Bidding for Firms or Bidding for Labor? Local Urban Land Allocation in China

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1. Introduction
2. Empirical Analysis
3. Theoretical Framework
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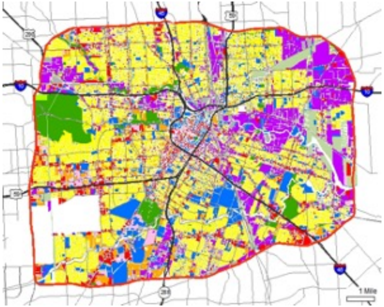
What is Land Allocation?

Figure 1: Urban Land Map of Houston



Allocating urban land area between INDUSTRIAL and RESIDENTIAL usages:

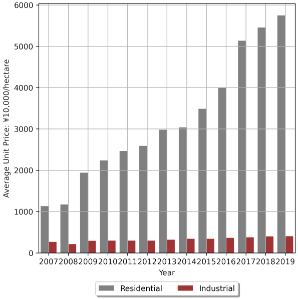
- **Industrial Land:** attract more firms, provide more jobs and higher wages.
- **Residential Land:** pushing up the housing prices and local living costs.

Motivation: China's Land Allocation

How would governments allocate local urban land when given authority to?

- Institutionally, all urban lands are owned by local governments in China

Figure 2: Unit Price of Land in China by Year



- A huge price gap between industrial and residential land price

⇒ Potential **Problem**: too much industrial land and too little residential land.

Questions

What is the the CAUSE and CONSEQUENCE of China's land allocation?

1. **Empirical patterns of urban land allocation across China:**

- Two Datasets:
  - Stock data: AREA of land of different usages at city-level.
  - Flow data: PRICE of land transactions between 2007 to 2019.
- Three stylized facts:
  - Price Gap Between Industrial and Residential Land
  - Price Gap is Wider in More Developed Region
  - Higher proportion of industrial land features higher price gap

$\Rightarrow$ Misallocation exists, and is more severe in more developed area.

Questions

What is the the CAUSE and CONSEQUENCE of land allocation?

2. **Build up a spatial model with endogenous land allocation:**

- Popular Belief on Causes: local governments want to boost local economic growth
  - Local industrial outputs v.s. Local welfare v.s Local public land revenue
  - Nash Equilibrium v.s. Cooperative Equilibrium
- Proposes an algorithm to compute Nash equilibrium by numerically evaluating gradients using backward propagation.

Results Preview

What did we find?

1. **In a Simplified Model with TWO Locations:**

- Local governments with higher city productivity tends to allocate higher proportions of land to industrial use
- Labor mobility (migration cost across cities) plays a key role in determining the share of industrial land.
  - Elasticity of Firm Relocation vs. Labor Migration
  - Land allocation vs. Population Management

Results Preview

What did we find?

2. **In the Quantitative Complete Model:**

- Calibrate the Nash Equilibrium with output-maximization governments
- Algorithm Contribution: "Backward Propagation"
- Counterfactual Analysis:
  - change government objectives to maximize local utilities
  - revise land allocation schemes towards price equalization in a free land market
  - reduce exogenous migration barriers.
  - harmonize land allocations with inter-regional transfers

Literature

- **Literature on Misallocation:**
  - Hsieh and Klenow (2009), Brandt et al. (2013), Hsieh and Moretti (2019)

  $\Rightarrow$ Endogenize the wedge in within-city land allocation.
- **Literature on Economic Geography:**
  - Redding and Rosi-hansberg (2017), Fajgelbaum et al. (2018), Parkhomenko (2020)

  $\Rightarrow$ Highlight the role of land as both housing source and industrial input.
- **Literature on Local Government Policies:**
  - Brueckner and Neumark (2014), Diamond (2017), Slattery (2018)

  $\Rightarrow$ A full-fledged quantitative evaluation.

Literature

- **Literature on land market distortions in China:**
  - **Impacts:** industrial selections with spillover effect (Fei, 2020; Tian et al., 2020); Limited effects in improving TFP (Tian et al., 2019)
  - **Cause:** corruption (Cai et al., 2013), fiscal revenue maximization (He et al., 2022), local economic growth (Henderson et al., 2022)

  $\Rightarrow$ Rigorously examine the "industrial competition hypothesis" in a GENERAL equilibrium.
- **Literature on computing Nash equilibrium in quantitative spatial economy:**
  - Ossa (2014), Wang (2020), Ferrari and Ossa (2023)

  $\Rightarrow$ Algorithm contribution in partial derivation of objective function w.r.t. policy instrument.

Background: Land Allocation Policy

- Institutionally, all urban "construction lands" are **state-owned** and leased to markets (1988).
    - 50 years for industrial land and 70 years for residential land.
    - Provincial governments: Quota for TOTAL construction land (protect agricultural land).
    - Local governments: discretion in land USAGE.

LandComposition LandDistribution AreaMap RevenueShare

Background: Land Allocation Policy

- Transfer methods: **Negotiation**, Bidding (seal-bid auction), Auction (English auction), and Listing (two-stage auction).
  - From 2007, all land transactions should be posted publicly.
    - **Flow Data From Transaction Records:** 2,243,010 land transactions from the Ministry of Land and Resources (2007-2019): Unit Price
    - **Stock Data From Yearbooks:** China Urban Construction Statistical Yearbook (1999-2019) from the Ministry of Housing and Urban-Rural Development: Accumulated Area

SummaryStat1 SummaryStat2 SummaryStat3

Stylized Fact 1: An Industrial Discount in Land Price

$$log(P_{ict}) = \beta_0 + \beta_1 IndustrialDummy_{ict} + \beta_2 IndD_{ict} \times Dist_c + \beta_3 X_{ict} + \alpha_{ct} + \varepsilon_{ict}$$

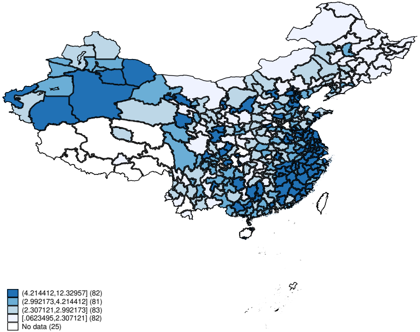
VARIABLES	(1) $log(P_{ict})$	(2) $log(P_{ict}/floor)$	(3) $log(P_{ict}/time)$	(4) $log(P_{ict})$	(5) $log(P_{ict}/floor)$	(6) $log(P_{ict}/time)$
$IndustrialDummy_{ict}$	-1.510***	-0.755***	-1.091***	-2.655***	-2.190***	-2.526***
	(-45.589)	(-26.714)	(-38.622)	(-10.255)	(-8.058)	(-9.296)
$log(DistanceCenter_{ict})$	-0.177***	-0.165***	-0.165***	-0.176***	-0.164***	-0.164***
	(-19.207)	(-22.664)	(-22.664)	(-18.804)	(-22.291)	(-22.291)
$InduDummy_{ict} \times log(DCoast_c)$				0.093***	0.117***	0.117***
				(4.449)	(5.460)	(5.460)
Other Characteristics	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**
City-Year FE	Y	Y	Y	Y	Y	Y
Observations	703,773	666,582	500,175	673,451	638,861	480,866
R-squared	0.475	0.471	0.588	0.471	0.468	0.584

Notes. X_{ict} is a vector of parcel characteristics for each land sale, including **the distance to the city center, the area of land, the rank of land quality, floor-area ratio (FAR) restrictions, the format of transactions, the source of land.**

Robustness1 Robustness2 Robustness3

Stylized Fact 2: Price Gap is Wider in More Developed Region

Figure 3: Geographical Distribution of Price Gap in China



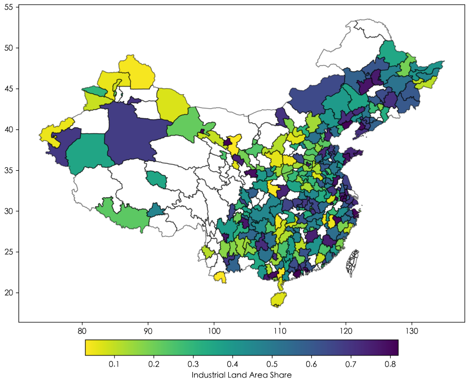
Notes. We run regressions above for each city and display the exponential of the coefficient of industrial dummy e^{β_1} in the map.

Stylized Fact 3: Price gap positively associated with higher industrial land area ratio

	Whole Sample Price Gap			Auction Sub-sample Price Gap		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	β_{IndD}	β_{IndD}^{FAR}	$\beta_{IndD}^{FAR\&time}$	β_{IndD}	β_{IndD}^{FAR}	$\beta_{IndD}^{FAR\&time}$
Panel A: Industrial Land Area Ratio in 2019						
IndustrialLandRatio2019	-0.348	-0.578**	-0.578**	-0.356	-0.539*	-0.539*
	(-1.369)	(-2.241)	(-2.240)	(-1.278)	(-1.857)	(-1.856)
log(DistanceCoast)	0.107***	0.117***	0.117***	0.130***	0.143***	0.143***
	(4.094)	(4.383)	(4.382)	(4.529)	(4.779)	(4.780)
Observations	273	273	273	274	274	274
R-squared	0.076	0.100	0.100	0.087	0.105	0.105
Panel B:Industrial Land Area Ratio in 2008						
IndustrialLandRatio2008	-0.487*	-0.459	-0.459	-0.271	-0.325	-0.325
	(-1.775)	(-1.635)	(-1.636)	(-0.899)	(-1.031)	(-1.031)
log(DistanceCoast)	0.107***	0.122***	0.122***	0.133***	0.149***	0.149***
	(4.106)	(4.586)	(4.585)	(4.655)	(4.993)	(4.993)
Observations	273	273	273	274	274	274
R-squared	0.080	0.092	0.092	0.084	0.097	0.097

Stylized Fact 3: Price gap positively associated with higher industrial land area ratio

Figure 4: Industrial Land Area Ratio in China



Summary:

The stylized facts we observed:

- A significant price gap between industrial and residential land price
- Developed areas tend to grant larger industrial land discount
- Higher industrial land share is correlated with a higher industrial discount

The questions we aim to answer:

- How is local governments allocating land usage?
- What is the Optimal/Efficient land allocation?
- What is the Consequence/Geographical results of different land allocation schemes?

Theoretical Framework

A spatial framework with N cities:

- Each city has a fixed total land endowment: industrial and residential usages.
- Representative firms produce a numeraire good using **labor and industrial land**.
  - Workers inelastically supply unit labor, and consume numeraire good and residential land.
  - Workers migrate based on local utility, realized preference shock, and migration cost.
- Local governments, taking conditions above and **other places'** land allocations as given, manipulate land shares to maximize **local output**, which forms a **Nash equilibrium**.

Theoretical Framework - Production

Production Location productivity is A_j.

- Representative firms produce a numeraire consumption good Y_j using labor L_j and industrial land K_j:

$$Y_j = A_j K_j^{\alpha} L_j^{1-\alpha}$$

- Wage and industrial land price equal to their marginal products.

$$P_j^k = \alpha A_j K_j^{\alpha-1} L_j^{1-\alpha} \tag{1}$$

$$W_j = (1-\alpha) A_j K_j^{\alpha} L_j^{-\alpha} \tag{2}$$

Theoretical Framework - Workers

Workers Location amenity is B_j. Worker spends its income W_j to maximize its utility by consuming goods c_j and residential land h_j:

$$\begin{aligned} max \quad U_j^o &= \varepsilon_j^o B_j (\frac{h_j}{\beta})^{\beta} (\frac{c_j}{1-\beta})^{1-\beta} \\ s.t \quad W_j &= P_j^h h_j + c_j \\ \Rightarrow V_j &= B_j \frac{W_j}{(P_j^h)^{\beta}} \end{aligned} \tag{3}$$

- Migration decisions subject to migration cost ($d_{ij} \leq 1$) with a Gumbel distribution preference shock:

$$\pi_{ij}^M = \frac{L_{ij}}{\bar{L}_i} = \frac{(d_{ij} V_j)^{\epsilon}}{\sum_{k=1}^N (d_{ik} V_k)^{\epsilon}} \tag{4}$$

- Population Distribution in the equilibrium follows: $L_j = \sum_{i=1}^N \pi_{ij} \bar{L}_i$

Theoretical Framework - Land and Government

- Local governments divide total land endowment $\bar{X}_j$ into K_j and H_j, and we use industrial land share $s_j \in (0,1)$ to denote the land allocation:

$$K_j = s_j \bar{X}_j$$
$$H_j = (1 - s_j)\bar{X}_j$$

- Residential and industrial land markets are cleared in each place to pin down their price:

$$p_j^H H_j = \beta W_j L_j \tag{5}$$
$$p_j^K K_j = \alpha Y_j \tag{6}$$

Equilibrium

An equilibrium with EXOGENOUS land allocations

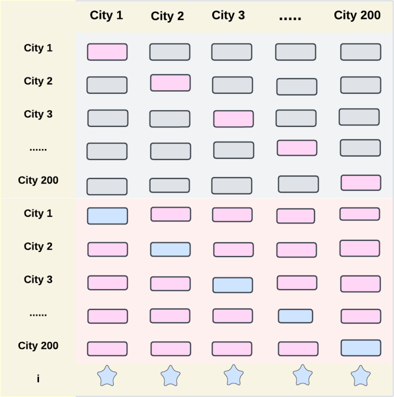
- Given a set of land allocations $\{s_j\}_{j=1}^N$ from local governments, a competitive equilibrium is a sequence of wages w_j, housing price p_j^H, industrial land price p_j^K and a sequence of worker allocations such that firms maximize their profits, households maximize their utility and all labor and land markets clear.
- Equilibrium proved to EXIST and is UNIQUE. Anatomy

Equilibrium with ENDOGENOUS land allocations

- Take other places' land allocations as given, each local ogvernment manipulates its own land allocation to maximize local output
- Strike a balance between bidding for firms (industrial output) and bidding for workers (household welfare).

Equilibrium

Figure 5: A Diagram of Nash Equilibrium



Theoretical Framework - Anatomy of Equilibrium

1 Uniqueness of Equilibrium

- The system of equations boil down to the following N equations:

$$U_j = \bar{M}\Big[\underbrace{B_j \bar{X}_j^{\alpha(1-\beta)+\beta} A_j^{\frac{1-\beta}{1-\gamma}}}_{\text{Exogenous Attractability for Workers}} \underbrace{s_j^{\alpha(1-\beta)}(1-s_j)^{\beta}}_{\text{Endogenous Attractability for Workers}}\Big]^{\frac{\epsilon}{\epsilon[\alpha(1-\beta)+\beta]+1}} \left\{\sum_{i=1}^{N} \frac{d_{ij}^{\epsilon}\bar{L}_i}{\sum_{k=1}^{N} d_{ik}^{\epsilon} U_k}\right\}^{-\frac{\epsilon[\alpha(1-\beta)+\beta]}{\epsilon[\alpha(1-\beta)+\beta]+1}} \quad (7)$$

- This is like a contraction mapping over $[U_1, U_2, ..., U_N]$, and we could iterate the equation till convergence to obtain a fixed point that is th equilibrium utility, then subsequently solve all the other variables.
  - ▷ To maximize local utility $\equiv$ maximize $[B_j \bar{X}_j^{\alpha(1-\beta)+\beta} A_j^{\frac{1-\beta}{1-\gamma}} s_j^{\alpha(1-\beta)}(1-s_j)^{\beta}]$: the "the strength to attract workers."
  - ▷ Optimal solution for local land allocation: $s^0 = \frac{\alpha(1-\beta)}{\alpha(1-\beta)+\beta}$ counterf1

Theoretical Framework - Anatomy of Equilibrium

2 Comparative Statics Analysis

- **Proposition 1:** Assuming perfect labor mobility ($d_{ij} = 1$ for all i, j), and taking the utilities of other locations as given, a local government's optimal industrial land ratio s_j to maximize local output Y_j increases with a higher local productivity A_j.

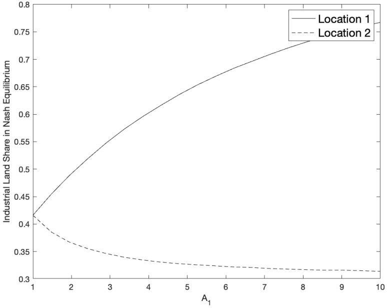
$$
\begin{aligned}
\max_{s_j} \quad & A_j K_j^{\alpha} L_j^{1-\alpha} \\
\text{subject to} \quad & \text{Equations } 1-3, 5, \\
\text{and } L_j = & \frac{V_j^{\epsilon}}{V_j^{\epsilon} + \underbrace{\sum_{i \neq j} V_i^{\epsilon}}_{\bar{V}}} \bar{L} \\
\Rightarrow & 1 + \frac{1}{f} + \frac{1}{f} \frac{V_j^{\epsilon}}{\bar{V}} = \frac{1-\alpha}{\alpha} [\frac{\beta}{\alpha(1-\beta)+\beta} \frac{1}{1-s_j} - 1]
\end{aligned}
$$

- From this equation, $\frac{\partial V_j}{\partial s_j} > 0$ and $\frac{\partial V_j}{\partial A_j} > 0$ and so $\frac{\partial s_j}{\partial A_j} > 0$

Theoretical Framework - Anatomy of Equilibrium

3. **Simulations with TWO locations** via brutal-force search
- Keeping other conditions constant, increasing the productivity difference: set $A_2 = 1$, and $A_1 \sim [1, 10]$:

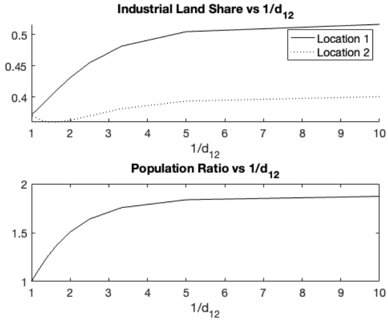
Figure 6: Comparative Statics: Impact of Productivity



Theoretical Framework - Anatomy of Equilibrium

3. **Simulations with TWO locations** via brutal-force search
   - Keeping other conditions constant, increasing one-way migration cost: set $d_2 1 = 1$, and $d_1 2 \sim [0.1, 1]$:

Figure 7: Comparative Statics: Impact of Migration Cost



Calibration Framework

1. Solve the Nash equilibrium where local governments are allocating urban land usage to maximize local industrial outputs
2. Match the equilibrium outcome with the observed land allocation in China for the years 2009 and 2019
3. Calibrate the city productivity, amenities, and migration costs by targeting spatial land allocations, population distribution, and industrial outputs observed in each city.

Algorithms: Solve the Nash Equilibrium

- Equilibrium with exogenous $\{s_i\}_{i=1}^N$ could be easily calculated.
- Equilibrium with endogenous land allocation could theoretically be calculated by a brute force grid search ($\times$).
- Expediting the computation by deriving the first order conditions($\times$).
  - ▷ It is difficult to obtain analytical form of $\frac{\partial Y}{\partial s}$.
- Ossa (2014) and Wang (2020): optimization routines in MATLAB or KNITRO($\times$).
  - ▷ 240 cities is still a heavy burden for both algorithms.

$\Rightarrow$ do not seek to fully characterize $\frac{\partial Y}{\partial s}$ but compute the numerical values of partial derivatives for each equation and employ the chain rule (commonly referred to as "backward propagation") to iteratively calculate $\frac{\partial Y}{\partial s}$.

Algorithms: Solve the Nash Equilibrium

- Let the bold symbol $\boldsymbol{x}$ denote the vector of variables $[x_1, x_2, \ldots, x_N]^T$. According to Equation 7, we can define the local utility $\boldsymbol{U}$ as an implicit function of $\boldsymbol{s}$:

$$\boldsymbol{U} = F_1(\boldsymbol{s})$$

$$\boldsymbol{L} = F_2(\boldsymbol{s}, \boldsymbol{U}), \text{which is} \quad L_j = \bar{M}\left[\frac{B_j H_j^{\beta} K_j^{\alpha(1-\beta)} A_j^{\frac{1-\beta}{1-\gamma}}}{U_j^{1/\epsilon}}\right]^{\frac{1}{\alpha(1-\beta)+\beta}}$$

$$\boldsymbol{Y} = F_3(\boldsymbol{s}, \boldsymbol{L}), \text{which is} \quad Y_j = A_j \bar{X}_j s_j^{\alpha} L_j^{1-\alpha}$$

- Therefore, a backward propagation to approximate the partial derivatives of local industrial output (objective functions) with respect to local land allocation (policy function) is:

$$\frac{\partial \boldsymbol{Y}}{\partial \boldsymbol{s}} = \frac{\partial F_3(\boldsymbol{s}, \boldsymbol{L})}{\partial \boldsymbol{s}} + \frac{\partial F_3(\boldsymbol{s}, \boldsymbol{L})}{\partial \boldsymbol{L}} \left\{ \frac{\partial F_2}{\partial \boldsymbol{s}} + \frac{\partial F_2}{\partial \boldsymbol{U}} \frac{\partial F_1}{\partial \boldsymbol{s}} \right\}$$

Algorithms: Solve the Nash Equilibrium

- Calculate the value of $\boldsymbol{U} = F_1(\boldsymbol{s})$ as an implicit function determined by $\Omega(\boldsymbol{U}, \boldsymbol{s}) = 0$, where

$$\Omega_j = U_j - \bar{M}^{\frac{\epsilon[\alpha(\mathbf{1}-\beta)+\beta]}{\epsilon[\alpha(\mathbf{1}-\beta)+\beta]+\mathbf{1}}} [B_j \bar{X}_j^{\alpha(\mathbf{1}-\beta)+\beta} A_j^{\frac{\mathbf{1}-\beta}{\mathbf{1}-\gamma}} s_j^{\alpha(\mathbf{1}-\beta)} (1-s_j)^{\beta}]^{\frac{\epsilon}{\epsilon[\alpha(\mathbf{1}-\beta)+\beta]+\mathbf{1}}} \left\{ \sum_{i=1}^{N} \frac{d_{ij}^{\epsilon} \bar{L}_i}{\sum_{k=1}^{N} d_{ik}^{\epsilon} U_k} \right\}^{-\frac{\epsilon[\alpha(\mathbf{1}-\beta)+\beta]}{\epsilon[\alpha(\mathbf{1}-\beta)+\beta]+\mathbf{1}}}$$

- Then, according to the implicit function theorem, we can obtain the $N \times N$ Jacobian matrix of $\boldsymbol{U}$ with respect to $\boldsymbol{s}$:

$$\frac{\partial \boldsymbol{U}}{\partial \boldsymbol{s}} = -[\frac{\partial \boldsymbol{\Omega}}{\partial \boldsymbol{s}}]^{-1} \frac{\partial \boldsymbol{\Omega}}{\partial \boldsymbol{U}}$$

Algorithms: Solve the Nash Equilibrium

- $\frac{\partial \boldsymbol{\Omega}}{\partial \boldsymbol{s}}$ and $\frac{\partial \boldsymbol{\Omega}}{\partial \boldsymbol{U}}$ are the corresponding $N \times N$ Jacobian matrix, whose $\{j,k\}-$th element could be derived as:

$$\frac{\partial \Omega_j}{\partial s_k} = \begin{cases} 0 & \text{if } j \neq k \\ -\frac{\epsilon}{\epsilon[\alpha(1-\beta)+\beta]+1} U_j \left(\frac{\alpha(1-\beta)}{s_j} - \frac{\beta}{1-s_j}\right) & \text{if } j = k \end{cases}$$

$$\frac{\partial \Omega_j}{\partial U_k} = I\{j=k\} - \frac{\epsilon[\alpha(1-\beta)+\beta]}{\epsilon[\alpha(1-\beta)+\beta]+1} U_j \left\{ \sum_{i=1}^{N} \frac{d_{ij}^{\epsilon} \bar{L}_i}{\sum_{k=1}^{N} d_{ik}^{\epsilon} U_k} \right\}^{-1} \left\{ \sum_{i=1}^{N} \frac{d_{ij}^{\epsilon} d_{ik}^{\epsilon} \bar{L}_i}{(\sum_{k=1}^{N} d_{ik}^{\epsilon} U_k)^2} \right\}$$

- We then proceed to update $\boldsymbol{s}$ at the $(i+1)$-th iteration, $\boldsymbol{s}^{(i+1)}$, based on $\boldsymbol{s}^{(i)}$ using the following rule:

$$\boldsymbol{s}^{(i+1)} = \boldsymbol{s}^{(i)} + step \cdot \frac{dY}{ds}$$

- Keep updating until $\frac{dY}{ds}$ approaches zero, where step is a small positive number.

Algorithms: Calibrate the Nash Equilibrium

- **External Calibration**

Table 1: Externally Calibrated Parameter Values

Parameter	Value	Description	Source
α	0.07	Land intensity of production	Henderson et al.(2022)
β	0.3	Expenditure share on housing	
η	3	Elasticity of migration	Tombe and Zhu(2019)

- **Internal Calibration**
  - match with 1) industrial output distribution, 2) population distribution, and 3) industrial land area ratio in each city.
  - city productivity A_i, and city amenity B_i, migration cost across cities d_{ij}, the initial population distribution $\{\bar{L}_i\}$,

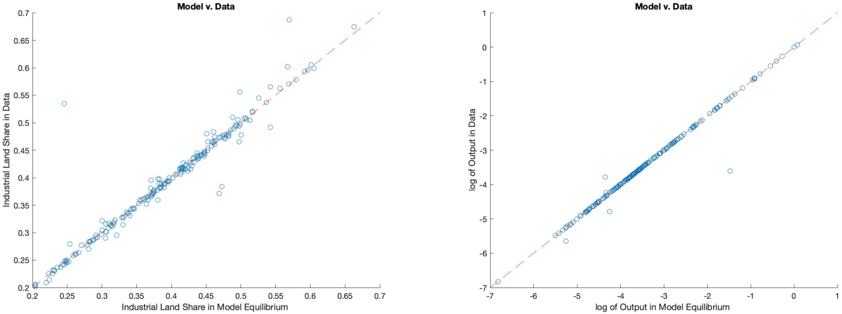
Algorithms: Calibrate the Nash Equilibrium

1. Use bisection method to adjust the values of city productivity A_j and migration cost $\tilde{d}_j$ in each city to ensure that the partial derivative $\frac{dY_j}{ds_j} = 0$ aligns when the industrial land share $\{s_j\}$ takes the realized values from data.
2. Using the city productivity A_j and migration cost $\tilde{d}_j$ above, calculate a Nash equilibrium and obtain the simulated industrial land area ratio from model, denoted as $\left\{s_j^0\right\}$.
3. Apply the bisection method to adjust the initial population distribution $\bar{L}_j$ until the population distribution across cities from the data matches the model under the specific industrial land share $\left\{s_j^0\right\}$.
4. Iterate the above steps until the simulated values closely approximate the empirical data.
5. Finally, adjust the value of A_j to match the industrial output distribution. Concurrently, modify B_j to ensure that the term $A_j^{\frac{1-\beta}{1-\gamma}} B_j$ remains consistent, thereby maintaining the Nash equilibrium land allocation.

Calibration Results

The model successfully matches all the relevant moments:

Figure 8: Model Fittings



(a) Land Allocations

(b) Population Distribution

Counterfactual Analysis

- **Counterfactual I: Utility Maximizing Local Governments**
  - ▷ According to Equation 7, local utility would be maximized when $\frac{\partial U_j}{\partial s_j} = 0$, which sets $s_j = \frac{\alpha(1-\beta)}{\alpha(1-\beta)+\beta}$. ▸ LocalUtility
  - ▷ the intensity of industrial land in firms' production, α, and the proportion of residential land (housing) in households' expenditure, β.
- **Counterfactual II: Perfectly Mobile Workers**
  - ▷ reduce the calibrated migration costs d_{ij} from the benchmark to be 1
  - ▷ should expect this adjustment to pressure local governments to slightly increase residential land shares to boost their local utility

Counterfactual Analysis

- **Counterfactual III: Free Land Market**
  - Local governments lose their control over land usage, and local landlords maximize total revenue from land sales.
  - Mathematically, equivalent to the case where local governments maximize land sales revenue and waste them.

$$\beta W_j L_j = p_j^h H_j$$

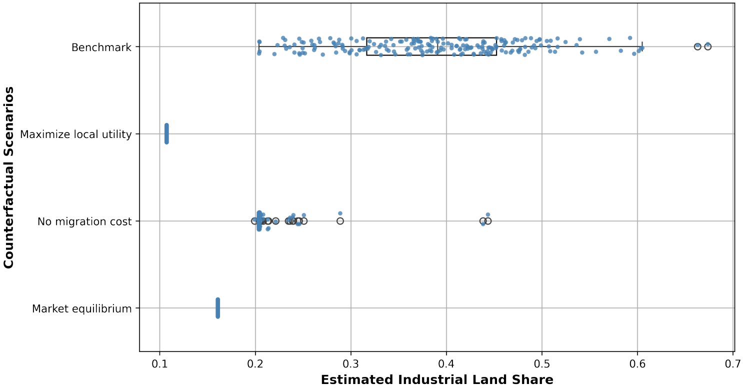
$$\frac{W_j L_j}{p_j^k K_j} = \frac{1-\alpha}{\alpha}$$

$$p_j^h = p_j^k$$

$$\Rightarrow K_j = \frac{\alpha}{\alpha + (1-\alpha)\beta}\bar{X}_j; \quad H_j = \frac{(1-\alpha)\beta}{\alpha + (1-\alpha)\beta}\bar{X}_j$$

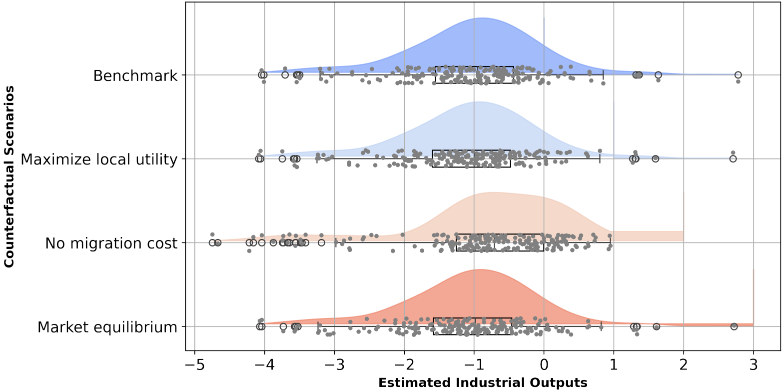
Counterfactual Analysis

Figure 9: Distribution of Estimated Industrial Land Share across Cities



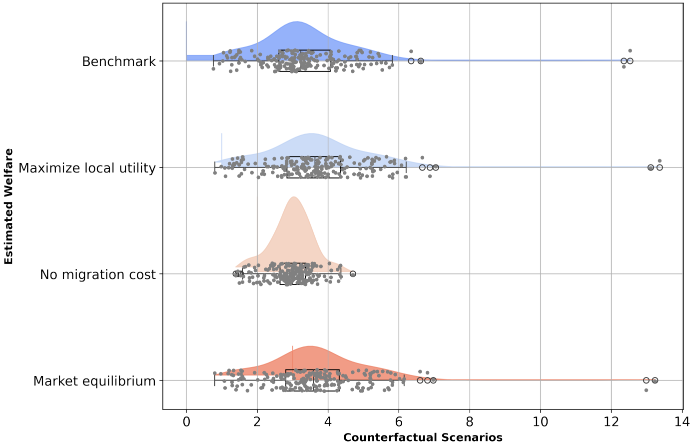
Counterfactual Analysis

Figure 10: Distribution of Estimated Industrial Outputs across Cities



Counterfactual Analysis

Figure 11: Distribution of Estimated Welfare across Cities



Counterfactual Analysis

- **Counterfactual IV: Central Government with Inter-regional Transfer**
  - ▷ From the perspective of a social planner, the objective is to find a policy that can increase aggregate industrial outputs without compromising the utility at either location.
  - ▷ Under the specified parameter and fundamental values, we search across a mesh grid for s_1 and s_2 spanning the range $[0, 1]$. However, we found that no land allocation policy under which the new equilibrium simultaneously meets the following three criteria:
    1. $U_1^{neweq} > U_1^{benchmark}$
    2. $U_2^{neweq} > U_2^{benchmark}$
    3. $Y_1^{neweq} + Y_2^{neweq} > Y_1^{benchmark} + Y_2^{benchmark}$

Counterfactual Analysis

- **Counterfactual IV: Central Government with Inter-regional Transfer**
  - Inspired by Fajgelbaum and Gaubert (2020), we now consider a scenario where the central government controls both the land allocation in each location and implements a lump-sum transfer of numeraire goods

Table 2: Central Government with Inter-regional Transfer

Moment	Notation	Benchmark	Cf IV
Industrial Land Ratio of Location 1	s_1	0.3463	0.4
Industrial Land Ratio of Location 2	s_2	0.4272	0.4
Utility of Location 1 Worker	V_1	0.9924	0.9930
Utility of Location 2 Worker	V_2	1.2677	1.2694
Population Ratio	L_2/L_1	1.6875	1.6875
Inter-regional Transfer/ Aggregate Consumption		0	1.06%
Aggregate Output	$Y_1 + Y_2$	0.7028	0.7029

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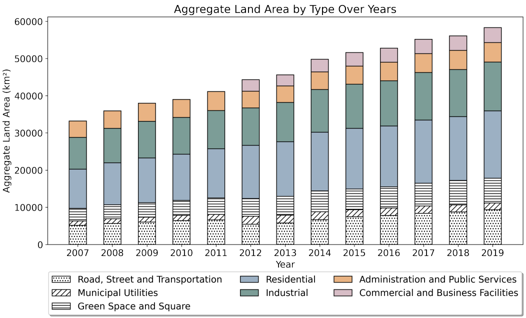
Figure 12: Aggregate Urban Land Area by Usages and Years (Unit: km^2)



Notes: Data Source: Urban Construction Statistical Yearbook of China (2007-2019). Back

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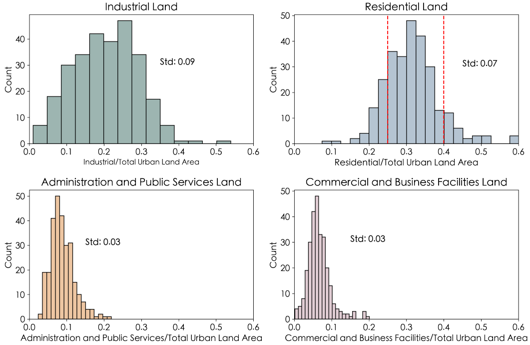
Figure 13: Distribution of Land Area Share in 2019 Across Cities



Notes: Data Source: Urban Construction Statistical Yearbook of China 2019. Back

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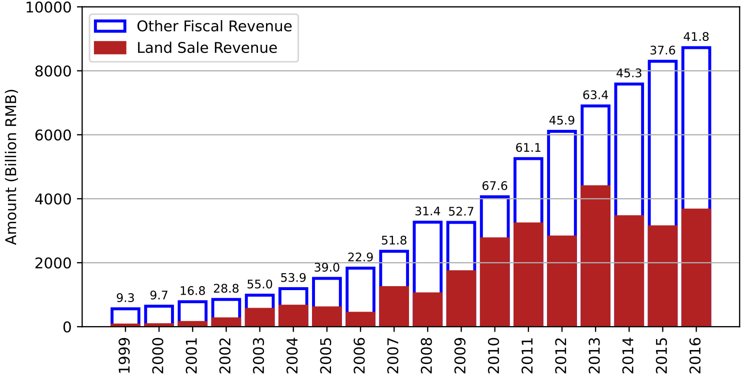
Figure 14: Sources of Local Government Revenue



Notes: Data Source: City Yearbooks of China.

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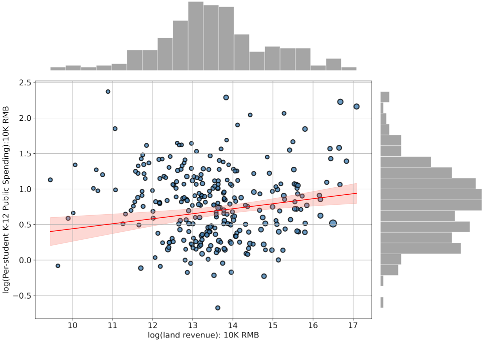
Figure 15: Land Sale Revenue and Public Education Expenditure, 2010



Background: Land Allocation Policy

Table 3: Summary Statistics of Statistics Yearbook Data (2007-2021)

	Industrial Land Area		Residential Land Area		Industrial Land Ratio		Number of
Year	Mean	SD	Mean	SD	Mean	SD($\times$100)	Observations
2007	15.182	3.639	22.698	6.399	0.370	0.542	610
2008	16.170	3.716	24.681	7.144	0.368	0.541	611
2009	17.999	4.656	26.084	7.371	0.369	0.539	612
2010	18.816	5.361	26.770	7.459	0.362	0.536	610
2011	19.353	5.883	28.519	8.018	0.356	0.539	609
2012	19.866	5.468	31.643	8.155	0.324	0.629	607
2013	20.864	5.747	32.651	8.538	0.329	0.598	608
2014	22.444	6.249	34.910	9.227	0.328	0.588	615
2015	23.421	6.655	36.251	9.791	0.331	0.596	616
2016	23.818	6.745	36.064	9.862	0.333	0.599	616
2017	25.116	6.739	37.937	9.963	0.332	0.582	614
2018	24.817	6.931	38.058	10.587	0.327	0.582	613
2019	25.713	7.166	39.888	10.979	0.327	0.579	614
2020	26.392	8.081	39.965	11.112	0.326	0.599	613
2021	26.367	8.511	41.122	11.709	0.323	0.574	612

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Background: Land Allocation Policy

Table 4: Summary Statistics of Land Transaction Database (2007-2019)

		Freq.	Percent	
Number of Transactions	Urban	802,864	35.79	
	Rural	1,440,146	64.21	
Urban Land Transactions				
Land source	New Construction Sites	344,598	42.92	
	New Construction Sites (from Stock Pool)	98,137	12.22	
	Existing Construction Sites	360,129	44.86	
Transaction Saleway	Allocation	251,004	31.26	
	Negotiation	247,625	30.84	
	Auction	38,247	4.76	
	Bidding	4,036	0.5	
	Listing	261,952	32.63	
Land Type	Residential Land	275,432	34.57	
	Industrial Land	161,898	20.32	
	Commercial Land	103,022	12.93	
	Transportation Land	84,569	10.61	
	Public Admin & Service Land	127,048	15.95	
	Other Types	44,782	5.62	
Other Characteristics	**Mean**	**Std.**	**Min**	**Max**
Area of Land Parcel	4.167	80.320	0	42559
Total Price of Land Parcel	16,123.450	5,943,619	0	3.62E+09
Unit Price Per Hectares	1,136.755	2,324.461	0	12750.02
FAR Lower Bound	0.831	0.790	0	5
FAR Upper Bound	1.731	1.473	0	7
Distance to City Center	40.360	153.878	0	2941.959

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Table 5: Summary Statistics of Land Transaction Database 2

	New Construction Sites		New Sites from Stock Pool		New Construction Sites	
Transaction Saleway	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
Allocation	151,556	43.98	36,812	37.51	62,636	17.39
Negotiation	20,549	5.96	24,701	25.17	202,375	56.2
Auction	19,303	5.6	5,515	5.62	13,429	3.73
Bidding	1,818	0.53	475	0.48	1,743	0.48
Listing	151,372	43.93	30,634	31.22	79,946	22.2
	New Construction Sites		New Sites from Stock Pool		New Construction Sites	
Land Usage	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
Residential Land	53,528	15.56	35,758	36.44	186,146	52.5
Industrial Land	103,028	29.94	14,571	14.85	44,299	12.49
Commercial Land	35,624	10.35	11,281	11.5	56,117	15.83
Transportation Land	58,760	17.08	13,053	13.3	12,756	3.6
Public Admin & Service Land	73,731	21.43	16,446	16.76	36,871	10.4
Water Facilities Land	1,700	0.49	361	0.37	471	0.13
Public Rental Housing Land	1,536	0.45	347	0.35	1,478	0.42
Low-Rent Housing Land	1,855	0.54	925	0.94	1,512	0.43
Affordable Housing Land	9,985	2.9	4,759	4.85	12,657	3.57
	Residential Land		Industrial Land		Commercial Land	
Transaction Saleway	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
Allocation	15,158	5.5	3,371	2.08	2,259	2.19
Negotiation	157,296	57.11	30,610	18.91	37,705	36.6
Auction	21,793	7.91	6,574	4.06	8,679	8.42
Bidding	1,728	0.63	1,082	0.67	1,068	1.04
Listing	79,457	28.85	120,261	74.28	53,311	51.75
	Residential Land		Industrial Land		Commercial Land	
Land Source	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
New Construction Sites	53,528	19.43	103,028	63.64	35,624	34.58
New Sites from Stock Pool	35,758	12.98	14,571	9	11,281	10.95
Existing Construction Sites	186,146	67.58	44,299	27.36	56,117	54.47

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Appendix 1: Robustness check of the price gap regressions

Table 6: Robustness Check 1: Subsamples of transactions via public auctions

VARIABLES	(1) $log(P_{ict}/floor)$	(2) $log(P_{ict}/time)$	(3) $log(P_{ict})$	(4) $log(P_{ict}/floor)$	(5) $log(P_{ict}/time)$	(6) $log(P_{ict})$
$IndDummy_{ict}$	-1.792***	-1.071***	-1.407***	-3.386***	-2.831***	-3.168***
	(-85.987)	(-56.323)	(-74.022)	(-19.221)	(-16.161)	(-18.082)
$IndDummy_{ict} \times Dist_c$				0.130***	0.143***	0.143***
				(9.096)	(10.174)	(10.174)
$log(dcity_{ict})$	-0.179***	-0.156***	-0.156***	-0.178***	-0.156***	-0.156***
	(-32.938)	(-29.616)	(-29.616)	(-32.776)	(-29.806)	(-29.806)
$log(area_{ict})$	0.001	0.013**	0.013**	-0.003	0.007	0.007
	(0.187)	(2.499)	(2.499)	(-0.721)	(1.464)	(1.464)
$log^2(area_{ict})$	-0.009***	-0.009***	-0.009***	-0.010***	-0.010***	-0.010***
	(-4.311)	(-4.009)	(-4.009)	(-4.645)	(-4.366)	(-4.366)
City - Year FE	Y	Y	Y	Y	Y	Y
Observations	147,065	152,081	152,081	147,065	152,081	152,081
R-squared	0.785	0.657	0.707	0.788	0.662	0.711

Notes. X_{ict} is a vector of parcel characteristics for each land sale, including **the distance to the urban district center or rural county center, the leasing time left, the area of land, the rank of land quality, floor-area ratio (FAR) restrictions, the format of transactions, the source of land.** Robustness check by excluding all transactions via negotiation or allocation.

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Appendix 1: Robustness check of the price gap regressions

Table 7: Robustness Check 2: Subsamples of TWO lands and only transactions via public auctions

VARIABLES	(1) $log(P_{ict}/floor)$	(2) $log(P_{ict}/time)$	(3) $log(P_{ict})$	(4) $log(P_{ict}/floor)$	(5) $log(P_{ict}/time)$	(6) $log(P_{ict})$
$IndDummy_{ict}$	-1.784***	-1.075***	-0.738***	-3.391***	-2.841***	-2.505***
	(-84.567)	(-56.452)	(-38.777)	(-19.178)	(-16.216)	(-14.296)
$IndDummy_{ict} \times Dist_c$				0.131***	0.143***	0.143***
				(9.137)	(10.208)	(10.208)
$log(dcity_{ict})$	-0.179***	-0.156***	-0.156***	-0.178***	-0.156***	-0.156***
	(-32.915)	(-29.578)	(-29.578)	(-32.729)	(-29.771)	(-29.771)
$log(area_{ict})$	0.001	0.012**	0.012**	-0.003	0.007	0.007
	(0.225)	(2.449)	(2.449)	(-0.686)	(1.405)	(1.405)
$log^2(area_{ict})$	-0.009***	-0.009***	-0.009***	-0.010***	-0.009***	-0.009***
	(-4.293)	(-3.948)	(-3.948)	(-4.628)	(-4.305)	(-4.305)
City - Year FE	Y	Y	Y	Y	Y	Y
Observations	147,065	152,081	152,081	147,065	152,081	152,081
R-squared	0.786	0.657	0.609	0.788	0.662	0.614

Notes. X_{ict} is a vector of parcel characteristics for each land sale, including **the distance to the urban district center or rural county center, the leasing time left, the area of land, the rank of land quality, floor-area ratio (FAR) restrictions, the format of transactions, the source of land.** Robustness check by keeping only residential and industrial land transaction records, excluding all transactions via negotiation or allocation.

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Appendix 1: Robustness Check of the Price Gap Regressions

Table 8: Robustness Check 3: Controlling Market Extremes

VARIABLES	(1) $log(P_{ict}/floor)$	(2) $log(P_{ict}/time)$	(3) $log(P_{ict})$	(4) $log(P_{ict}/floor)$	(5) $log(P_{ict}/time)$	(6) $log(P_{ict})$
$IndDummy_{ict}$	-1.709***	-1.011***	-0.675***	-3.439***	-2.907***	-2.570***
	(-76.782)	(-50.520)	(-33.709)	(-19.710)	(-16.821)	(-14.874)
$IndDummy_{ict} \times Dist_c$				0.141***	0.154***	0.154***
				(10.037)	(11.196)	(11.196)
$log(dcity_{ict})$	-0.179***	-0.156***	-0.156***	-0.178***	-0.156***	-0.156***
	(-31.277)	(-28.224)	(-28.224)	(-31.167)	(-28.409)	(-28.409)
$log(area_{ict})$	-0.004	0.010**	0.010**	-0.009**	0.004	0.004
	(-0.830)	(2.162)	(2.162)	(-1.978)	(0.860)	(0.860)
$log^2(area_{ict})$	-0.009***	-0.008***	-0.008***	-0.009***	-0.009***	-0.009***
	(-3.815)	(-3.703)	(-3.703)	(-4.144)	(-4.044)	(-4.044)
City - Year FE	Y	Y	Y	Y	Y	Y
Observations	129,462	132,887	132,887	129,462	132,887	132,887
R-squared	0.777	0.647	0.599	0.780	0.653	0.606

Notes. X_{ict} is a vector of parcel characteristics for each land sale, including **the distance to the urban district center or rural county center, the leasing time left, the area of land, the rank of land quality, floor-area ratio (FAR) restrictions, the format of transactions, the source of land.** Robustness check by keeping only residential and industrial land transaction records, excluding all transactions via negotiation or allocation. Robustness check by controlling buyer information (firms, governments, or urban construction investment enterprises) and excluding submarkets with extreme concentrations (one single agent holding more than 10% of land area) or scarce samples (less than 100 transactions).

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