The Monocentric City Model with Heterogeneity: LeRoy and Sonstelie 1983 Jerch et. al. 2024

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Flash Presentations: Start Next Class

Each *registered* student should present an idea for a paper weakly related to urban economics or economic geography (auditors also welcome)

Presentations can be very short: 5 minutes is fine, no longer than 10 minutes

Presentation should explain:

1. **Question:** What is the research question of your paper idea?
2. **Motivation:** Why is this important? Is it different from the existing literature in method or context (ex: country, time)?
3. **Implementation:** how will you implement this idea? What data (if empirical) and what methods?
4. **Challenges:** are there identification challenges or theoretical issues?

Most important are 1 and 2; you may not know 3 and 4 yet, and may even need help from the class

Leroy and Sonstelie

Leroy and Sonstelie, JUE 1983

Paper tries to explain how commuting costs can affect location choices of rich and poor

Shows that changes in fixed and variable costs of commuting, relative to wages, can lead to different location patterns by income

Main intuition:

- when faster commuting technology is very expensive for poor, then rich will locate in suburbs to take advantage of cheaper housing
- when poor are able to afford this technology they also wish to live in suburbs, bidding up suburban house prices, making central city locations more attractive to rich

Argues that these predictions are consistent with location patterns of rich and poor over a period of US history with significant innovation in transportation

Commuting Modes

Two commuting modes m: automobile a and bus b, $m \in \{a, b\}$

Each commuting mode has a i) fixed cost (f^m) ii) variable cost in distance ($c^m/2$) iii) time cost, measured in lost wages

Speed for each mode is 2 miles in t^m hours, which implies $2 * (1/t^m)$ miles per hour

Daily commute is $2 * d$ (back and forth at dist d to CBD), thus with wage w time cost is: $w * d * t^m$

They will normalize total time to 1 and thus wage with no commuting (d=0) is just w

Commuting cost: $f^m + c^m * d + w * d * t^m$

We assume cars are more costly in both fixed and variable costs, $f^a > f^b$, $c^a > c^b$, but are faster $t^a < t^b$

Commuting Mode Choice by Distance

When wages are “high enough” there will be a distance d^* where the cost of commuting by car is equal to that of the bus

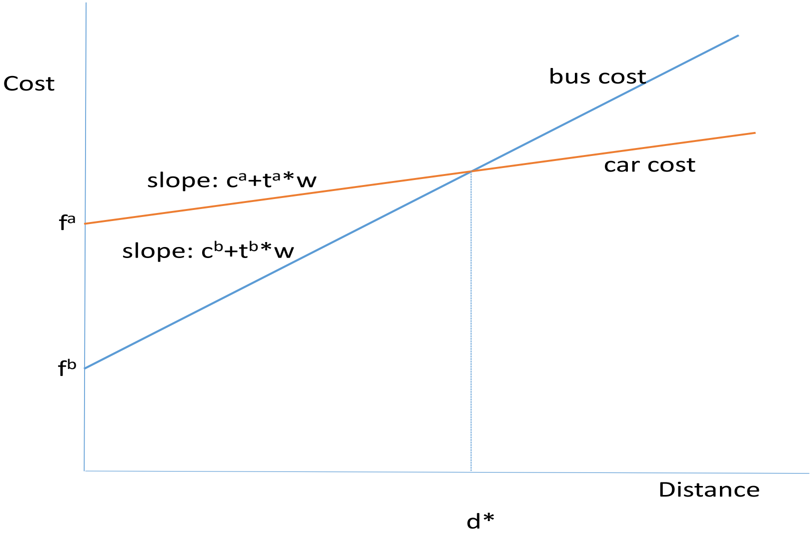
This is because a high wage makes the marginal cost of commuting (wrt distance) higher for buses than for cars: $c^a + w * t^a < c^b + w * t^b$

$$d* = \frac{f^a - f^b}{c^b + w * t^b - c^a - w * t^a} \tag{1}$$

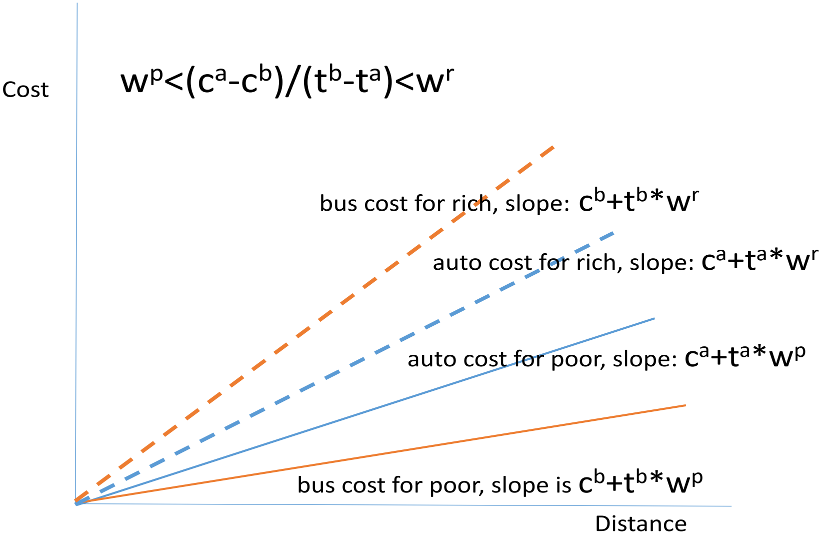
Note: this distance d^* could be beyond the city limits for low wages

Easiest to see this in a graph

Commuting Cost by Distance



Commuting Cost: Zero Fixed Cost, Two Incomes



Bid Rent by Commuting Mode

Consumers have utility over housing and numeraire $U(h, z)$

Budget constraint for mode m (total time is 1):
$z + r(d) * h + f^m + c^m * d + w * d * t^m = w$

Bid rent is max r subject to $U(h, z) = \bar{u}$:

$$r^m(d; u, w) \equiv \max_{h,x} \left(\frac{w - f^m - c^m * d - w * t * d^m - z}{h} \right) \tag{2}$$

This gives gradient (envelope theorem) as

$$\frac{\partial r^m(d; u, w)}{\partial d} = -\frac{c^m + w * t^m}{h} \tag{3}$$

This Alonso-Muth condition replaces τ with marginal commuting cost

Bid Rent by Distance

The bid-rent is then the envelope of the commuting mode bid-rent curves: whichever is higher at distance d is the bid-rent curve

We know that costs of two commuting modes intersect at d^* and thus bid-rent must also intersect at this point

Note: housing is not a function of commute mode (parking might complicate this)

Commuting Cost by Distance

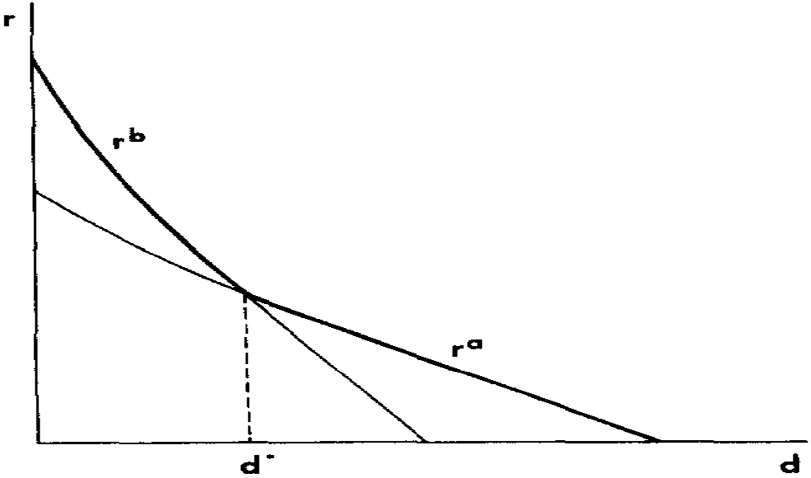


FIG. 1. The bid-rent function.

Who Lives Where?

We now want to figure where the rich (w_r) and poor (w_p) live in the city

All individuals in a group must have the same utility; rich utility should be higher than poor utility

The group with the highest bid-rent for each location lives in that spot

Question: if the rich have more income, how can the poor have a higher bid-rent curve at some locations?

When two bid rent curves intersect at distance d, the group with the steeper bid rent gradient must live on the side closer to the CBD

We first examine the simple case of zero fixed costs in commuting–why is this simpler?

Zero Fixed Cost

With zero fixed costs the commuting cost of one mode is always higher than the other, for each group (the cost lines never intersect or $d^* = 0$)

This means that each group will only use one commuting mode at all distances

Say c^a is so high that both groups commute by bus b, $c^a + t^a * w_r > c^b + t^b * w_r$, who will live where?

Turns out it depends on whether the effect of income on housing demand is greater than the effect of income on marginal commuting costs:

Do the rich live in the center because their time is so valuable or do they live in the suburbs because they have high housing demand?

Commuting and Housing Income Elasticities

When both commute by bus, the poor will live closer to the CBD if their bid-rent curve is steeper at the intersection with bid-rent curve of rich:

$$\frac{c_p + w_p * t_p}{h_p} > \frac{c_r + w_r * t_r}{h_r} \tag{7}$$

Define $M_g \equiv c_g + w_g * t_g$ and then let η_c and η_h be the *arc* elasticities of commuting cost and housing wrt income:

$\eta_c = \frac{\frac{M_r - M_p}{M_p}}{\frac{w_r - w_p}{w_p}}$ and $\eta_h = \frac{\frac{h_r - h_p}{h_p}}{\frac{w_r - w_p}{w_p}}$

Then if $\eta_h > \eta_c$ the rich live in the suburbs and the poor closer to the CBD; we often assume $\eta_c > \eta_h$ (as does this paper)

Notice that $\eta_c \approx 1$ when $c_p = c_r$ and c_p is small

Three Eras

"Paradise Lost" and "Paradise Regained" are famous poems by John Milton (17th century England); authors use these to describe location patterns

1. Paradise: cars are very expensive, both groups use bus, rich live in center
2. Paradise Lost: variable cost of auto drops enough relative to wages that rich can afford cars but poor cannot; rich live in suburbs, poor in center
3. Paradise Regained: variable cost of auto drops so much both groups can afford cars; rich again live in center, poor in suburbs

Paradise and Paradise Regained

Paradise

- if both groups use bus then we already know location pattern depends on η_c vs η_h
- Author argues that variable commuting cost of bus c^b is low and thus $\eta_c \approx 1$. Empirical evidence argues for $\eta_h < 1$ and thus if both groups commute by bus the rich live in center.

Paradise Regained

- authors make same argument that when c^a has fallen sufficiently so that both groups can afford cars then $\eta_c > \eta_h$

Most interesting case is Paradise Lost: why do rich live in suburbs when poor can't afford cars but then in center when the poor also drive (Paradise Regained)?

Paradise Lost

Variable commuting cost c^a is such that the rich drive, poor take bus

Question is how gradients compare at intersection point:

$$\frac{c_b + w_p * t_b}{h_p} > \frac{c_a + w_r * t_a}{h_r} \tag{PL}$$

Since $c_a > c_b$, $w_r > w_p$, and $t_a < t_b$, it's possible that marginal commuting costs are lower for the rich, or that housing demand h_r is large enough to make *PL* true

Notice that when the rich live in the suburbs they will enjoy low housing prices because there is no competition for space from the poor, who cannot drive

Leroy and Sonstelie Model: Adding Fixed Costs

LR Model with Positive Fixed Costs

With positive fixed costs we can have equilibria where both groups use both commuting modes if fixed and variable commuting costs are low enough

Then each group will have a separate distance where commuting by car becomes cheaper, d_r^* and d_p^*

For $d < d_r^*$, rich and poor use buses, for $d_r^* < d$ the rich drive but the poor still take the bus

This is the Paradise case where rich live in the center

Paradise with Fixed Costs

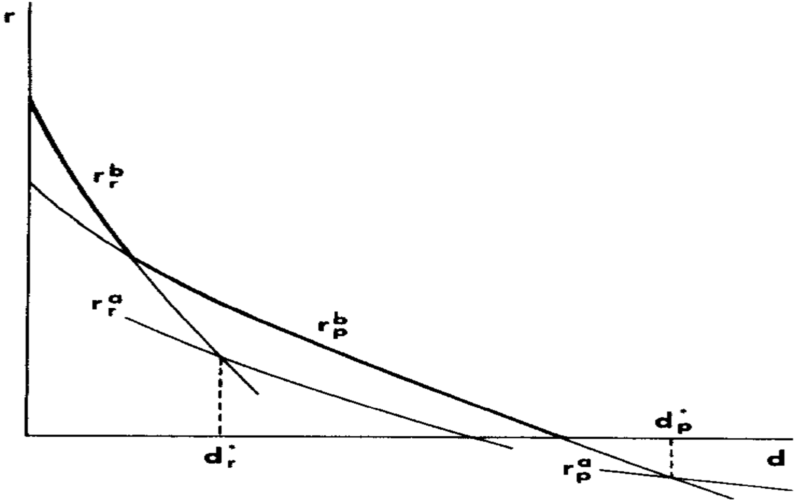


FIG. 2. Paradise.

Paradise Lost with Fixed Costs

As f^a and c^a drop further the d^* points shift closer to the CBD, decreasing the area where the rich would want to live in the center and take the bus

Some rich will now decide to live in suburbs and drive

As costs continue to decline all of the rich may then move to the suburbs (Paradise Lost)

Paradise Lost with Fixed Costs

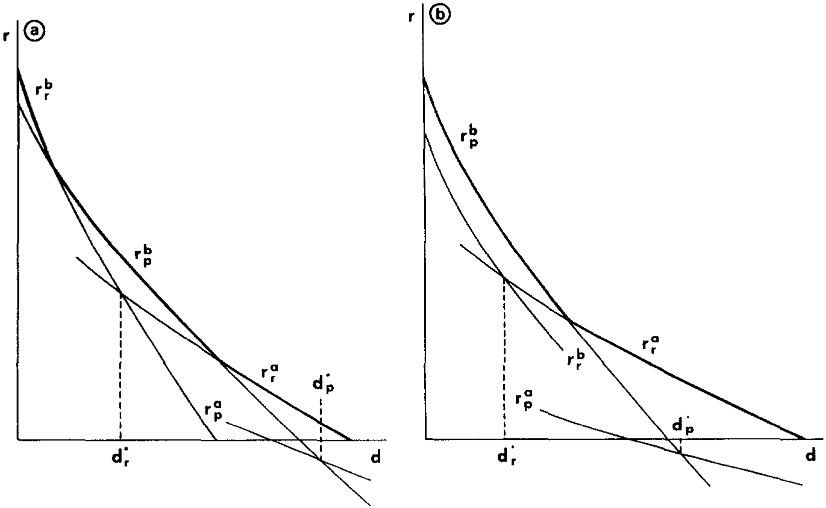


FIG. 3. Paradise lost.

Paradise Regained

Now as f^a and c^a drop further the poor also drive in the suburbs, putting pressure on suburban housing prices

This pressure causes some rich to move back to the center but some rich also stay in the suburbs

This creates four zones: rich bus, poor bus, rich auto, poor auto; the authors call this regentrifiction

Finally, costs fall enough that we get the Paradise Regained equilibrium with rich in the center (both bus and auto) and poor in the suburbs

Note: authors show case where poor only drive in suburbs but an equilibrium where they also use the bus (and then car) might be possible depending upon population sizes

Regentrification

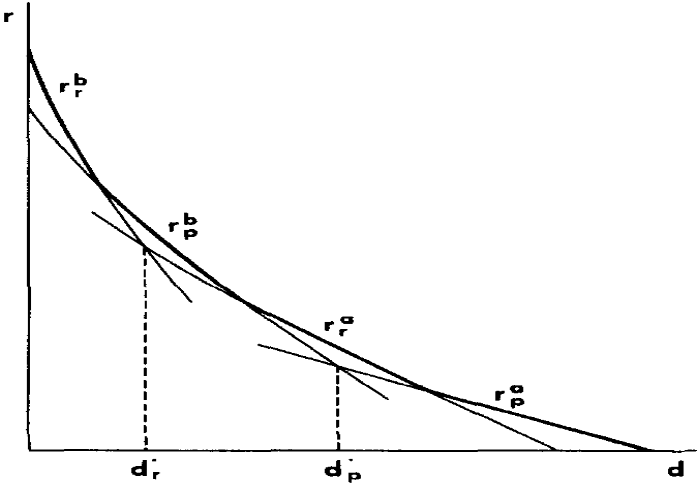


FIG. 4. Regentrification.

Paradise Regained with Fixed Costs

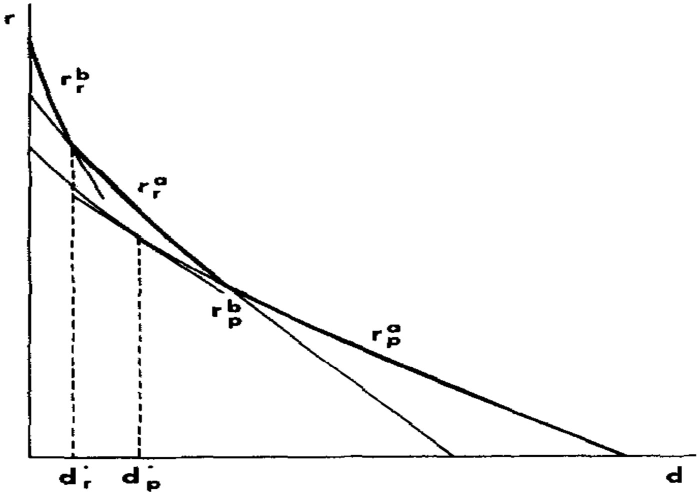


FIG. 5. Paradise regained.

Evidence from US Transport History

1. In 18th and 1st half of 19th century everyone walks so rich live in center (Paradise)
2. From 1830-1850 the "omnibus" and commuter rail started being used but commuting was only affordable for very rich; some very rich use these and move into suburbs (Paradise Lost)
3. Next, in 1850's and 1860's streetcar is introduced; commuting by street car is expensive but affordable for professional workers, wealthy suburbs grow in size (more Paradise Lost)
4. Streetcar gets cheaper and cheaper but before Paradise Regained occurs the car is invented. This new technology is faster but expensive, thus rich continue to live in suburbs (and middle class or poor can take street car)
5. Finally, authors argue that in 1980's as cars become cheaper there is evidence of rich moving back to cities

Jerch, Barwick, Li, and Wu, “Road Rationing Policies and Housing Markets”, *Journal of Urban Economics*, 2024

Jerch et. al.: Class Discussion

1. What is the main research question of the paper? What are they trying to estimate?
2. What prediction do they take from the theoretical model?
3. What data are they using? What is the identification strategy?
4. What are the results? Do you find them convincing and robust?

Jerch et. al.: Main Idea

In July 2008 Beijing started a road rationing policy (RRP) limiting drivers to only driving half the week (or later 4 of 5 workdays)

Drivers in Beijing tend to be upper-income workers, poor use subway, walking, and biking

Policy thus provides arguably exogenous increase in transport cost that only affects upper income residents

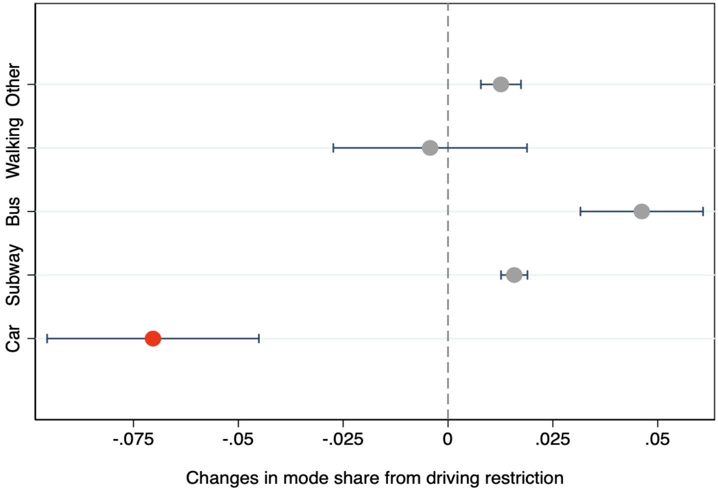
Authors use data on real estate transactions and government subsidized mortgages (provident fund) to evaluate effect of RRP on house price gradients to CBDs and subway stations

Further, they examine whether changes in gradients differ by income

Consistent with no fixed cost LS model, they find RRP causes steeper price gradients and steeper income gradients

RRP: less car, increased mass-transit

Figure A3: Effect of Driving Restriction on Mode Choice



Transportation Cost

Budget constraint where $T()$ is commuting time, w is wage per unit time, y is total income:

$z + ph + w * T(n, x, \delta) = y$

$$T(n, x, \delta) = n\left[\frac{\delta}{\omega} + \frac{x}{\sigma}\right] + (1 - n)\frac{x}{\nu} \tag{1}$$

n: likelihood of taking subway, assume $n = 1$ for poor

δ is distance to subway, x is dist to closest CBD

ω is walking speed (dist/time), σ subway speed, ν driving speed

Assume driving faster than subway: $\frac{x}{\nu} < \left(\frac{\delta}{\omega} + \frac{x}{\sigma}\right)$

Note: model assumes distance from subway to CBD same as from house to CBD, or δ is very small compared to x. Empirically not true for large x (suburbs), but empirical specification will have jiedao/zipcode FE.

Bid-rent Gradients

They derive the bid-rent gradients in exactly the same way as Brueckner by using consumer optimization conditions (FOC wrt z, h) and spatial equilibrium condition (total differentiate equation)

$$\frac{\partial p}{\partial x} = -\left[\frac{n}{\sigma} + \frac{1-n}{\nu}\right]\frac{w}{h} \tag{2}$$

$$\frac{\partial p}{\partial \delta} = -\left[\frac{n}{\omega}\right]\frac{w}{h} \tag{3}$$

Like Leroy and Sonstelie, the gradients are analogous to $-\tau/h$: we replace the marginal cost of distance τ with the marginal cost of distance to CBD or subway in terms of lost wages

Note: $n()$ can be a function of both δ and x–authors are not assuming gradients are orthogonal

Who Lives Where in Beijing?

Assuming slope of bid-rent monotonically declines from CBD (always get flatter with x), then we only need to know slope at a given distance to know who (rich, poor) lives where: $\frac{\partial p_r}{\partial x} <> \frac{\partial p_p}{\partial x}$

$$\left[\frac{n_r}{\sigma} + \frac{1-n_r}{\nu}\right] \frac{w_r}{h_r} <> \left[\frac{n_p}{\sigma} + \frac{1-n_p}{\nu}\right] \frac{w_p}{h_p}$$

Authors assume $n_p = 1$ so term in brackets is greater for poor

Key is then how w/h compares for two groups, same as LS model: if income elasticity of housing consumption exceeds income elasticity of commuting, then poor live closer to CBD

However, in this paper authors don't try to explain who lives where, but simply note that RRP increase n_r, thus rich are *more likely* to live closer than before RRP

Similar derivation and explanation for distance to subway δ

Effect of RRP on Bid-rent Gradients

Authors assume that RRP leads to an increase in n_r and no change in n_p ($n_p = 1$). Then show effect of increase in n on each gradient is:

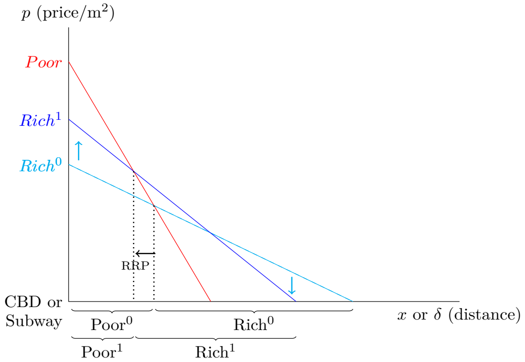
$$\frac{\partial^2 p}{\partial x \partial n} = -\frac{w}{h}\left[\frac{1}{\sigma} - \frac{1}{\nu}\right] \tag{6}$$

$$\frac{\partial^2 p}{\partial \delta \partial n} = -\frac{w}{h}\left[\frac{1}{\omega}\right] \tag{7}$$

Model implies that RRP will lead to steeper gradients (both from CBDs and subway stations), and that change in gradient slopes should be larger for rich

Illustration of Theoretical Prediction

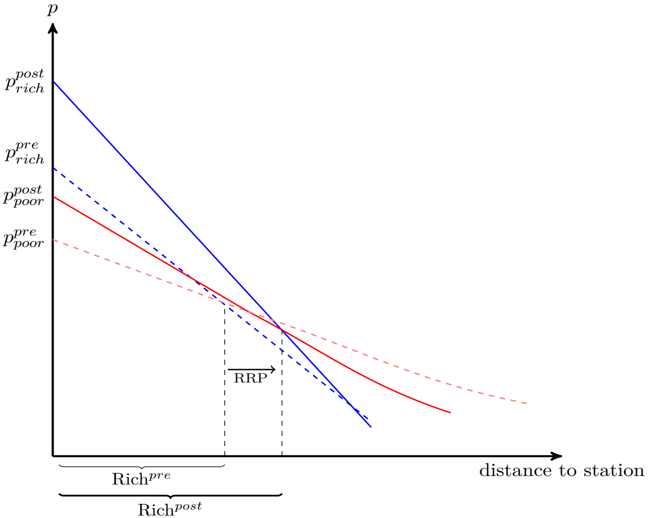
Figure A15: Urban Land Use and Equilibrium Sorting with Income Heterogeneity



Note: y-axis is price per square meter and the x-axis is distance from the CBD or a subway station, respectively. Location in the city is defined by x conditional on δ and vice verca. Each income group has a distinct bid-rent gradient. Let $\epsilon_{h,y} > \epsilon_{t,y}$ (i.e., income elasticity of housing > income elasticity of time costs). Consequently, the poor have a steeper gradient than the rich, *ex ante*. The RRP increases the cost of commuting for the rich, thus they increase their demand for locations proximate to both the CBD and subway stations, depicted as a tilt from $Rich^0$ to $Rich^1$. The RRP identifies $\frac{\partial p^2}{\partial x \partial (RRP)}$ and $\frac{\partial p^2}{\partial \delta \partial (RRP)}$. The RRP causes the price per square meter to increase for all units from the intersection of *Poor* and $Rich^1$ to the intersection of *Poor* and $Rich^0$. This also causes the rich to outbid the poor for units along the x-axis within the horizontal dotted lines.

Illustration of Theoretical Prediction: New Version

Figure 3: Road Rationing Policy and Urban Land Use with Income Heterogeneity



Jerch, Barwick, Li, and Wu, 2024: Estimation Strategy and Results

Estimation Strategy

The model predicts that the house price gradients (CBD, subway station) will steepen after RRP and higher incomes will move closer.

How can the authors evaluate these hypotheses?

What identification challenges are there? How will address these?

Empirical Specifications

Price of house i in jiedao j at time t over 28 quarters q:

$$ln(p_{ijt}) = \sum_{q=1}^{28} \kappa_q (Km_{it} \times D_q) + \alpha Km_{it} + X_{ijt}\theta + \gamma_j + \tau_t + \epsilon_{ijt} \tag{8}$$

Notation: Km_{it} is distance to *nearest* CBD or subway, X is vector of controls, γ_j is jiedao FE, τ is time FE (they try various ones)

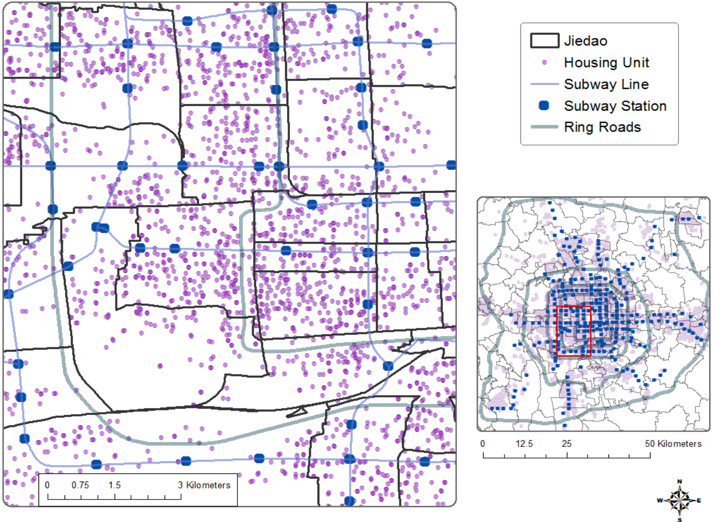
Why do they call this difference-in-difference?

Income specification: distance as function of income I_{izt} with zipcode z level data

$$ln(Km_{izt}) = \sum_{q=1}^{28} \alpha_q (I_{izt} \times D_q) + \phi ln(I_{izt}) + Z_{izt}\theta + \xi_z + \tau_t + \mu_{izt} \tag{9}$$

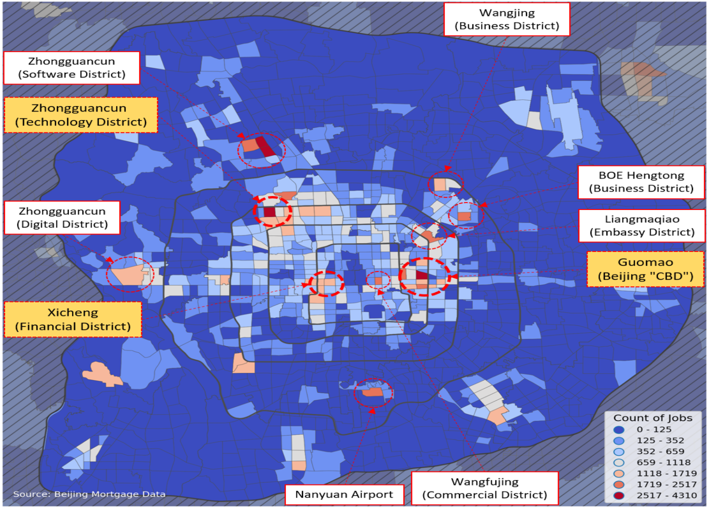
Example Map of Spatial Variation

Figure A4: Neighborhood Variation



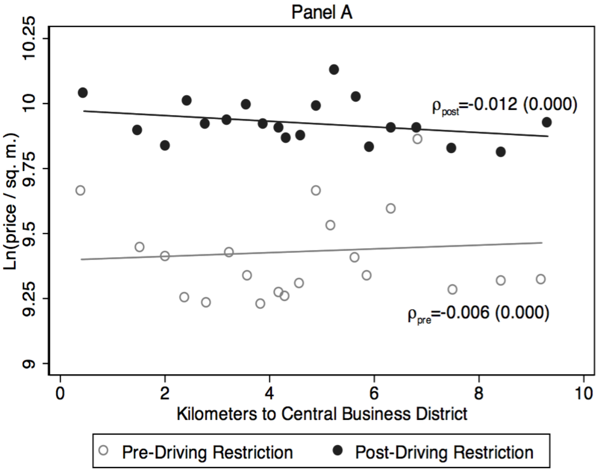
CBDs in Beijing

Figure A5: Business Districts of Beijing

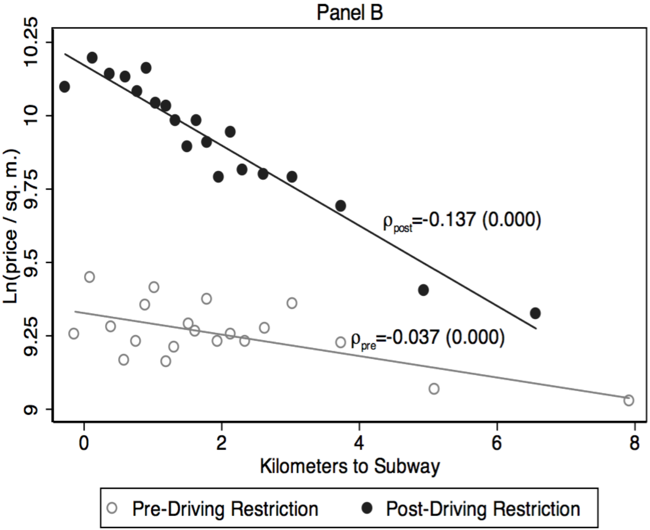


Price Gradient to CBDs: Binned Means

Figure 1: The Bid-Rent Gradient and Beijing's Road Rationing Policy

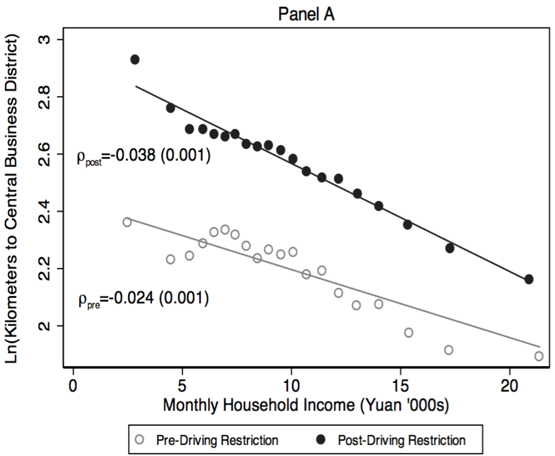


Price Gradient to Closest Subway Station

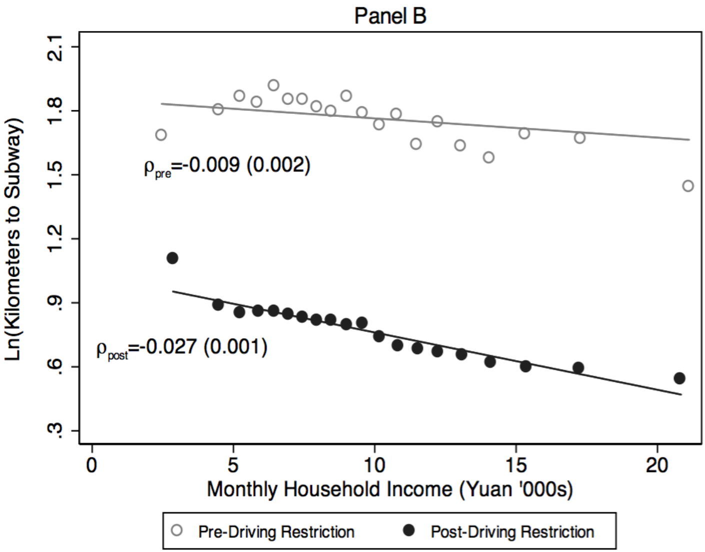


Income Gradient to CBDs

Figure 2: The Income Sorting Gradient and Beijing's Road Rationing Policy

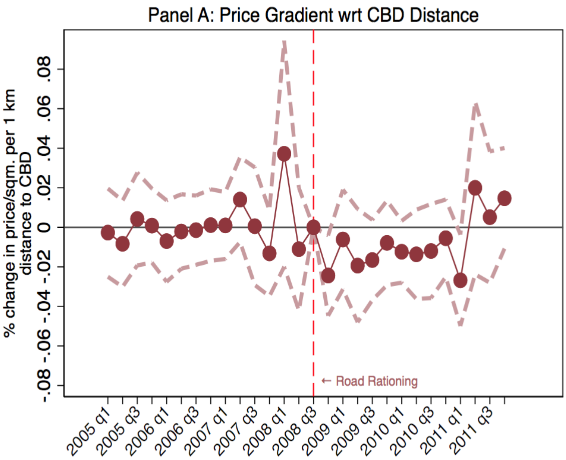


Income Gradient to Closest Subway Station

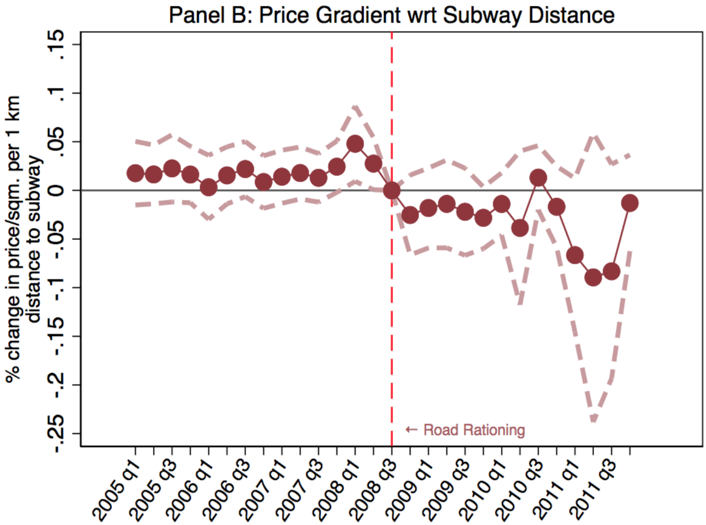


Price Gradient to CBDs: Event Study

Figure 3: The Effect of Road Rationing on the Price Premium for Proximity

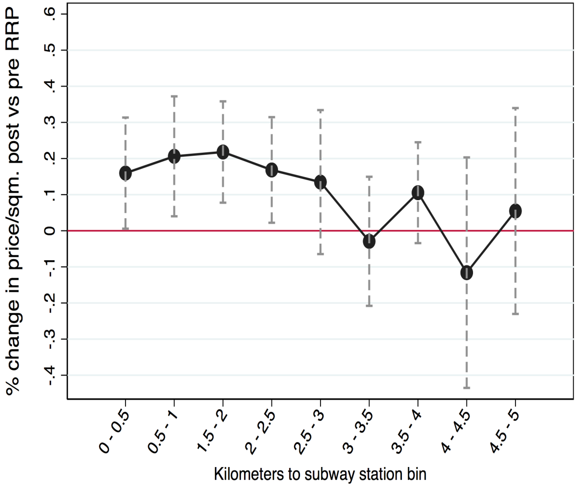


Price Gradient to Subway: Event Study



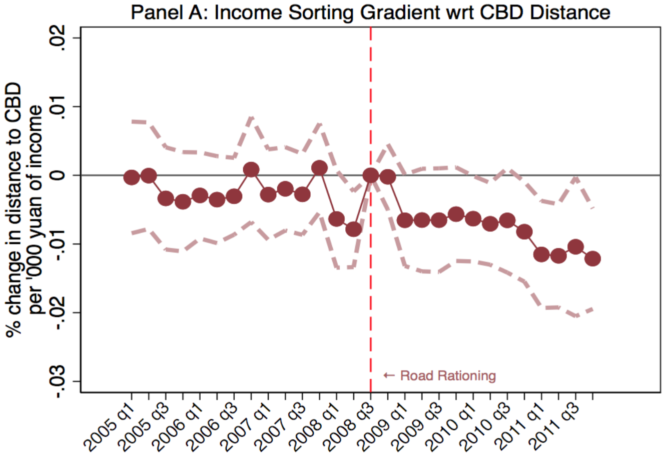
Price Change by Distance to Subway

Figure 4: Effect of Road Rationing on the Price Gradient w.r.t Subway Distance by Distance Bin

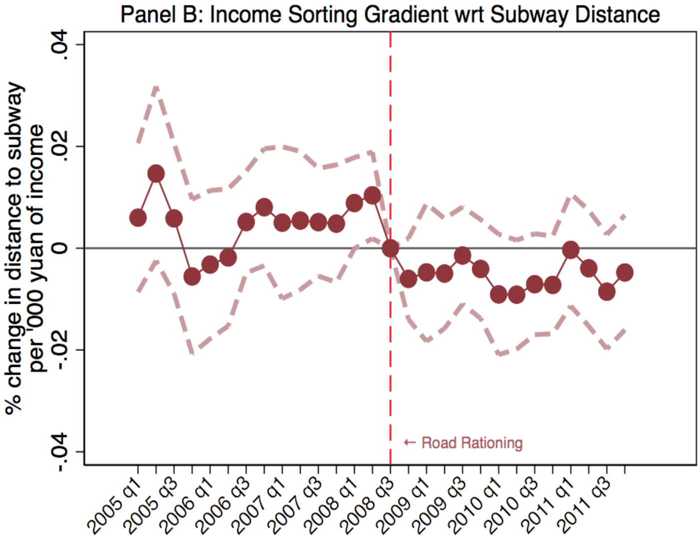


Income Gradient to CBDs: Event Study

Figure 5: Road Rationing and Income Sorting Gradients



Income Gradient to Subway: Event Study



RRP on CBDs Price Gradient: Twoway FE

Table 2: The Effect of Road Rationing on the Price Gradient w.r.t. CBD Distance

Outcome: ln(price/sq.m.)	(1)	(2)	(3)	(4)	(5)
Km to CBD x RRP	-0.005	-0.014**	-0.013***	-0.013***	-0.019***
	(0.010)	(0.007)	(0.005)	(0.005)	(0.007)
Km to CBD	-0.035***	-0.005	0.012	0.010	0.015
	(0.009)	(0.017)	(0.017)	(0.016)	(0.017)
Avg Proximity Premium / Km	$425.59	$1187.01	$1141.44	$1079.57	$1602.42
Jiedao FE		Y	Y	Y	Y
Controls			Y	Y	Y
Year-Month FE				Y	
DistrictxYear-Month Trend					Y
Observations	82002	82002	82002	82002	82002
Adjusted R^2	0.184	0.513	0.609	0.619	0.614

Note: Dependent variable is ln(total price per square meter in 2007 real Yuan). Standard errors clustered at jiedao level. Sample spans July 20, 2007 - July 20, 2009. All specifications include year and month fixed effects. Average price premium is evaluated at a unit size of 122 sq.m., the size at the mean distance to the nearest business district (5km and 7km), and at a conversion rate of 6.95 yuan per USD. Controls include fixed effects for unit type (newsale vs resale), top floor, floor level, facing direction, no. bedrooms, decoration level, ownership type, and total number of floors in building. Continuous controls include distance to nearest subway station, age, age^2, size, floor-area ratio, green space, property management fees, parking fees, and size, number of housing units and number of buildings of the complex.* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

RRP on Subway Price Gradient: Twoway FE

Table 3: The Effect of Road Rationing on the Price Gradient w.r.t. Subway Distance

Outcome: ln(price/sq.m)	(1)	(2)	(3)	(4)	(5)
Km to Subway x RRP	-0.046**	-0.041***	-0.038***	-0.033***	-0.037***
	(0.020)	(0.011)	(0.011)	(0.011)	(0.009)
Km to Subway	-0.048***	-0.004	-0.016	-0.011	-0.013
	(0.014)	(0.011)	(0.009)	(0.008)	(0.010)
Avg Proximity Premium / Km	$3772.96	$3371.82	$3111.84	$2683.51	$3032.76
Jiedao & Subway Line FE		Y	Y	Y	Y
Controls			Y	Y	Y
Year-Month FE				Y	
DistrictxYear-Month Trend					Y
Observations	82002	82002	82002	81995	82002
Adjusted R^2	0.161	0.524	0.614	0.619	0.617

RRP on CBDs Income Gradient: Twoway FE

Table 4: The Effect of Road Rationing on Income Sorting w.r.t. CBD Distance

Outcome: ln(km to CBD)	(1)	(2)	(3)	(4)	(5)
Monthly Income× RRP	-0.001	-0.004*	-0.005**	-0.005**	-0.004*
	(0.012)	(0.002)	(0.002)	(0.002)	(0.002)
Monthly Income	-0.090***	-0.000	0.001	0.001	0.000
	(0.012)	(0.002)	(0.001)	(0.001)	(0.001)
Zip FE		Y	Y	Y	Y
Controls			Y	Y	Y
Year-Month FE				Y	
DistrictxYear-Month Trend					Y
Observations	8107	8107	8107	8107	8107
Adjusted R^2	0.196	0.942	0.944	0.944	0.946

Note: Dependent variable is ln(Km to CBD). Income is household monthly income ('000 yuan). Standard errors clustered by zip code. Sample spans July 20, 2007-July 20, 2009. All specifications include controls for year, month, and distance to subway. Controls include husband and wife age, employment rank, education, employer type, and tenure. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

RRP on Subway Income Gradient: Twoway FE

Table 5: The Effect of Road Rationing on Income Sorting w.r.t. Subway Distance

Outcome: ln(km to subway)	(1)	(2)	(3)	(4)	(5)
Monthly Income× RRP	0.004	-0.006	-0.007*	-0.007**	-0.007**
	(0.008)	(0.003)	(0.003)	(0.003)	(0.003)
Monthly Income	-0.018**	0.005*	0.006**	0.006**	0.006**
	(0.009)	(0.003)	(0.003)	(0.003)	(0.003)
Zip & Subway Line FE		Y	Y	Y	Y
Controls			Y	Y	Y
Year-Month FE				Y	
DistrictxYear-Month Trend					Y
Observations	8107	8107	8107	8107	8107
Adjusted R^2	0.649	0.927	0.928	0.928	0.930

Identification, Robustness, Discussion

Identification

"The identifying assumption is that housing prices and location choices would have trended similarly with respect to their distances to subways and CBDs in absence of the RRP."

In other words, authors are concerned with estimation of κ_q from the interaction term $\kappa_q(Km_{it} \times D_q)$, not the coefficient α from the main effect αKm_{it} (distance)

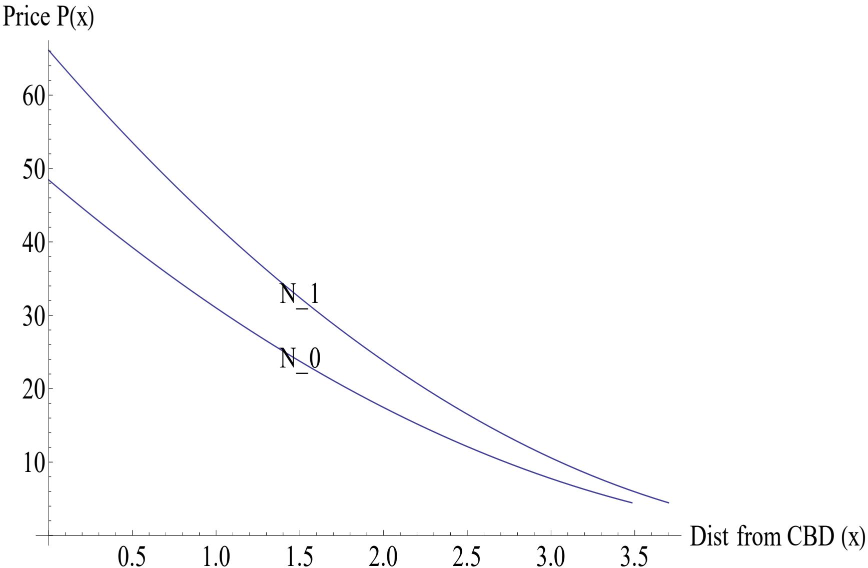
Two main concerns:

1) Omitted variable bias: unobservables changed at the time of policy, affecting outcomes (prices, income). For ex., amenities grew faster near subways, which increased prices

2) Reverse causality, prices$\rightarrow$subways: subways are placed in areas with growing house prices

Authors show there are no trends in price gradients or income sorting in quarters before RRP (short-run). Is this assumption consistent with the AMM model in the long run?

Example: Closed City, Population Increase



Addressing Threats to Identification

First: check whether subway stations are more likely to open in neighborhoods with growing prices (result: no)

Second: limit sample to houses near subways built before RRP (results: similar to full sample)

Third: add controls for subway network density, interaction b/t density and distance to station (results: similar)

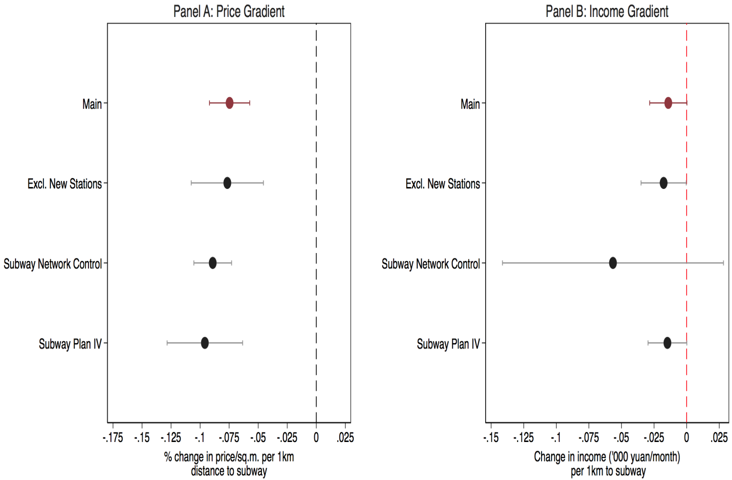
Fourth: instrument for subway placement using Beijing's 2003 subway plan (Baum-Snow QJE 2007 idea)

Fifth: "out-of-sample test"; examine if areas receiving future subways also have differential price trends, which couldn't have been due to RRP

Sixth: placebo test looking at price trends around manufacturing sites, which should not be due to RRP. And then a triple diff test, which I will not cover.

Comparing Coefficients from Different Estimates

Figure A9: Sensitivity of RRP Effect Accounting for Subway System Growth & Network Effects



Discussion

Impressive paper, great example of testing monocentric city model's predictions for price and income sorting

Shows that transportation policy changes can have general equilibrium effects through prices that differ by group (ex: income groups)

Thoughts? Comments?