Evaluating the Impact of Urban Transit Infrastructure: Evidence from Bogotá's TransMilenio

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Urban Transit Infrastructure

Empirical Questions:

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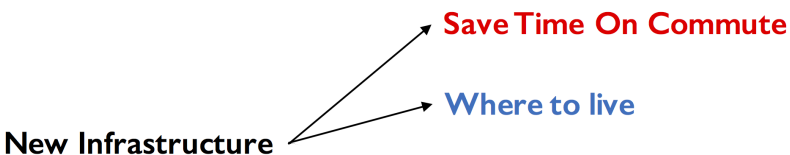

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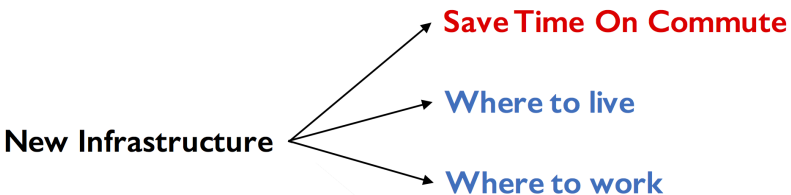

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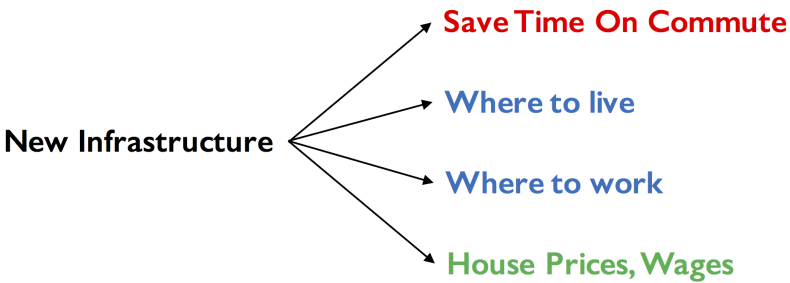

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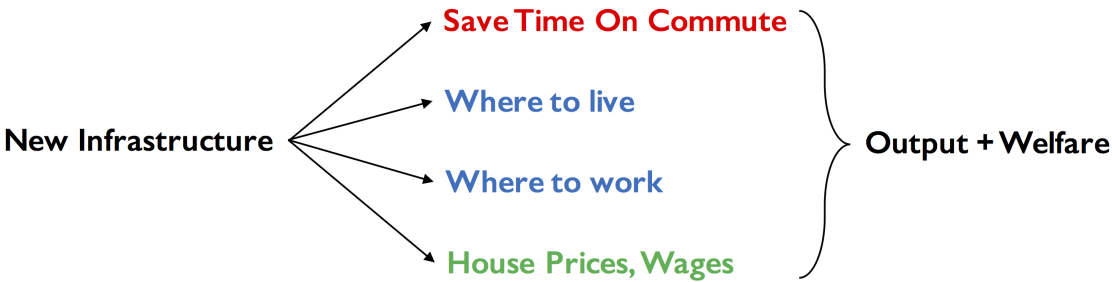

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   - Bogotá in 1995: low-skilled 25% more likely to commute using informal bus...
   - Which were 32% slower than cars

TransMilenio: World's Most Used Bus Rapid Transit System

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Combine with detailed **tract-level data** to examine impact

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2. **Quantitative general equilibrium model of a city**:
   - New Features: Low/High-skill workers + Multiple transit modes

3. **Quantification+Counterfactuals**:
   - Quantify welfare effects through value of time savings (VTTS) + realllocation and general equilibrium effects

Main Results

1. **Aggregate Effects**: Large gains, worth the cost
   - Welfare $\uparrow$ 1.63%, Output (net of costs) $\uparrow$ 1.44%
   - VTTS accounts for 60-80% of welfare gains, remainder by reallocation+GE effects

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3. **Key Policy Implication**: Large gains to integrated transit + land use policy
   - Average welfare gain 19% higher under more accommodative zoning policy
   - Revenue from Land Value Capture scheme covers 10-40% of const. costs

Roadmap

1. **Empirical Approach & Results**
2. Quantification and Counterfactuals

Simple Model to Guide Empirics

- **Ingredients**:
  - Many discrete locations indexed by $i = 1, \ldots, N$ (e.g. blocks or census tracts)
  - Locations differ in amenities, productivities, commute times, floorspace
  - Individuals decide where to live and work
  - Firms in each location decide how much labor+commercial floorspace to hire
  - House prices and wages adjust to clear markets

Simple Model to Guide Empirics

Individuals: Choose between pairs of where to live *i* and work *j* that depends on:

- **Residential Location Characteristics:** Amenities, house prices in *i*
- **Workplace Location Characteristics:** Wages in *j*
- **Pairwise Commute Characteristics**: Cost of commuting from *i* to *j*

Simple Model to Guide Empirics

Supply of Residents: Depends on amenities u_i, house prices r_{Ri} and access to well-paid jobs Φ_{Ri} (RCMA)

$$L_{Ri} \propto \left(u_i r_{Ri}^{\beta - 1} \right)^{\theta} \Phi_{Ri}$$

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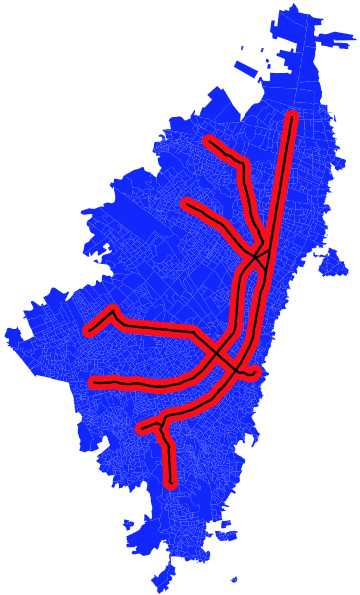
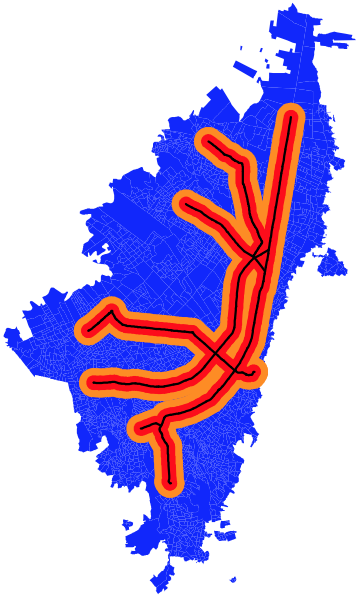
Computing CMA: Unique values of RCMA and FCMA can be recovered from data (L_{Fj}, L_{Ri}) and parameterization of commute costs (e.g. commute times computed in ArcMap).

Distance-Based Treatment Effect: Close vs Far

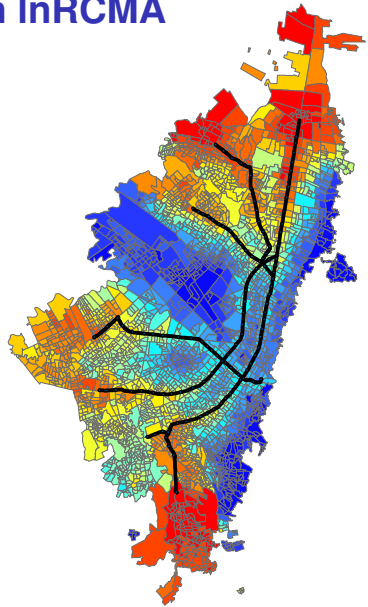


Distance-Based Treatment Effect: Close vs Interm. vs Far



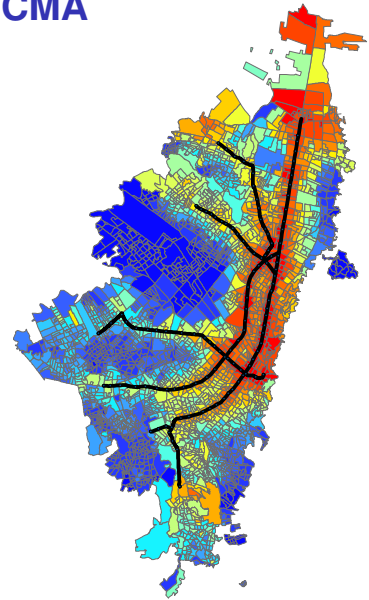
Residents: Change in InRCMA

Hot: Larger increase
Cool: Smaller increase



Firms: Change in lnFCMA

Hot: Larger increase
Cool: Smaller increase



Reduced Form Representation

Equilibrium can be written as:

$$\Delta \ln \mathbf{Y}_{Ri} = \beta_R \Delta \ln \Phi_{Ri} + \mathbf{e}_{Ri}$$
$$\Delta \ln \mathbf{Y}_{Fi} = \beta_F \Delta \ln \Phi_{Fi} + \mathbf{e}_{Fi}$$

where

- $\Delta \ln Y_{Ri} = \begin{bmatrix} \Delta \ln L_{Ri} & \Delta \ln r_{Ri} \end{bmatrix}$ and $\Delta \ln Y_{Fi} = \begin{bmatrix} \Delta \ln L_{Fi} & \Delta \ln r_{Fi} \end{bmatrix}'$ are changes in endogenous outcomes
- $\beta_R . \beta_{\boldsymbol{F}}$ are reduced form coefficients capturing direct+indirect effects of CMA on outcomes
- $\mathbf{e}_{Ri}, \mathbf{e}_{Fi}$ are structural errors containing changes in amenities/productivities

Data

Dataset	Source	Year	Variables
Population	General Census/DANE	1993, 2005,2015	Residential Population by Education Group
Commuting	DANE Mobility Survey	1995, 2005, 2011, 2015	Trip-diaries (trip and person characteristics)
Housing	Cadastral Department	2000-2013	Property value and characteristics, land use, land and floorspace area
Employment (Firms)	General Census	1990, 2005	Employment and industry (universe of estab.)
	Business Registry (Chamber of Commerce)	2000, 2014	Employment and industry (formal estab.)
Employment (Workers)	DANE Household Surveys (ECH/GEIH)	2000-2014	Worker demographics and employment characteristics
Commute Times	City Maps	-	Times by mode computed in ArcMap

Establishing Causal Impact of BRT

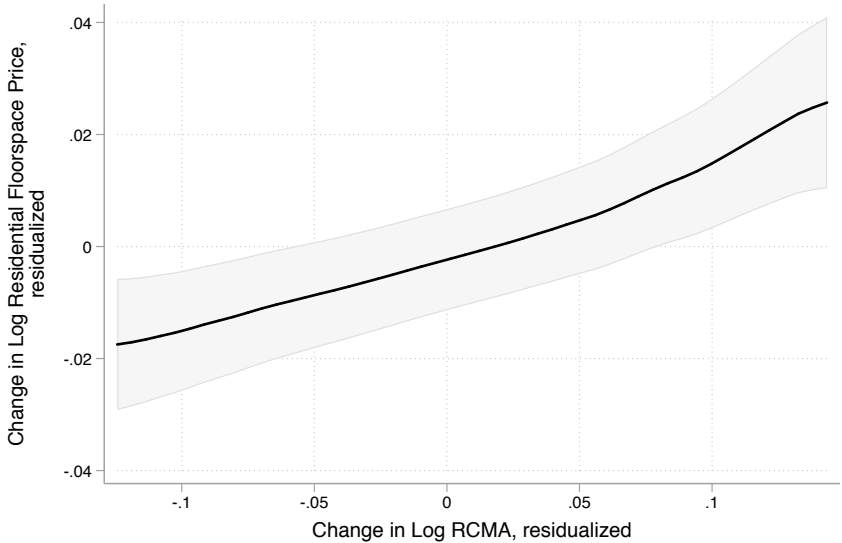
- **Challenge**: BRT routes chosen by government, may be correlated with other drivers of economic activity

- **Approach**:
  1. Predict TransMi routes using (i) historical tram and (ii) least cost construction routes
  2. Exploit opening across 3 phases to show no impacts until lines open
  3. Use changes in accessibility due to new lines >1.5km away

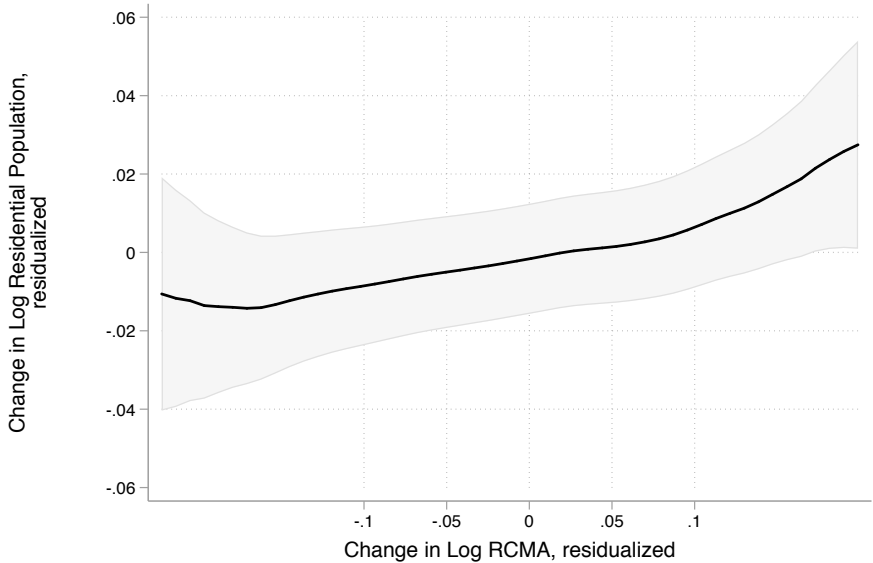
- **Additional Outcomes**: In paper, look at effect on commute distances, wages and gentrification

CMA Captures Differential Response Across Space

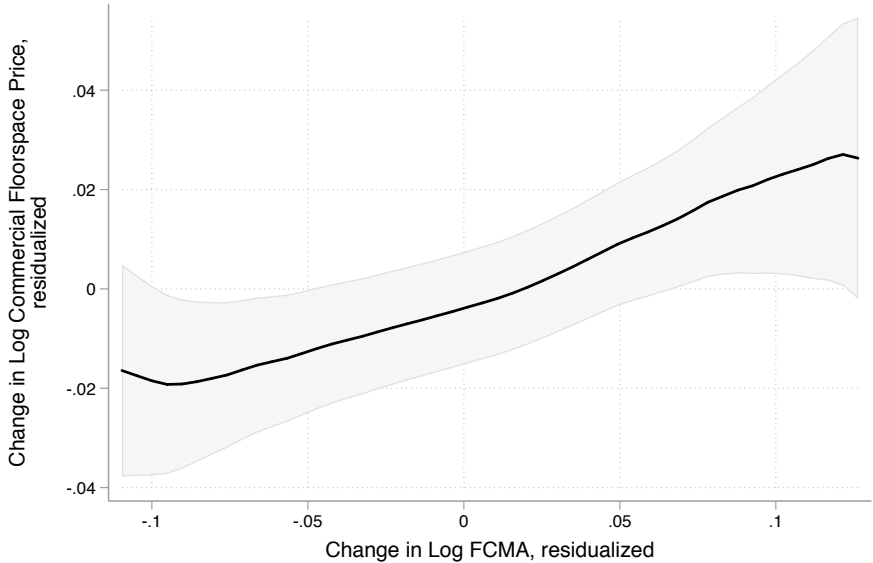
Residential Floorspace Prices vs RCMA



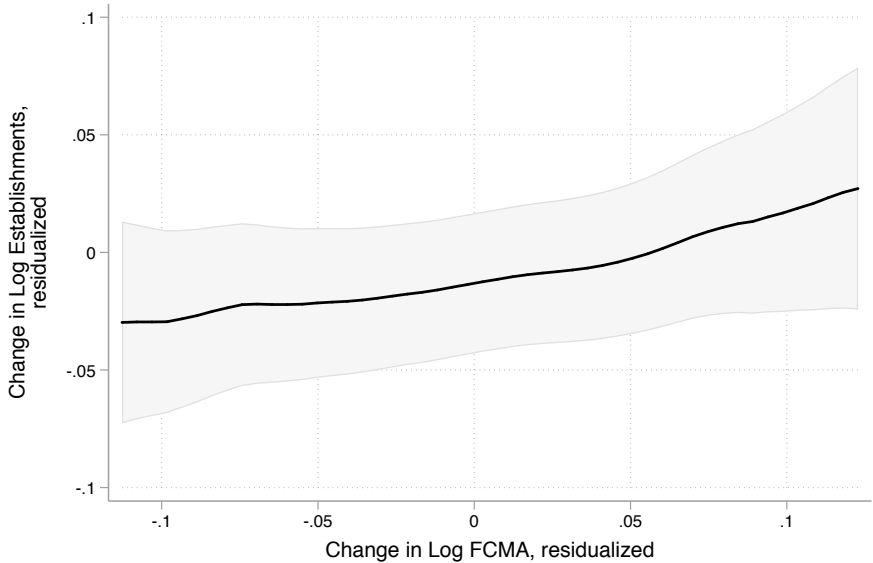
Res Pop vs RCMA



Commercial Floorspace Price vs FCMA



Employment vs FCMA



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Summary of Identification:

1. **Mode Choice Parameters**: Responsiveness of mode choices to differences in commute times
2. **Commuting Elasticity**: Responsiveness of change in commute flows to changes in commute times
3. **Agglomeration Externalities**: Responsiveness of change in productivities + amenities to exogenous shift in supply of residents and labor across city provided by ΔCMA instruments

Aggregate Impacts of TransMilenio

Panel A: Aggregate Gains	
Output	1.82%
Average Welfare	1.63%
Rents	1.91%
Panel B: Costs vs Benefits	
Capital Costs (mm)	1,137
NPV Operating Costs (mm)	5,963
NPV Total Costs (mm)	7,101
NPV Net Increase Output (mm)	26,808
Net Increase Output	1.44%

Welfare Decomposition

- **Theoretical Result**: In an efficient equilibrium, the first order welfare impact in the full GE model is simply the VTTS
- **Empirical Question**: How important are reallocation + GE effects?

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	Average Welfare	Inequality
First Order Approximation (VTTS)	1.308	-0.172
General Equilibrium	1.628	0.085

- **Implication**: Reallocation + GE effects are important for large shocks + distributional consequences

Policy Counterfactuals 1: Network Components

1. **Geography Matters**: Low-skilled benefit most from lines connecting where they live with areas of dense employment

2. **Large Returns to Complementary Services**: “Feeder” network increases welfare more than any other line

Policy Counterfactuals 2: Land Value Capture

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- **2 Policies**: Allocate the same amount of new floorspace permits via
  1. Increase density by 30% within 500m of stations
  2. Increase density proportional to predicted change in CMA

Policy Counterfactuals 2: Land Value Capture

	Avg Welfare	Inequality	Gvt. Rev Closed City	Gvt. Rev Open City
Baseline	1.63%	0.09%		
LVC-Distance	1.71%	0.03%	5.72%	17.82%
LVC-CMA	1.93%	0.01%	10.21%	41.07%

1. Average welfare gain 19% larger under LVC
2. Welfare + Revenue Gain greater under CMA-based scheme
3. Low-skilled benefit the most

Conclusion

- **My Contribution**:
  - Develop new empirical approach to measure effects of transit
  - Quantitative model to assess aggregate and distributional effects across groups
  - Combine rich microdata + construction of world's largest BRT to assess causal impact

- **My Findings**:
  1. Investments in transit such as BRT have large aggregate net benefits to cities
  2. Low- and high-skilled benefit about the same $\Rightarrow$ less precise policy tool to target the poor than implied by standard approach
  3. Complementary change in zoning policies $\Rightarrow$ maximize returns from these investments