Applying the Quantitative Urban Model to Cities in Developing Countries

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Motivation for this Paper

- Recent advances in modeling the internal structure of cities have primarily been applied to cities in developed countries.
- In these settings we often have access to rich data at a fine geographical scale.
- However, the majority of the world's urban population lives in cities in developing countries.
- For many cities in developing countries data from traditional sources, particularly on prices, is scarce or non-existent.
- How useful are quantitative urban models in these settings?

This Paper

- In this paper we use Dhaka as an example to show how quantitative urban models can be calibrated in data-sparse environments.
- We build on recent work by Kreindler and Miyauchi (2020) who use cell phone data from Dhaka to estimate commuting costs.
- We show how these estimates can be combined with newly available satellite data on the built-up area and building heights to estimate the housing supply elasticity and land prices.
- To illustrate how the calibrated model can be used for policy analysis we consider model counterfactuals in which the housing supply elasticity is increased by 25% and a radial road is constructed.

Related Literature

- Size and internal structure of cities
  - Lucas Rossi-Hansberg (2002), Ahlfeldt Redding Sturm Wolf (2015), Allen Arkolakis Li (2016), Tsivanidis (2019), Heblich Redding Sturm (2020), and Redding and Rossi-Hansberg (2017)
- Agglomeration economies
  - Ciccone Hall (1996), Moretti (2004), Combes Duranton Gobillon Roux (2010), Kline Moretti (2014), Allen Arkolakis (2014), Rosenthal Strange (2004), and Melo Graham Noland (2009)
- Housing Supply
  - Saiz (2010), Ahlfeldt McMillen (2018), Ahlfeldt and Barr (2021), Combes Duranton Gobillion (2021), Baum-Snow Lu (2021), Henderson Regan Venables (2021)

Outline of the Talk

- Data
- Theoretical model
- Estimation of the model
- Counterfactuals
- Conclusion

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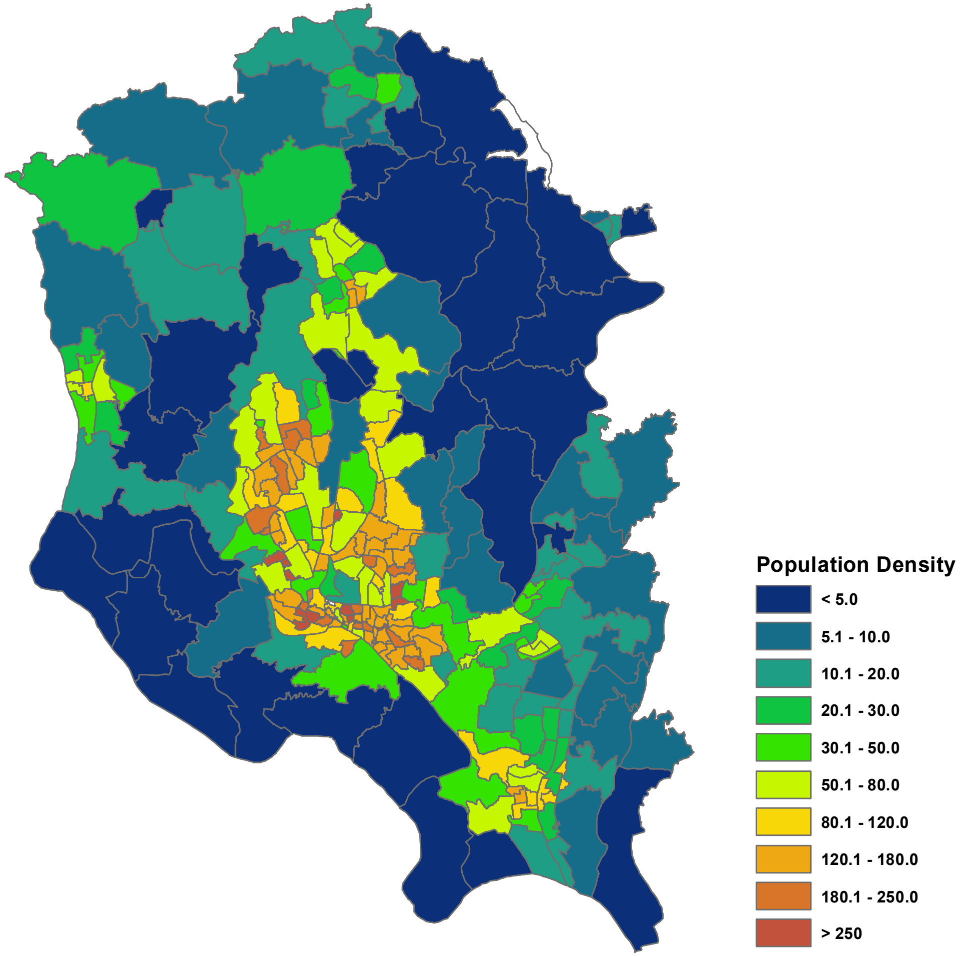
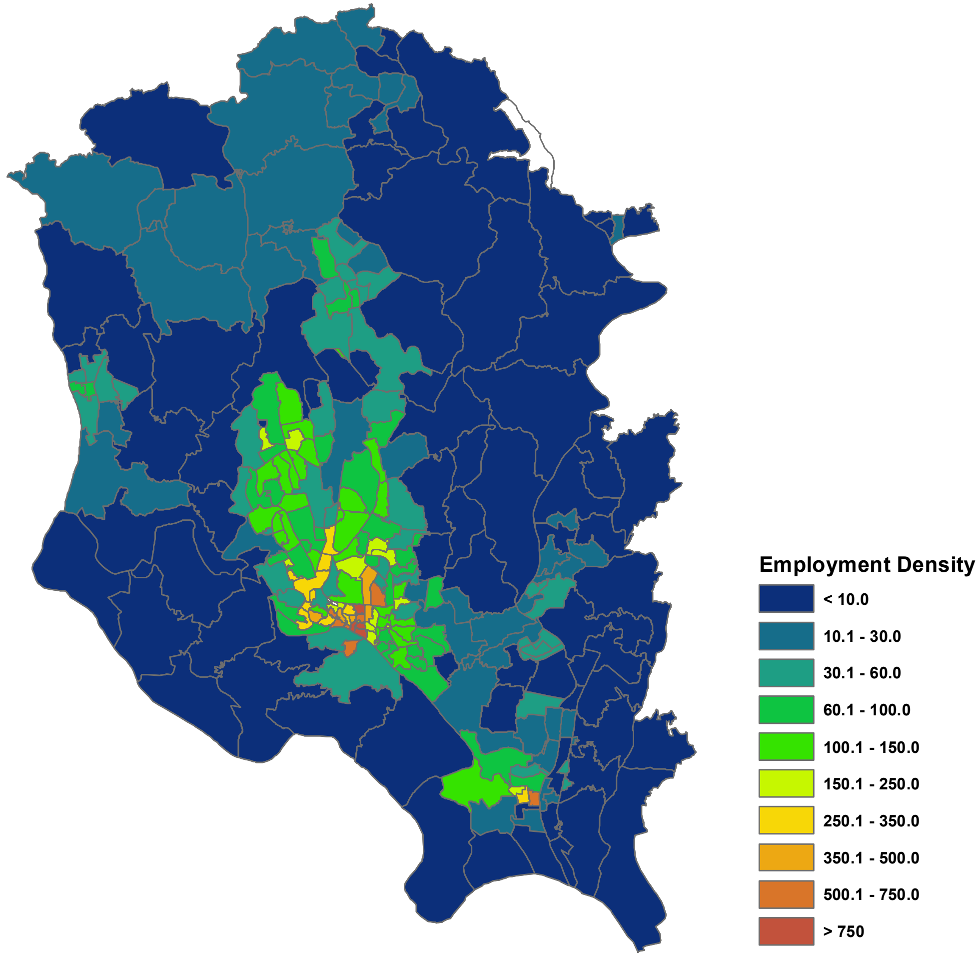
Data for Dhaka

- Bird and Venables (2019) define the metropolitan area of Dhaka and partition this area into 266 wards ("unions").
- For each ward we observe population from the 2010 Population Census and employment at workplace from the 2013 Employment Census.
- We use driving time data between cell phone towers from Kreindler and Miyauchi (2020) to estimate travel times between all wards.
- The key new data source is new satellite data on the built-up area and average height of buildings in all wards of Dhaka from the German Aerospace Center (DLR).

Population and Employment Density

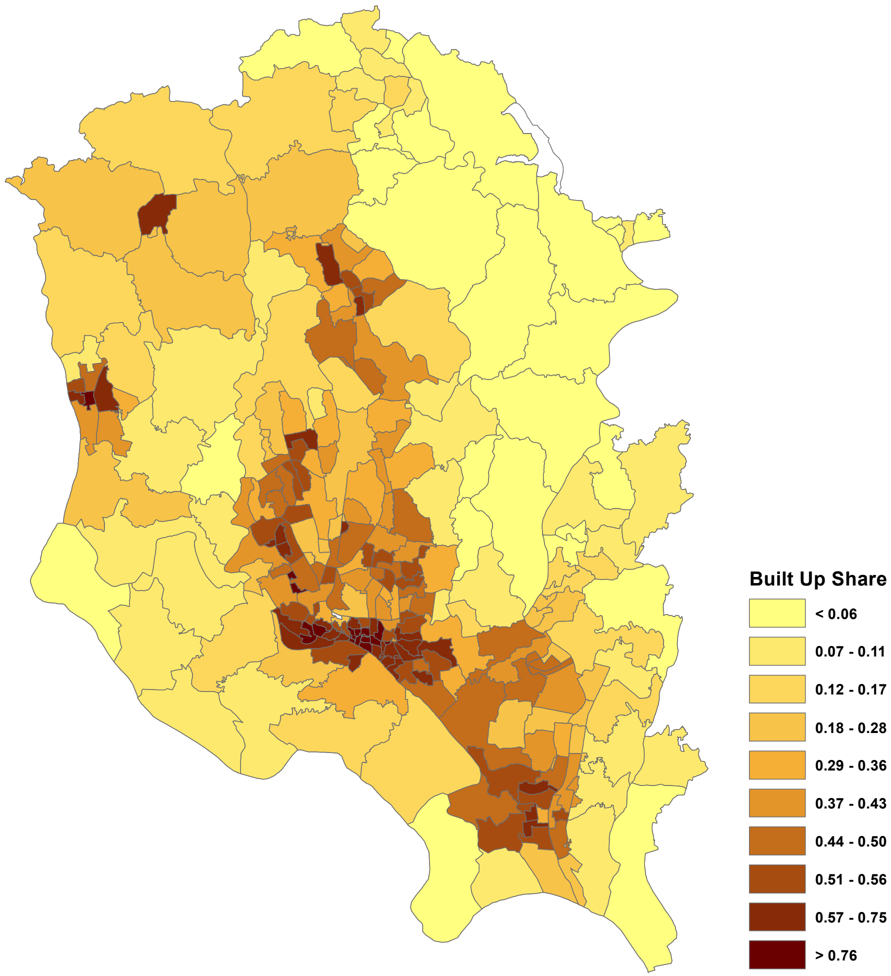


(a) Population Density (person per hectare)

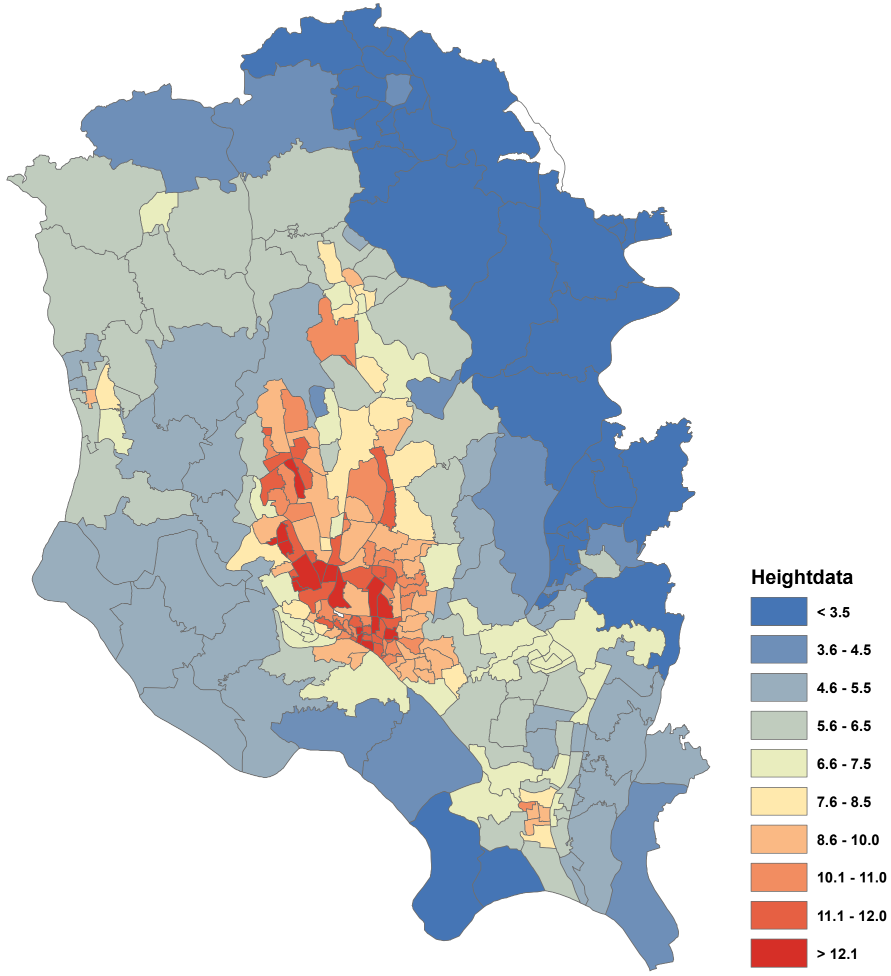


(b) Employment Density (person per hectare)

Built-up Area and Height



(a) Share of Developed Land in the DLR data



(b) Average Height in the DLR data (meters)

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Model Overview

- We consider a simple quantitative urban model, which builds closely on the literature that has developed in the wake of Ahlfeldt et al. (2015).
- The city consists of a discrete number of locations in which land is transformed into floor space by a competitive construction sector.
- The transport network determines travel times between locations.
- The city is populated by homogenous workers who consume housing and a freely tradable final good and decide where to live and work.
- Labour supply to the city depends on the relative attractiveness of the city and the wider economy.
- Competitive firms use floor space, labour and capital to produce the final good and their productivity varies across locations in the city.

Consumption

- Worker preferences take the Cobb-Douglas form, so that the indirect utility for a worker ω residing in location n and working in location i is:

$$V_{ni}(\omega) = \frac{b_{ni}(\omega) B_n}{d_{ni}} \frac{w_i}{P_n^{\alpha} Q_n^{1-\alpha}} \tag{1}$$

  - w_i is the wage the worker earns at location i
  - P_n denotes the price of consumption goods in location n
  - Q_n denotes the price of residential floor space in location n
  - $d_{ni} = (t_{ni})^{\delta}$ are commuting costs as a function of travel time (t_{ni})
  - B_n is the common residential amenity of location n
  - $b_{ni}(\omega)$ is an idiosyncratic utility shock which is a draw from a Frechet distribution with shape parameter ϵ

- Landlords own all land and for simplicity only consume the final good.

Commuting

- These worker preferences result in the following commuting probabilities from location n to location i:

$$\lambda_{ni} = \frac{(B_n w_i)^{\epsilon} \left(d_{ni} P_n^{\alpha} Q_n^{1-\alpha}\right)^{-\epsilon}}{\sum_{k=1}^{N} \sum_{j=1}^{N} \left(B_k w_j\right)^{\epsilon} \left(d_{kj} P_k^{\alpha} Q_k^{1-\alpha}\right)^{-\epsilon}}. \tag{2}$$

- The model also yields a simple expression for the conditional probability of commuting from n to i conditional on living in location n:

$$\lambda_{ni|n} = \frac{(w_i/d_{ni})^{\epsilon}}{\sum_{j=1}^{N} (w_j/d_{nj})^{\epsilon}}. \tag{3}$$

Production

- In each location of the city, perfectly competitive firms produce a composite final good using labor, floor space and capital.
- Their production function takes the Cobb-Douglas form:

$$Y_i = A_i(L_i)^{\beta}(H_i^B)^{\gamma}(X_i)^{1-\beta-\gamma}, \quad \beta,\ \gamma \in (0,1), \tag{4}$$

  where L_i is labor input, H_i^B is floor space used for production, and X_i denotes the freely tradeable capital.
- Overall productivity, A_i, depends both on an exogenous component, a_i, and externalities that are a function of employment density:

$$A_i = a_i \left(\frac{L_i}{K_i}\right)^{\chi} \tag{5}$$

Developers

- Each location in the city is endowed with K_n units of land of which $T_n \leq K_n$ units are available for construction.
- A large number of perfectly competitive developers combine land and freely tradable capital to produce floor space per unit of land (h_n):

$$h_n = \left(\frac{Q_n}{\nu \kappa_n}\right)^{\frac{1}{\nu-1}} \tag{6}$$

  where $1/(\nu - 1)$ is the housing supply elasticity κ_n is a supply shifter.
- In equilibrium the price of residential floor space (Q_n) and commercial floor space (q_n) in a location is assumed to be the same ($Q_n = q_n$).
- The land rent, r_n, is the maximum price that developers can pay for a unit of land in a zero profit equilibrium.

Equilibrium Conditions

- Commuter market clearing requires that the number of workers that are working in location i (L_i) is equal to the number of residents (R_n) commuting to this location in equilibrium:

$$L_i = \sum_{n=1}^{N} \frac{(w_i/(t_{ni})^{\delta})^{\epsilon}}{\sum_{j=1}^{N}(w_j/(t_{nj})^{\delta})^{\epsilon}} R_n \tag{7}$$

- The floor space clearing condition requires that demand and supply of floor space are equalized :

$$\frac{(1-\alpha)\bar{w}_n R_n}{Q_n} + \frac{\gamma}{\beta}\frac{w_n L_n}{Q_n} = H_n \tag{8}$$

where supply of floor space is $H_n = h_n T_n$.

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Overview Structural Estimation

- Step 1: We need values for the two structural parameters of the commuting market clearing condition, ϵ and δ.
  - With estimates of these parameters this system of equations can be solved for wages in each location of the city.
- Step 2: We use the height data to estimate floor space (and land) prices and the housing supply elasticity.
  - The estimated wages and floor space prices allow us to also estimate productivity and amenities in each location of the city
- Step 3: We set the elasticity of productivity with respect to employment density to $\chi = 0.05$, but can in principle also estimate this value.

Step 1: Commuting Parameters

- Probably the only reliable and cheap source of information on commuting flows in most developing country cities is cell phone data.
- Using cell phone data for Dhaka, Kreindler and Miyauchi (2020) estimate a gravity equation for commuting flows find an elasticity of commuting flows with respect to travel time of approximately -2.5.
- They decompose this estimate into a Frechet shape parameter (ϵ) of 8 and an elasticity of commuting costs to time (δ) of $2.5/8 = 0.31$.
- Using these values, we can solve the commuting market clearing conditions for wages in each location of Dhaka.
- Intuitively, there is only one set of wages that induce the commuting flows to clear labour markets in each location.

Step 2: Floor Space Prices and Housing Supply Elasticity

- Combining the floor space clearing condition (8) with the housing supply function (6), taking into account that $H_n = h_n T_n$ yields:

$$\frac{(1-\alpha)\bar{w}_n R_n}{Q_n} + \frac{\gamma}{\beta}\frac{w_n L_n}{Q_n} = H_n = \left(\frac{Q_n}{\nu \kappa_n}\right)^{\frac{1}{\nu-1}} T_n. \tag{9}$$

- The left hand side is demand for floor space from residents and firms and can be solved for the floor space price (Q_n) if we use our satellite data to measure supply H_n.
- Replacing H_n with the housing supply function, we can use (9) to also estimate ν if we make assumptions about the structural residuals κ_n.
- We set the expenditure share on housing to 25% ($1 - \alpha = 0.25$)
- We assume that the labour share is 60% ($\beta = 0.6$); floor space is 20% of firms' costs ($\gamma = 0.2$); this implies a capital share of 20%.

Moment Condition for the Housing Supply Elasticity

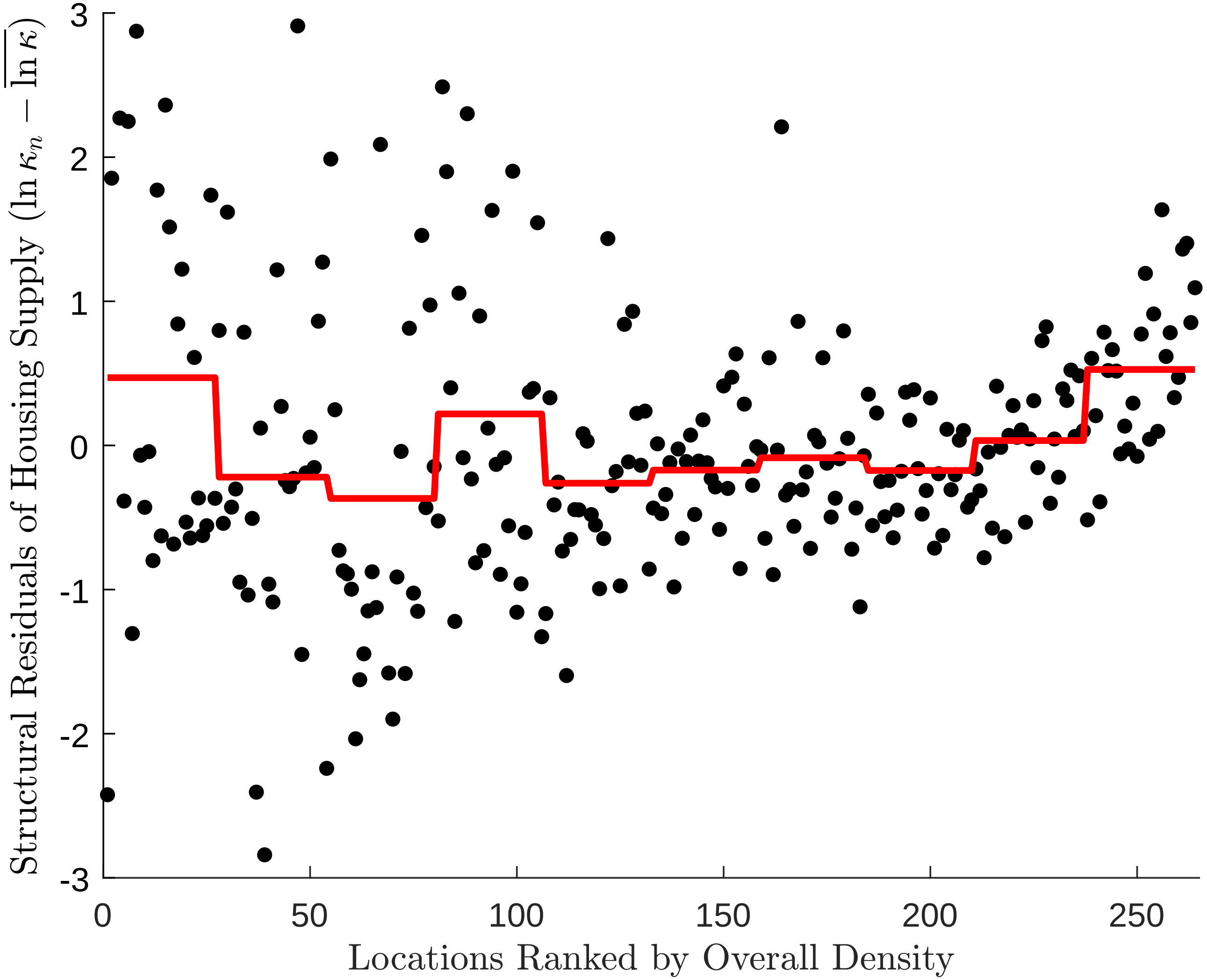
- The structural residuals κ_n capture idiosyncratic shocks to height such as building age or ownership and allow us to fit the data exactly.
- Our moment condition requires that variation in κ_n is uncorrelated with 10 grid cells that capture distance to the center of Dhaka.
- Formally, we require that:

$$\mathbb{E}\left[\mathbf{I}^K \times (\ln \kappa_n - \overline{\ln \kappa_n})\right] = 0, \tag{10}$$

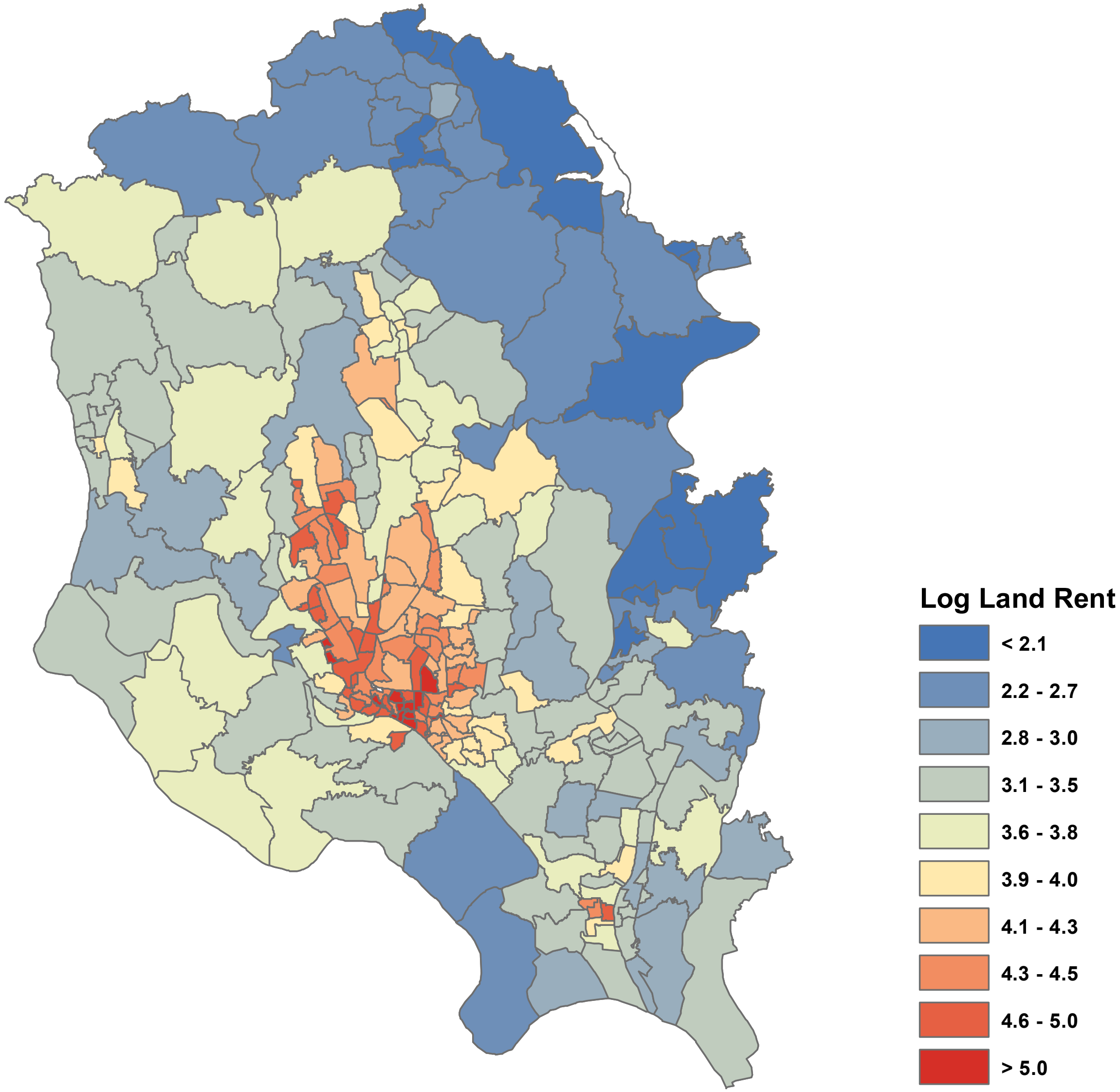
where $\mathbf{I}^K$ are indicator variables for our 10 grid cells.

- Using this approach we estimate a floor space supply elasticity of 1.45.

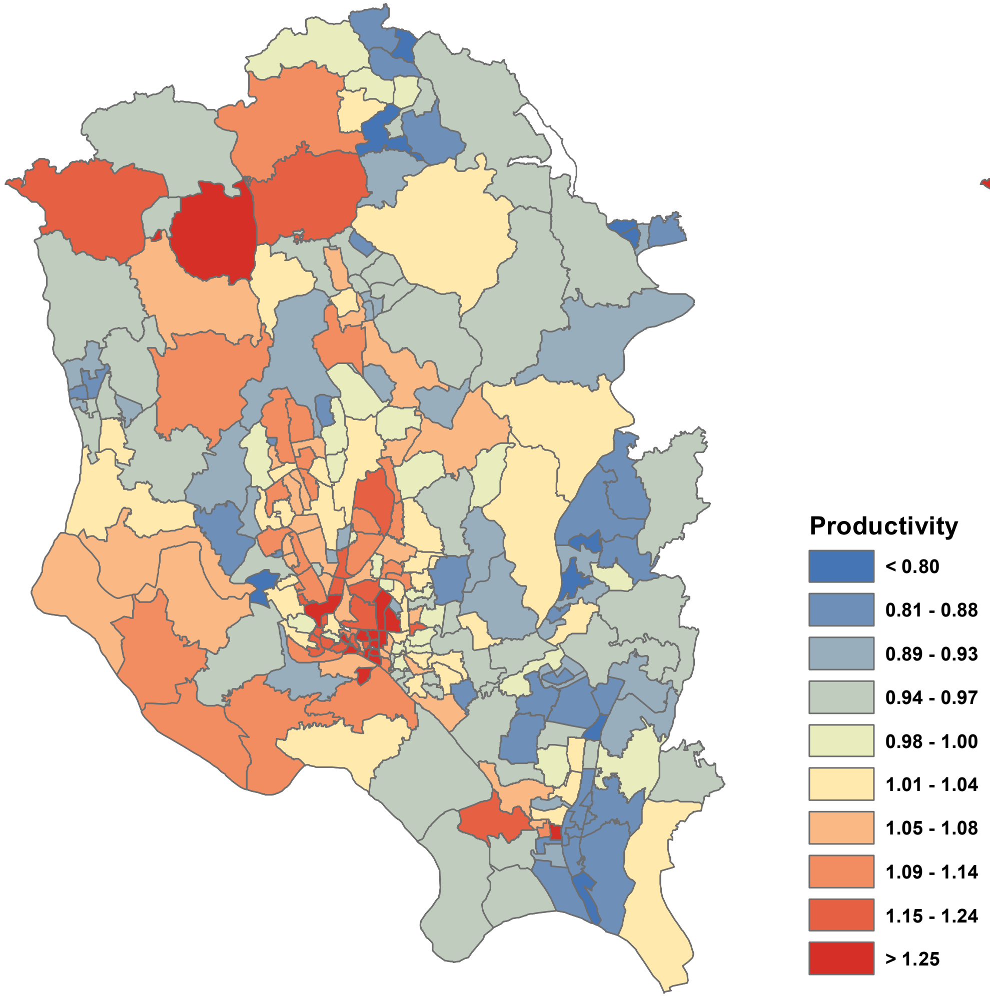
Examining the Moment Condition



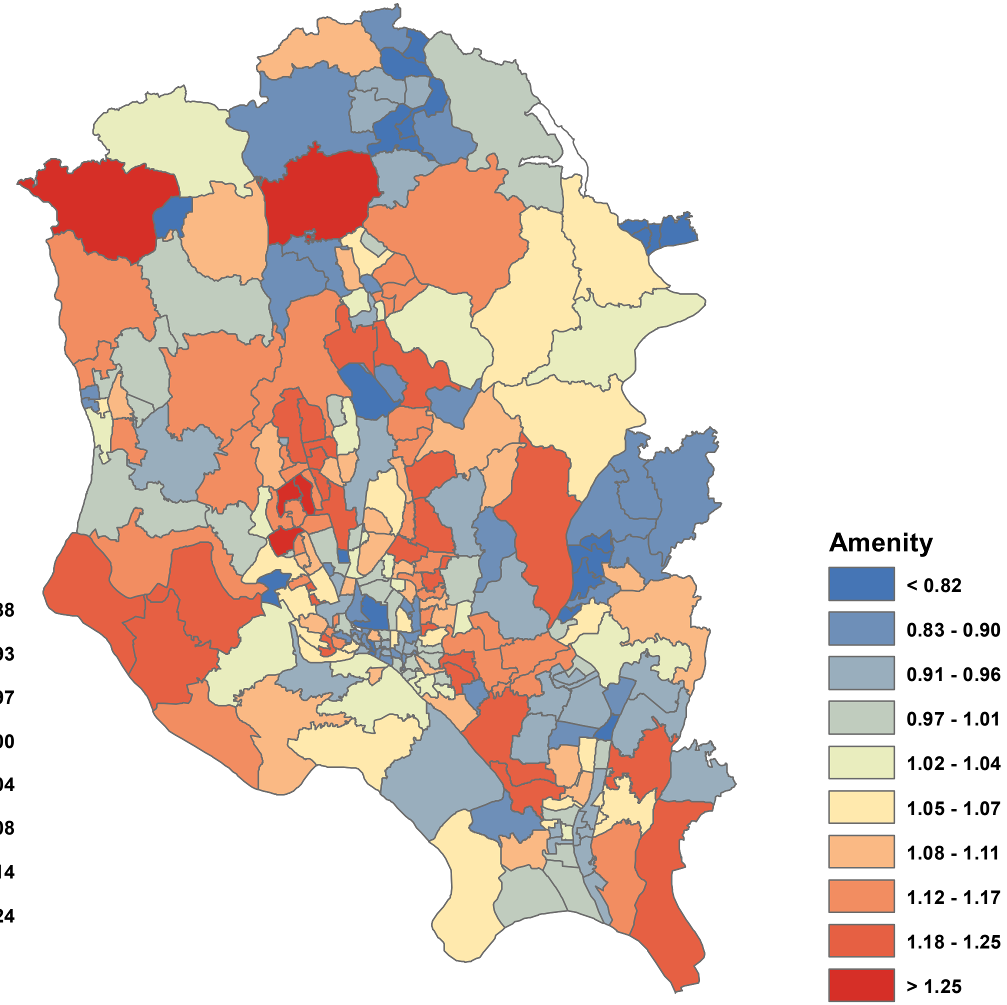
Estimated Land Rents



Estimated Productivity and Amenities



(a) Workplace Productivity



(b) Residential Amenity

Step 3: Productivity and Employment Density

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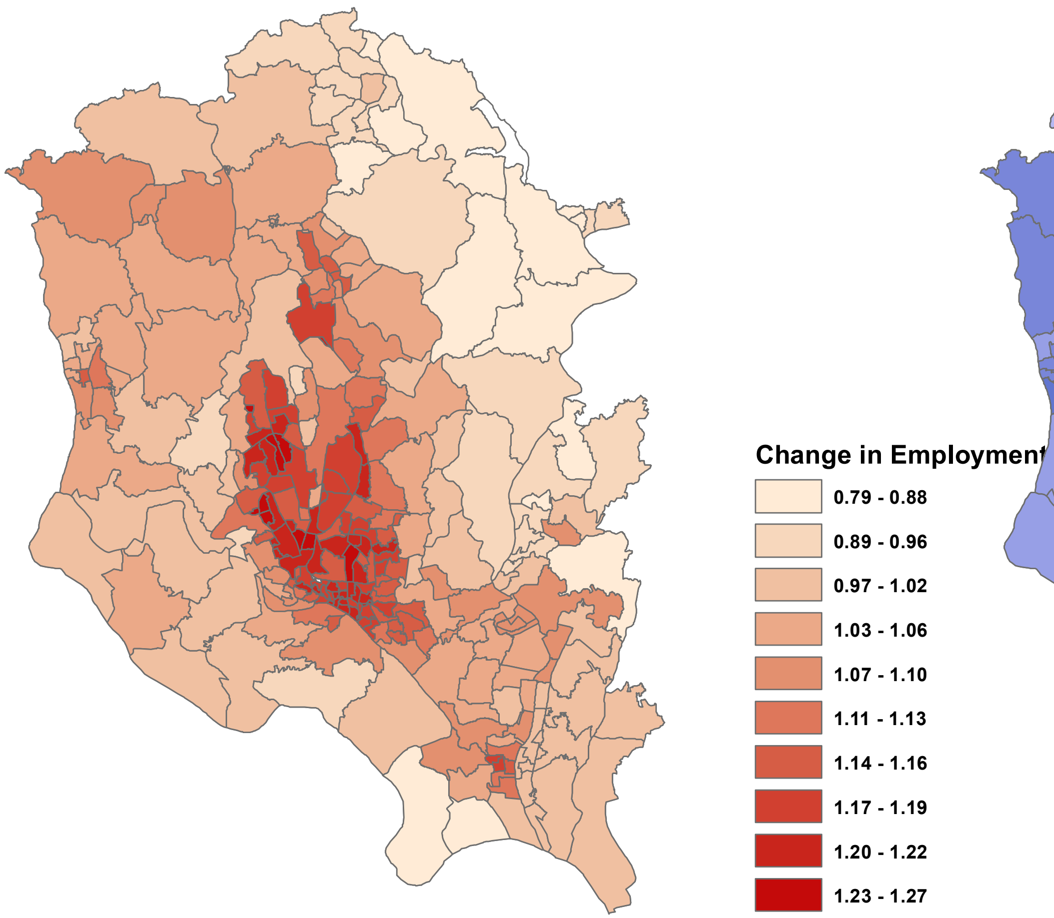
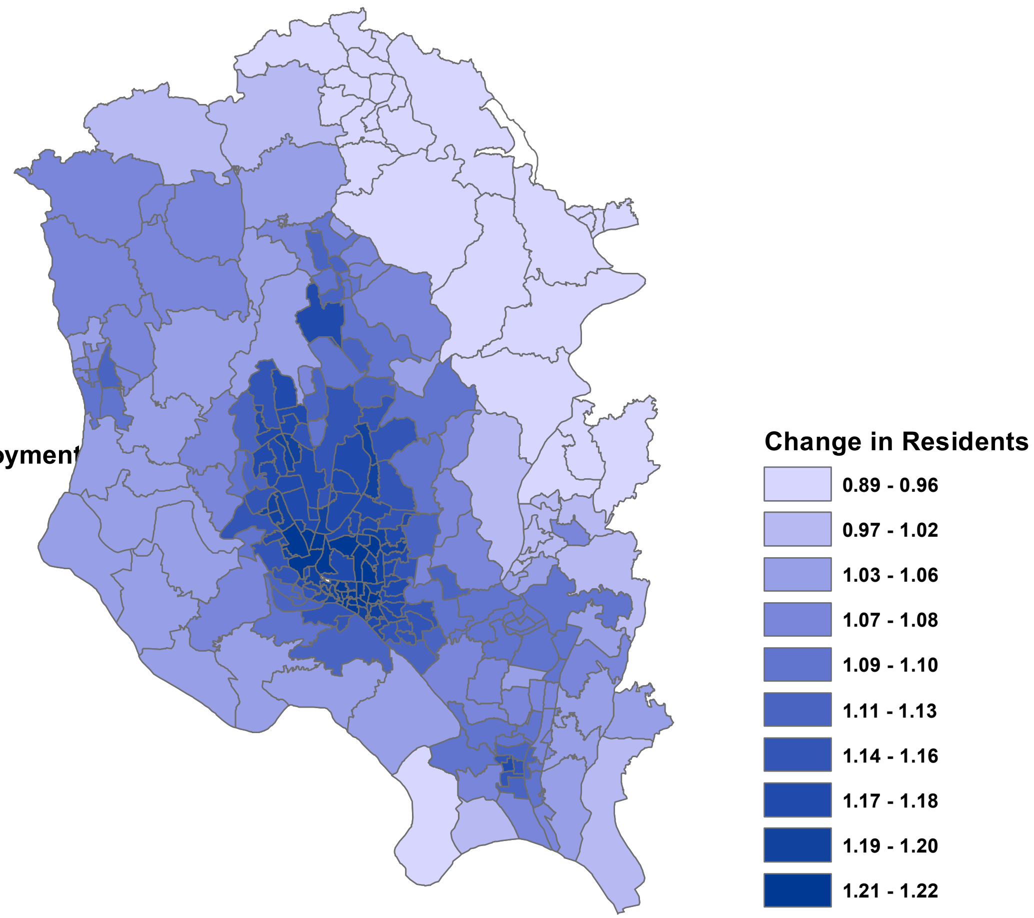
Overview Counterfactuals

- We use the calibrated model to examine two model counterfactuals
  - An increase of the housing supply elasticity by 25%
  - The construction of a radial road through Dhaka
- We will concentrate here on the first counterfactual.
- For these counterfactuals we assume that the labour supply elasticity to the city is equal to 2 (and discuss robustness in the paper).

Housing Supply Couterfactual - Employment and Residents

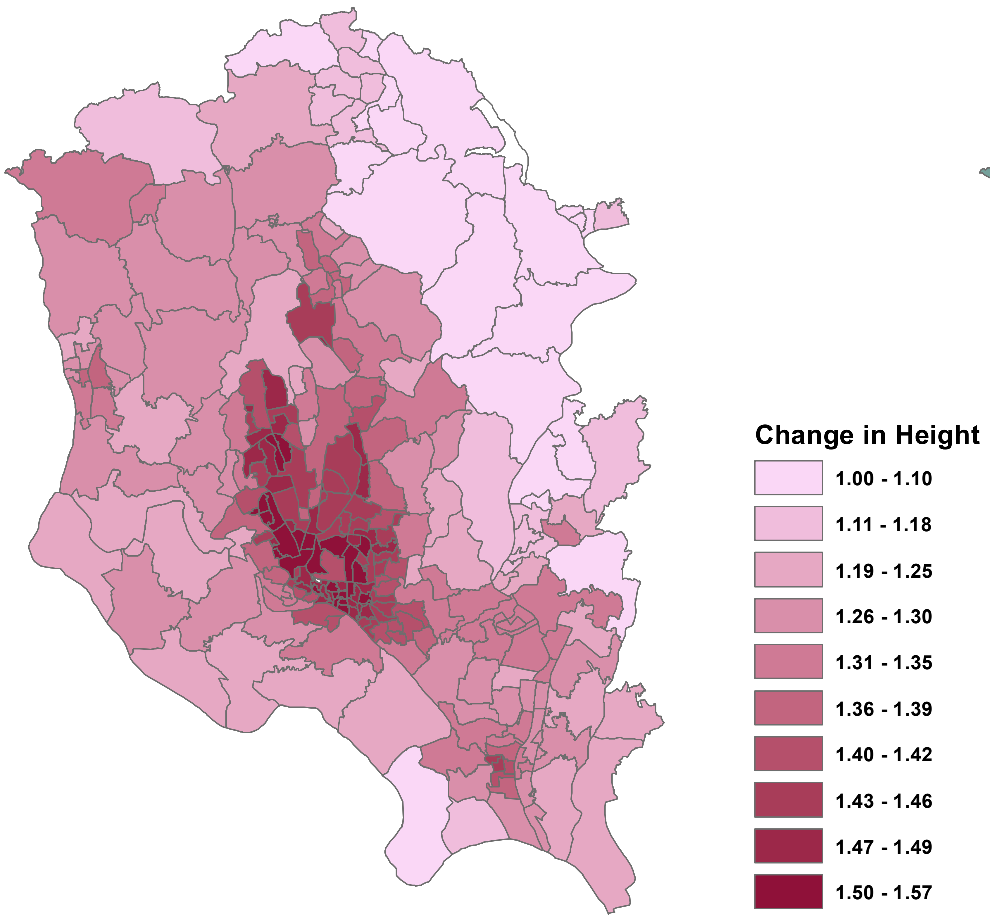


(a) Change in Employment

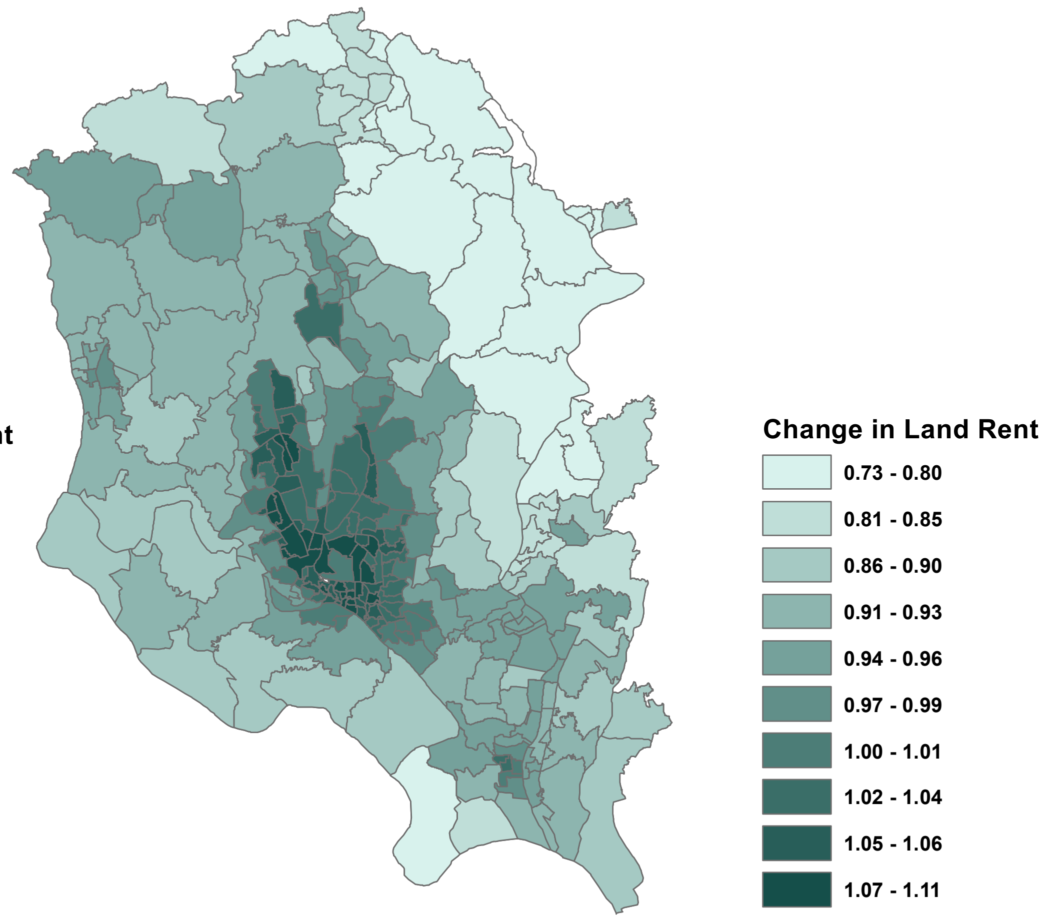


(b) Change in Residents

Housing Supply Couterfactual - Heights and Land Rents

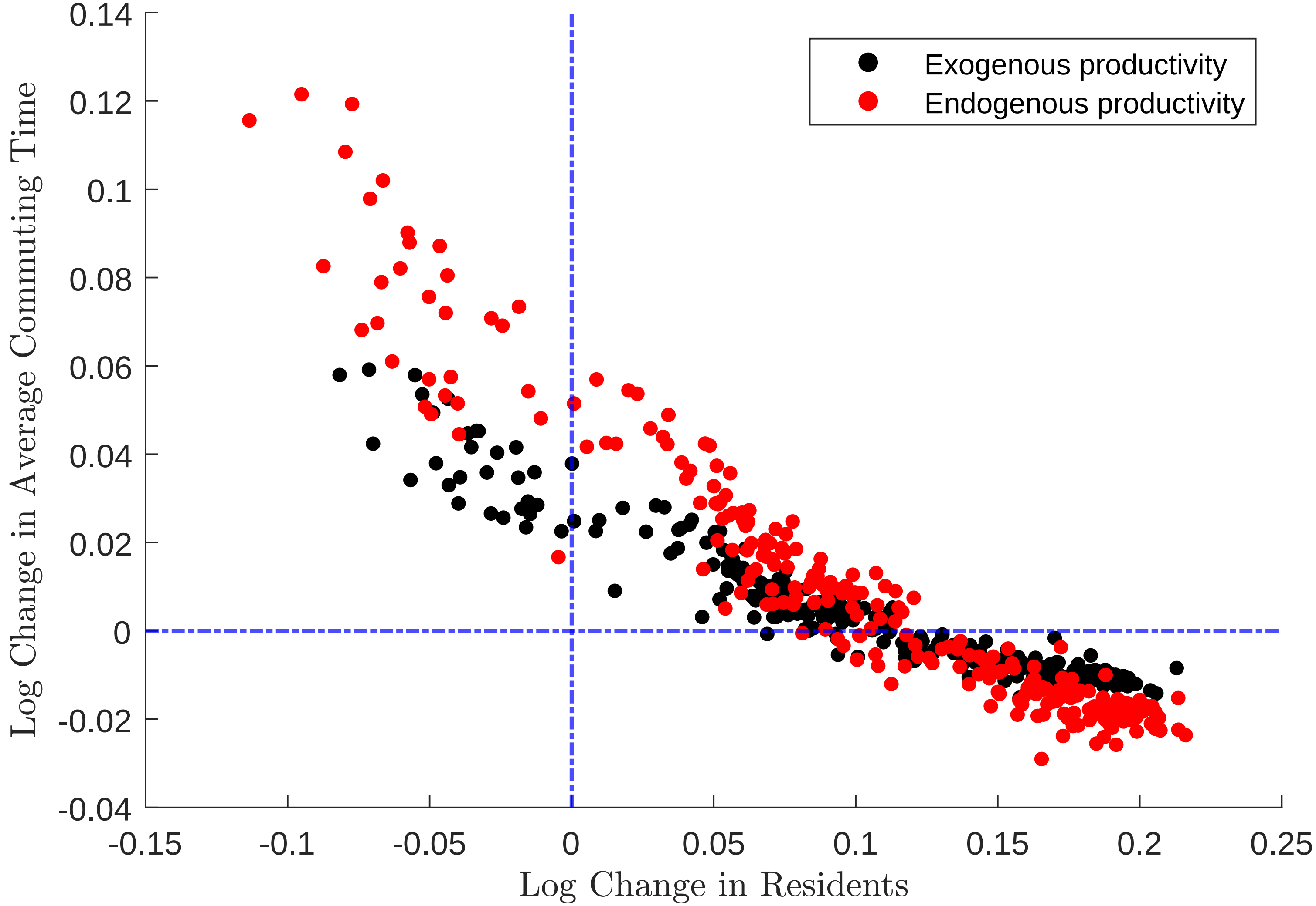


(a) Change in Average Height



(b) Change in Land Rents

Housing Supply Couterfactual - Commuting



Welfare Effects of Higher Housing Supply Elasticity

- Counterfactual changes with exogenous productivity (relative to the baseline value of a variable and therefore 1 means "no change"):
  - Worker welfare: 1.052
  - Total land rents: 0.966
- Counterfactual changes with endogenous productivity:
  - Worker welfare: 1.054
  - Total land rents: 0.971

Conclusion

- In this paper we show how quantitative urban models can be calibrated in data-sparse environments using Dhaka as our application.
- We argue that a combination of cell phone data, satellite data, and Google travel times contains powerful information on such cities.
- This data can be used to estimate the housing supply elasticity, land prices and floor space prices with information just on quantities.
- We illustrate the usefulness of calibrated model for policy analysis with counterfactuals.
- The results suggest that an increase in the housing supply elasticity has powerful re-distributive effects between workers and landlords but does not cut average commuting times in the city.