ASIAN BUREAU OF FINANCE AND ECONOMIC RESEARCH

Asian Bureau of Finance and Economic Research (ABFER) Conference
21-23 May 2018

# Analysis of Housing Price Distributions Near MRT Stations

## - The Spatial Autoregressive and Quantile Approaches

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May 21, 2018

# Introduction

- Rail based transit system (RTS) has been an important transportation in densely populated cities
- In Singapore, high land costs, traffic congestion and high car-ownership costs has influenced the housing location choice of households
- RTS/MRT has significant impact on the urban landscape
- Ring-shaped urban land use plan connected by high efficient MRT network
- Flattening bid rent gradient with very high density CBD encircled by five regional centres
- This study empirically tests the capitalization effects of MRT stations on housing prices and marginal willingness to pay to live near MRT stations

# Outline of Presentation

- Motivations of the study
- Why Singapore?
- Data analysis
- Empirical Analysis
  - Spatial autoregressive DID model (SDID)
  - Quantile version (QSDID)
  - Conditional Quantile Decomposition
- Conclusion

# Past studies

- One of the most widely studied topics in real estate and urban economic literature
- 3 commonly applied methodologies
  - Hedonic pricing model using a Euclidean distance to the closest station as the control variable
    - Debrezion et al (2017) provide a meta analysis of 57 cities, and they show that property values increase 2.3% for every 250 m to a railway station
    - Mostly found positive capitalization effects
    - Some found insignificant and other show negative effects (Gatzlaff and Smith, 1993; Landis et al 1995)
  - Temporal change in prices showing evidence of flattening price gradient (McDonald and Osuji, 1995; MacDonald and McMillen, 2004, etc. )
  - Quasi-experiment method – using the opening of RTS/MRT stations as the treatment (Gibbon and Machin, 2005; Billings, 2011)
- Addressing endogeneity issues
  - Repeat sales data and DID

# Motivations of the Study

- What incremental values could we add to the literature?
  - Measurement issue – spatial and topographical features/obstacles
  - Resolving endogeneity – causality and selection bias
  - Spillover and dynamic effects of new MRT line
  - Heterogeneity in marginal willingness to pay (MWTP)
- Difficult to establish the causal-relationships between MWTP and accessibility premium to MRT stations
  - Do people really trade-off commuting costs in housing price premiums?
  - Baum-Snow and Kahn (2000) found push factor and substitution effects

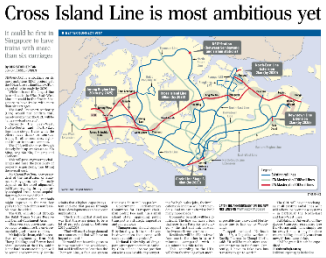
# Methodological Innovations and Challenges

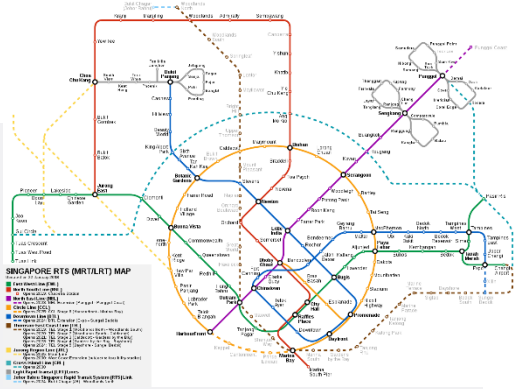
- **Four challenges and related literature**
  - Network distance versus Euclidean Distance
  - Non-linear capitalization effects
    - Local polynomial regression (LPR) (Linden and Rockoff, 2008)
  - Endogeneity issues
    - ATE and DID (Gibbons and Machin, 2005, Billings, 2011)
  - Spatial Dynamic and spillover effects
    - Spatial DID applications - Changas et al (2016) on sugarcane production and health; Bransignton et al (2016) on school enrolment choice; Heckert and Mennis (2012) on vacant land greening programm
    - Dube et al (2014) uses SDID to study public mass transit system in Montreal, Canada, but found no significant treatment effects
    - Spatial econometric (Anselin, 1988)
  - Heterogeneity and compositional effects
    - Distributional treatment effects / Quantile approach (McMillen, 1996, 2015)
    - Quantile decomposition (McMillen, 2008)

# Why Singapore? Why Circle Line?

- Singapore is a unique laboratory to test the policy shocks
- High housing price and high car ownership costs
- Public transportation / MRT network could have significant impact on the trade-off in housing location choice
- A highly efficient private market
- The government has long term planning, and it plans to double the MRT lines to 360 km by 2030
- 8 out of 10 households will live within 10-minute walking distance to the closest MRT stations
- Why CCL? – the fourth MRT lines in the island opened from 2009 to 2011 in phases
- CCL encircles the urban fringe areas covering a very diverse mixed of housing types in the neighbourhoods
- Heterogeneity of housing types from luxury to mass market housing options
- Land recapture is used as an effective public financing resource to finance MRT development
- Highly dynamic at local neighbourhood levels – en bloc sales by private developers to drive urban renewal

# MRT Network in Singapore


Cross Island Line is most ambitious yet





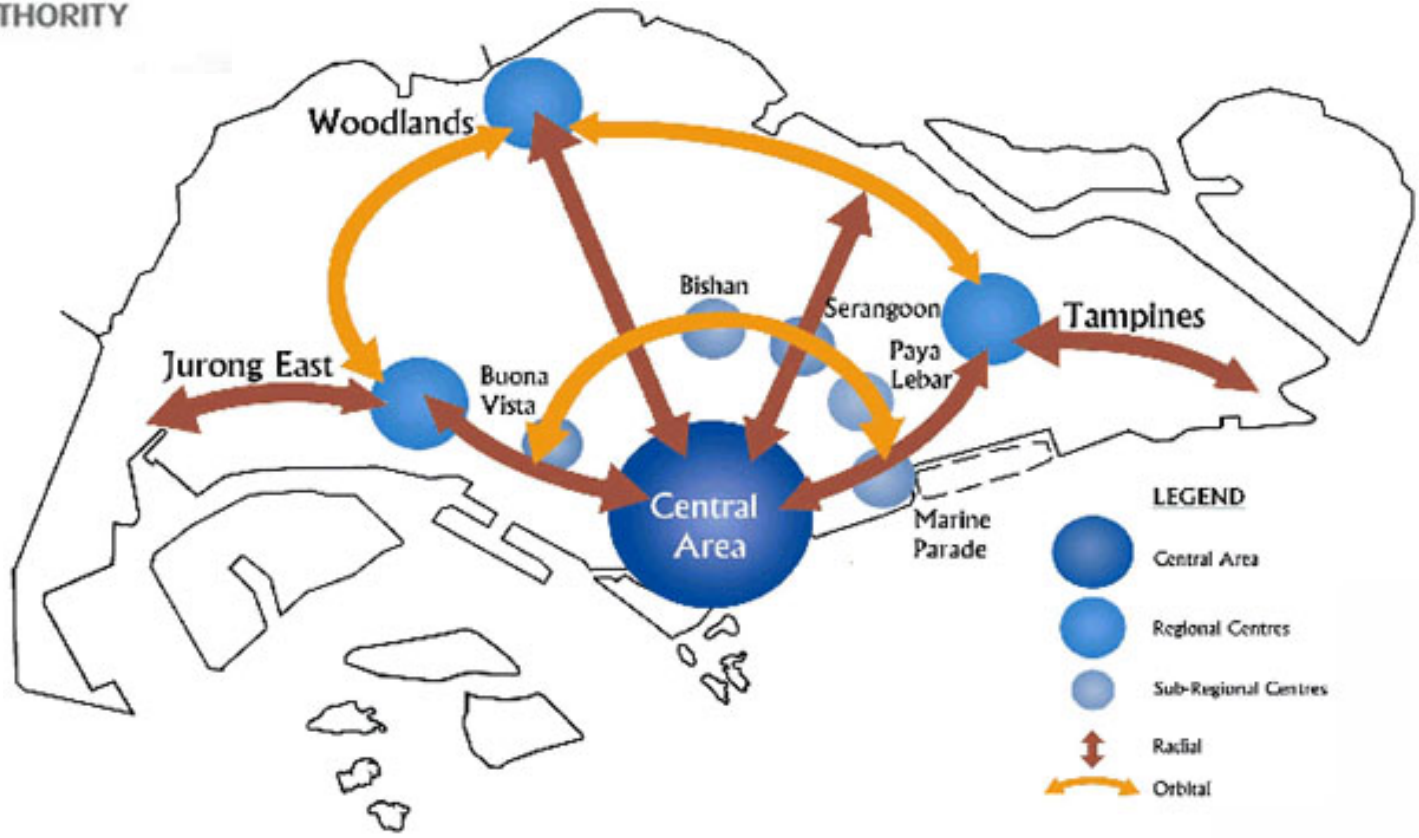

Source: LTA

# Circle Line Stations and Openings

| No | Name of Station | MRT Station Code | Interchange Code | Connecting to |
|---|---|---|---|---|
| **Phase 1 (Opening Date: 28 May 2009)** | | | | |
| 1 | Bartley | CC12 | | |
| 2 | Serangoon | CC13 | NE12 / CC13 | North-East Line |
| 3 | Lorong Chuan | CC14 | | |
| 4 | Bishan | CC15 | NS17 / CC15 | North-South Line |
| 5 | Marymount | CC16 | | |
| **Phase 2 (Opening Date: 17 April 2010)** | | | | |
| 6 | Dhoby Ghaut | CC1 | NS24 / NE6 / CC1 | North-South/North-East Lines |
| 7 | Bras Basah | CC2 | | |
| 8 | Esplanade | CC3 | | |
| 9 | Nicoll Highway | CC5 | | |
| 10 | Stadium | CC6 | | |
| 11 | Mountbatten | CC7 | | |
| 12 | Dakota | CC8 | | |
| 13 | Paya Lebar | CC9 | EW8 / CC9 | East-West Line |
| 14 | Macpherson | CC10 | | |
| 15 | Tai Seng | CC11 | | |
| **Phase 3 (Opening Date: 8 October 2011)** | | | | |
| 16 | Caldecott | CC17 | | |
| 17 | Bukit Brown[#] | CC18 | | |
| 18 | Botanic Gardens | CC19 | | |
| 19 | Farrer Road | CC20 | | |
| 20 | Holland Village | CC21 | | |
| 21 | Buona Vista | CC22 | CC22/EW21 | East-West Line |
| 22 | One North | CC23 | | |
| 23 | Kent Ridge | CC24 | | |
| 24 | Haw Par Villa | CC25 | | |
| 25 | Pasir Panjang | CC26 | | |
| 26 | Labrador | CC27 | | |
| 27 | Telok Blangah | CC28 | | |
| 28 | Harborfront | CC29 | CC29/NE1 | North-East line |
| **Circle Line Extension (14 January 2012)** | | | | |
| 29 | Marina Bay | CC30 | NS27 / CE2 / TS20 | North-South Line /Terminal |
| 30 | Bayfront | CE1 | CE1/DT16 | Terminal / Downtown Line |

# 城市和基础设施的规划

向外分散化的区域性策略




资料来源：仲量行研究部（Jones Lang LaSalle Research, 4Q12

# Data sources

- We collect non-landed housing transaction data from REALIS covering the period 2007 -2013 (2 years before and after the CCL opening)
- 3 different housing types: executive condominiums (0.6%), apartments (37.1%) and condominiums (62.3%)
- Demarcate the study boundary to 1.6km from the CCL MRT stations
  - Final sample consists of 21,954 transactions
- The data includes information on housing size, floor, land tenure, sale type, buyer type, address and date of sales
- Using GIS too, we also define various spatial measures, which include distance to school, CBD, shopping malls, bus stop and expressway

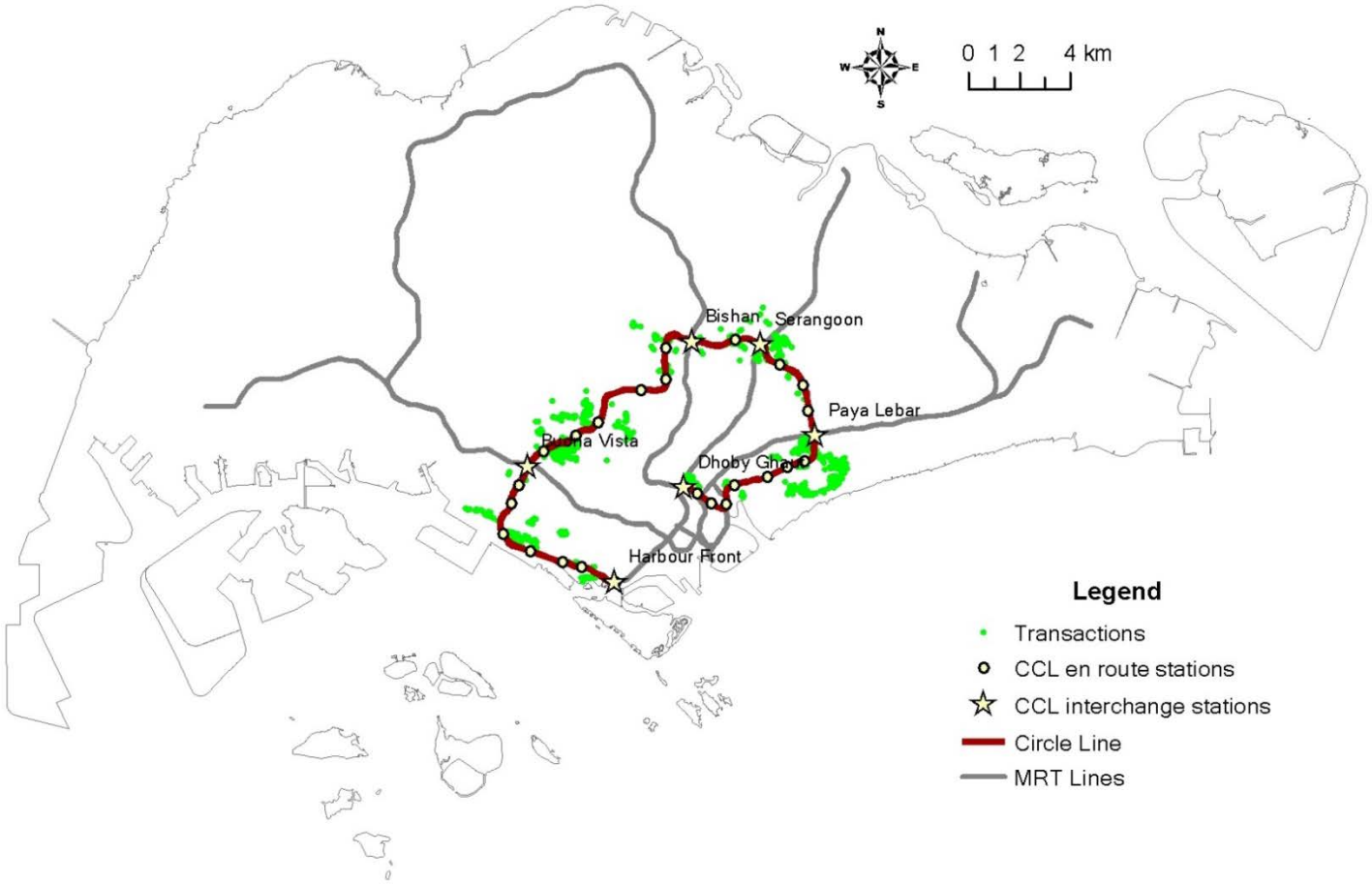
# Summary Statistics

| | Full Sample | | Treatment Group Network Distance ≤600m | | Control Group Network Distance >600m | | Linear group Linear Distance ≤600m | |
|---|---|---|---|---|---|---|---|---|
| **Observation** | 21,954 | | 7,388 | | 14,566 | | 15,429 | |
| | Mean | S.D. | Mean | S. D. | Mean | S. D. | Mean | S.D. |
| Price per housing unit (S$) | 1,402,168 | 985,590 | 1,192,170 | 620,144 | 1,512,530 | 1,111,137 | 1,358,329 | 994,618 |
| Price per square metre (S$/m$^2$) | 12,234 | 3,971 | 11,693 | 3,361 | 12,509 | 4,220 | 12,349 | 4,088 |
| Ln Price | 13.999 | 0.552 | 13.895 | 0.435 | 14.05 | 0.596 | 13.967 | 0.543 |
| Ln Floor Area | 4.640 | 0.492 | 4.572 | 0.435 | 4.674 | 0.515 | 4.601 | 0.487 |
| Floor Level | 7.799 | 6.151 | 8.950 | 6.275 | 7.215 | 6.003 | 8.027 | 6.429 |
| Property Type | | | | | | | | |
| Apartment | 0.371 | 0.483 | 0.397 | 0.489 | 0.357 | 0.479 | 0.401 | 0.490 |
| Condominium | 0.623 | 0.485 | 0.603 | 0.489 | 0.633 | 0.482 | 0.590 | 0.492 |
| Executive Condominium | 0.006 | 0.078 | 0.000 | 0.000 | 0.009 | 0.096 | 0.009 | 0.093 |
| Lease Type | | | | | | | | |
| Freehold | 0.512 | 0.500 | 0.349 | 0.477 | 0.595 | 0.491 | 0.477 | 0.499 |
| Leasehold | 0.488 | 0.500 | 0.651 | 0.477 | 0.405 | 0.491 | 0.523 | 0.499 |
| Purchaser Type | | | | | | | | |
| HDB | 0.323 | 0.468 | 0.342 | 0.475 | 0.313 | 0.464 | 0.333 | 0.471 |
| Private | 0.677 | 0.468 | 0.658 | 0.475 | 0.687 | 0.464 | 0.667 | 0.471 |
| Sale Type | | | | | | | | |
| New Sale | 0.512 | 0.500 | 0.534 | 0.499 | 0.500 | 0.500 | 0.535 | 0.499 |
| Sub Sale | 0.082 | 0.275 | 0.088 | 0.284 | 0.079 | 0.270 | 0.075 | 0.264 |
| Resale | 0.406 | 0.491 | 0.378 | 0.485 | 0.420 | 0.494 | 0.390 | 0.488 |
| Network Distance to MRT (m) | 803.193 | 397.163 | 376.064 | 149.674 | 1,019.836 | 294.805 | 626.568 | 311.164 |
| Euclidean Distance to MRT (m) | 490.773 | 309.308 | 219.997 | 111.977 | 628.113 | 285.983 | 320.653 | 151.716 |
| Distance to School (m) | 1,667.153 | 688.148 | 1,528.906 | 702.179 | 1,737.273 | 670.130 | 1,576.231 | 655.794 |
| Distance to CBD (m) | 6,014.183 | 1,647.860 | 6,280.275 | 1,509.667 | 5,879.219 | 1,697.882 | 5,934.527 | 1,691.017 |
| Distance to Expressway (m) | 1,111.423 | 663.418 | 1,091.656 | 553.056 | 1121.449 | 712.70 | 1,141.424 | 594.320 |
| Distance to Bus Stop (m) | 157.840 | 97.852 | 135.459 | 67.821 | 169.192 | 108.556 | 163.027 | 97.807 |
| Distance to Mall (m) | 1,834.797 | 880.697 | 1900.909 | 895.742 | 1,801.264 | 871.082 | 1,830.326 | 915.378 |

# “Before” and “After” Samples

| | Full Sample | | Treatment Group | | | | |
|---|---|---|---|---|---|---|---|
| | | | Before Treatment | | After Treatment | | |
| Observation | 21,954 | | 3,633 | | 3,755 | | |
| | Mean | S.D. | Mean | S. D. | Mean | S. D. | |
| Price per housing unit (S$) | 1,402,168 | 985,590 | 1,235,567 | 691,279 | 1,146,814 | 539,671 | 1 |
| Price per square metre (S$/m2) | 12,234 | 3,971 | 11,632 | 3,876 | 11,752 | 2,773 | |
| Ln Price | 13.999 | 0.552 | 13.909 | 0.485 | 13.881 | 0.379 | |
| Ln Floor Area | 4.640 | 0.492 | 4.607 | 0.459 | 4.539 | 0.408 | |
| Floor Level | 7.799 | 6.151 | 8.195 | 6.025 | 9.680 | 6.424 | |
| Property Type | | | | | | | |
| Apartment | 0.371 | 0.483 | 0.390 | 0.488 | 0.403 | 0.491 | |
| Condominium | 0.623 | 0.485 | 0.610 | 0.488 | 0.597 | 0.491 | |
| Executive Condominium | 0.006 | 0.078 | 0.000 | 0.000 | 0.000 | 0.000 | |
| Property Lease Type | | | | | | | |
| Freehold | 0.512 | 0.500 | 0.445 | 0.497 | 0.255 | 0.436 | |
| Leasehold | 0.488 | 0.500 | 0.555 | 0.497 | 0.745 | 0.436 | |
| Purchaser Type | | | | | | | |
| HDB | 0.323 | 0.468 | 0.304 | 0.460 | 0.379 | 0.485 | |
| Private | 0.677 | 0.468 | 0.696 | 0.460 | 0.621 | 0.485 | |
| Sale Type | | | | | | | |
| New Sale | 0.512 | 0.500 | 0.496 | 0.500 | 0.571 | 0.495 | |
| Sub Sale | 0.082 | 0.275 | 0.119 | 0.324 | 0.058 | 0.234 | |
| Resale | 0.406 | 0.491 | 0.385 | 0.487 | 0.371 | 0.483 | |
| Network Distance to MRT (m) | 803.193 | 397.163 | 418.035 | 126.353 | 335.457 | 159.003 | |
| Euclidean Distance to MRT (m) | 490.773 | 309.308 | 245.221 | 101.232 | 195.593 | 116.393 | |
| Distance to School (km) | 1.667 | 688.148 | 1.413 | 0.745 | 1.641 | 0.638 | |
| Distance to CBD (km) | 6.014 | 1647.860 | 6.140 | 1.588 | 6.416 | 1.416 | |
| Distance to Expressway (km) | 1.111 | 663.418 | 1.162 | 0.597 | 1.024 | 0.497 | |
| Distance to Bus Stop (km) | 0.158 | 97.852 | 0.140 | 0.056 | 0.131 | 0.075 | |
| Distance to Mall (km) | 1.835 | 880.697 | 2.221 | 0.905 | 1.591 | 0.770 | |

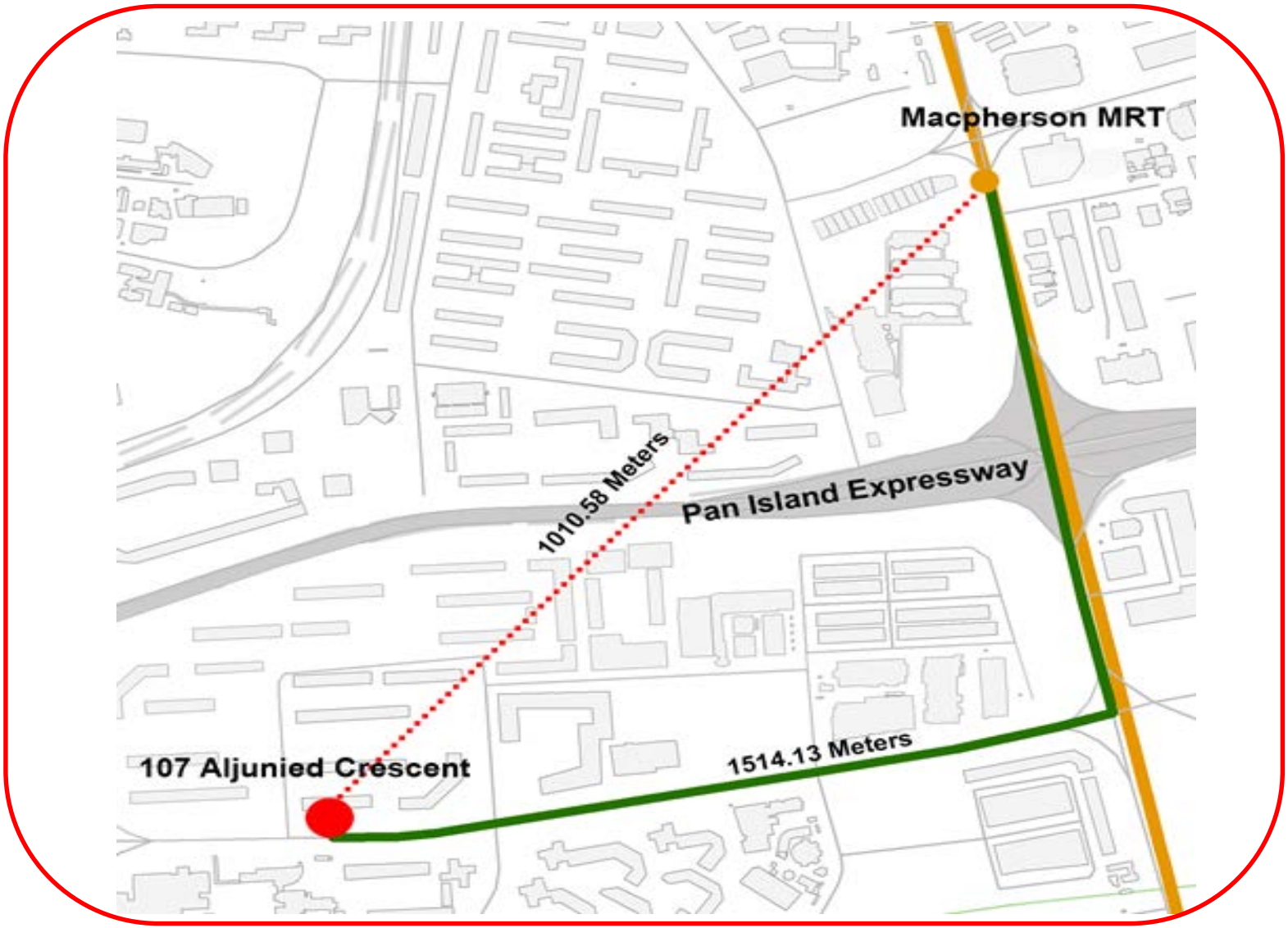
# MRT Network and Non-Landed Private Housing Transactions



# Network Distance Measures

- Monocentric city model assumes plain and smooth urban form
- Saiz (2010) that regulatory controls on land use are highly endogenous on topography and geographical features of a city
- Ignoring spatial and topographical constraints could create measurement errors
- Overestimation of the capitalization effects of MRT connectivity
- We are one of the few study in urban literature that uses the network-based distance
- We overlay the road network layer of GIS map by SLA over the housing transaction and MRT maps
- We simulate the shortest route to walk to the closest MRT station on the CCL
- The average network distance is 803.19 m compared to the average Euclidean distance of 490.77m

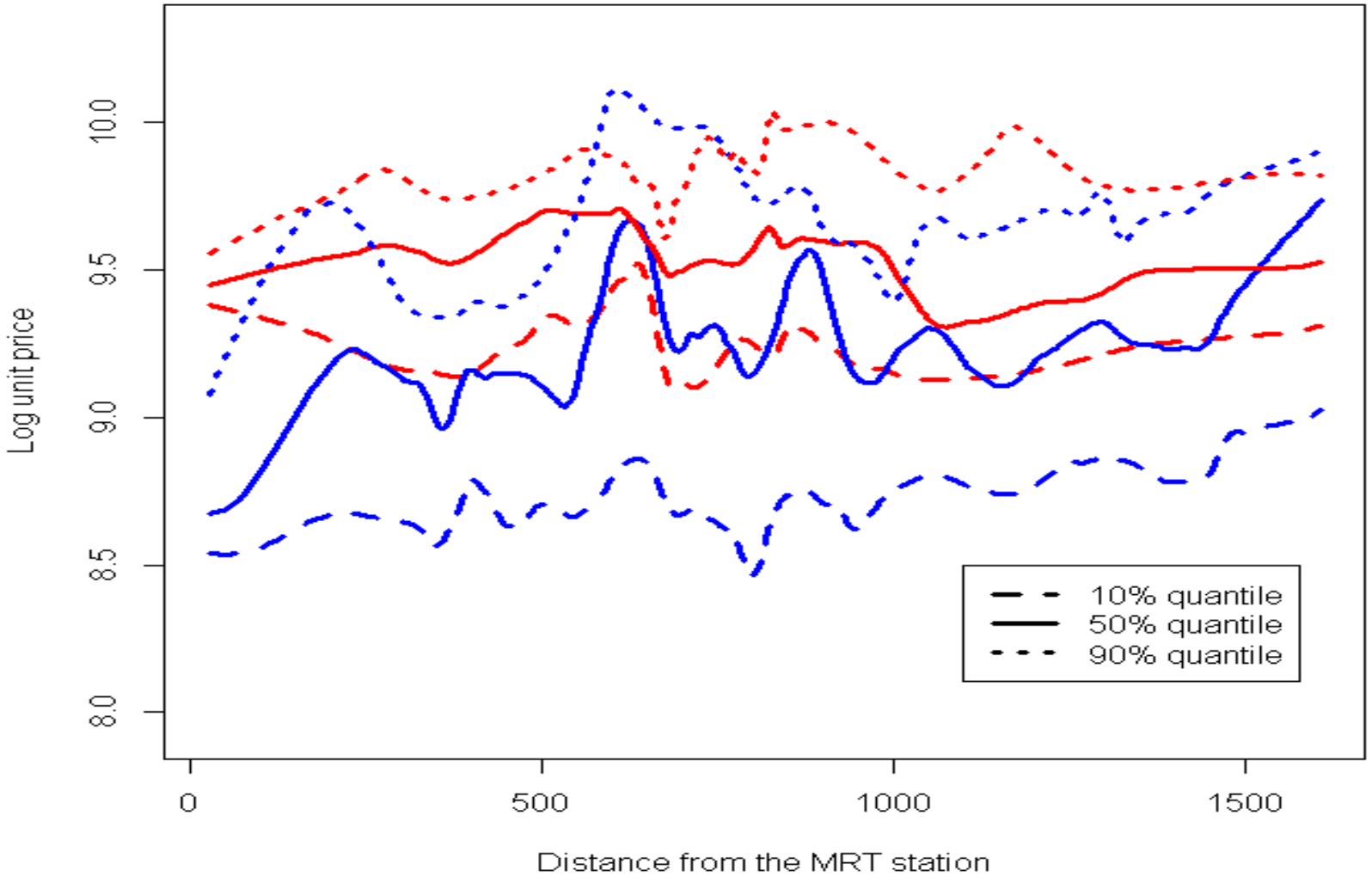
# Network distance and Euclidean distance



# Non-linear treatment effects

- Hedonic model uses continuous distance measure to capture the capitalization effects
- In DID design, some use a walkable distance, which is subjective, and 400m has been used to define the treatment zone
- Owners living near MRT stations may also trade off accessibility for other negative externalities, such as congestion, noise, loss of exclusivity (privacy), crime, etc.
- Treatment effect is non-linear
- Linden and Rockoff (2008) shows significant dis-amenities effects when examining the moving of sex offenders into neighbourhoods, and but negative externalities diminish quickly with distances
- There is also selection issue, where the offender will tend to move into low income neighbourhoods, which have different spatial characteristics from high income neighborhoods
- The constant treatment effects may be bias
  - We use the local polynomial regression (LPR) and also the quantile version of LPR to plot the non-linear treatment effects

# Quantile LPR and heterogeneity in capitalization effects



# Unconditional Quantile Price Distributions

| | Treatment Group | | Control Group | | Differences | | Difference in Differences |
|---|---|---|---|---|---|---|---|
| | Before Treatment (1) | After Treatment (2) | Before Treatment (3) | After Treatment (4) | [(2)-(1)] (5) | [(4)-(3)] (6) | [(5)-(6)] (7) |
| Ln Price (Mean) | 13.909 | 13.881 | 14.187 | 13.889 | -0.027 | -0.298 | 0.271 |
| Ln Price (Median) | 13.856 | 13.869 | 14.159 | 13.854 | 0.013 | -0.305 | 0.318 |
| ln Price (10th percentile) | 13.299 | 13.375 | 13.479 | 13.141 | 0.076 | -0.338 | 0.414 |
| ln Price (25th percentile) | 13.551 | 13.635 | 13.767 | 13.517 | 0.084 | -0.250 | 0.334 |
| ln Price (75th percentile) | 14.213 | 14.095 | 14.561 | 14.229 | -0.118 | -0.332 | 0.214 |
| ln Price (90th percentile) | 14.597 | 14.331 | 14.934 | 14.635 | -0.266 | -0.299 | 0.033 |
| Observation | 3,633 | 3,755 | 7,945 | 6,621 | | | |

Notes: Standard errors are in parentheses.

# Quasi-Experiment Designs - SDID and QSDID

- Define the treatment zone based on 600m cutoff (network distance), “Treat{
- Use the opening of CCL as the exogenous shock, “Post”
- DID effects include “Treat”, “Post” and “Treat x Post”
- SDID Model Specification

$$Y_{i,j,k} = \theta WY_{i,j,k} + X_i\beta + DID_{i,j,k}\Phi + \mu_i$$

$$DID\Phi = {}_{\delta 1} \times Post_{i,j,k} + \delta_2 \times Treat_{i,j} + \delta_3 \times (Treat_{i,j} \times Post_{i,j,k})$$

$$\mu_i = \alpha_i \ \lambda_i + \zeta_t + \varepsilon_i$$

- QSDID Model Specification

$$Y_{i,j,k} = \theta(\tau)WY_{i,j,k} + X_i\beta(\tau) + DID_{i,j,k}\Phi(\tau) + \mu_i(\tau)$$

# Basic DID Results

| | 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|
| Treatment measure | | | Network distance ≤600m | | | |
| Study boundary | 1.6km | | 1.6km | | 1.6km | |
| Within 600 m of CCL station | -0.115 | *** | -0.081 | *** | 0.025 | *** |
| | (0.005) | | (0.005) | | (0.004) | |
| Within 600 m of CCL station × Post Operation | 0.129 | *** | 0.130 | *** | 0.106 | *** |
| | (0.008) | | (0.007) | | (0.005) | |
| Post operation | -0.077 | *** | -0.032 | *** | -0.037 | *** |
| | (0.005) | | (0.004) | | (0.005) | |
| Constant | 9.730 | *** | 10.170 | *** | 10.270 | *** |
| | (0.019) | | (0.020) | | (0.022) | |
| Structural characteristics | No | | Yes | | Yes | |
| Neighborhood characteristics | No | | Yes | | Yes | |
| Postal sector fixed effect | No | | No | | Yes | |
| Transaction quarter fixed effect | No | | No | | Yes | |
| Observations | 21,954 | | 21,954 | | 21,954 | |
| R-squared | 0.7705 | | 0.8245 | | 0.9160 | |
| Adjusted R-squared | 0.7704 | | 0.8244 | | 0.9158 | |

# Discrete Treatment Effects

| | 1 | |
|---|---|---|
| Study boundary | 0.6km | |
| Treat(0-200m) | -0.049 | *** |
| | (0.012) | |
| Treat(200-400m) | -0.032 | *** |
| | (0.006) | |
| Treat(400-600m) | | |
| Treat(0-600m) | | |
| Treat(600-1000m) | | |
| Interactive variable: | | |
| Treat(0-200m) × Post operation | 0.116 | *** |
| | (0.013) | |
| Treat(200-400m) × Post operation | 0.076 | *** |
| | (0.008) | |
| Treat(400-600m) × Post operation | | |
| Treat(0-600m)× Post operation | | |
| Treat(600 -1000m) × Post operation | | |
| Post operation | -0.059 | *** |
| | (0.007) | |
| Constant | 9.878 | *** |
| | (0.068) | |
| Structural characteristics | Yes | |
| Neighborhood characteristics | Yes | |
| Postal sector fixed effect | Yes | |
| Transaction quarter fixed effect | Yes | |
| Observations | 7,388 | |
| R-squared | 0.9190 | |
| Adjusted R-squared | 0.9184 | |

# “Anticipatory” effects

| | 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|
| Sample period | 2007-2013 | | 2007-2013 | | 2007-2013 | |
| Within 600 m of CCL station | -0.064 | *** | -0.033 | *** | -0.034 | *** |
| | (0.006) | | (0.006) | | (0.006) | |
| $Post_{t-12}$ | -0.061 | ** | | | | |
| | (0.020) | | | | | |
| $Post_{t-6}$ | | | -0.225 | *** | -0.211 | *** |
| | | | (0.026) | | (0.026) | |
| $Post_{t=0}$ | | | | | 0.011 | |
| | | | | | (0.011) | |
| Within 600 m of CCL station × $Post_{t-12}$ | 0.166 | *** | | | | |
| | (0.006) | | | | | |
| Within 600 m of CCL station × $Post_{t-6}$ | | | 0.136 | *** | 0.090 | *** |
| | | | (0.006) | | (0.015) | |
| Within 600 m of CCL station × $Post_{t=0}$ | | | | | 0.048 | ** |
| | | | | | (0.015) | |
| Constant | 10.310 | *** | 10.290 | *** | 10.290 | *** |
| | (0.022) | | (0.022) | | (0.022) | |
| Structural characteristics | Yes | | Yes | | Yes | |
| Neighborhood characteristics | Yes | | Yes | | Yes | |
| Postal sector fixed effect | Yes | | Yes | | Yes | |
| Transaction quarter fixed effect | Yes | | Yes | | Yes | |
| Observations | 21,954 | | 21,954 | | 21,954 | |
| R-squared | 0.9168 | | 0.9165 | | 0.9166 | |
| Adjusted R-squared | 0.9166 | | 0.9163 | | 0.9163 | |

*#We reset the reference CCL opening date as the event date*

# “Calendar Date” as the Shocks

| | 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|
| Treatment measure | Network Distance ≤ 600m | | | | | |
| Study boundary | 1.6km | | 1.6km | | 1.6km | |
| CCL Operation Phase | Phase 1 | | Phase 2 | | Phase 3 | |
| Within 600 m of CCL station | 0.022 | ** | 0.031 | *** | -0.025 | *** |
| | (0.008) | | (0.007) | | (0.005) | |
| Within 600 m of CCL station × Post Operation | 0.002 | | 0.040 | *** | 0.095 | *** |
| | (0.008) | | (0.008) | | (0.009) | |
| Post operation | 0.088 | *** | -0.014 | | -0.001 | |
| | (0.016) | | (0.018) | | (0.043) | |
| Constant | 10.360 | *** | 9.356 | *** | 10.310 | *** |
| | (0.072) | | (0.037) | | (0.036) | |
| Structural characteristics | Yes | | Yes | | Yes | |
| Neighborhood characteristics | Yes | | Yes | | Yes | |
| Postal sector fixed effect | Yes | | Yes | | Yes | |
| Transaction quarter fixed effect | Yes | | Yes | | Yes | |
| Observations | 4,975 | | 7,900 | | 9,079 | |
| R-squared | 0.9177 | | 0.9270 | | 0.9203 | |
| Adjusted R-squared | 0.9170 | | 0.9266 | | 0.9199 | |

# Adjusting for Spatial Spillovers

| | 0<br>OLS | | 1<br>SAC | | 2<br>SARAR | | 3<br>SAC/SARAR | |
|---|---|---|---|---|---|---|---|---|
| Within 600 m of CCL station | 0.025 | *** | 0.025 | *** | 0.039 | *** | 0.051 | *** |
| | (0.004) | | (0.004) | | (0.004) | | (0.004) | |
| Within 600 m of CCL station * Post Operation | 0.106 | *** | 0.108 | *** | 0.097 | *** | 0.086 | *** |
| | (0.005) | | (0.005) | | (0.005) | | (0.005) | |
| Post operation | -0.037 | *** | -0.043 | *** | -0.026 | ** | -0.024 | *** |
| | (0.005) | | (0.005) | | (0.005) | | (0.005) | |
| Constant | 10.270 | *** | 2.936 | *** | 10.128 | *** | 1.667 | *** |
| | (0.022) | | (0.224) | | (0.021) | | (0.234) | |
| Rho (spatial lag of dependent variable) | | | 0.488 | *** | | | 0.573 | *** |
| | | | (0.015) | | | | (0.016) | |
| Lambda (spatial error) | | | | | -2.178 | *** | -2.178 | *** |
| | | | | | (0.002) | | (0.002) | |
| Structural characteristics | Yes | | Yes | | Yes | | Yes | |
| Neighborhood characteristics | Yes | | Yes | | Yes | | Yes | |
| Postal sector fixed effect | Yes | | Yes | | Yes | | Yes | |
| Transaction quarter fixed effect | Yes | | Yes | | Yes | | Yes | |
| Observations | 21,954 | | 21,954 | | 21,954 | | 21,954 | |
| AIC | -18,045 | | -19,103 | | -19,891 | | -21,125 | |

# Empirical Results of QSDID

- McMillen (1996) first introduced this approach as “geographical weighted regression”
- We adopt the conditional parametric (CPAC) estimator to examine the heterogeneity in distributional DID effects for a target point, in our context, the nearest MRT $\beta$station, by fitting the log-price function by finding the best-fit quantile, $\tau$.
- The ATE does not reflect the issues of heterogeneity responses by different housing quantiles
- Compared to the ATE of 8.96% in the DID model, the ATE effects are smaller at 10% and 90% price quantiles at 4.14% and 6.56%
- The higher ATE is found in the 50% housing quantile with an estimated ATE of 9.26%
- The CCL has significantly stronger impact on the Mid- to low- priced housing segment than the more expensive segment of the housing market
- The results are consistent with the spatial autoregressive term is added

# Heterogeneity in Treatment Effects

| | OLS | | | Quanile 0.1 | | | Quantile 0.5 | | | Quantile 0.9 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef. | Std. Error | | Coef. | Std. Error | | Coef. | Std. Error | | Coef. | Std. Error | |
| (Intercept) | 10.4001 | 0.0284 | *** | 10.4413 | 0.0352 | *** | 10.3343 | 0.0337 | *** | 10.3509 | 0.0325 | *** |
| Within 600 m of CCL station * Post operation | 0.0896 | 0.0054 | *** | 0.0414 | 0.0051 | *** | 0.0926 | 0.0042 | *** | 0.0656 | 0.0054 | *** |
| Within 600 m of CCL station | 0.0196 | 0.0040 | *** | 0.0388 | 0.0038 | *** | 0.0229 | 0.0034 | *** | 0.0049 | 0.0047 | |
| Post operation | -0.0348 | 0.0053 | *** | -0.0414 | 0.0044 | *** | -0.0449 | 0.0055 | *** | -0.0263 | 0.0064 | *** |
| ln(property_area) | 0.8668 | 0.0029 | *** | 0.7811 | 0.0030 | *** | 0.8621 | 0.0025 | *** | 0.8908 | 0.0031 | *** |
| Level | 0.0066 | 0.0002 | *** | 0.0066 | 0.0002 | *** | 0.0068 | 0.0001 | *** | 0.0071 | 0.0003 | *** |
| factor(PROPERTY_TYPE)Condominium | 0.1147 | 0.0031 | *** | 0.1733 | 0.0033 | *** | 0.1114 | 0.0032 | *** | 0.0621 | 0.0035 | *** |
| factor(PROPERTY_TYPE)EC | 0.1184 | 0.0170 | *** | 0.2087 | 0.0228 | *** | 0.1320 | 0.0098 | *** | -0.0451 | 0.0280 | |
| FREEHOLD | 0.1913 | 0.0033 | *** | 0.1445 | 0.0032 | *** | 0.2168 | 0.0031 | *** | 0.1715 | 0.0043 | *** |
| factor(PURCHASER_TYPE)Private | 0.0341 | 0.0027 | *** | 0.0177 | 0.0019 | *** | 0.0290 | 0.0018 | *** | 0.0200 | 0.0024 | *** |
| factor(SALE_TYPE)Resale | -0.2653 | 0.0029 | *** | -0.2983 | 0.0030 | *** | -0.2604 | 0.0031 | *** | -0.2158 | 0.0036 | *** |
| factor(SALE_TYPE)Sub Sale | -0.0339 | 0.0045 | *** | -0.0715 | 0.0034 | *** | -0.0091 | 0.0044 | * | -0.0276 | 0.0030 | *** |
| Dis_PMS30 (km) | -0.0323 | 0.0036 | *** | -0.0135 | 0.0040 | *** | -0.0319 | 0.0036 | *** | -0.0376 | 0.0047 | *** |
| Dis_CBD (km) | -0.1000 | 0.0031 | *** | -0.0860 | 0.0036 | *** | -0.0900 | 0.0038 | *** | -0.0636 | 0.0033 | *** |
| Dis_Expres (km) | 0.0362 | 0.0029 | *** | 0.0409 | 0.0033 | *** | 0.0374 | 0.0027 | *** | 0.0227 | 0.0038 | *** |
| Dis_bus (km) | 0.4041 | 0.0151 | *** | 0.3520 | 0.0111 | *** | 0.3605 | 0.0156 | *** | 0.4257 | 0.0220 | *** |
| Dis_Mall (km) | -0.0689 | 0.0027 | *** | -0.0761 | 0.0028 | *** | -0.0845 | 0.0031 | *** | -0.0814 | 0.0031 | *** |
| wy | | | | | | | | | | | | |
| Planning area fixed effect | Yes | | | Yes | | | Yes | | | Yes | | |
| Transaction quarter fixed effect | Yes | | | Yes | | | Yes | | | Yes | | |

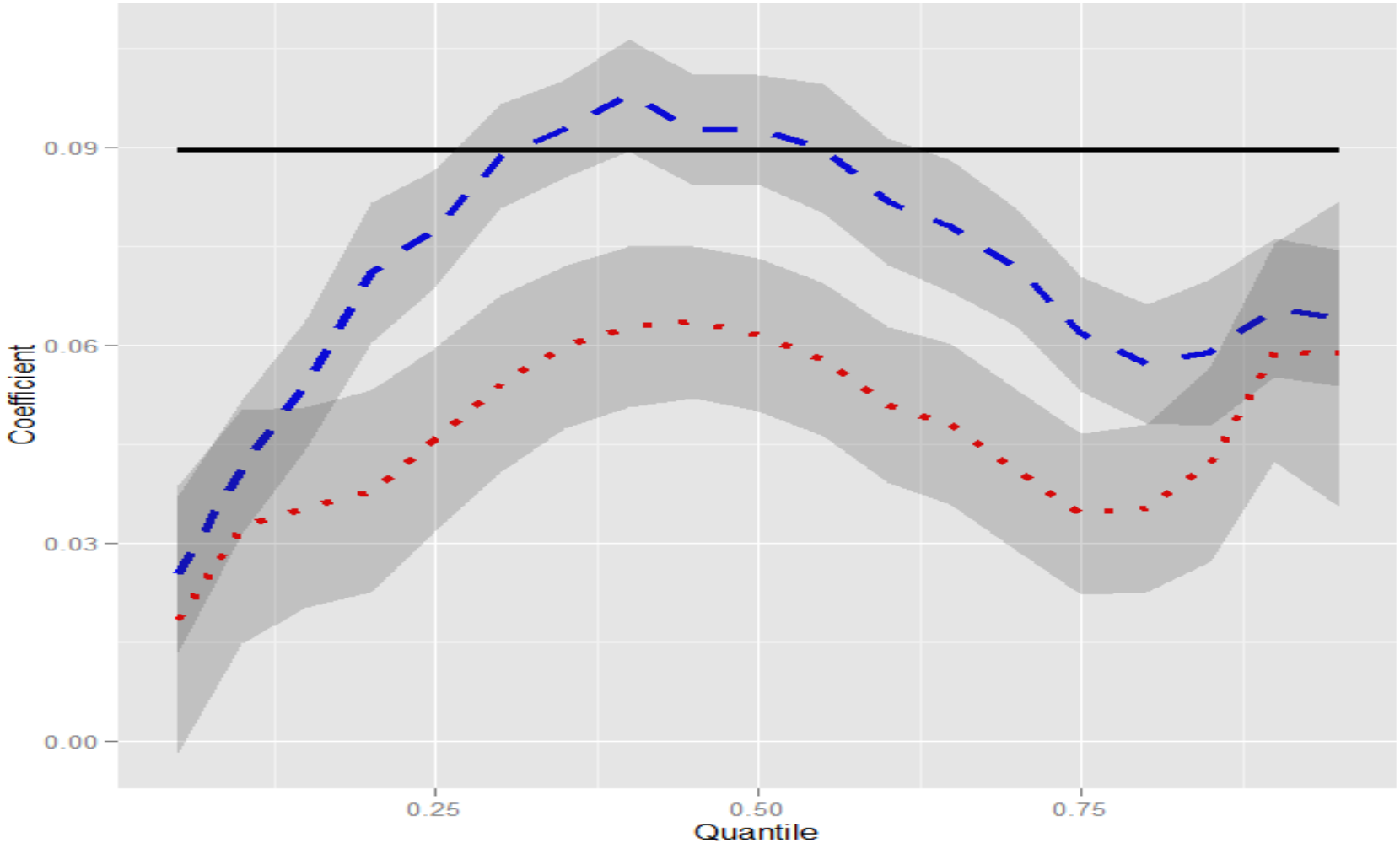
Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

# Spatial Dynamics and Heterogeneity Effects

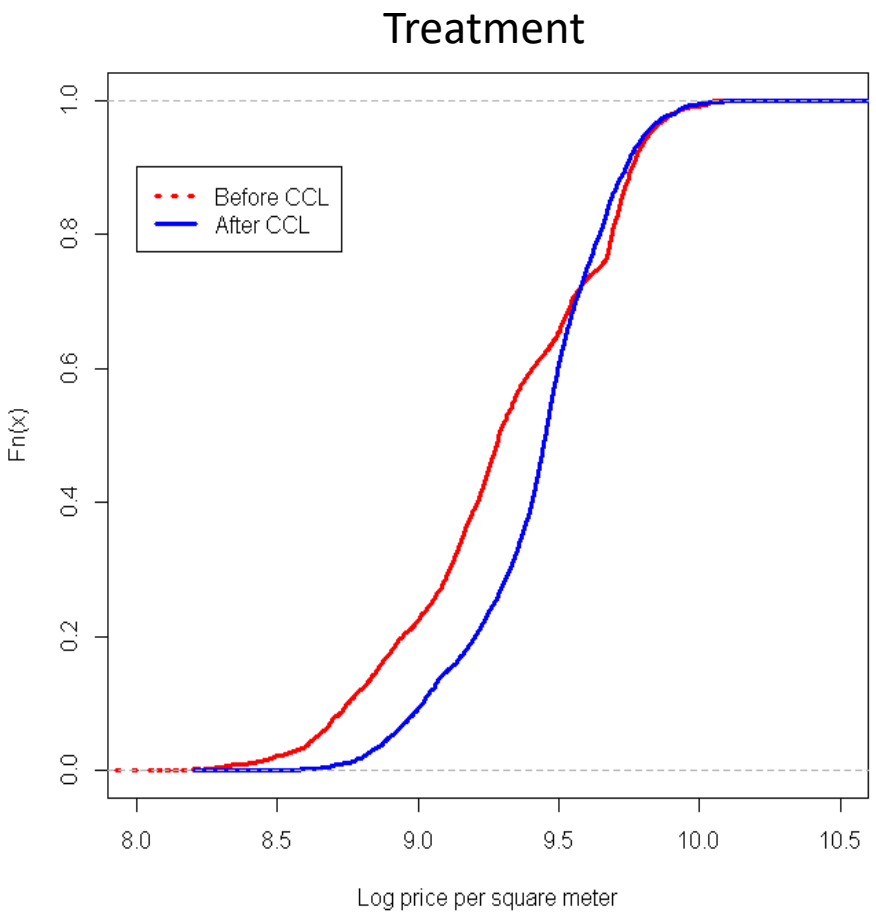
| | Spatial IV Quanile 0.1 | | | Spatial IV Quanile 0.5 | | | Spatial IV Quanile 0.9 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coef. | Std. Err. | | Coef. | Std. Err. | | Coef. | Std. Err. | |
| (Intercept) | 3.1186 | 0.3528 | *** | 1.5874 | 0.2103 | *** | 0.6381 | 0.4444 | |
| Within 600 m of CCL station * Post operation | 0.0324 | 0.0090 | *** | 0.0615 | 0.0059 | *** | 0.0589 | 0.0084 | *** |
| Within 600 m of CCL station | 0.0405 | 0.0093 | *** | 0.0338 | 0.0048 | *** | 0.0030 | 0.0066 | |
| Post operation | -0.0240 | 0.0092 | ** | -0.0198 | 0.0061 | ** | -0.0010 | 0.0096 | |
| ln(property_area) | 0.7867 | 0.0057 | *** | 0.8736 | 0.0035 | *** | 0.8995 | 0.0052 | *** |
| Level | 0.0063 | 0.0003 | *** | 0.0054 | 0.0002 | *** | 0.0061 | 0.0004 | *** |
| factor(PROPERTY_TYPE)Condominium | 0.1476 | 0.0076 | *** | 0.0563 | 0.0044 | *** | 0.0163 | 0.0067 | * |
| factor(PROPERTY_TYPE)EC | 0.0107 | 0.0215 | | -0.1051 | 0.0150 | *** | -0.2199 | 0.0229 | *** |
| FREEHOLD | 0.1522 | 0.0078 | *** | 0.1857 | 0.0042 | *** | 0.1637 | 0.0061 | *** |
| factor(PURCHASER_TYPE)Private | 0.0163 | 0.0030 | *** | 0.0222 | 0.0023 | *** | 0.0177 | 0.0032 | *** |
| factor(SALE_TYPE)Resale | -0.2910 | 0.0086 | *** | -0.2516 | 0.0036 | *** | -0.1961 | 0.0062 | *** |
| factor(SALE_TYPE)Sub Sale | -0.1034 | 0.0113 | *** | -0.0136 | 0.0054 | * | -0.0107 | 0.0060 | . |
| Dis_PMS30 (km) | 0.0140 | 0.0105 | | -0.0007 | 0.0047 | | -0.0534 | 0.0118 | *** |
| Dis_CBD (km) | -0.0202 | 0.0064 | ** | -0.0152 | 0.0046 | *** | -0.0561 | 0.0091 | *** |
| Dis_Expres (km) | 0.0035 | 0.0058 | | -0.0083 | 0.0033 | * | 0.0145 | 0.0078 | . |
| Dis_bus (km) | 0.4414 | 0.0302 | *** | 0.4118 | 0.0187 | *** | 0.3832 | 0.0291 | *** |
| Dis_Mall (km) | -0.0694 | 0.0047 | *** | -0.1006 | 0.0034 | *** | -0.0932 | 0.0051 | *** |
| wy | 0.5000 | 0.0233 | *** | 0.6000 | 0.0142 | *** | 0.7000 | 0.0323 | *** |
| | | | | | | | | | |
| Planning area fixed effect | Yes | | | Yes | | | Yes | | |
| Transaction quarter fixed effect | Yes | | | Yes | | | Yes | | |

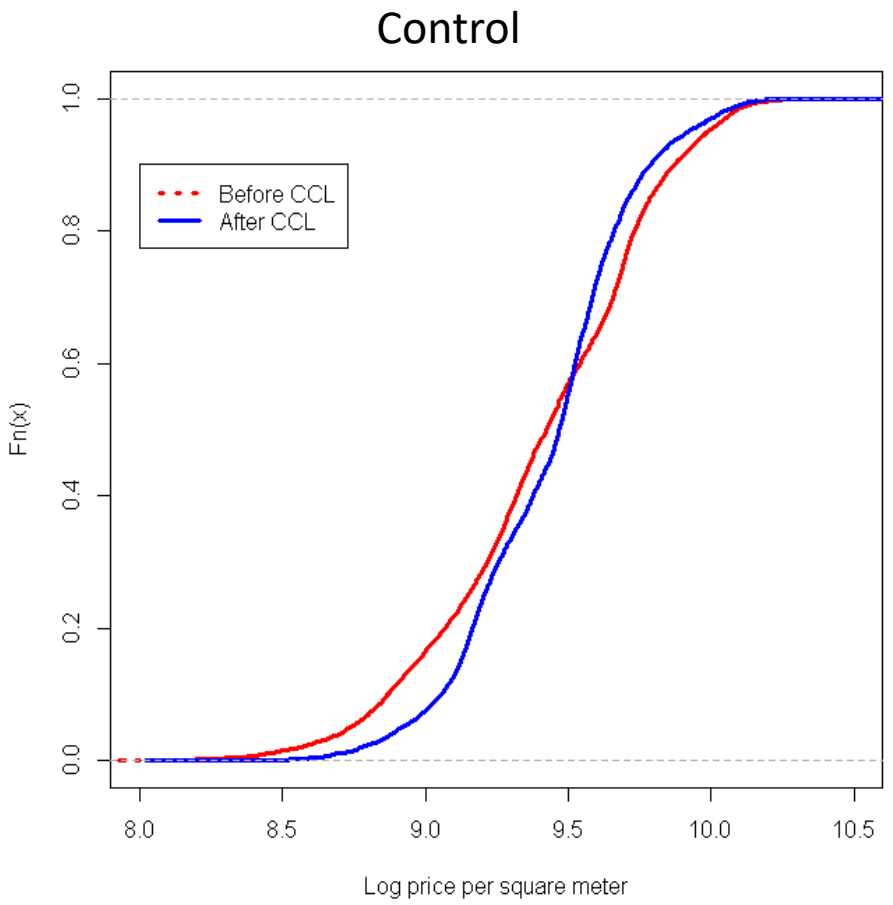
Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

# Heterogeneity Treatment Effects

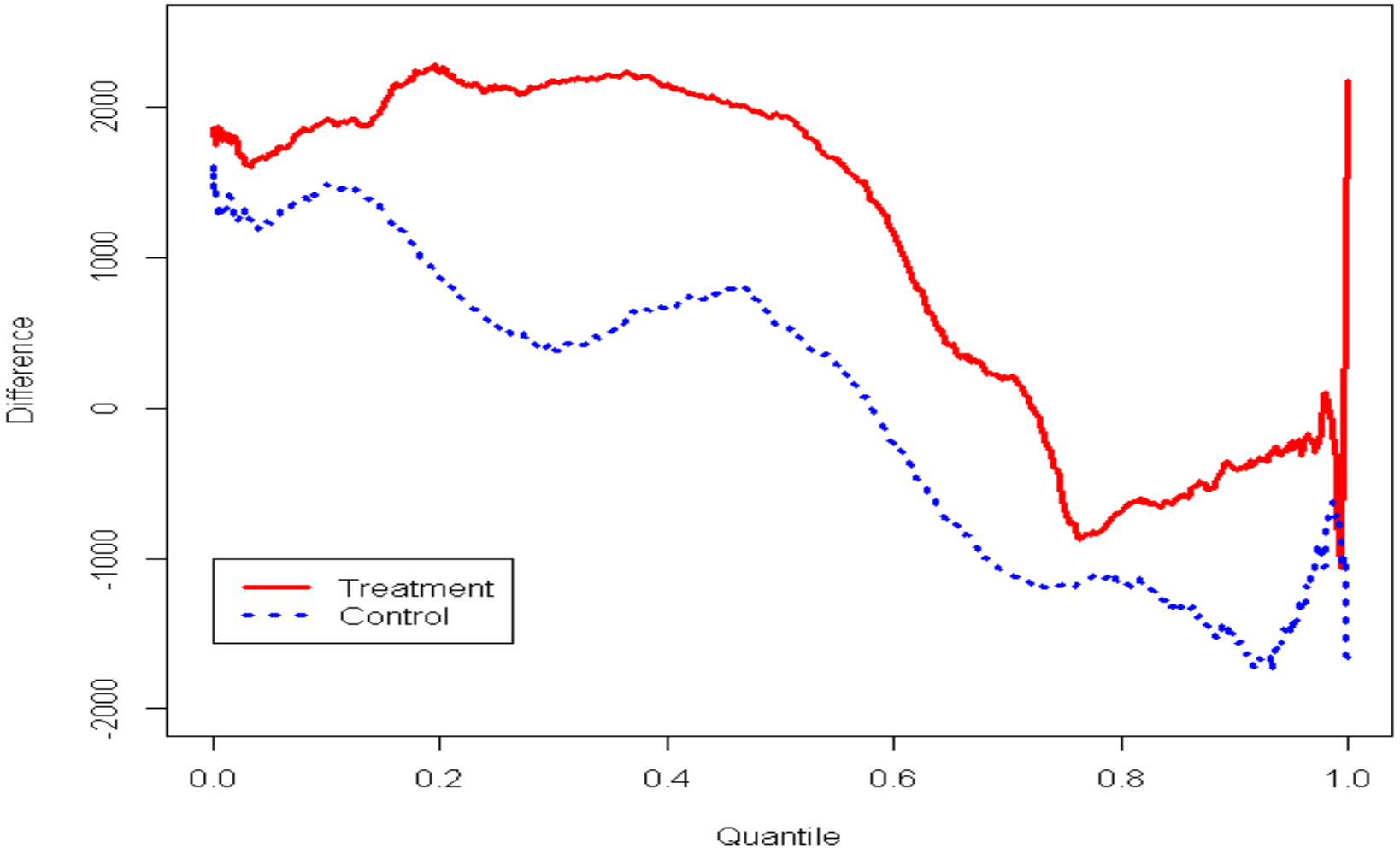


# Cumulative Kernel Density Functions



# Change in Kernel Density



# Distributional Treatment Effects

- What cause the heterogeneity in the ATE?
- Does the composition of the housing samples change before and after the CCL opening?
- Have more cheaper (low-priced) houses been replaced by more expensive houses?
- If so, price increases are not caused by the elasticity of price effects, but the change in the structural attributes
- In the linear decomposition approach by Oaxaca (1973)

$$E(Y_1 - Y_0) = (Z_1 - Z_0)\rho_1 + Z_0(\rho_1 - \rho_0)$$

- We follow a more general procedure proposed Machato and Mata (2005) using the conditional quantile version of decomposition approach:

$$\widehat{(f_{11} - \hat{f}_{00})} = (\hat{f}_{11} - \hat{f}_{01}) + (\hat{f}_{01} - \hat{f}_{00})$$

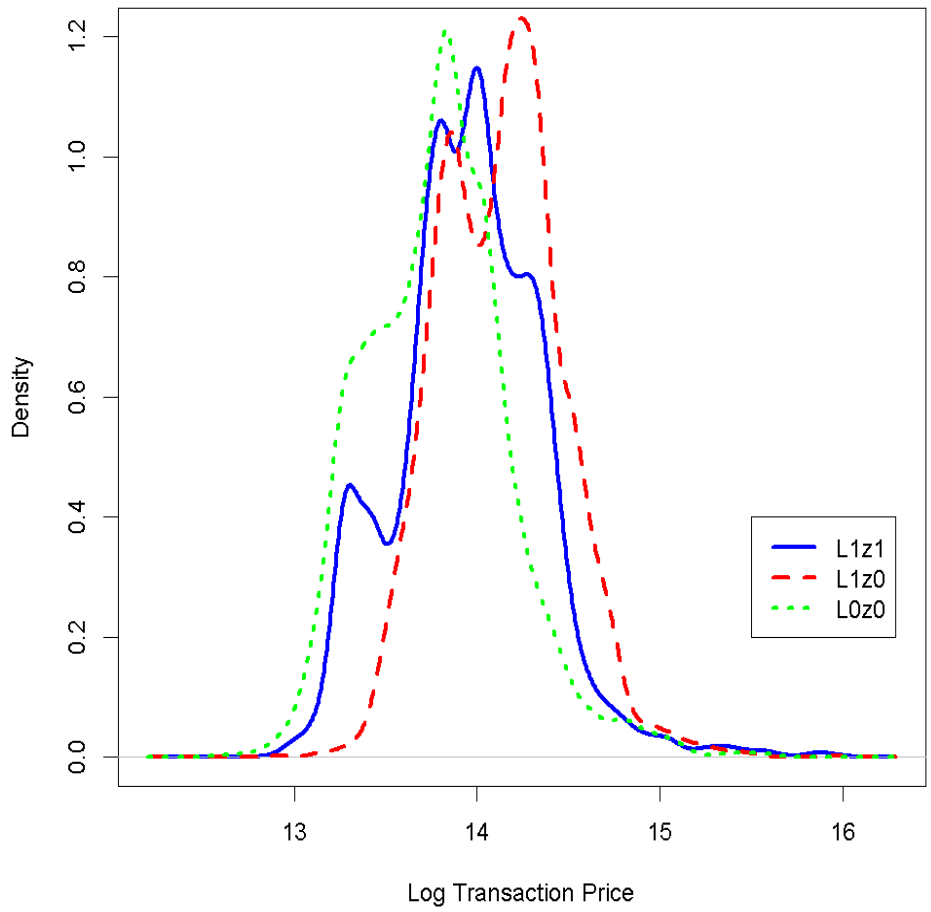
# Decomposition Results

| Quantile | Treatment | | | | | | Control | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Difference | | Variable Effect | | Coefficient Effect | | Total Difference | | Variable Effect | | Coefficient Effect | |
| 0.10 | 0.118 | *** | -0.303 | *** | 0.421 | *** | -0.201 | *** | -0.539 | *** | 0.338 | *** |
| | (0.008) | | (0.008) | | (0.004) | | (0.012) | | (0.007) | | (0.009) | |
| 0.20 | 0.220 | *** | -0.170 | *** | 0.390 | *** | -0.150 | *** | -0.441 | *** | 0.291 | *** |
| | (0.009) | | (0.008) | | (0.005) | | (0.022) | | (0.023) | | (0.005) | |
| 0.30 | 0.193 | *** | -0.151 | *** | 0.344 | *** | -0.077 | *** | -0.338 | *** | 0.261 | *** |
| | (0.008) | | (0.007) | | (0.004) | | (0.012) | | (0.011) | | (0.005) | |
| 0.40 | 0.154 | *** | -0.178 | *** | 0.332 | *** | -0.084 | *** | -0.320 | *** | 0.236 | *** |
| | (0.008) | | (0.008) | | (0.004) | | (0.012) | | (0.009) | | (0.005) | |
| 0.50 | 0.160 | *** | -0.184 | *** | 0.344 | *** | -0.113 | *** | -0.296 | *** | 0.183 | *** |
| | (0.006) | | (0.005) | | (0.003) | | (0.012) | | (0.011) | | (0.005) | |
| 0.60 | 0.166 | *** | -0.184 | *** | 0.350 | *** | -0.149 | *** | -0.248 | *** | 0.098 | *** |
| | (0.006) | | (0.006) | | (0.004) | | (0.015) | | (0.012) | | (0.007) | |
| 0.70 | 0.176 | *** | -0.153 | *** | 0.329 | *** | -0.191 | *** | -0.224 | *** | 0.032 | *** |
| | (0.007) | | (0.007) | | (0.003) | | (0.014) | | (0.012) | | (0.006) | |
| 0.80 | 0.200 | *** | -0.120 | *** | 0.320 | *** | -0.264 | *** | -0.230 | *** | -0.035 | *** |
| | (0.007) | | (0.007) | | (0.004) | | (0.010) | | (0.008) | | (0.005) | |
| 0.90 | 0.152 | *** | -0.151 | *** | 0.302 | *** | -0.281 | *** | -0.197 | *** | -0.084 | *** |
| | (0.009) | | (0.007) | | (0.007) | | (0.016) | | (0.015) | | (0.006) | |

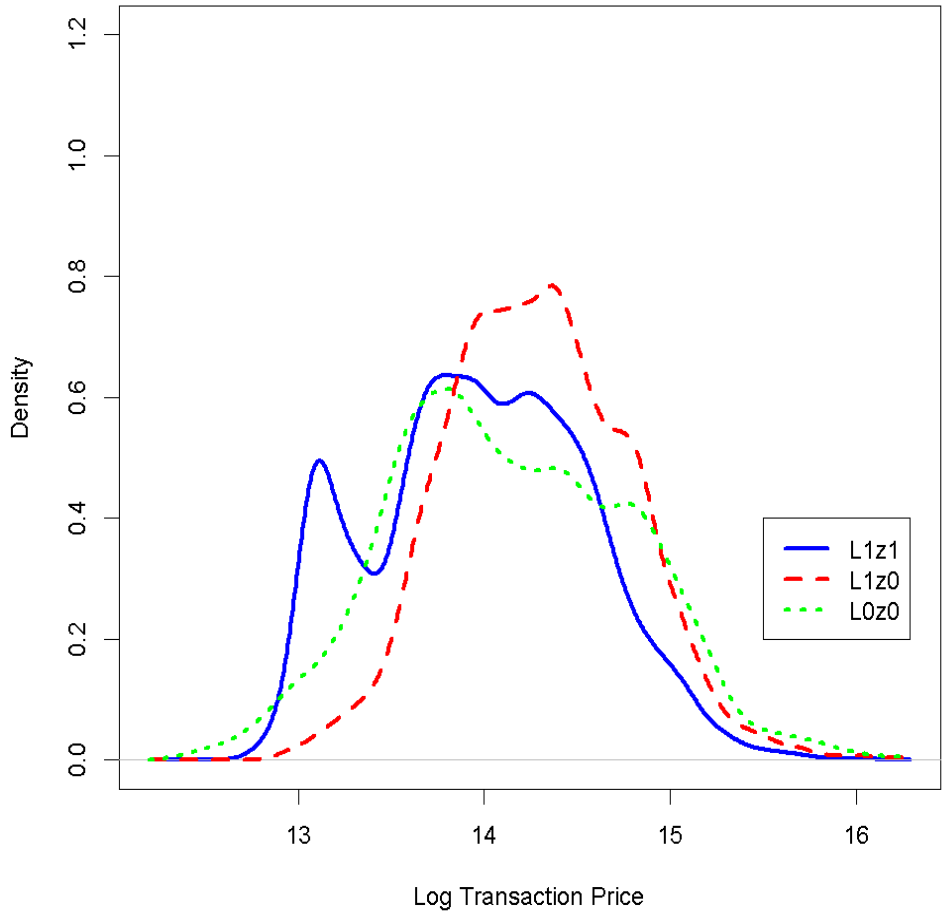
Note: *** p<0.01. Sttandard error in parenthese.

# Densities

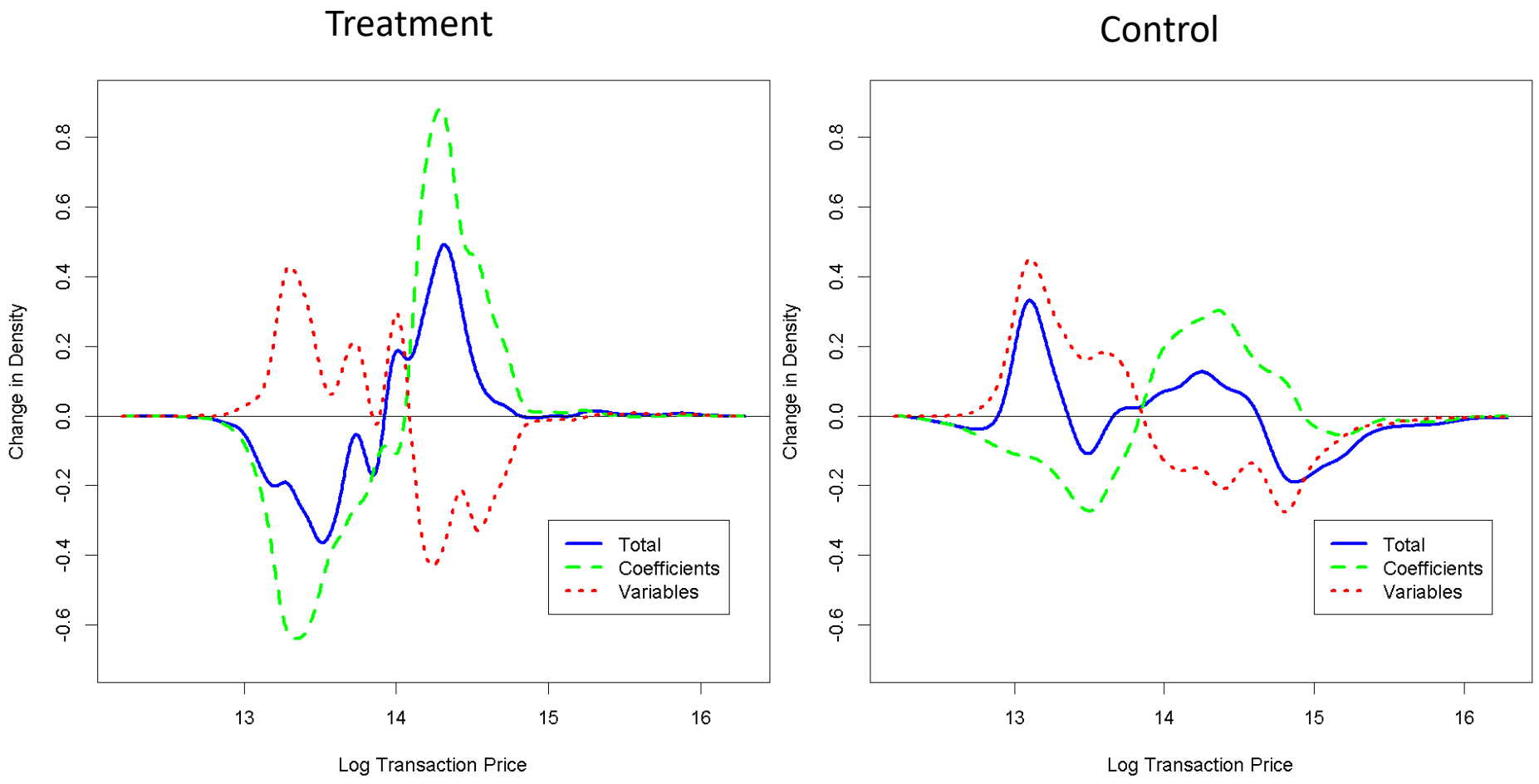
Treatment




Control



# Decomposition of Density Change



# Conclusion

- This study not only confirm the early study that there are positive capitalization effects associated with the CCL opening
- More importantly, we find when estimating the housing price premiums, the following issues matters:
  - Measurement of network distance
  - Allowing for non-linear DID effects
  - Taking into account for spatial spillovers
  - Heterogeneity in DID effects
- In the decomposition, we show that the price and structural changes are different between the treatment and the control zones
- The CCL treatment cause more larger (90% quantile) houses to be replaced by smaller (10% quantile) houses, but price elasticity for smaller houses increases more significantly that price elasticity for larger houses
- Both compositional changes and price elasticity changes contribute to the total treatment effects
- More tests to be done in the future to see if more high income households have since more away from areas near MRT stations

Comments and suggestions are much appreciated!

# THANK YOU!