ROAD RATIONING POLICIES AND HOUSING MARKETS

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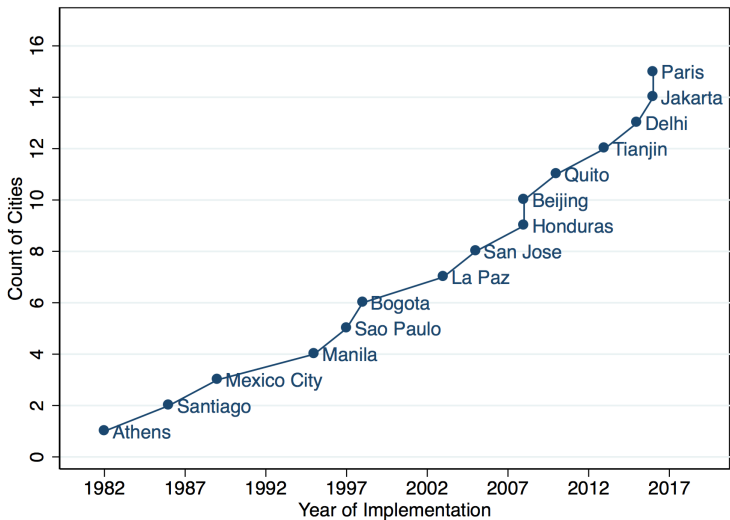[2]Department of Economics, Cornell University & NBER

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TRAFFIC IN BEIJING

Global growth in urban road rationing policies

Sources: http://www.chinadaily.com; https://www.bbc.com;
https://en.wikipedia.org/wiki/Road_space_rationing

- ▶ Road rationing affects transportation costs
  - ▶ Direct costs: fines for violating rules
  - ▶ Indirect costs: substitute to alternative travel modes or travel at different times of day

- ▶ We explore how road rationing affects residential location decisions
  - ▶ → house prices
  - ▶ → distribution of income

- ▶ Difference-in-differences design to compare house prices and income:
  1. Before vs after a city-wide road rationing policy
  2. Locations near vs far from **business districts** and **subway stations**

CONTRIBUTIONS

- ▶ Focus on how road rationing affects the **housing market** & **income-based sorting**
    - ▶ Prior work mainly focused on air pollution &/or congestion: (Carrillo et al. 2016; Viard & Fu 2015; Wolff 2014; Chen et al. 2013; Davis 2008; Zhang et al. 2017; Eskeland & Geyzioglu 1997; Langer & Winston 2008; Xu et al 2015)

- ▶ Quasi-experimental test of the "monocentric city model" predictions on **income sorting** (Alonso-Muth-Mills; LeRoy & Sonstelie 1983)
    - ▶ **Key prediction**: rich decentralize relative to poor *if* faster transit modes are more $$$ than slower modes
    - ▶ Descriptive support of this pattern (Margo 1992; Gin & Sonstelie 1992; Glaeser et al 2008; Bruckner & Rosenthal 2009; Lee & Lin 2017) ....but little causal support

SETTING & DATA SOURCES

Beijing's Road Space Rationing

- Road Rationing Policy (RRP): July 2008 (announced in fall 2007)
    - Restricts use of private vehicles within the 5th ring road
    - Aimed at reducing exhaust gas generated by motor vehicles
    - Enforced through traffic cameras
    - Fine of 200 yuan (about $40 USD, or 15% of average weekly income)

- Private car owners restricted 1 day per week, depending on last digit of license plate

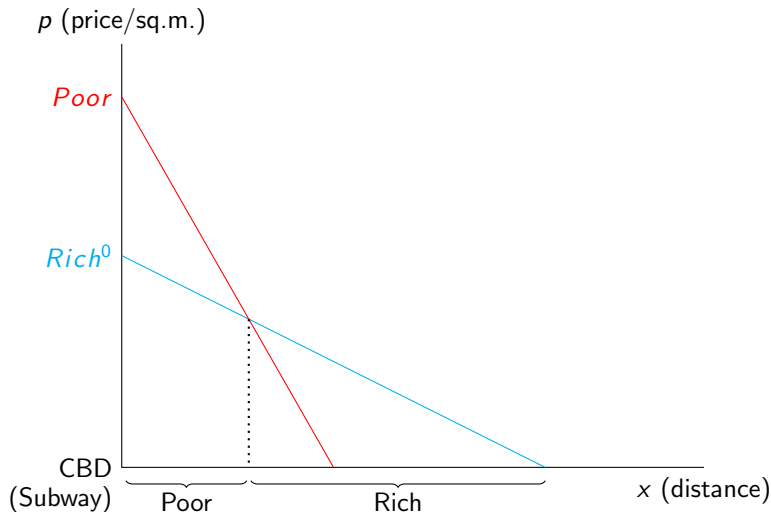- Effectively increased the cost of commuting by car

Data Sources

Unit of observation is a house purchase (or mortgage loan start date) at time t for a housing unit in location j from 2005-2011

1. Real estate transaction data (17% of all transactions)
   - Provides housing unit sale price, location, characteristics
   - 84,000 observations ($\sim$170 neighborhoods)

2. Mortgage loan application data (universe of government-backed mortgages)
   - Housing unit location, demographics of loan applicants
   - 18,000 observations ($\sim$165 neighborhoods)
   - Households are mostly middle-income

- Covers 2/3 of neighborhoods in Beijing, each is $\sim$ 1.65 sq. miles

- Use only transactions prior to 2012 because several confounding policies (house purchase restriction, license plate lottery, etc)
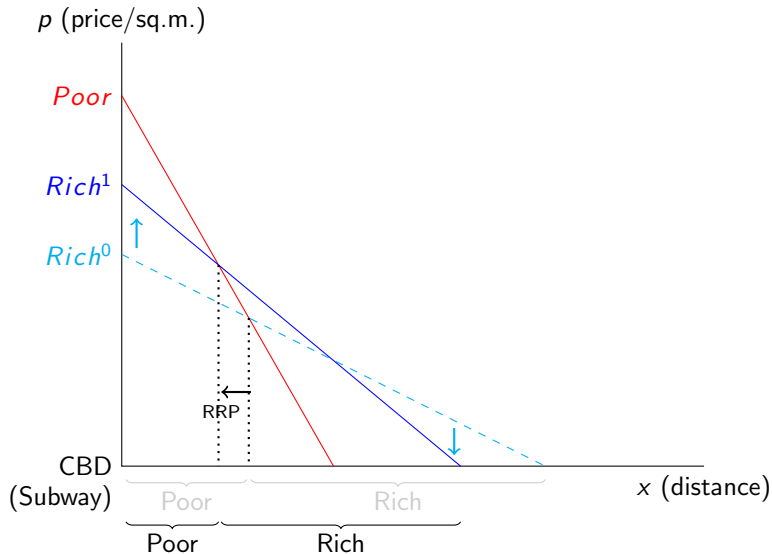
Note: Let $\epsilon_{h,y} > \epsilon_{t,y}$ (i.e., income elasticity of housing > income elasticity of time costs)
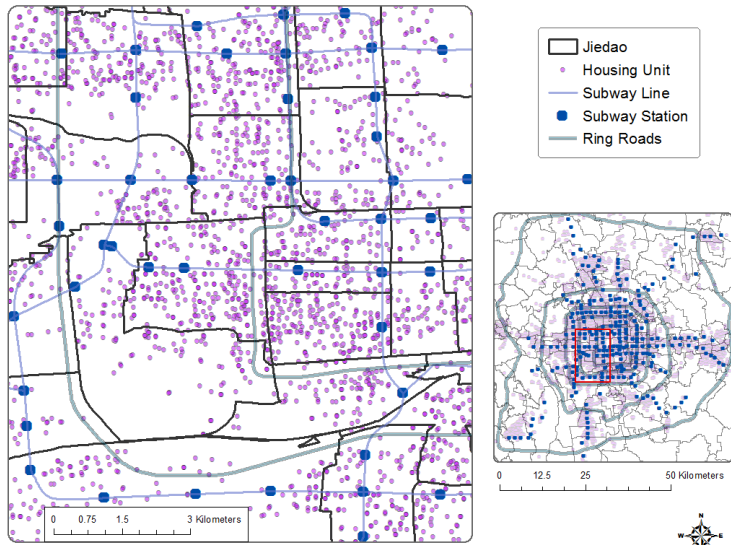
▶ ModebyIncome

Note: Let $\epsilon_{h,y} > \epsilon_{t,y}$ (i.e., income elasticity of housing $>$ income elasticity of time costs)

EMPIRICAL APPROACH

- ▶ Identify variation in:
    - ▶ house price–distance, and
    - ▶ distance–income gradient

    before and after driving restriction *within* a neighborhood ("jiedao" or zip code) of Beijing

- ▶ Median neighborhood is ~ 1.65 square miles

GEOGRAPHIC IDENTIFYING VARIATION

Legend:
- Jiedao
- Housing Unit
- Subway Line
- Subway Station
- Ring Roads

Sources: Beijing Real estate data; Housing Provident Fund data

EMPIRICS & RESULTS

EMPIRICAL APPROACH: HOUSING MARKET

For housing unit i in neighborhood j at day t and quarter q:

$$\ln(p_{ijt}) = \sum_{q=1(\ni 15)}^{28} \kappa_q(Km_{it} \times D_q) + \alpha Km_{it} + \mathbf{X_{ijt}}\theta + \gamma + \tau + \varepsilon_{ijt}$$

where

p = price of housing per square meter

Km = distance to the nearest station or CBD

D = quarter dummies

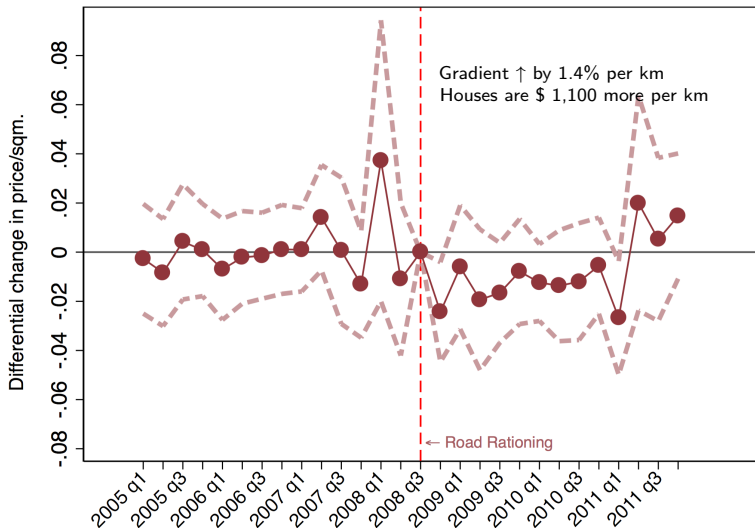$\mathbf{X}$ = controls for housing unit and building complex characteristics

γ and τ are neighborhood and time fixed effects

ε_{ijt} error term, clustered at neighborhood level

κ_q = price premium (discount) demanded for 1 km of proximity (distance) in quarter q relative to RRP quarter (July-Sept 2008)

Identifying Assumption: Prices would have trended similarly for close relative to far housing units (within a neighborhood) in absence of RRP

ROAD RATIONING INCREASED PREMIUM FOR CBD PROXIMITY

Gradient ↑ by 1.4% per km
Houses are $ 1,100 more per km

← Road Rationing

Note: Includes control for distance to nearest subway station.

Road rationing increased premium for CBD proximity

Outcome: ln(price/sq.m.)	(1)	(2)	(3)	(4)	(5)
Km to CBD × 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: Sample spans July 20, 2007 - July 20, 2009. All specifications include year and month fixed effects. 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.* $p < 0.10$,** $p < 0.05$,*** $p < 0.01$

ROAD RATIONING INCREASED PREMIUM FOR SUBWAY PROXIMITY

Gradient ↑ by 3.5% per km
Houses are $ 3,000 more per km

← Road Rationing

Note: Includes control for distance to nearest CBD and subway line fixed effects.

Road rationing increased premium for subway proximity

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

Note: Sample spans July 20, 2007 - July 20, 2009. All specifications include year and month fixed effects. 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 CBD, 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.* $p < 0.10$,** $p < 0.05$,*** $p < 0.01$

EMPIRICAL APPROACH: INCOME SORTING

For household i in neighborhood z at time t and quarter q:

$$\ln(Km_{izt}) = \sum_{q=1(\ni 15)}^{28} \alpha_q(I_{izt} \times D_q) + \psi I_{izt} + \mathbf{Z}_{izt}\theta + \zeta_z + \tau + \mu_{izt}$$
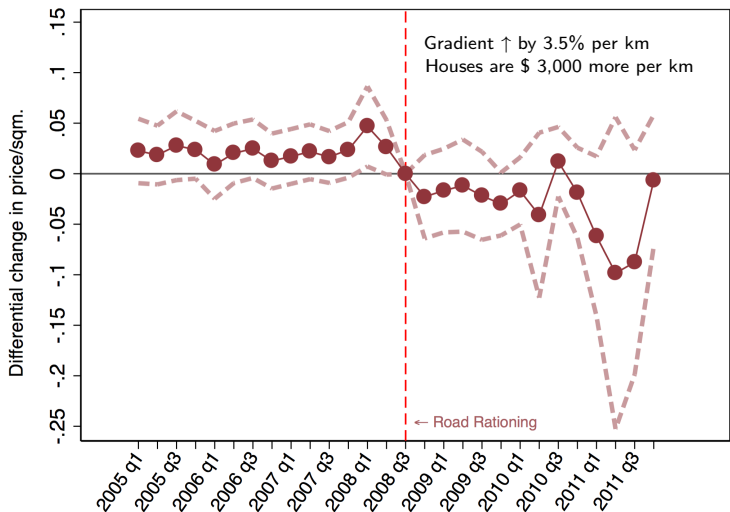
where

Km = distance to the nearest station or CBD

I = monthly household income

D = quarter dummies

$\mathbf{Z}$ = controls for buyer demographics (age, education, job title, industry, tenure etc.)

ζ_z and τ_t are neighborhood and time fixed effects

μ_{izt} error term, clustered by neighborhood

α = change in distance to CBD or subway given a 1,000 yuan change in monthly income in quarter q relative to RRP quarter (July-Sept 2008)

Identifying Assumption: Difference in distance across income groups would have remained stable in absence of RRP restriction

INCOME SORTING NEAR THE CENTRAL BUSINESS DISTRICTS
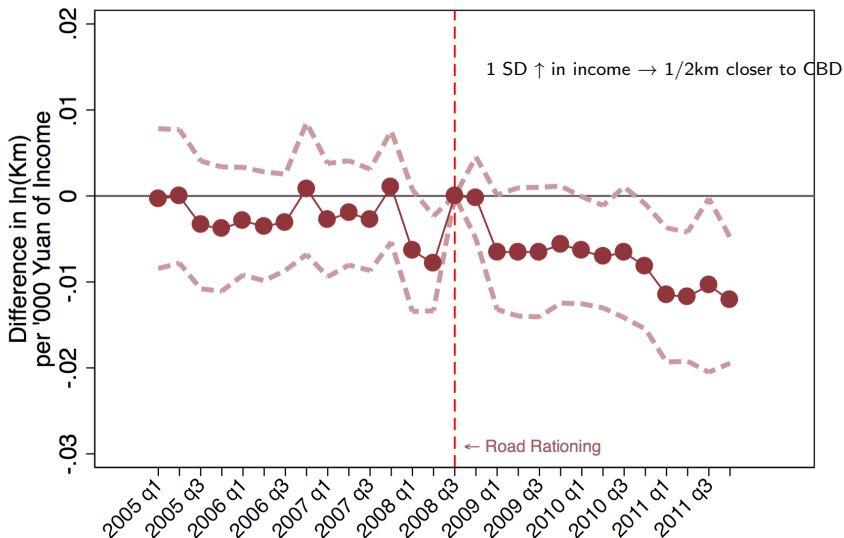
Note: Includes control for distance to nearest subway station.

Average income near CBDs increased after road rationing

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: 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.* $p < 0.10$,** $p < 0.05$,*** $p < 0.01$

INCOME SORTING NEAR SUBWAY STATIONS
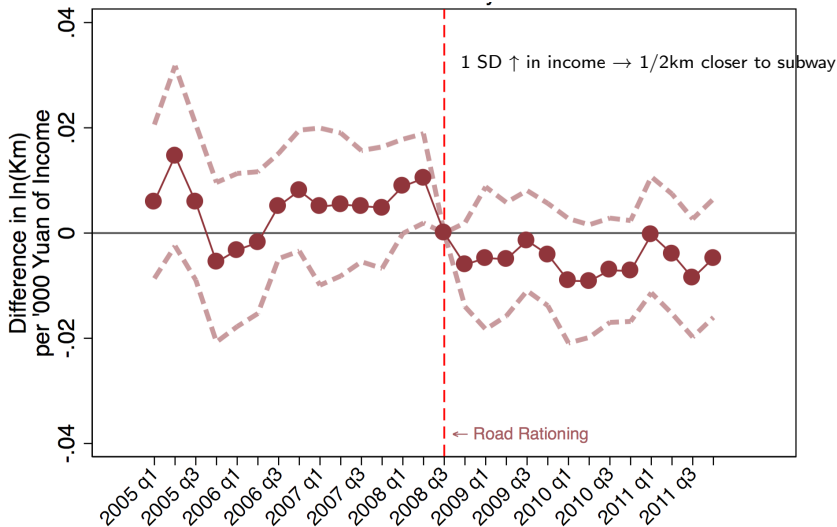
Note: Includes control for distance to nearest CBD and subway line fixed effects.

AVERAGE INCOME NEAR STATIONS INCREASED AFTER ROAD RATIONING

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	
District×Year-Month Trend					Y
Observations	8107	8107	8107	8107	8107
Adjusted R^2	0.649	0.927	0.928	0.928	0.930

Note: Sample spans July 20, 2007-July 20, 2009. All specifications include controls for year, month, and distance to nearest CBD. Controls include husband and wife age, employment rank, education, employer type, and tenure. Subway Line FE is a fixed effect for the subway line associated with the housing unit's closest subway station. $*p < 0.10,** p < 0.05,*** p < 0.01$

Robustness Checks

- Endogeneity of Subway Locations
  - Test for "gentrification" trends in areas with new stations (▸ gentri)
  - Exclude areas with new stations (▸ oldsub)
  - Out-of-sample test with new stations 5 years after RRP (▸ outsample)
  - Test for subway network density effects (▸ density)

- Placebo Analysis (▸ Placebo)
  - Test how RRP affects premium for proximity to pollution sites
  - ...and income sorting near pollution

- Specification Tests
  - Drop Jan-July 2008 (anticipation effects) (▸ drop2q)
  - Alternative CBD definitions (▸ IncomeCBD)

SUMMARY

- ▶ Road rationing policies increasingly common among major cities
- ▶ We show how these policies affect location decisions
- ▶ Beijing road rationing made proximity
  1. **more expensive**: price/sq.m.↑ by
     1.9% for km to CBD; 3.7% for km to subway
  2. **higher income**: household earning 5,000 yuan more per month lives
     1/2 km closer to CBD and subway
- ▶ Consistent with predictions of AMM, LeRoy & Sonstelie (1983)
- ▶ Mechanism: greater inflow of high income households ▸ mech

EXTERNAL VALIDITY

- ▶ Effects will depend on enforcement & compliance; as well as complementary transit investment

Evidence that road rationing policies can limit access to public transit for lower income households
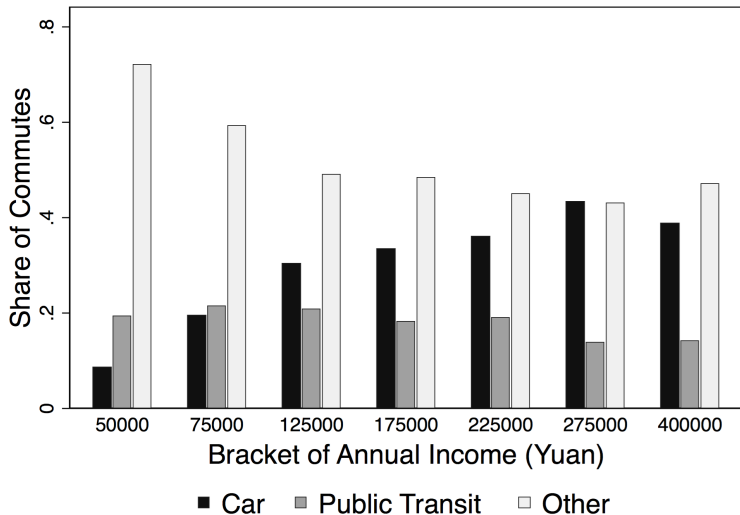
Thank you!
rhiannon.jerch@temple.edu

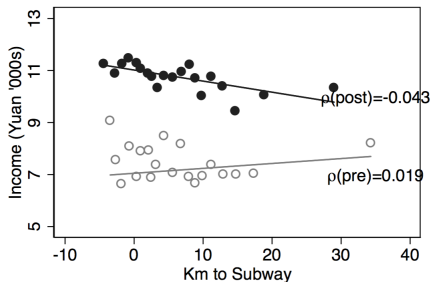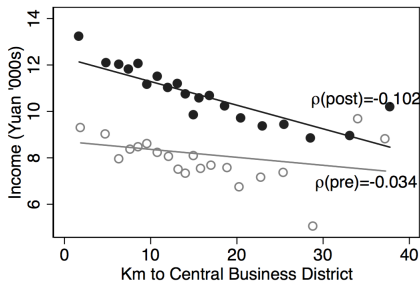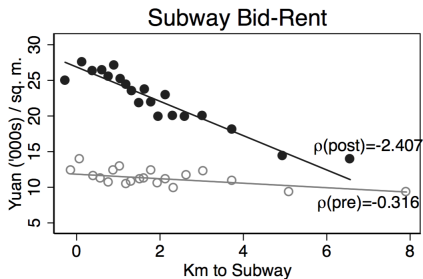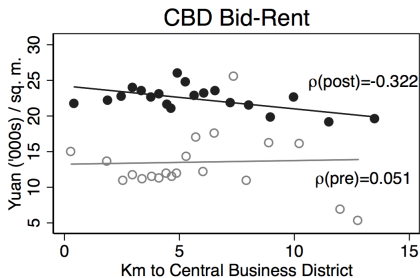# Subway Proximity Premium Dissipates after 3km
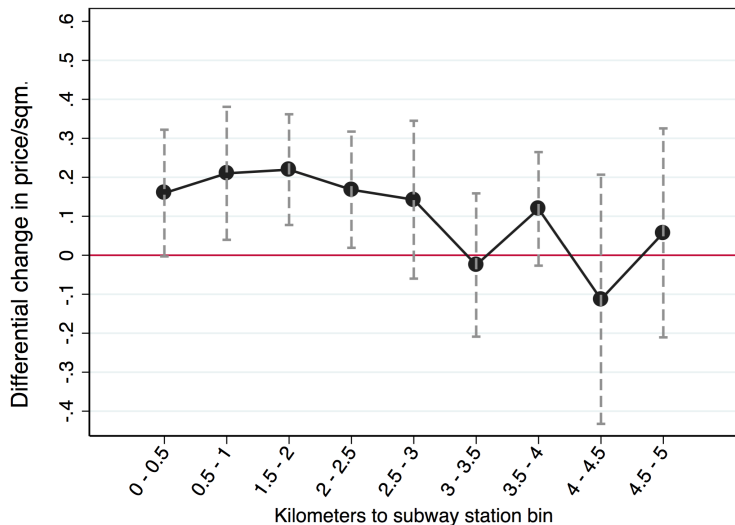
Note: Includes controls for distance to nearest CBD and subway line fixed effects.

TRANSIT MODE CHOICE BY INCOME ▸ CONTRIBUTIONS

Note: Source is 2010 Beijing Transport Institute Travel Survey. Based on 276,377 responses. "Other" includes walking, cycling, taxi, company shuttle, mixed modes.

CBD Bid-Rent

Yuan ('000s) / sq. m.

ρ(post)=-0.322

ρ(pre)=0.051

Km to Central Business District

Subway Bid-Rent

Yuan ('000s) / sq. m.

ρ(post)=-2.407

ρ(pre)=-0.316

Km to Subway

Income (Yuan '000s)

ρ(post)=-0.102

ρ(pre)=-0.034

Km to Central Business District

Income (Yuan '000s)

ρ(post)=-0.043

ρ(pre)=0.019

Km to Subway

Note: Left graph binned-means residualized by distance to subway. Right graph binned-means residualized by distance to CBD.
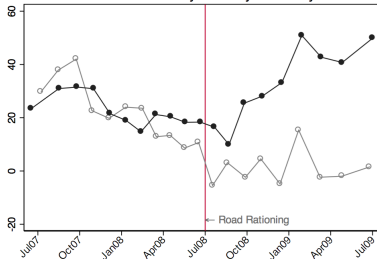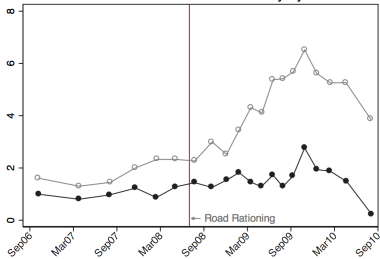
- Does average income near CBDs and subways ↑ due to **displacement of low income** or **larger inflows of high income** households?

- Compare new housing development under vs over 5km

- Compare count of below-median-income households under vs over 5km (based on pre-RRP income distribution)
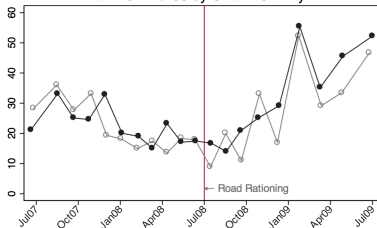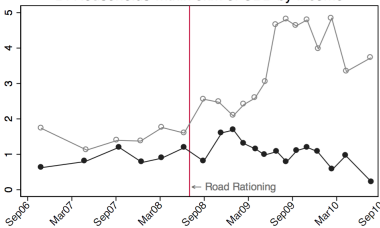
A. New Builds by Subway Proximity

B. New Builds by CBD Proximity

C. Households within 5km of Subway by Income

D. Households within 5km of CBD by Income

● Under 5km   ○ Over 5km

● Below Median Income   ○ Above Median Income

Driving Restriction Effect on "Premium" for Proximity to Pollution

PLACEBO TEST WITH POLLUTION SITES ▶ ROBUST

Driving Restriction Effect on "Premium" for Proximity to Pollution

Diff. in ln(Km) per '000 Yuan of Income
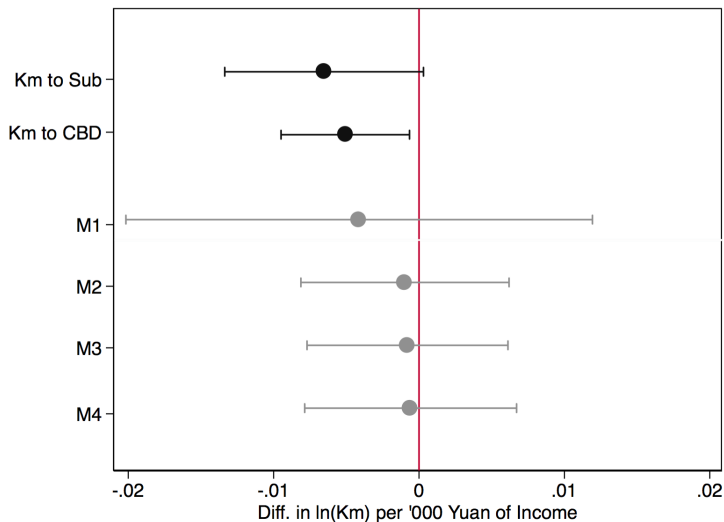
MEAN INCOME TRENDS BY JIEDAO BEFORE & AFTER SUBWAY STATION OPENING
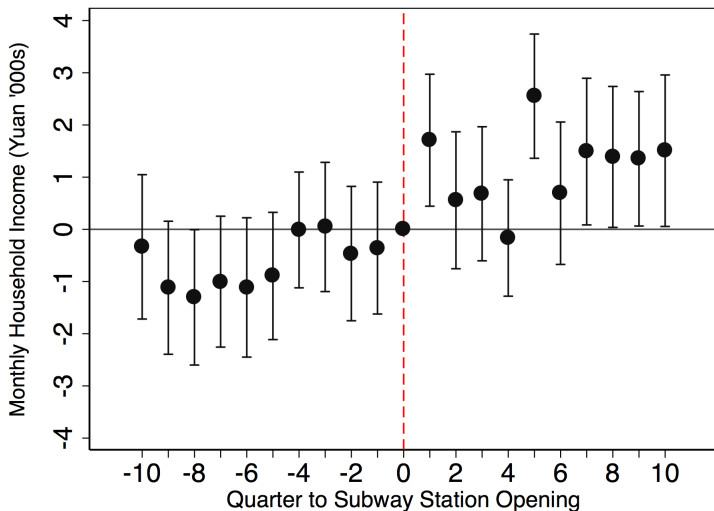
Note: Point estimates residualized by quarter-of-year fixed effects. Includes a balanced panel of 24 jiedao. Sample spans 2005 through 2014 and includes 56 station openings. ▶ Robust

PLACEBO TEST OF RRP:

HOUSING UNITS OVER 3KM FROM STATION UNTIL 2013 ▸ ROBUST
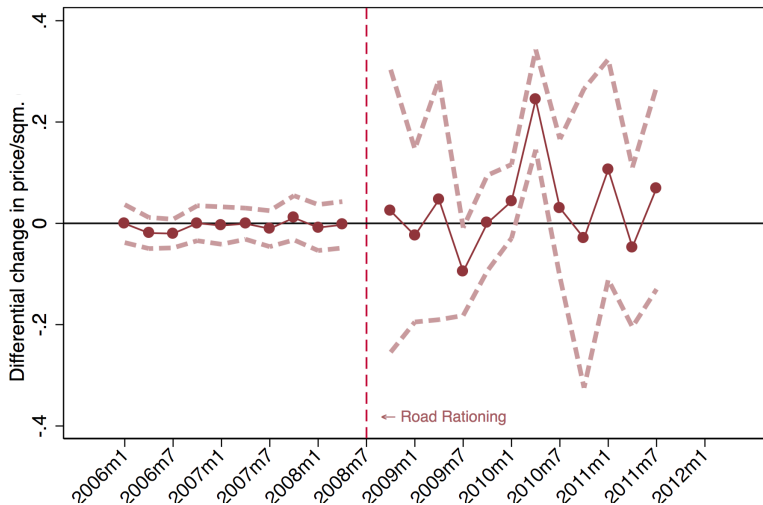
Note: Sample includes housing units located over 3km from the nearest station through 2012; but become within 3km from a station after 2013.

EFFECT OF RRP ON HOUSE PRICE-DISTANCE GRADIENT

EXCLUDING HOUSES NEAR NEWLY-BUILT STATIONS ▸ Robust

Outcome: ln(price/sq.m)	(1)	(2)	(3)	(4)	(5)
Km to Subway x RRP	-0.020	-0.022***	-0.025***	-0.012***	-0.028***
	(0.019)	(0.006)	(0.005)	(0.004)	(0.005)
Km to Subway	-0.109***	-0.053***	-0.043***	-0.050***	-0.040**
	(0.015)	(0.009)	(0.015)	(0.015)	(0.015)
Avg Price Premium / Km	$1694.84	$1902.35	$2105.61	$1053.99	$2418.66
Controls		Y	Y	Y	Y
Jiedao & Subway Line FE			Y	Y	Y
Year-Month FE				Y	
DistrictxYear-Month Trend					Y
Observations	12474	12474	12474	12474	12474
Adjusted R^2	0.191	0.635	0.733	0.742	0.734

Note: Sample includes housing units in building complexes that do not change in their proximity to subway stations from 2005 through 2016. Sample spans July 20, 2007 - July 20, 2009. All specifications include year and month fixed effects. 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 CBD, 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.* $p < 0.10$,** $p < 0.05$,*** $p < 0.01$

CONTROLLING FOR SUBWAY NETWORK DENSITY ▸ ROBUST

Outcome: ln(price/sq.m.)	(1)	(2)	(3)	(4)	(5)	(6)
Km to Subway × RRP	-0.040*	-0.043***	-0.046***	-0.039***	-0.036***	-0.037***
	(0.020)	(0.013)	(0.013)	(0.012)	(0.012)	(0.011)
Km to Subway	-0.042***	0.002	-0.000	-0.012	-0.009	-0.010
	(0.013)	(0.013)	(0.011)	(0.009)	(0.008)	(0.009)
Km to Subway × Network Density	-0.001	0.001	0.001	0.000	0.001	0.000
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Network Density	0.002	0.000	-0.001	-0.000	-0.000	-0.000
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Avg Proximity Premium / Km	$3232.07	$3525.87	$3768.40	$3206.90	$2927.12	$3025.98
Jiedao FE		Y	Y	Y	Y	Y
Subway Line FE			Y	Y	Y	Y
Controls				Y	Y	Y
Year-Month FE					Y	
District×Year-Month Trend						Y
Observations	70307	70307	70307	70307	70299	70307
Adjusted R^2	0.161	0.518	0.524	0.623	0.629	0.629

Note: Sample spans July 20, 2007 - July 20, 2009. Network Density is the inverse distance-weighted sum of subway stations from each station location. All specifications include year and month fixed effects. 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 CBD, 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.$*p < 0.10,** p < 0.05,*** p < 0.01$

Outcome: ln(price/sq.m.)	Technology District	Software District	Financial District	Beijing "CBD"	Business Park	Shopping District
Km to [CBD] × RRP	-0.006	-0.005	-0.016**	-0.010**	-0.011***	-0.018***
	(0.004)	(0.003)	(0.008)	(0.004)	(0.003)	(0.006)
Km to [CBD]	0.020	0.014	0.042**	0.008	0.010	0.027
	(0.013)	(0.013)	(0.018)	(0.014)	(0.013)	(0.017)
Year & Month FE	Y	Y	Y	Y	Y	Y
Jiedao FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
District×Year-Month Trend	Y	Y	Y	Y	Y	Y
Observations	82002	82002	82002	82002	82002	82002
Adjusted R^2	0.613	0.612	0.616	0.613	0.614	0.615

Note: Sample spans July 20, 2007 - July 20, 2009. 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.* $p < 0.10$,** $p < 0.05$,*** $p < 0.01$

EFFECT OF RRP ON CBD-INCOME GRADIENT ▸ Robust

Outcome: ln(km to [CBD])	Technology District	Software District	Financial District	Beijing "CBD"	Business Park	Shopping District
Monthly Income× RRP	-0.004**	-0.003***	-0.004*	-0.004***	-0.003*	-0.004**
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)
Monthly Income	0.001	0.001	0.002	0.003**	0.001	0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Year & Month FE	Y	Y	Y	Y	Y	Y
Zip FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
DistrictxYear-Month Trend	Y	Y	Y	Y	Y	Y
Observations	18022	18022	18022	18022	18022	18022
Adjusted R^2	0.954	0.951	0.974	0.968	0.956	0.974

Note: Sample spans July 20, 2007-July 2009. Controls include distance to nearest subway, husband and wife age, employment rank, education, employer type, and tenure.*$p < 0.10$,** $p < 0.05$,*** $p < 0.01$

	ln(price/sqm) (1)	ln(price/sqm) (2)	ln(km to CBD) (3)	ln(km to subway) (4)
Km to CBD × RRP	-0.012* (0.007)			
Km to Subway × RRP		-0.034*** (0.010)		
Monthly Income× RRP			-0.006** (0.002)	-0.008** (0.004)
Jiedao FE	Y	Y		
Zip Code FE			Y	Y
Subway Line FE		Y		Y
Housing Controls	Y	Y		
Demographic Controls			Y	Y
District×Year-Month Trend	Y	Y	Y	Y
Observations	68658	68658	6506	6506
Adjusted R^2	0.668	0.672	0.946	0.927

Dependent variable denoted in top row. Sample spans July 20, 2007 - July 20, 2009, excluding the first two quarters of 2008: January 1, 2008 through July 20, 2008. All specifications include year and month fixed effects.
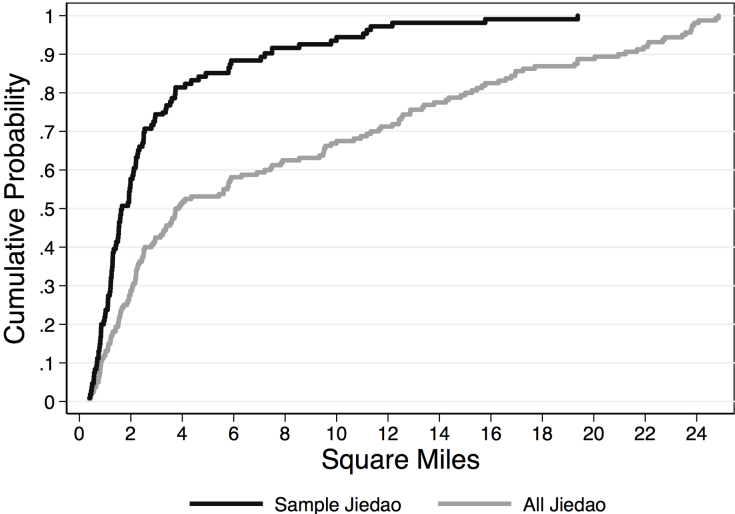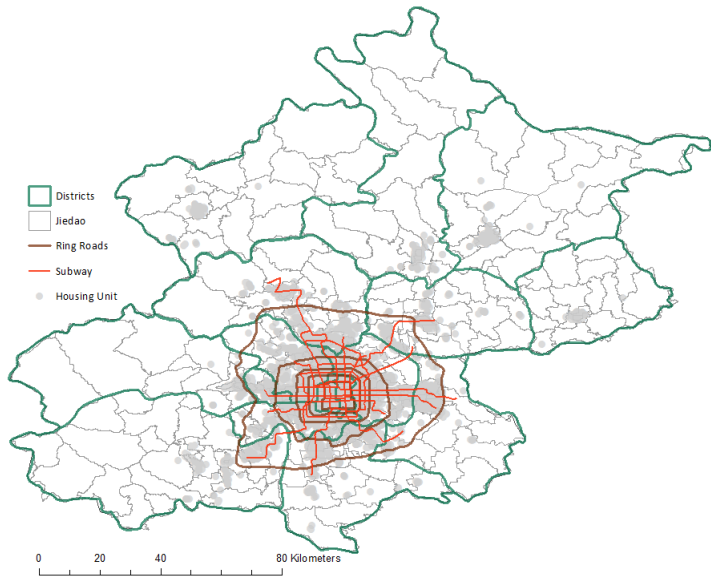
BEIJING SUBWAY SYSTEM GROWTH ▸ RRP
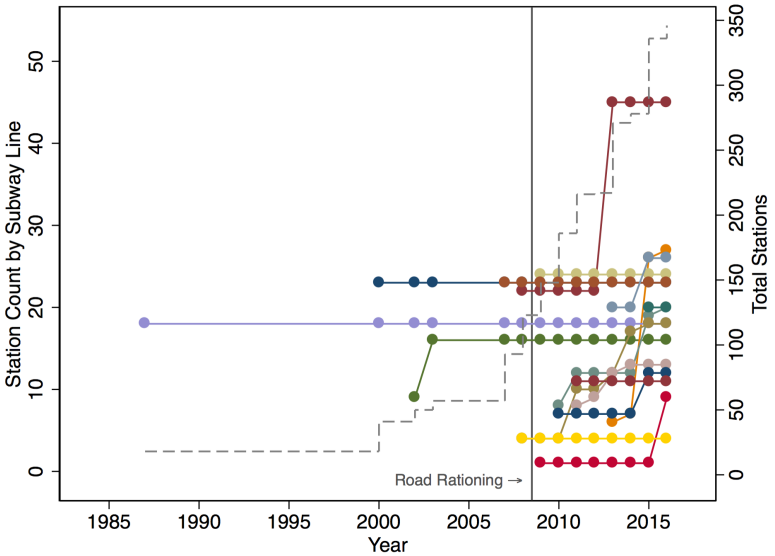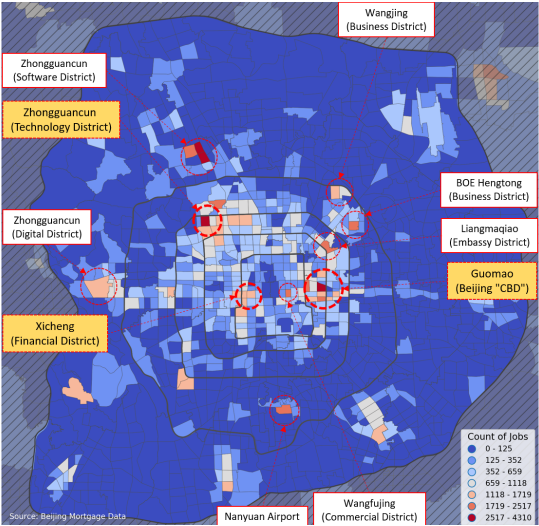
Distribution of Jiedao Size

Note: Sample Jiedao include 188 neighborhoods. "All Jiedao" include population of neighborhoods, or 307 jiedao.

HOUSING UNITS & SUBWAY NETWORK IN BEIJING

BUSINESS DISTRICTS OF BEIJING

Sources: Ziye Zhang, HPF Mortgage Data. Figure shows employment concentration by transportation analysis zone.