heights+1)	0.13***	-0.16***	-0.18**	0.31***
	[0.03]	[0.04]	[0.08]	[0.08]
First Stage F	22.84	22.84	22.84	22.84

- Doubling heights increases city pop by 12%, decreases city built area by 17% (urban area: 15%), increases city pop density by 27% (relative).
- Driven by cities in developing countries (88% of sample)
- Radiance calibrated lights (not top-coded) 1990-2015: 15% (not shown)

Robustness Checks for g(Bedrock Depth, Pop 1975) IVs

- **Identifying assumption:** IVs uncorrelated with city level tall building demand growth conditional on f_1(bedrock), f_2(pop 1975), FE

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- Results hold if we restrict the sample to cities with a mean bedrock depth deeper than the 25th pctile in the data (6 m $\approx$ 20 feet):
  - Topsoil up to 0.25 m; Subsoil up to 0.9 m; Root systems up to 2 m
  - Utility lines typically buried max 1-2 m deep
  - Subgrade (formation level) underneath highways never as deep
  - Sometimes deep subway stations (e.g., underground bunkers) $\rightarrow$ drop

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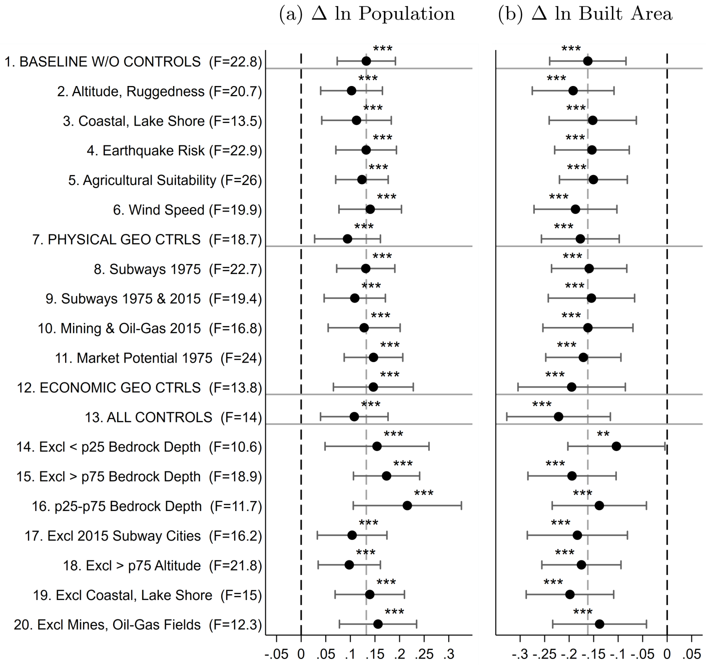
- No placebo effects of IV pre-1975 or in height-constrained countries. Effects of central bedrock on central heights only (within-city placebo)

Temporal and Spatial Placebo Checks

Table 2: Temporal and Spatial Placebo Checks

	(1)	(2)	(3)		(4)		(5)
Dependent Variable:	Δ ln Pop (Buringh)		Δ ln Central Heights (H)		Δ ln Peripheral H		Δ ln Pop
	1975-2015 Baseline	1950-1975 Pre-Trend	Central Bedrock	Periph. Bedrock	Central Bedrock	Periph. Bedrock	Constrained Countries
Bedrock*ln 1975 Pop	0.017***	0.004	0.035**	-0.015	0.022	-0.003	0.004
	[0.006]	[0.014]	[0.017]	[0.018]	[0.022]	[0.023]	[0.007]
Bedrock^2*ln 1975 Pop	-0.0005***	0.0000	-0.000	-0.000	-0.000	-0.000	-0.0000
	[0.0001]	[0.0004]	[0.000]	[0.000]	[0.000]	[0.000]	[0.0001]
Partial First Stage F	-	-	7.54	2.16	1.54	0.29	-
Observations (Cities)	560	560	9,377		9,377		3,315

- No placebo effects of IV pre-1975 or in height-constrained countries.
- Height-constrained countries: using the data in 2015, identify whether cities have relatively less heights given pop, economic size, controls
- Effects of central bedrock on central heights only (within-city placebo)


(a) Δ ln Population
(b) Δ ln Built Area
1. BASELINE W/O CONTROLS (F=22.8)
2. Altitude, Ruggedness (F=20.7)
3. Coastal, Lake Shore (F=13.5)
4. Earthquake Risk (F=22.9)
5. Agricultural Suitability (F=26)
6. Wind Speed (F=19.9)
7. PHYSICAL GEO CTRLS (F=18.7)
8. Subways 1975 (F=22.7)
9. Subways 1975 & 2015 (F=19.4)
10. Mining & Oil-Gas 2015 (F=16.8)
11. Market Potential 1975 (F=24)
12. ECONOMIC GEO CTRLS (F=13.8)
13. ALL CONTROLS (F=14)
14. Excl < p25 Bedrock Depth (F=10.6)
15. Excl > p75 Bedrock Depth (F=18.9)
16. p25-p75 Bedrock Depth (F=11.7)
17. Excl 2015 Subway Cities (F=16.2)
18. Excl > p75 Altitude (F=21.8)
19. Excl Coastal, Lake Shore (F=15)
20. Excl Mines, Oil-Gas Fields (F=12.3)
-.05 0 .05 .1 .15 .2 .25 .3
-.3 -.25 -.2 -.15 -.1 -.05 0 .05

Interpretation: Urban Growth vs. Redistribution

Borusyak et al. (2022) shows that with internal migration between cities, regressions like this can be biased: Violation of SUTVA.

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- Estimates driven by developing economies where "clean slate" as of 1975 and context of rural-to-urban (not city-to-city) migration
- Similar estimates if developed economies before 1975 when similar context of rural-to-urban (not city-to-city) migration [IN ONE SLIDE]
- Using sample of countries $<$20% urbanized in 1975, pop estimate unchanged, built area estimate -0.08 (not significantly different)

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- Similar estimates if developed economies before 1975 when similar context of rural-to-urban (not city-to-city) migration [IN ONE SLIDE]
- Using sample of countries <20% urbanized in 1975, pop estimate unchanged, built area estimate -0.08 (not significantly different)
- Estimates only slightly larger with 1st or 2nd level admin division FE making us compare neighboring cities (China: provinces, prefectures)
- Using as controls (similarly instrumented) market potential changes from ΔHeights of neighboring cities (with Euclidean distance as weights)

Historical IVs

Table 4: IV Results by World Region and Time Period

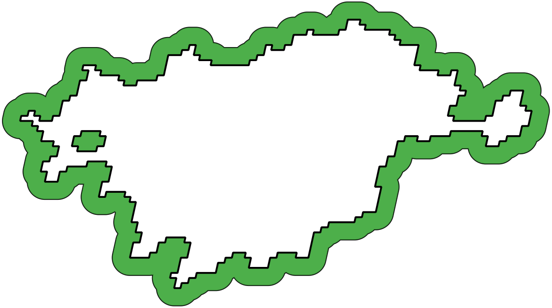
	(1)-(3) Developing Economies (1975-2015)			(4)-(6) Developed Economies		
	Asia (no Middle-East)	Other Countries	Unconstrained Countries	1975-2015 All	1850-1975 (Historical) 55 Developed	39 European
			Panel A: Δ ln Population			
Δ ln(Heights+1)	0.17***	0.15**	0.21***	0.00	0.14**	0.20**
	[0.03]	[0.07]	[0.04]	[0.03]	[0.06]	[0.10]
			Panel B: Δ ln Built Area			
Δ ln(Heights+1)	-0.20***	-0.26***	-0.39***	-0.04	-	-
	[0.04]	[0.09]	[0.09]	[0.03]	-	-
First Stage F	20.92	7.88	11.36	14.28	10.94	5.51
Observations	6,990	4,267	5,315	1,592	918	1,095

- Focus on 1850-1975 when developed economies still developing

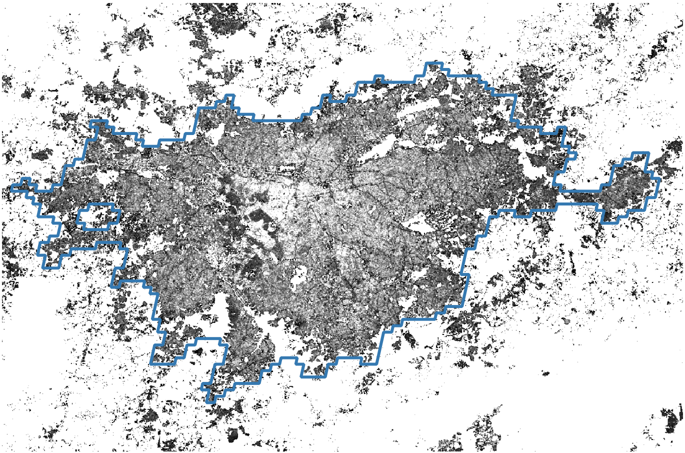
  Sources: (5) Buringh and Hub (2013), (6) Bairoch (1988).
- IVs from bedrock depth x log pop 1850 → similar pop elasticities

Implied Magnitude and Land Savings

- Absent construction, 1975-2015 agg urban pop change would be ∼20% smaller and agg built area change ∼20% larger
- 12% from tree cover, 73% other veg (incl cropland), 15% non-veg
  - Use height elasticity of area by city size to predict land expansion
  - Assume spatially uniform land expansion and study land use



Prediction for São Paulo (had the city not built tall buildings)



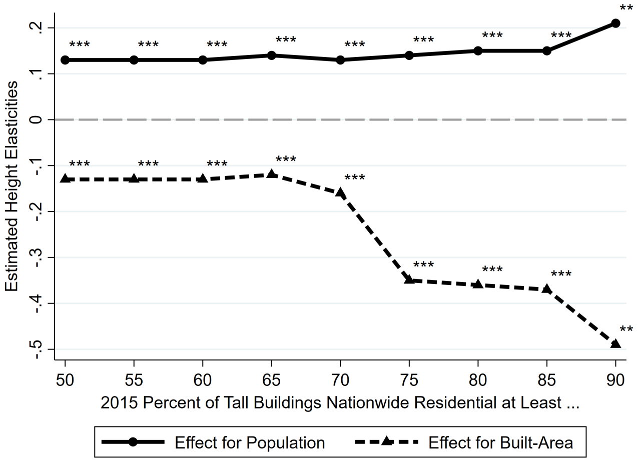
Building volumes c. 2015 at resolution of 90m*90m (satellite synthetic aperture radar (SAR) data). Source: Esch, Deininger, Jedwab & Palacios-Lopez 2024

1) Elasticity of tall built volume wrt tall building heights = 0.93*** (close to 1)

2) Results hold if control for non-tall ($<$ 55 m) buildings (bedrock doesn't matter)

3) Elasticity of volume wrt tall building heights = -0.26*** (i.e., compactness)

Results by Country Tall Building Residential Share



Developing economies with higher residential shares in tall buildings (on the right) have greater population *and* land savings responses to height.

Strong response for area (vertical housing and suburbs clear substitutes)

Outline

Taking stock

- Empirics show that supply of height
  - increases city population
  - shrinks city area
- Canonical models
  - Population fixed in standard monocentric city model (Alonso, 1964)
  - City area fixed endowment in QSM (Ahlfeldt et al. 2015)
  - City area *grows* in open-city model (Ahlfeldt & Barr, 2022)
- **Need an imperfectly open-city model**
  - Blend standard land-use model (Duranton & Puga, 2015) and QSM
  - Stylized monocentric city structure with endogenous CBD area
  - Designed for quantitative analysis

Monocentric City Model with Endogenous CBD

- Highlights causal mechanisms and facilitates evaluation of the welfare consequences of different planning regimes and technological change.
- **Residents:** preferences over floorspace and an outside good; amenity from vertical distance (views) and horizontal distance (commuting);

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	Parameter	Value	Source
$1-\alpha^C$	Share of floor space in production	0.15	Lucas and Rossi-Hansberg (2002)
$1-\alpha^R$	Share of floor space in consumption	0.33	Combes et al. (2019)
β	Agglomeration elasticity in production	0.03	Combes and Gobillon (2015)
θ^C	Commercial height elasticity of construction cost	0.5	Ahlfeldt and McMillen (2018)
θ^R	Residential height elasticity of construction cost	0.55	Ahlfeldt and McMillen (2018)
ω^C	Commercial height elasticity of rent	0.03	Liu et al. (2018)
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τ^C	Production amenity decay	0.014	See text and Appendix Section C.2
τ^R	Residential amenity decay	0.016	See text and Appendix Section C.2
ζ	Preference heterogeneity	3.3	See text and Appendix Section C.2

Notes: We set the scale parameters to $\bar{a}^C = \bar{a}^R = 2, c^C = c^R = 150$, $r^A = 50$, $\bar{N} = 6$ million, $\ell = 0.5$, $\bar{x} = 100$ km and invert $\widetilde{U}$ so that $\mu = 0.5$. In the baseline parameterization, height limits are not binding ($\bar{S}^C = \bar{S}^R = \infty$).

- Set amenity decay values to match average height gradients in data:
  - CoreLogic for Chicago, patterns verified for the world using satellite-based building volumes for unconstrained 1m+ cities (Esch et al 2024)

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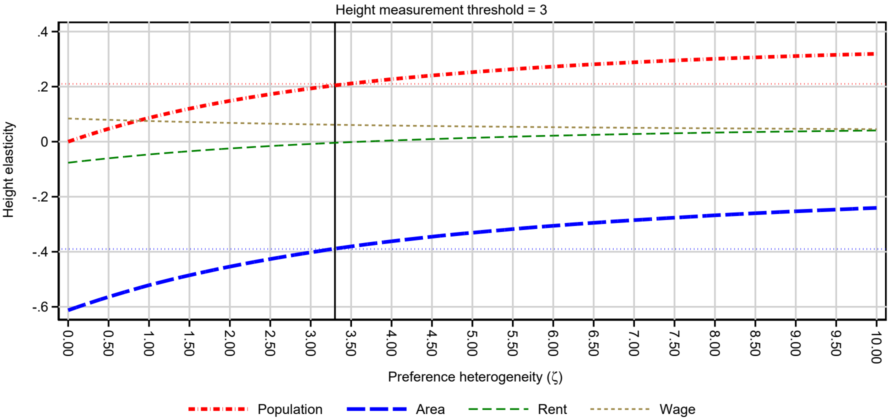
- Set amenity decay values to match average height gradients in data:
  - CoreLogic for Chicago, patterns verified for the world using satellite-based building volumes for unconstrained 1m+ cities (Esch et al 2024)
- Preference heterogeneity = 3.3 to match height elasticity estimates
  - From countries with most cities *unconstrained* by height regulation.
  - From conditional height gaps estimated globally (Barr & Jedwab 2023)
  - Implied LR migration elasticity ≈ 1.7, close to US and intl literature



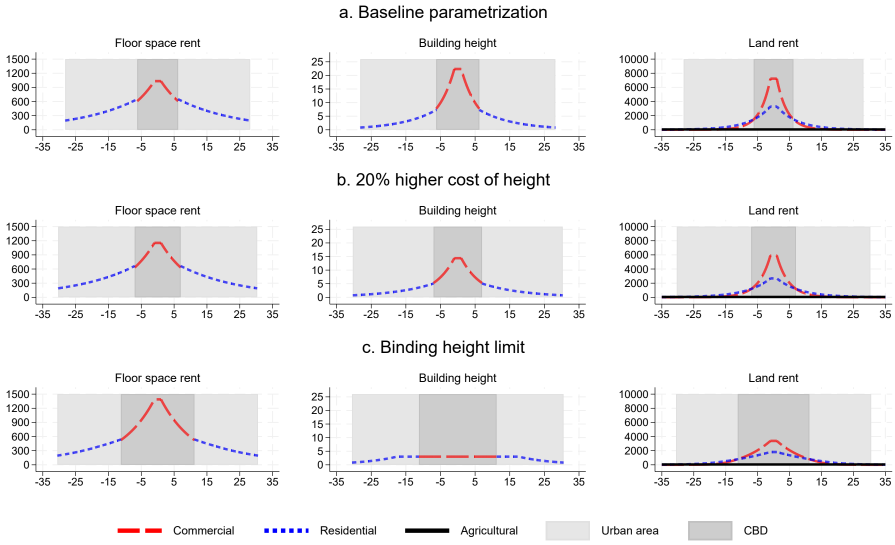
The larger ζ, the stronger the pop and area responses to heights

$\Rightarrow$ Also calibrate height measurement threshold ($\mathcal{T}$) (must be positive)

$\Rightarrow$ Under $\zeta = 3.3, \mathcal{T} = 3$, we exactly match moments in data

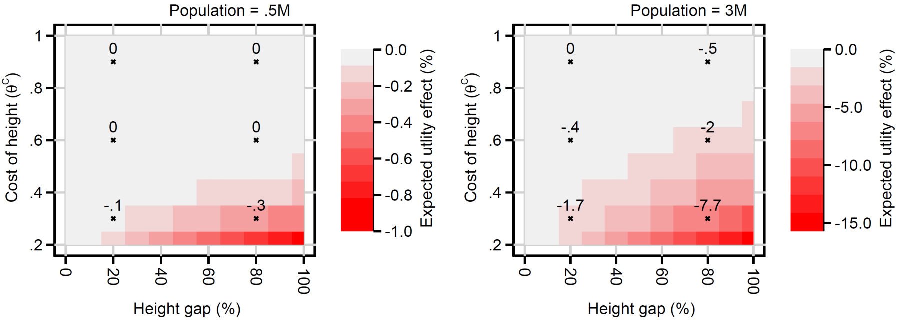
$\Rightarrow$ And elasticity of rent wrt heights ≈ 0 (rents won't vary with heights)

Objective Function



Increasing cost of height and height limits reduce expected utility

[For our stylized city of 3 million]



Utility losses increase with the stringency of height restrictions (height gap)

But the utility loss from height restrictions ...

... increases with city population size (here, 3000K vs. 500K)

... especially when the cost of height is low ("good" bedrock)

We then conduct city-specific counterfactual for the 12,877 world cities

$\rightarrow$ Map bedrock to cost of height, invert $\{\bar{S}^U, \tilde{U}\}$ to match height gap, pop

Global worker welfare effects

World region	City characteristics			Expected utility $\mathcal{V}$		Agg land rent $\mathcal{R}$	
	In cities >1 mill.	Cost of height θ (bedrock)	Est. height gap	No tall building	No height limit	No tall building	No height limit
Developing Economies	43.3%	0.54	44.8%	–1.6%	4.9%	–1.2%	–4.3%
	• *Wage in City* (A):			–2.5%	4.7%		
	• *Rent in City* (B):			–3.6%	7.1%		
	• *Commute Cost in City* (C):			2.9%	–5.6%		
	Urban Utility (A-0.33*B-C)			–4.2%	7.9%		
	Share Adjusted Rent (-0.33*B-C)			0.40	0.41		
Developed Economies	59.6%	0.39	75.9%	–3.1%	11.1%	–2.3%	–10.0%
	• *Wage in City* (A):			–3.0%	9.4%		
	• *Rent in City* (B):			–2.2%	13.0%		
	• *Commute Cost in City* (C):			3.7%	–10.2%		
	Urban Utility (A-0.33*B-C)			–6.0%	–15.6%		
	Share Adjusted Rent (-0.33*B-C)			0.50	0.40		
All Economies	46.3%	0.51	50.5%	–1.8%	6.0%	–1.4%	–5.4%

- Tall buildings have the potential to increase worker welfare by **6.0%**
  Larger in developed economies (large gap*large cities*low cost of height)
- **3/4** to be realized (likely due to height restrictions, which could be justified)

North America vs. Europe

World region	Urban pop. (BN)	City characteristics: In cities >1 mill.	Cost of height θ	Est. height gap	Expected utility ($\mathcal{V}$): No tall building	No height limit	Agg. land rent ($\mathcal{R}$): No tall building	No height limit
Africa, G	0.55	34.7%	0.44	48.1%	-0.8%	7.5%	-0.3%	-6.4%
Asia, G	1.95	44.5%	0.59	40.8%	-1.6%	3.7%	-1.3%	-3.2%
Europe, G	0.04	29.2%	0.49	48.5%	-0.8%	1.2%	0.2%	-0.8%
Latin America, G	0.33	52.9%	0.41	62.7%	-2.6%	7.9%	-2.1%	-7.2%
Mean, G	2.87	43.3%	0.54	44.8%	-1.6%	4.9%	-1.2%	-4.3%
Asia, D	0.19	77.2%	0.39	64.0%	-6.5%	15.7%	-0.4%	-14.6%
Europe, D	0.25	41.4%	0.32	84.6%	-1.3%	8.8%	-3.2%	-7.4%
Latin America, D	0.02	48.6%	0.99	59.4%	-0.8%	1.8%	0.4%	-1.3%
North America, D	0.17	67.4%	0.43	76.6%	-2.6%	10.4%	-3.6%	-9.4%
Oceania, D	0.01	64.2%	0.34	90.0%	-0.6%	12.2%	-0.3%	-8.0%
Mean, D	0.64	59.6%	0.39	75.9%	-3.1%	11.1%	-2.3%	-10.0%
Mean, all	3.51	46.3%	0.51	50.5%	-1.6%	6.0%	-1.4%	-5.4%

- Slighty larger in North America than Europe

  (larger cities effect >> higher cost of height and lower gap effects)

Mechanisms

World region	City characteristics: In cities >1 mill.	City characteristics: Cost of height θ (bedrock)	City characteristics: Est. height gap	Expected utility $\mathcal{V}$: No tall building	Expected utility $\mathcal{V}$: No height limit	Agg land rent $\mathcal{R}$: No tall building	Agg land rent $\mathcal{R}$: No height limit
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- Wage goes up (localized and city-wide agglomeration economies)
- Rent goes up due to in-migration (but decreases conditional on pop.)
- Local amenities improve / commute costs decrease
- Urban utility goes up (= wage - 0.33*rent - commute cost)
- Wage accounts for ∼60%, adjusted rent (rent & commute) ∼40%
- Same patterns for developed economies

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All Economies	46.3%	0.51	50.5%	–1.8%	6.0%	–1.4%	–5.4%

- Aggregate land rent would fall by **5.4%** if height limits removed
- Land rent increases in center but city more compact, less land
- Leads to transfers from the immobile land factor to the mobile labor force.

Sensitivity Analyses

	Implied ζ	Implied $\mathcal{T}$	Expected utility $\mathcal{V}$ No tall building	Expected utility $\mathcal{V}$ No height limit	Agg land rent $\mathcal{R}$ No tall building	Agg land rent $\mathcal{R}$ No height limit
Baseline parameterization	3.3	3.0	-1.8%	6.0%	-1.4%	-5.4%
Height gap cutoff 75^{th} percentile	3.3	3.0	-3.3%	3.4%	-0.4%	-3.6%
Floorspace production share = 0.10	3.7	3.0	-1.7%	5.6%	-1.2%	-7.4%
Floorspace production share = 0.20	3.1	2.7	-2.0%	6.3%	-1.5%	-3.8%
Citywide agglomeration elasticity = 0.00	3.6	4.3	-1.0%	3.0%	0.1%	-3.6%
Citywide agglomeration elasticity = 0.06	2.5	2.4	-2.9%	8.9%	-2.3%	-7.9%
Amenity decay parameters 10% higher	3.2	3.2	-1.9%	6.1%	-1.3%	-5.6%
Amenity decay parameters 10% lower	3.6	2.7	-1.7%	5.7%	-1.5%	-5.1%

- Results overall robust
- Work from home: gains remain large thanks to residential towers
- Agglomeration economies: gains halved if shut down

Conclusions

- The Skyscraper Revolution has fundamentally changed the nature of cities around the world, especially in developing economies.
- Estimated elasticities of city population of 0.12, built up area of -0.17 and city population density of 0.29 with respect to city height.
- Implication is that skyscraper construction has accommodated a large share of urbanization and facilitated large land savings globally.
- Land savings largest for short vegetation/cropland, then forested land
- Calibrated model indicates economic benefits of $\sim$6%, of which about only one-fourth has been realized. We ignore the costs.

  Welfare cost will increase over time as cost of height falls (in our construction costs data, the cost of height decreased by $\approx$2% per year)