BUILD UP A METROPOLIS: LAND USE REGULATIONS, SPATIAL MISALLOCATION, AND WELFARE

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PART ONE INTRODUCTION

Motivation

- Land use regulations are prevalent in both developed and developing countries.

- Evidence has suggested market distortion caused by land use regulations in various studies. However, the general equilibrium effect of land policies via reshaping the spatial organization of economic activities within a city remains unclear, and the quantitative evaluation of their welfare implications is limited.

- Evaluating land use policies for cities is challenging because it requires balancing the fundamental trade-off between two externalities: agglomeration benefits and costs.

Motivation

- On the one hand, high-density land development can enhance the positive externalities of agglomeration economies.

- On the other hand, high residential and workplace employment densities are likely to generate congestion, which plagues many global metropolises.
  - Shanghai, has an average travel speed of merely 25 km per hour. Other populous cities worldwide, such as Manila, London, Tokyo, and Mumbai, face similar challenges, with travel speeds hovering between 19 km per hour and 26 km per hour.
  - High densities tend to induce the construction of tall buildings, escalating construction costs. Notably, according to Ahlfeldt et al. (2023), the costs of height are particularly pronounced in many East Asian cities.

- Although there have been recent works (see Allen, Arkolakis, and Li, 2016; Acosta, 2021; Gechter and Tsivanidis, 2023; Koster, 2024) that study land policies in a spatial GE framework considering endogenous positive externality of agglomeration as in Ahlfeldt et al. (2015), few works in the current literature seriously consider endogenous urban costs when evaluating land use regulations.

What we do in this paper

- This paper examines the general equilibrium effect of land use regulations within a city using a novel model of internal urban structure that has both the benefits and costs of urban agglomeration to be endogenous to the spatial layout of jobs and people:

  - It incorporates the congestion effects of densities on bilateral commuting

  - It allows the unit construction cost to be a function of the building height while considering the impact of geological characteristics

  - It incorporates endogenous public goods provision financed by net rental income, a common practice in many cities worldwide where local governments rely on land sales to finance public goods provisions.

What we do in this paper

- We estimate and calibrate the model's key parameters using a spatially disaggregated data set for Shanghai.

- Counterfactual analyses:
  - Quantify the welfare loss due to current misallocations caused by land use regulations.
  - Provide guidance to design more efficient land policies for the spatial expansion of large metropolises like Shanghai in the future.

Preview of findings

- Our model has a better explanatory power for the actual data and provides more realistic counterfactual predictions regarding the outcomes of various land development policies, compared with an alternative model without considering endogenous congestion effect.

- Using this model in conjunction with a newly constructed, spatially disaggregated dataset for Shanghai, we uncover spatial misallocations and welfare losses resulting from current land use regulations that do not align with market demand.

- Allowing market forces to determine land allocation between business and residential uses could improve welfare by 6.7 percentage points. An additional 2.4 percentage points could be gained by lifting height restrictions. These welfare gains are primarily the result of enhanced agglomeration economies and reduced housing costs.

Preview of findings

- This paper provides important insights that could guide future spatial development of an expanding metropolis like Shanghai.

- Government interventions might be necessary to address the coordination failure due to a city's historical layout of existing urban structures that presents spatial misallocation.

- Specifically, regarding the construction of an additional 270 million sqm of new floor space as outlined in Shanghai's Master plan 2017-2035, we show that prioritizing land development in subcenters could raise welfare by 21.1% relative to the initial level, exceeding the welfare gains of a citywide market-driven approach by 6.2 percentage points. The gains mainly come from enhanced productivities and living amenities and reduced commuting costs.

Related literature

- **On the effects of land use regulations (for a review, see Gyourko and Molloy, 2015)**
  - Existing studies have found substantial effects of regulations on housing supply, real estate prices, city shape and urban growth, and have drawn efficiency implications of land use regulations, such as Bertaud and Brueckner (2005), Glaeser, Gyourko, and Saks (2005), Saiz (2010), Turner, Haughwout, and van der Klaauw (2014), Cai, Wang, and Zhang (2017), Hsieh and Moretti (2019), Harari, 2020; Tan, Wang and Zhang (2020), Wang, Zhang and Zhou (2020), Henderson et al. (2022), among others.
  - Our paper adds to this literature by developing a quantitative spatial equilibrium model incorporating both the benefits and costs of urban agglomeration.

Related Literature

- **On urban land planning for cities facing increased demand for redevelopment and spatial expansion, especially in the developing world**
  - Henderson, Regan, and Venables (2021) presented a comprehensive framework that delineates the dynamic nature of urban structures in African cities, suggesting that institutional frictions may hinder the upgrading of slums to achieve more efficient land use.
  - Harari and Wang (2024) explored policy interventions aimed at upgrading slum areas in Indonesian cities.
  - Gechter and Tsivanidis (2023) studied the redevelopment of old industrial plots in India and its general equilibrium impact.
  - Loumeau (2024) examined the effect of developing edge cities on inner-city structure and urban growth.
  - Wang, Zhang and Zhou (2020) investigated the political reasons underlying the urban expansion pattern of Chinese cities and highlighted the high redevelopment costs in the central city relative to the new development costs in the outer rings.
  - This paper demonstrates that although aligning land use regulations with market demands can enhance welfare, the misallocation presented by the historical constraints of the existing urban structure justifies government intervention in allocating new land development quotas to overcome coordination failures.

Related literature

- **On the impacts of urban determinants on commuting outcomes such as travel speeds, travel distances, and travel times**
  - Notable studies include Gordon et al. (1989), Giuliano and Small (1993), Bento et al. (2005), Brownstone and Golob (2009), Duranton and Turner (2011, 2018), and Akbar, Couture, Duranton, and Storeygard (2023a, b).
  - Akbar et al. (2023b) show that urban population density significantly impacts urban commuting speed and congestion factor at the city level using a global database on motor vehicle speed in over 1,200 large cities in 152 countries.
  - Recent studies integrate endogenous congestion to study the impact of urban transportation policies (Brinkman, 2016; Zhang and Kockelman, 2016; Allen and Arkolakis, 2022; Barwick, Li, Waxman, Wu, and Xia, 2024).
  - Our paper makes a valuable contribution by analyzing Chinese data at a more detailed spatial scale within a city and estimating the effect of densities on bilateral commuting time. We further incorporate endogenous congestion into a unified framework to quantitatively evaluate various land regulation policies, utilizing the congestion elasticities estimated based on the above microdata.

Related Literature

- **On how the spatial distribution of people and jobs affects local amenities**
  - This literature has examined both **production amenities**, as reviewed by Rosenthal and Strange (2004), Duranton and Puga (2004), Moretti (2011), and Combes and Gobillon (2015), and **consumption amenities**, as discussed by Glaeser, Kolko and Saiz (2001), Couture and Handbury (2020), Baum-Snow and Hartley (2020), Brinkman and Lin (2024), Su (2022), and Couture, Gaubert, Handbury, and Hurst (2024).
  - Consistent with this literature, our paper allows localities within a city to have different production and residential amenities that are endogenous to the spatial distribution of residential and workplace employment.
  - Moreover, we also endogenize public goods provision to land development policies, an essential factor influencing local amenities as well.

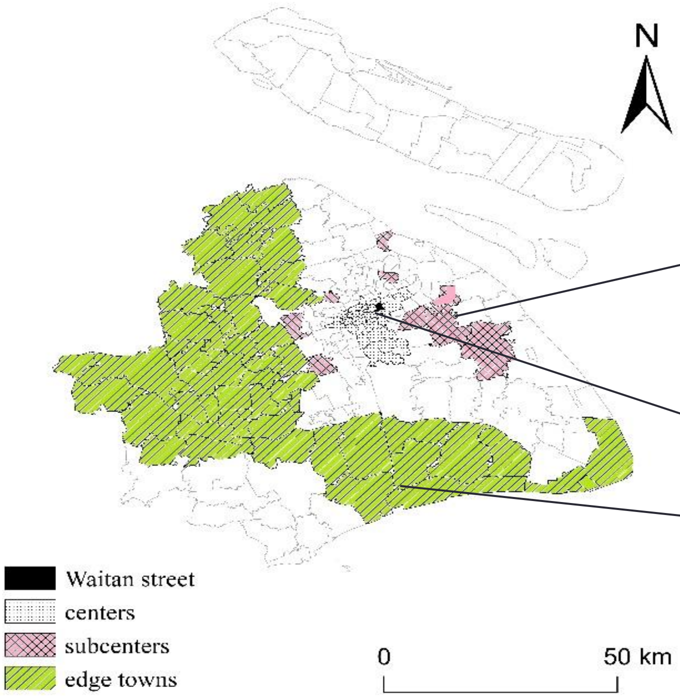
PART TWO BACKGROUND

Why do we focus on Shanghai?

- Largest Population and Highest GDP in China. Like numerous global megacities, Shanghai features high population densities, constrained land availability, and severe traffic congestion.
- The city government of Shanghai enforces stringent land use regulations, a common practice in many Chinese cities, especially within the top 20 largest cities with over 10 million residents as of 2020：
  - Zoning restrictions on land use types in each street tract, generating an endogenous price wedge between business and residential land.
  - Regulations on housing development densities on each land parcel through the floor-to-area ratio (FAR hereafter).
  - Similar to other cities in China and the developing world, Shanghai faces an urgent need to expand its construction space. The city government guides the allocation of new land development by issuing development quotas across various localities within the city.

An overview of Shanghai: descriptive analysis

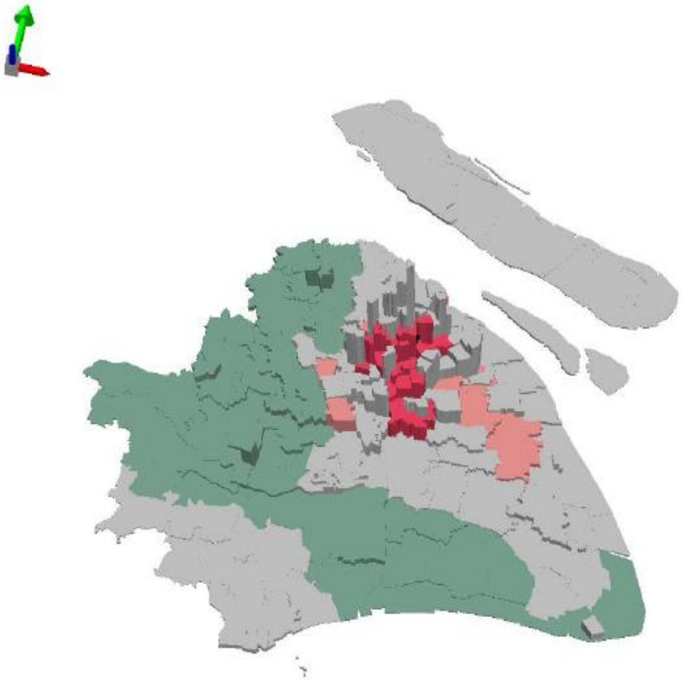
- Shanghai is a provincial-level city, with 16 urban districts and no rural counties. There are 209 street tracts in Shanghai.
  - The mean area of Shanghai's street tracts is approximately 31.8 square kilometers, while within the 20 km ring around the city center, there are 118 street tracts with a mean area of about 9 square kilometers.
- As of 2015, Shanghai has 25 million people, the most populous city in China (1.7% of China's population; 3.7% of China's GDP). The GDP shares of the secondary and tertiary sectors are 32% and 68%, respectively.



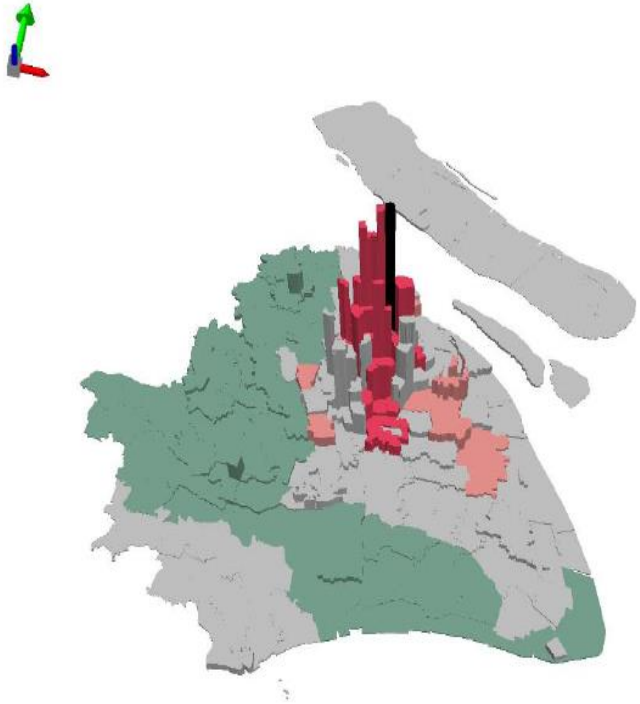
The core area (<10 km to CBD; dotted polygons)
The sub-centers (~10-20 km to CBD; pink polygons)
The five edge towns (~50-60 km to CBD; green polygons)

Map of residential and workplace employment densities

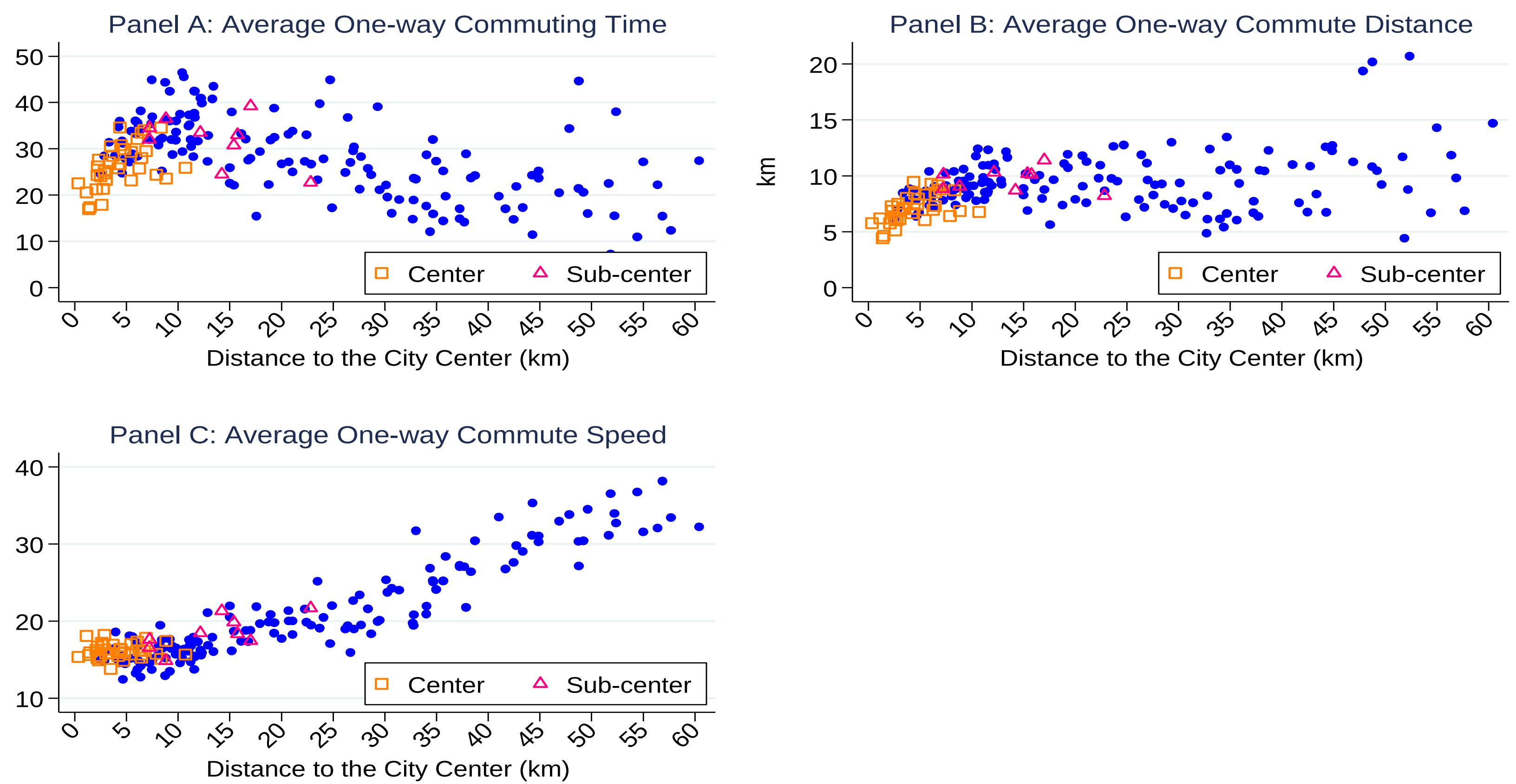
Residential Employment Density



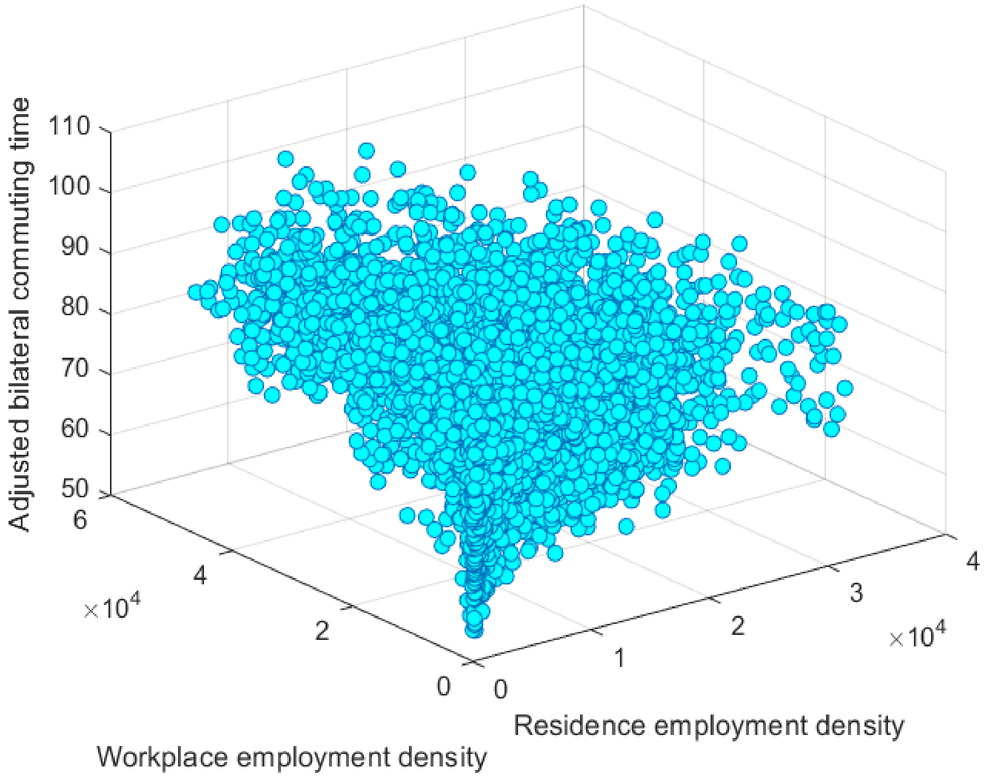
Workplace Employment Density



Descriptive evidence: commuting time, distance and speed by residential street tract

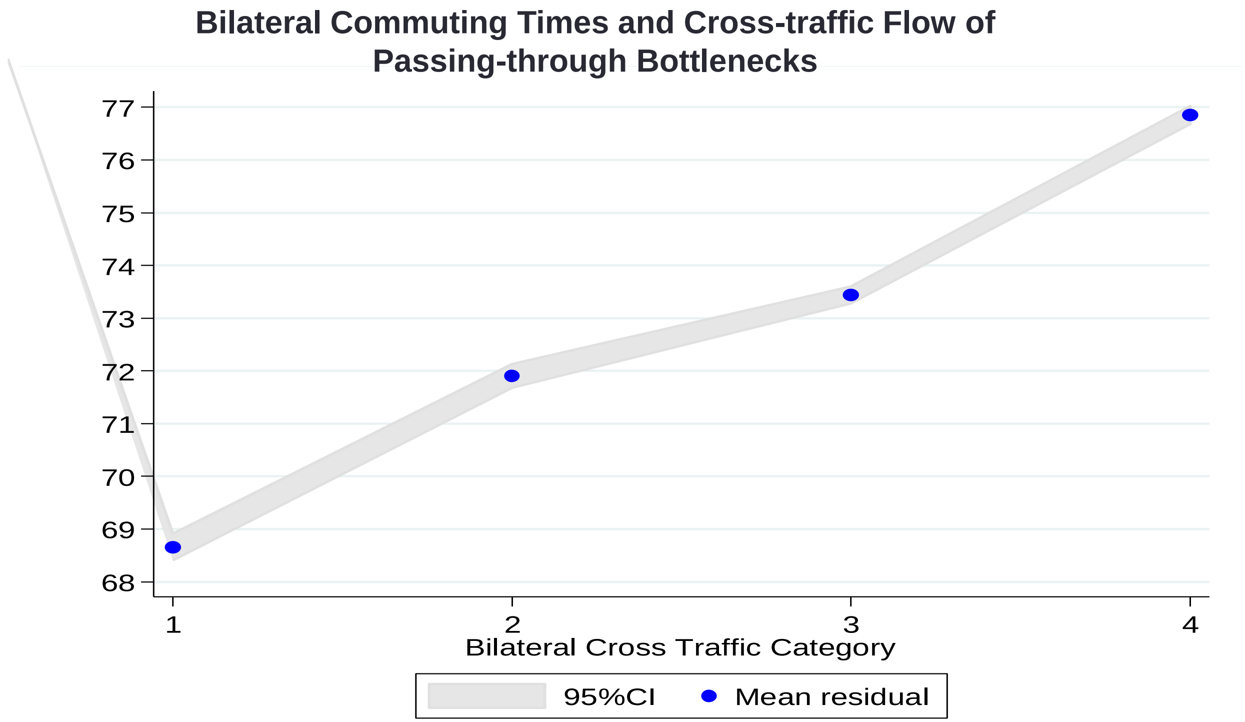


Descriptive evidence: bilateral commute times and densities at origins and destinations



Note: Panel A presents the relationships between bilateral commuting times and the employment densities of residences and workplaces. The two axes on the plane represent the employment densities of residential and workplace street tracts and the axis along the third dimension represents the adjusted commute time, obtained by subtracting the nonlinear effect of bilateral travel distance from the travel times. To estimate the effect of travel distance on travel time, we regress bilateral travel time on travel distance and its squared term, controlling for the fixed effects of residential and workplace street tracts. To help visualize the relationships, the graph above includes the street tract pairs with bilateral travel distances of 10 km or less (the average travel distance of the commuters in the Census sample is 10 km).

Descriptive evidence: cross-traffic flow



Note: The right figure presents the relationship between bilateral commuting times and the cross-traffic flow of the bottlenecks each bilateral travel route passes through. We divide all the 209*208 bilateral routes into four categories based on the size of the cross-traffic flow of the bottlenecks along the respective bilateral route: 1 (light), 2 (moderate), 3 (**crowded**), and 4 (**extremely crowded**) as shown along the x-axis. The travel routes in these categories are 10894, 10844, 10881, and 10853, respectively. The y-axis represents the residual of bilateral commuting times from the regression of bilateral travel time on travel distance, its squared term, and the fixed effects of residential and workplace street tracts.

PART THREE MODEL

Model environment

- A city has a fixed set of discrete locations (street tracts) and a fixed number of workers.

- Production and residential amenities (A and B)
  - Production and residential fundamental amenities (a and b): local natural and geological conditions, and public goods provisions, such as transport connection, schools, hospitals, and etc.
  - Endogenous to densities: agglomeration economies, positive externalities

- Land use regulations
  - Land quota & density restrictions: supply of floor space (L)
  - Zoning restrictions determine the allocation of land (or floor space) across different land use types

- Commuting time differs across bilateral tract pairs, endogenous to densities

Workers

- The indirect utility of worker k who lives in tract i and works in tract j is

$$U_{ijk} = \frac{z_{ijk} B_i w_j Q_i^{\beta-1}}{d_{ij}}$$

- B_i represents residential amenities of street i; Q_i represents residential floor price; w_j represents the wage income paid at workplace j
- d_{ij} represents the disutility from commuting from residence tract i to workplace tract j ($d_{ij} > 1$)

$$d_{ij} = e^{\kappa * \tau_{ij}}$$

τ_{ij} is the travel time between tracts i and j

- z_{ijk} is an idiosyncratic utility preference specific to individual worker k and varies with the worker's choices of residence and workplace pair. It follows an extreme value distribution:

$$F(z_{ij}) = e^{-z_{ij}^{-\varepsilon}}$$

The shape parameter $\varepsilon > 1$ reflects the dispersion of the idiosyncratic utility (a larger ε implies smaller dispersion of these random draws; so location decisions are more responsive to fundamentals).

Workers (cont'd)

- After observing the realization of z, each worker chooses where to live and work to maximize the utility, taking wages, residential amenities, housing prices, commuting costs and the location decisions of other workers and firms as given.
- **Bilateral commute probability** (the probability that a worker chooses to live in street i and work in street j; the gravity model):

$$\pi_{ij} = \frac{\left(d_{ij}Q_i^{1-\beta}\right)^{-\varepsilon}(B_i w_j)^{\varepsilon}}{\sum_{r=1}^{S}\sum_{s=1}^{S}\left(d_{rs}Q_r^{1-\beta}\right)^{-\varepsilon}(B_r w_s)^{\varepsilon}} \equiv \frac{\Phi_{ij}}{\Phi}$$

- Commuting equilibrium condition:

$$H_{Mj} = \sum_{i=1}^{S}\pi_{ij|i}H_{Ri} = \sum_{i=1}^{S}\frac{(w_j/d_{ij})^{\varepsilon}}{\sum_{s=1}^{S}(w_s/d_{is})^{\varepsilon}}H_{Ri}$$

- Expected utility of each worker:

$$\mathrm{E(u)} = \gamma[\sum_{r=1}^{S}\sum_{s=1}^{S}\left(B_r Q_r^{\beta-1}\right)^{\varepsilon}(w_s/d_{rs})^{\varepsilon}]^{1/\varepsilon}$$

Firms

- Competitive firms produce a single final good using labor and floor space.
- The final good is freely traded within the city and the larger economy. Price is normalized to one.
- The output of the final good of a representative firm in tract j:

$$y_j = A_j H_{Mj}^{\alpha} L_{Mj}^{1-\alpha}$$

A_j is final goods productivity specific to the tract; L_{Mj} is the measure of floor space used for production in tract j.

- Profit maximization gives the labor demand and the floor space demand in street j

$$H_{Mj} = (\frac{\alpha A_j}{w_j})^{1/(1-\alpha)} L_{Mj}$$

$$L_{Mj} = (\frac{(1-\alpha) A_j}{q_j})^{1/\alpha} H_{Mj}$$

- FOCs of the profit maximization and the zero profit condition give

$$q_j = (1-\alpha)(\frac{\alpha}{w_j})^{\alpha/(1-\alpha)} (A_j)^{1/(1-\alpha)}$$

Housing: housing production

- The supply of floor space at tract i is exogenously set by the government.

$$L_i = \varphi_i K_i^L$$

φ_i measures the density of development (height regulation); and K^L is land (quota). Assuming that the building density constraint is the same across land use types,

- The government divides land supply btw business (θ_i) and residential use ($1-\theta_i$) (zoning restrictions). Such manipulation generates an endogenous price wedge between business land and residential land, denoted ξ_i^0, and will be reflected by the price wedge between business and residential floor space prices:

$$\frac{q_i}{Q_i} = \frac{\xi_i^0 + c_i(\varphi_i) * \varphi_i / pr_i}{1 + c_i(\varphi_i) * \varphi_i / pr_i}$$

where pr_i represents the price per unit of residential land

- The construction cost at tract i

$$cost_i(L_i, \varphi_i) \equiv c_i(\varphi_i) * \varphi_i * K_i^L$$

$c_i(\varphi_i)$ is the construction cost per floor area on each unit of land :

$$c_i(\varphi_i) = \bar{c} * \varphi_i{}^{ec_i}$$

ec_i is the elasticity of per floor area construction cost w.r.t building density:

$$ec_i = e0 + e1 * |depth_i - \overline{depth}|$$

$depth_i$ is the depth of bedrock under the ground at street tract i. We set $\overline{depth}$ =35 m (Ahlfeldt, Baum-Snow, and Jedwab, 2023).

Housing: housing market

- The residential floor space supply is $(1-\theta_i)\ L_i$, and the business floor space supply is $\theta_i L_i$.

- Housing market clearance requires demand equal to supply by use type. In equilibrium, for each street tract, we have

$$H_{Ri}\left(\frac{1-\beta}{Q_i}\right)\sum_{j=1}^{S}\frac{\left(w_j/d_{ij}\right)^{\varepsilon}}{\sum_{s=1}^{S}(w_s/d_{is})^{\varepsilon}}w_j=(1-\theta_i)L_i$$

$$\left(\frac{(1-\alpha)A_j}{q_i}\right)^{1/\alpha}H_{Mi}=\theta_i L_i$$

- In counterfactual analyses, we will lift the zoning restrictions and building density constraints so that the developer can choose building density to maximize the value per unit of land:

$$Max_{\varphi_i}Q_i*\varphi_i-\varphi_i*\bar{c}*{\varphi_i}^{ec_i}$$

The optimal building density is $\varphi_i=\left({}^{Q_i}/_{\bar{c}(1+ec_i)}\right)^{\frac{1}{ec_i}}$

Endogenous AE and endogenous public good provision

- Each tract's final good production productivity

$$A_i = a_i Y_i^{\lambda},\ Y_j \equiv \sum_{s=1}^{S} e^{-\delta\tau_{js}} \left(\frac{H_{Ms}}{K_s}\right)$$

where a_i is production fundamental amenities; Y_j is production spillovers

- Each tract's residential amenities

$$B_i = b_i \Omega_i^{\eta},\ \Omega_i \equiv \sum_{r=1}^{S} e^{-\rho\tau_{ir}} \left(\frac{H_{Rr}}{K_r}\right)$$

where b_i is residential fundamental amenities; Ω_i is consumption spillovers

- Introducing endogenous public good provision

$$a_i = a_i^0 (g_{ai} S_a G)^{\tilde{\gamma}},\ b_i = b_i^0 (g_{bi} S_b G)^{\tilde{\gamma}}$$

a_i^0 and b_i^0 are the local natural and geographical conditions

g_{ai} and g_{bi} are the shares of public expenditures this locality receives on improving its local production amenities and residential amenities

S_a and S_b are shares of G that are used to provide public goods related to production amenities and residential amenities

- The net rental income G

$$G = \sum_{i}^{I=209} (Q_i L_{Ri} + q_i L_{Mi}) - \sum_{i}^{I=209} cost_i(L_i, \varphi_i).$$

Endogenous bilateral commuting time

- Transportation technology
  - Commuting time differs across bilateral tract pairs, endogenous to densities

$$\mathrm{Log}\tau_{ij} = t_0 + t_1 \log\left(\frac{H_{Ri}}{K_i}\right) + t_2 \log\left(\frac{H_{Mj}}{K_j}\right) + t_3 \log(C_{ij}) + \phi(dist_{ij}) + t_4 T_{Ri} + t_5 T_{Mj}$$

Origin's density — Destination's density — Cross-traffic flow — Bilateral distance — Transport infrastructure

Equilibrium

- Given the parameter space of the model $\Theta \equiv \{\alpha, \beta, \kappa, \varepsilon, H, \boldsymbol{a^0}(\boldsymbol{g_a S_a})^{\tilde{\gamma}}, \boldsymbol{b^0}(\boldsymbol{g_b S_b})^{\tilde{\gamma}}, \boldsymbol{K}, \boldsymbol{\varphi}, \boldsymbol{\theta}, \tilde{\gamma}, \lambda, \delta, \eta, \rho, t_1, t_2, t_3, \phi, \bar{c}, e_0, e_1, \overline{depth}\}$, we can solve the following set of variables $\{\boldsymbol{\pi_R}, \boldsymbol{\pi_M}, \boldsymbol{q}, \boldsymbol{Q}, \boldsymbol{w}, E(U), \boldsymbol{\xi^0}, G\}$.

PART FOUR DATA

Data and variable construction

- Bilateral commuting flows and residential and workplace employment: the mini census 2015 supplemented by the commuting flow data from a leading location service provider based on mobile device App (2019)

- Bilateral commuting time: the Baidu Map App (Dec. 2020)

- Housing prices and FARs: a data set of 11,860 RDPs from the China Index Academy (Oct. 2016)

- Prices of business land and residential land : land transactions from landchina.com

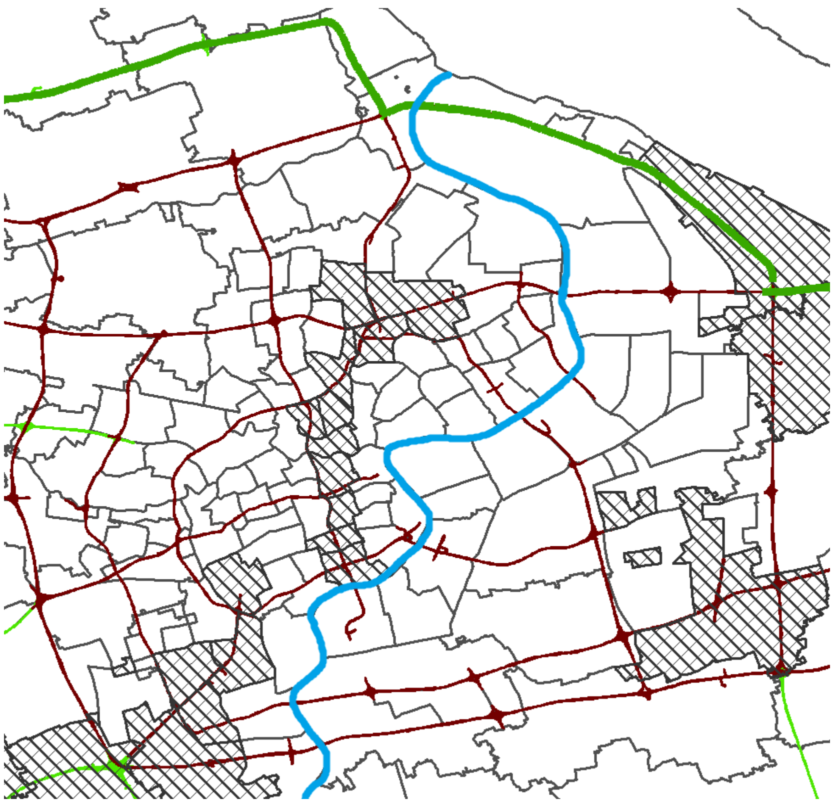
Data and variable construction

- Geological condition: the land surface slope (Geographic Data Sharing Infrastructure, College of Urban and Environmental Science, Peking University) and depth of bedrock (http://globalchange.bnu.edu.cn/research/cdtb.jsp)
- Workplace street tract's average wage: each street tract's one-digit industry employment from the 2008 Economic Census & one-digit industry's average wage in Shanghai from the Bureau of Statistics of Shanghai
- District-level housing stock of various uses in 2015: the Shanghai Statistical Yearbook 2016
- Street's land use conditions: a land classification data developed by Chinese Academy of Sciences based on satellite images (2010)
- POI data: NavInfo, a leading provider of automotive navigation services (2015)

Data and variable construction

- Constructing the cross-traffic flow for each bilateral commuting route:
  - Geocode all the highways and freeways in Shanghai's transportation map as of 2015
  - Use ArcGIS to find the shortest route between any two street tracts' centroids in the highway network
  - Bottlenecks: the street tracts passed through most frequently (top 10 percentile: 21)
  - The cross-traffic flow for each bottleneck b: $traffic_b = \sum_{i=1}^{209} \frac{N_{ib}}{209} \times H_{Ri}$, where N_{ib} represents the number of the bilateral commuting routes starting from street tract i and passing through bottleneck street tract b, and H_{Ri} represents the residential employment population living in street tract i
  - $C_{ij} = \begin{cases} \sum_{b \in B(ij)} traffic_b, \ if\ i \notin B(ij) \\ \sum_{b \in B(ij)} traffic_b - HR_i, \ if\ i \in B(ij) \end{cases}$, where $B(ij)$ represents the set of bottlenecks route ij passes through

Bottle necks



Driving speed in rush hours

PART FIVE ESTIMATION AND CALIBRATION

Calibrated parameters

Parameters borrowed		Value	Source
$1-\alpha$	Share of business floor space in production	0.2	Valentinyi and Herrendorf (2008)
$1-\beta$	Share of residential floor space in utility	0.25	Cao, Chen, and Zhang (2018)
η	Residential agglomeration elasticity	0.155	Ahlfeldt et al. (2015)
ρ	Spatial decay rate of residential agglomeration	0.76	Ahlfeldt et al. (2015)
λ	Production agglomeration elasticity	0.071	Ahlfeldt et al. (2015)
δ	Spatial decay rate of production agglomeration	0.362	Ahlfeldt et al. (2015)
$\tilde{\gamma}$	Productivity of public goods provision	0.06	Henderson et. al (2022)
$\overline{threshold}$	The threshold bedrock depth	35	Ahlfeldt et al. (2023)

Calibrated parameters

Parameters estimated or calibrated		Value
$\nu = \varepsilon * \kappa$	Semi-Elasticity of travel flow w.r.t. travel time	0.075
ε	Dispersion parameter of the idiosyncratic preference's distribution	8.4486
κ	Elasticity of travel cost w.r.t travel time	0.0088
t_1	Elasticity of bilateral travel time w.r.t. employment density at residence tract	0.21
t_2	Elasticity of bilateral travel time w.r.t. employment density at workplace tract	0.21
t_3	Elasticity of bilateral commute time w.r.t. cross-traffic flow of route-specific bottlenecks	0.007
$\bar{c}$	Scale parameter in the per-floor-area construction cost function	204
$e1$	Parameter defining how the elasticity of per-floor-area construction costs w.r.t. building height varies with bedrock depth	0
$e0$	Elasticity of per-floor-area construction costs w.r.t. building height, invariant to bedrock depth	1.29

Gravity model regressions

- Based on the commute probability equation, we derive the gravity equation regression model:

$$\log\pi_{ij} = -\upsilon t_{ij} + \vartheta_i + \varsigma_j + e_{ij}, \text{ where } \nu = \varepsilon * \kappa$$

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Log (Bilateral Commuting Probability)					
	All bilateral street tract pairs	Subsample of bilateral street tract pairs	All bilateral street tract pairs	All bilateral district pairs	All bilateral street tract pairs
Travel time	-0.0759***	-0.0806***	-0.0749***	-0.0807***	-0.0874***
	(0.0010)	(0.0010)	(0.0011)	(0.0031)	(0.0014)
Estimation	PPML	PPML	PPML	PPML	PPML
Workplace and residence street tract FE	Yes	Yes	Yes		
Workplace and residence district FE				Yes	
Bilateral distance less than 30 km		Yes			
Bilateral region pair FE (pudong, puxi, Chongming Island)			Yes		
First-stage residual					Yes
Observations	43,681	22,199	43,681	256	43,681

Commute congestion effects (Bilateral-route-level regression)

- The regression model is

$$\log\tau_{ij} = t_0 + t_1 logempden_{Ri} + t_2 logempden_{Mj} + t_3 LogC_{ij} + \phi_1 \, logdist_{ij} + t_4 T_{Ri} + t_5 T_{Mj} + u_{ij}$$

	(1)	(2)	(3)	(4)	(5)
Dependent Variable	Log (Bilateral Shortest Commute Times from Baidu App)				
	OLS	OLS	IV	IV	OLS
Log employment density of residence street tract	0.0699***		0.2134***		
	(0.0020)		(0.0118)		
Log employment density of workplace street tract		-0.0169***		0.2140***	
		(0.0023)		(0.0073)	
Log route-specific cross-traffic congestion proxy	0.0079***	0.0102***	0.0065***	0.0095***	0.0070***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Log bilateral commute distance	0.6760***	0.6634***	0.7081***	0.6977***	0.6935***
	(0.0028)	(0.0027)	(0.0041)	(0.0031)	(0.0030)
Residence street tract's transportation infrastructure	Y		Y		
Workplace street tract's transportation infrastructure		Y		Y	
Residence street tract FE		Y		Y	Y
Workplace street tract FE	Y		Y		Y
Observations	43,472	43,472	43,472	43,472	43,472
R-squared	0.8823	0.8842	0.8319	0.8120	0.9209
First-stage F-statistic			603.87	2928.3	

Estimate and calibrate parameters defining per floor area construction cost function

- Per floor space construction cost:

$$c_i(\varphi_i) = \bar{c} * \varphi_i^{ec_i}, \text{ where } ec_i = e0 + e1 * (depth_i - \overline{depth})$$

- Run the following regression to estimate $e0$ and $e1$:

$$logc_l(\varphi_l) = cons + e_0 log\varphi_l + e_1 log\varphi_l * (depth_l - 35) + error_l$$

  - Data: a sample of residential land parcels (sold through public auctions) and the *ex-post* housing development information in the vicinity of the land parcel
  - Calculate the per floor area construction cost: $c(\varphi) = \frac{Q*\varphi*K - pr*K}{\varphi*K}$
  - Instrumental variable for φ_l: the log distance to the city center

- Finally we calibrate the value of $\bar{c}$ such that the predicted total net rental income matches the actual total land sale revenues of the whole city. We obtain $\bar{c} = 204$.

Construction Cost Elasticities Estimation

	(1)	(2)	(3)	(4)
Dependent Variable:	Log (Per-Floor-Area Construction Cost)			
	OLS	OLS	IV	IV
Log FAR	0.9477***	1.2557***	1.2938***	1.3328**
	(0.2069)	(0.4715)	(0.3015)	(0.6633)
Log FAR * (Bedrock depth-35)		-0.0036		-0.0006
		(0.0053)		(0.0089)
Observations	312	312	312	312
R-squared	0.1156	0.1181	0.1002	0.1018
F-stat			25.482	4.8145

Calibrated local un-observables

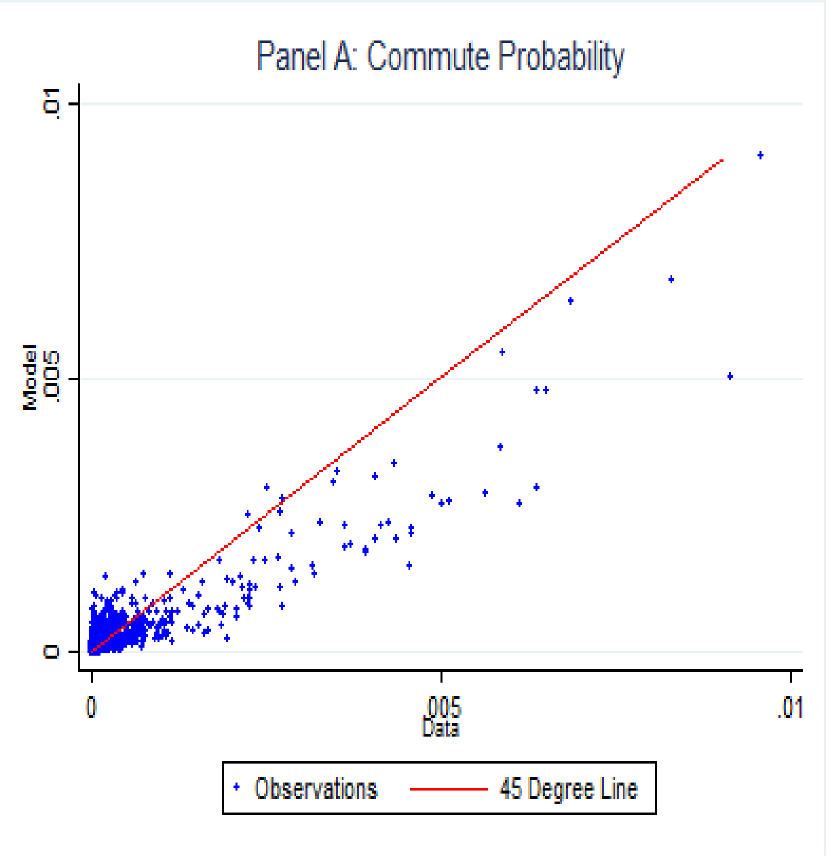
- Local production amenities A and B

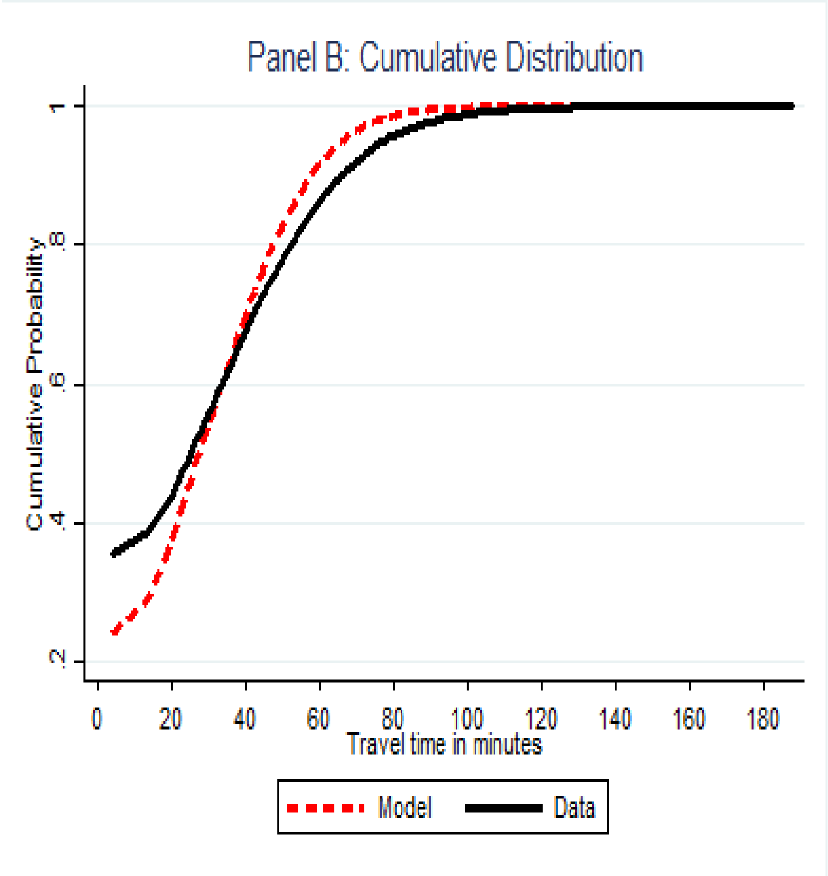
- Local floor space supply L, share of business floor space θ, construction land supply K^L, net rental income G (land sales income)

We aggregate the tract-level calibrated floor space supply to the district level and compare the thus-obtained district-level floor supply with the actual district-level floor space. The correlation coefficients are 0.88, 0.92, and 0.80 for the total, business, and residential floor space, respectively.

- Local fundamentals $\bar{a}$ and $\bar{b}$.

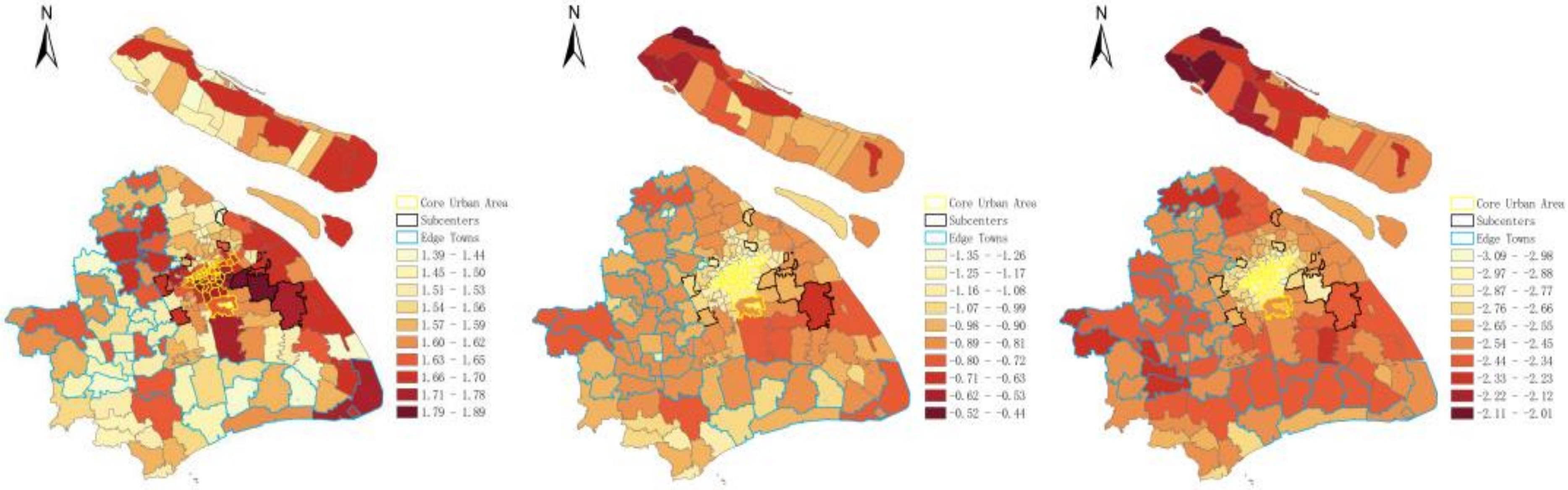
Over-identification checks on bilateral commute flows





Spatial distribution of fundamentals

Figure 6: Spatial Distributions of Local Fundamentals



Panel A: $log(\bar{a})$ Panel B: $log(\bar{b})$ Panel C: $log(\bar{b}) - log(\bar{a})$

PART SIX COUNTERFACTUAL ANALYSIS

Spatial misallocation: Floor space allocation between use types and local comparative advantage

	(1)	(2)	(3)	(4)	(5)
Dependent Variable	Initial Ratio of Business to Residential Land prices	Initial Residential Floor Space Share	Simulated Residential Floor Space Share: Counterfactual C1	Simulated Residential Floor Space Share: Counterfactual C1	Simulated Residential Floor Space Share: Counterfactual C2
	All 209 Tracts	All 209 Tracts	All 209 Tracts	Exclude Chongming Island	Exclude Chongming Island
$\log(\bar{b}) - \log(\bar{a})$	-2.331***	0.019	0.679***	0.766***	0.635***
	(0.563)	(0.041)	(0.056)	(0.054)	(0.061)
Constant	-4.892***	0.537***	2.217***	2.466***	2.131***
	(1.391)	(0.106)	(0.148)	(0.144)	(0.162)
Observations	209	209	209	191	191
R-squared	0.072	0.001	0.328	0.386	0.277

Spatial misallocation: Floor space supply and local fundamentals

	(1)	(2)	(3)
Dependent Variable	Log(Initial Floor Space Supply)	Log(Initial Floor Space Supply)	Log (Simulated Floor Space Supply): Counterfactual C2
	All 209 Tracts	Exclude Chongming Island	Exclude Chongming Island
$\log(\bar{a})$	-0.104	-0.373	0.785**
	(0.431)	(0.326)	(0.337)
$\log(\bar{b})$	-2.399**	0.150	1.459***
	(1.056)	(0.504)	(0.548)
Log land area	0.677***	0.460***	0.166**
	(0.124)	(0.063)	(0.068)
Constant	1.842	5.574***	15.034***
	(1.678)	(0.896)	(0.935)
Observations	209	191	191
R-squared	0.497	0.716	0.502
p-value testing exclusion of tract's fundamentals	0.0640	0.512	0.002

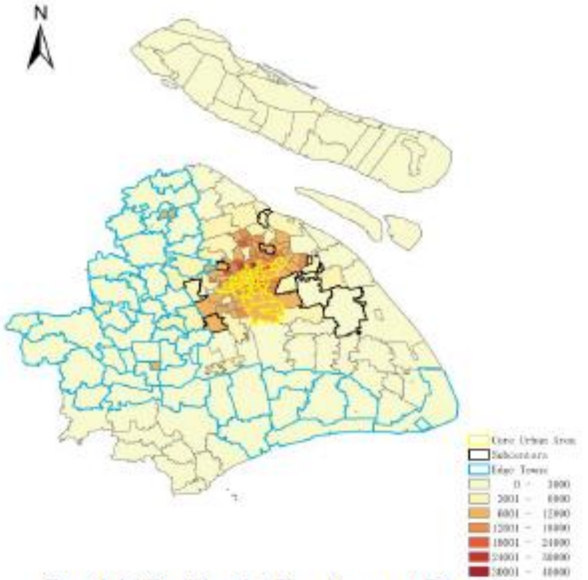
Counterfactual analysis I: Relax zoning restriction and building density constraints

Counterfactual C1: Lift zoning restriction by allowing free arbitrage between business land and residential land

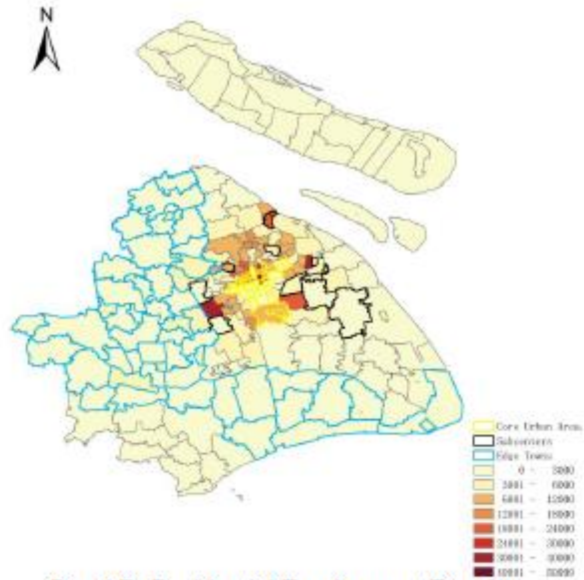
--- Welfare gain 6.7%

Counterfactual C2: Allow developers to set building heights following market price signals

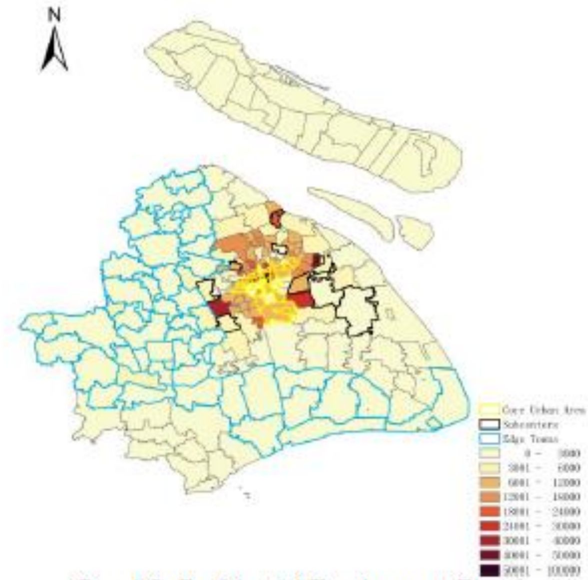
--- Welfare gain 9.1%



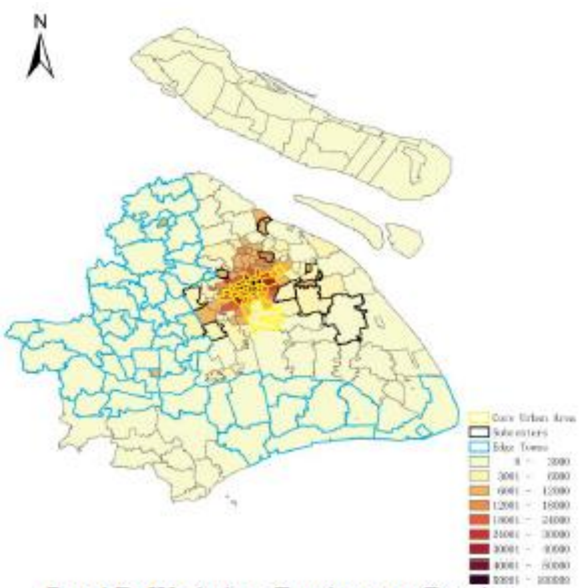
Panel A: Residential Employment Density (Benchmark)



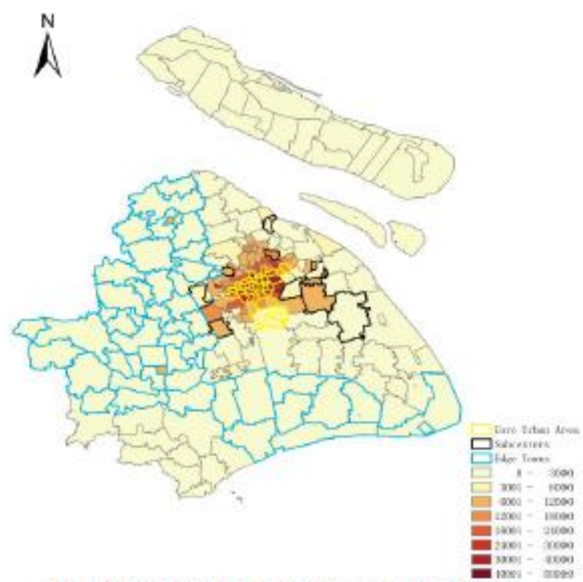
Panel B: Residential Employment Density (Counterfactual C1)



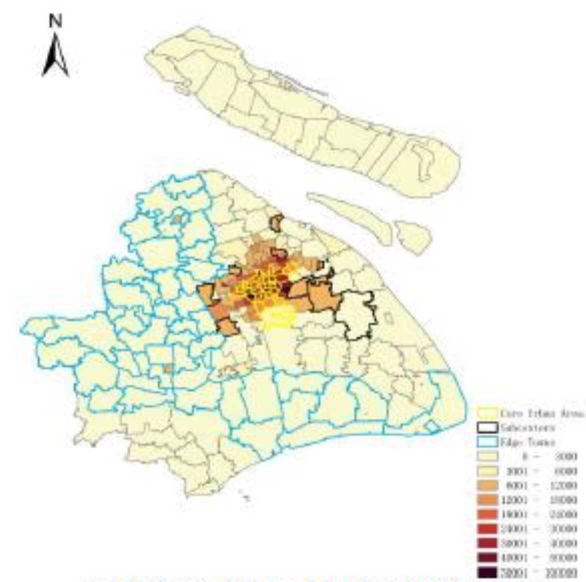
Panel C: Residential Employment Density (Counterfactual C2)



Panel D: Workplace Employment Density (Benchmark)



Panel E: Workplace Employment Density (Counterfactual C1)



Panel F: Workplace Employment Density (Counterfactual C2)

Changes in the spatial distributions of residents and workers

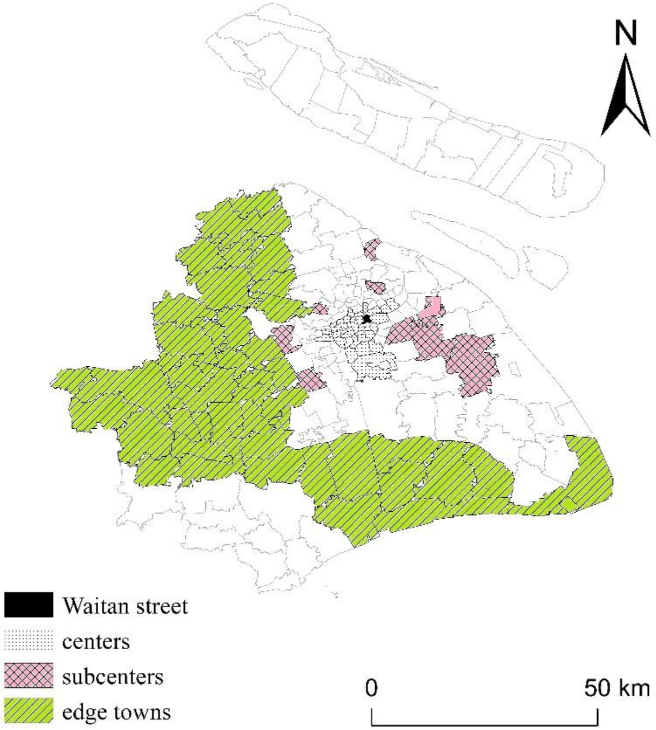
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Residential Employment Growth Rate	Workplace Employment Growth Rate	Residential Employment Growth Rate	Workplace Employment Growth Rate	Residential Employment Growth Rate	Workplace Employment Growth Rate
	From C0 to C1; All 209 Tracts		From C0 to C1; Exclude Chongming Island		From C0 to C2; Exclude Chongming Island	
$\log(\bar{b}) - \log(\bar{a})$	1.4037***	-0.0506	1.5611***	-0.4169***	0.1752	-0.9853***
	(0.3590)	(0.1884)	(0.3337)	(0.1184)	(0.3713)	(0.1224)
$\log(\bar{a})$	-4.6104***	0.9625***	-4.5241***	0.5524*	-3.3539***	0.8039**
	(0.8440)	(0.3478)	(0.8273)	(0.2915)	(1.0110)	(0.3238)
Constant	10.4585***	-1.6664***	10.7965***	-2.0123***	5.2994***	-3.9556***
	(1.1118)	(0.5198)	(1.1411)	(0.5235)	(1.3912)	(0.5739)
Observations	209	209	191	191	191	191
R-squared	0.3246	0.0599	0.3641	0.1273	0.0941	0.3799

Counterfactual analyses

	(1)	(2)	(3)	(4)	(5)	(6)
	Social Welfare in Eqn. (9)	**Average Transformed Wage ω**	**Average House Price Q**	**Average Commuting Time (minute)**	**Average Commuting Distance (km)**	**Average Residential Amenities B**
C0: Initial equilibrium (Benchmark)	**1.000**	**27,995.310**	**1,153.931**	**29.172**	**10.300**	**0.738**
C1: Remove zoning restrictions on land use types	**1.067**	**38,367.560**	**872.411**	**33.566**	**10.919**	**0.788**
C2: Remove zoning restrictions on land use types and relax building height constraints, excluding Chongming	**1.091**	**51,519.610**	**959.761**	**33.806**	**10.599**	**0.797**
NewC0: Allocate new floor space following initial share of floor space across street tracts, excluding Chongming	**1.087**	**39,782.100**	**960.674**	**29.217**	**10.293**	**0.735**
NewC1: Allow developers to build new floor space throughout Shanghai following market signals, excluding Chongming	**1.149**	**56,147.600**	**767.396**	**33.834**	**11.103**	**0.781**
NewC2: Allow developers to build new floor space only in subcenters	**1.211**	**98,677.430**	**795.406**	**28.360**	**9.676**	**0.854**
NewC3: Allow developers to build new floor space only in edge towns	**1.122**	**47,502.400**	**766.578**	**32.680**	**10.889**	**0.777**

The Shanghai Master Plan 2017-2035 （上海市城市总体规划2017-2035年）

- By 2035 the city will build additional 270 million square meters of floor space in addition to the current 1.05 billion square meters of total floor space
- Although the plan did not mention where and how to build, it pointed out that some particular locations will enjoy priority for land development such as houses, business facilities, and transport connections
  - The core urban area (<10 km to CBD; dotted polygons)
  - The sub-centers (~10-20 km to CBD; pink polygons)
  - Five edge towns (~50-60 km to CBD; green polygons)



Counterfactual analysis II: How to develop Shanghai in the future? Where to allocate new land quota?

- Counterfactual NewC1: purely market driven, allocate land quota allover the city

--- Welfare gain 14.9%

- Counterfactual NewC2: Combine market forces with intervention of land quota assignment to subcenters only

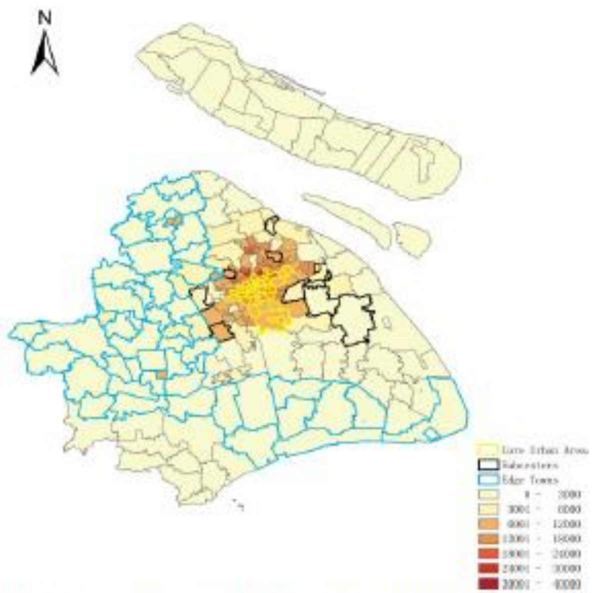
--- Welfare gain 21.1%

- Counterfactual New C3: Combine market forces with intervention of land quota assignment to edge-towns only

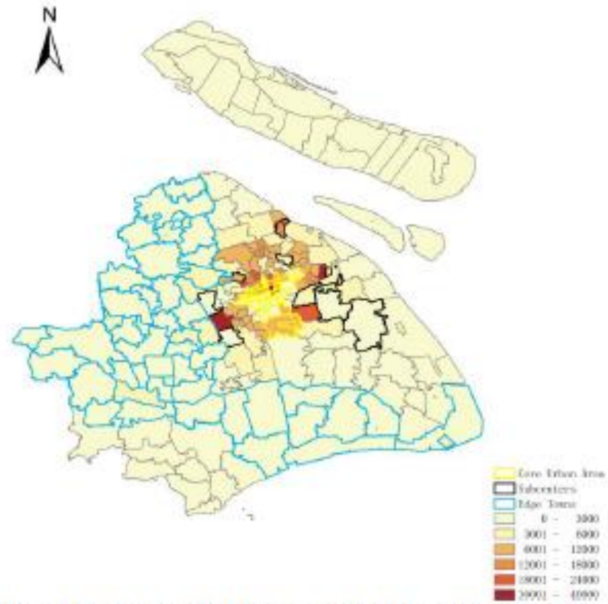
---- Welfare gain 12.2%

Counterfactual analyses

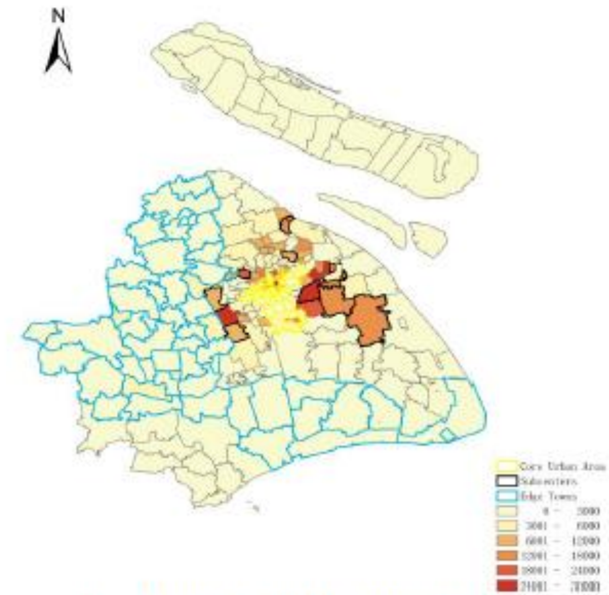
	(1)	(2)	(3)	(4)	(5)	(6)
	Social Welfare in Eqn. (9)	**Average Transformed Wage *ω***	**Average House Price *Q***	**Average Commuting Time (minute)**	**Average Commuting Distance (km)**	**Average Residential Amenities *B***
C0: Initial equilibrium (Benchmark)	**1.000**	**27,995.310**	**1,153.931**	**29.172**	**10.300**	**0.738**
C1: Remove zoning restrictions on land use types	**1.067**	**38,367.560**	**872.411**	**33.566**	**10.919**	**0.788**
C2: Remove zoning restrictions on land use types and relax building height constraints, excluding Chongming	**1.091**	**51,519.610**	**959.761**	**33.806**	**10.599**	**0.797**
NewC0: Allocate new floor space following initial share of floor space across street tracts, excluding Chongming	**1.087**	**39,782.100**	**960.674**	**29.217**	**10.293**	**0.735**
NewC1: Allow developers to build new floor space throughout Shanghai following market signals, excluding Chongming	**1.149**	**56,147.600**	**767.396**	**33.834**	**11.103**	**0.781**
NewC2: Allow developers to build new floor space only in subcenters	**1.211**	**98,677.430**	**795.406**	**28.360**	**9.676**	**0.854**
NewC3: Allow developers to build new floor space only in edge towns	**1.122**	**47,502.400**	**766.578**	**32.680**	**10.889**	**0.777**



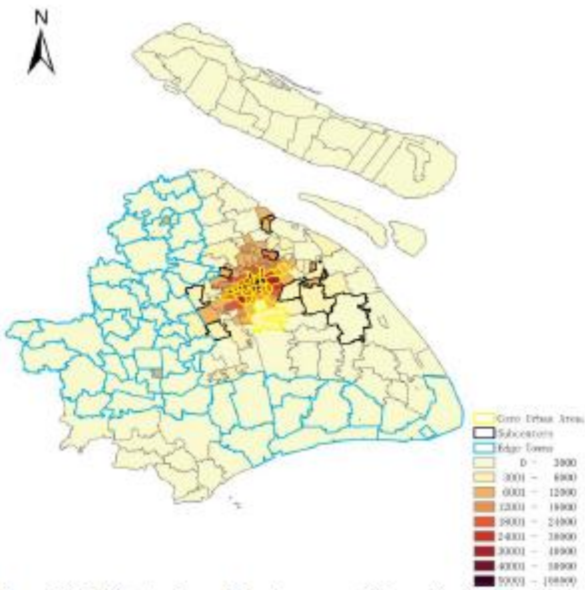
Panel A: Residential Employment Density (NewC0: Build following Initial Share)



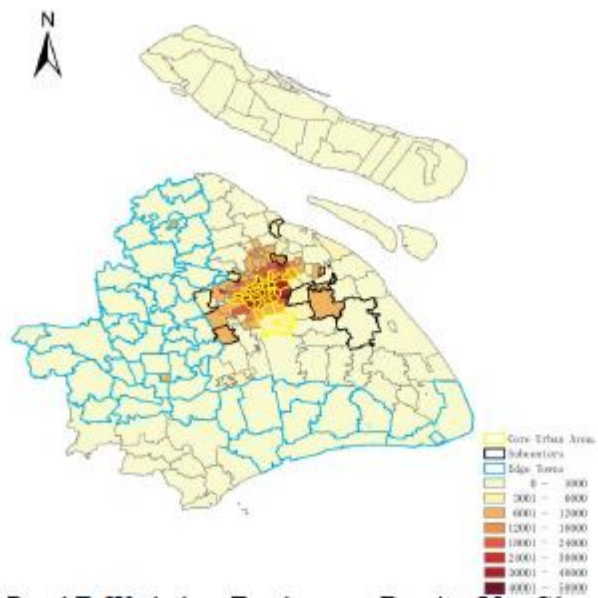
Panel B: Residential Employment Density (NewC1: Developers Choose Where to Build in the City)



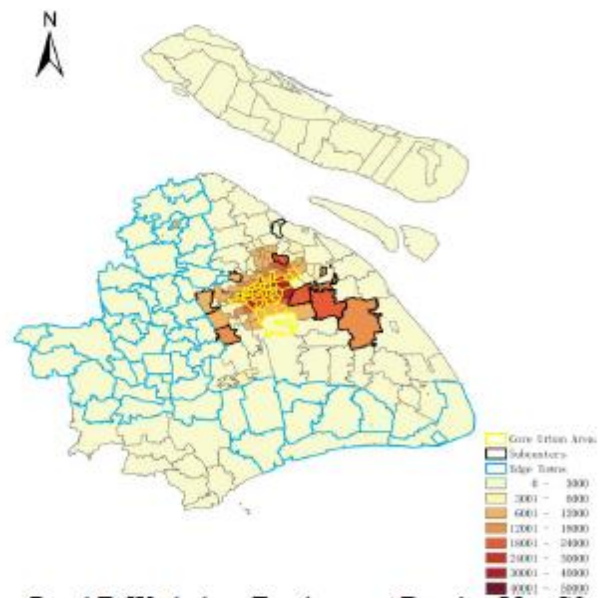
Panel C: Residential Employment Density (NewC2: Build in Subcenters)



Panel D: Workplace Employment Density (NewC0: Build following Initial Share)



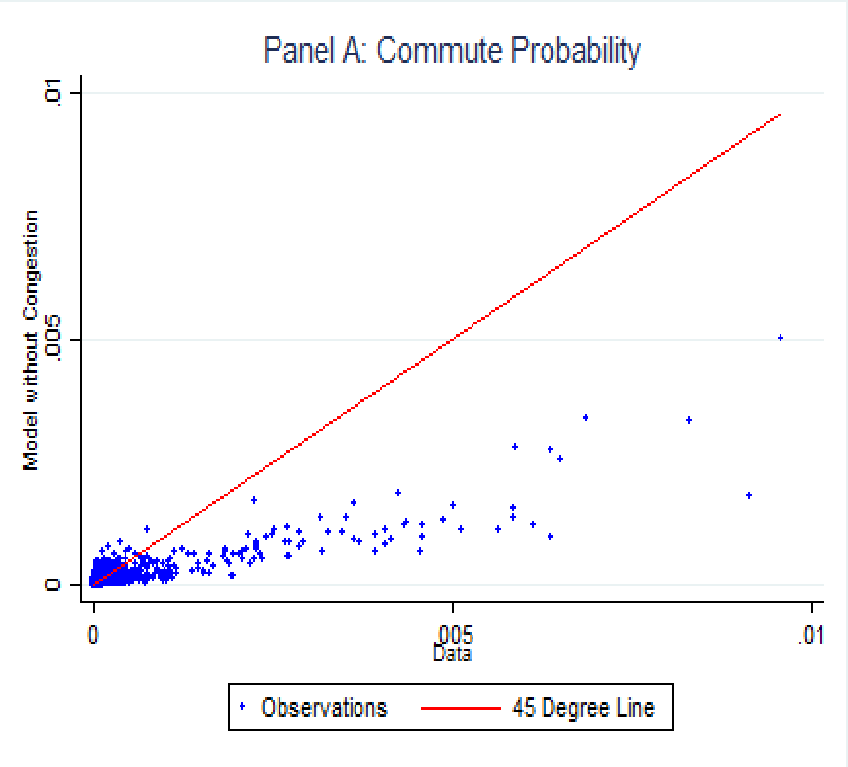
Panel E: Workplace Employment Density (NewC1: Developers Choose Where to Build in the City)

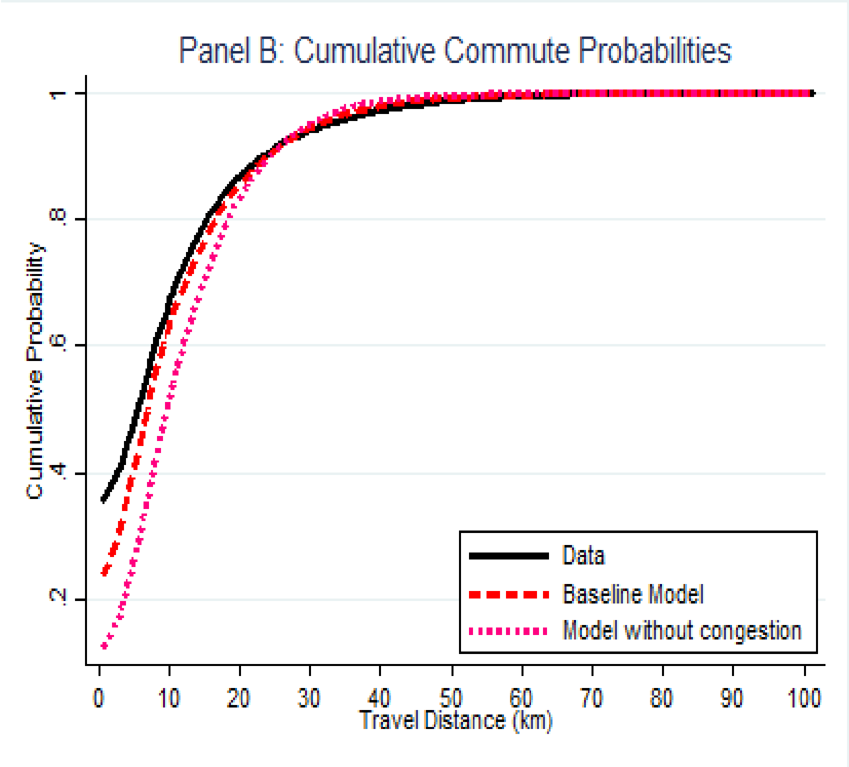


Panel F: Workplace Employment Density (NewC2: Build in Subcenters)

PART SEVEN AN ALTERNATIVE MODEL WITHOUT ENDOGENOUS CONGESTION

Bilateral Commute Flows: The Actual Data, Baseline Model Predictions, and Alterative Model without Congestion

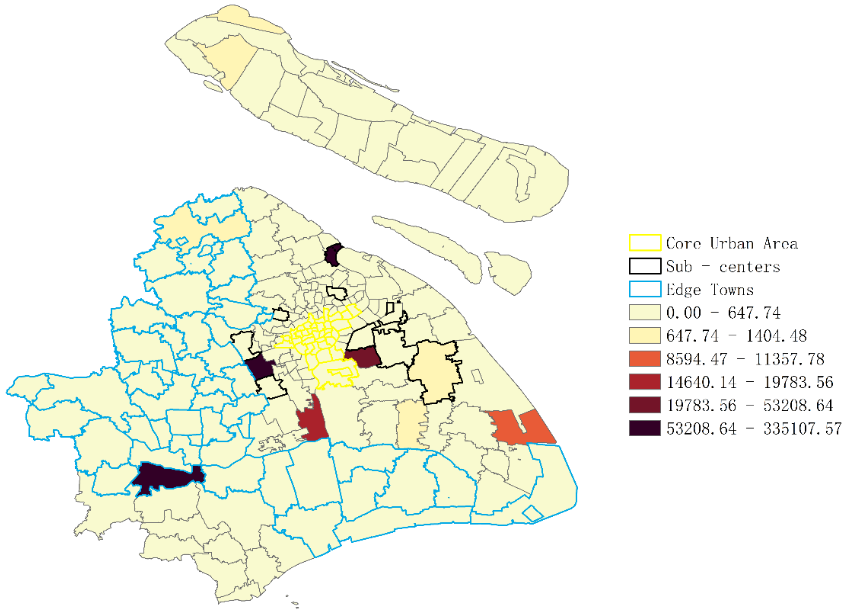




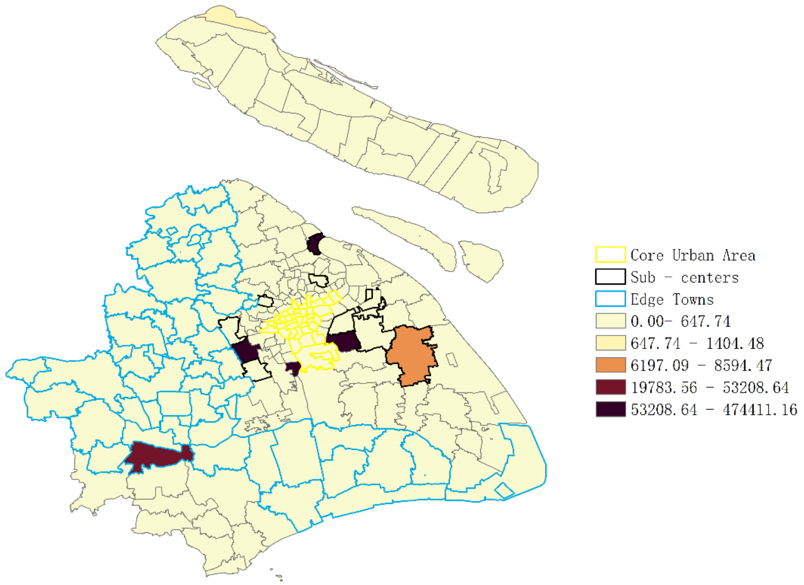
Counterfactual simulation results without congestion effects

Residential employment density

C2: Follow market signals



NewC2: Build within subcenters



PART EIGHT CONCLUSION

Conclusions

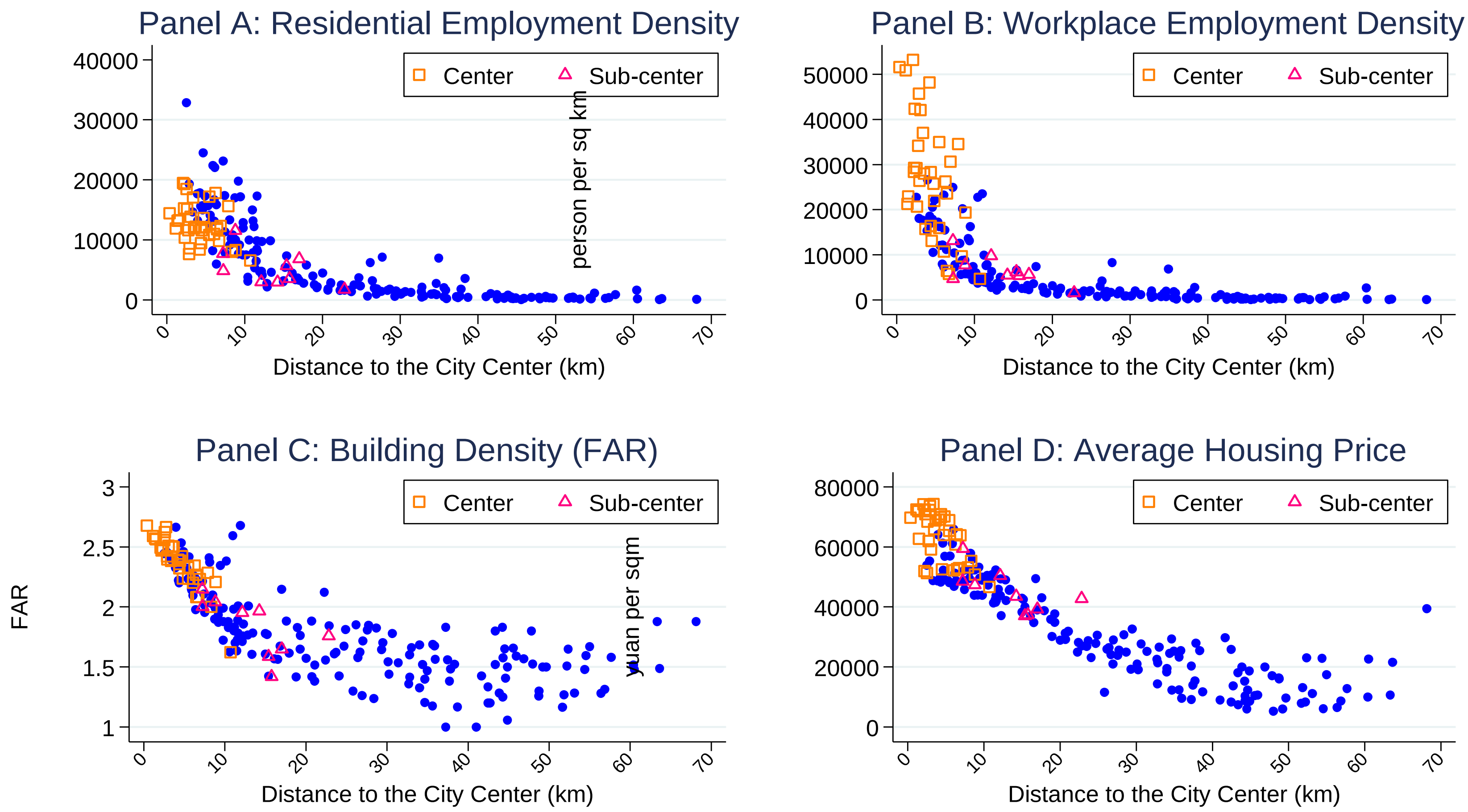
- A spatial GE model that incorporates both the benefits and costs of urban agglomeration economies endogenous to densities can fit the actual data better and provide more realistic counterfactual predictions regarding the outcomes of various land development policies.

- There exists spatial misallocation of floor space caused by restrictive zoning and building density constraints that do not align well with market demand. Lifting those constraints could enhance welfare by 9.1%.

- Given the historical spatial layout of floor space which presents spatial misallocation, the government's intervention on land quota allocation can overcome the coordination failure resulting from externalities. In particular, the prioritized development of the sub-centers would be a sensible approach to building up Shanghai in the future.
  - It can bring a welfare gain of 21.1% relative to the benchmark level, which is 6.2 pp. higher than the alternative plan that permits developers to build citywide following market signals.

Q&A

An overview of Shanghai: descriptive analysis



Commuting in Shanghai

- The average one-way commuting time is 43 minutes in Shanghai, the second longest in China. The average commuting speed is 25 km per hour, much slower than the average speed in the U.S. (45 km per hour). (Source: Baidu Map Open Platform)

- About 33% of commuters use public transit, particularly subways, 27% use cars or taxies, 24% walk and 16% bike. (Source: The 2020 Shanghai Transportation Annual Report) For commuters who travel more than 10 km, at least 80% of them use subway or cars. (Source: The 2015 mini census)

- Shanghai has a well-developed subway network, with a total length of subway lines was 705 km and 415 subway stations as of the end of 2018. (Source: Shanghai Municipal Transportation Commission)
  - Congestion in the subway mainly occurs at the starting and ending points when people enter or exit the subway stations. In rush hours, it may take as long as 10-20 minutes waiting in line to get on the train in a busy station.

- For car riders, over 80% of the car commute routes recommended by the popular navigation APPs utilize elevated highways ("*gao jia kuai su lu*") or controlled-access freeways ("*gao su lu*").
  - Most congestion happens at the entries and exits of highways/freeways.
  - Cross-traffic flows also affect commute speed on the highways/freeways, primarily through the slowdown at specific traffic bottlenecks along the routes.

Correlations between observed local attributes and calibrated fundamentals

	(1)	(2)
Dependent Variable	$\log(\bar{a})$	$\log(\bar{b})$
Log density of parking lots, train stations, airports, and docks	0.048***	-0.002
	(0.009)	(0.011)
Log density of subway stops	0.024***	0.001
	(0.006)	(0.006)
Log density of bus stops	-0.057***	-0.031
	(0.016)	(0.023)
Log density of general hospitals	-0.002	0.036***
	(0.011)	(0.012)
Log density of specialized hospitals	0.003	-0.016**
	(0.010)	(0.007)
Log density of emergency medical centers	-0.017	-0.055***
	(0.013)	(0.012)
Log density of disease control and prevention centers	-0.012	-0.052***
	(0.013)	(0.011)
Log density of kindergartens	-0.027***	0.001
	(0.009)	(0.012)
Green space share (forest and grass)	-0.138***	0.261***
	(0.048)	(0.092)
Observations	209	209
R-squared	0.295	0.788