Evaluating the Impact of Transit Infrastructure

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Spatial Reading Group

April 15, 2020

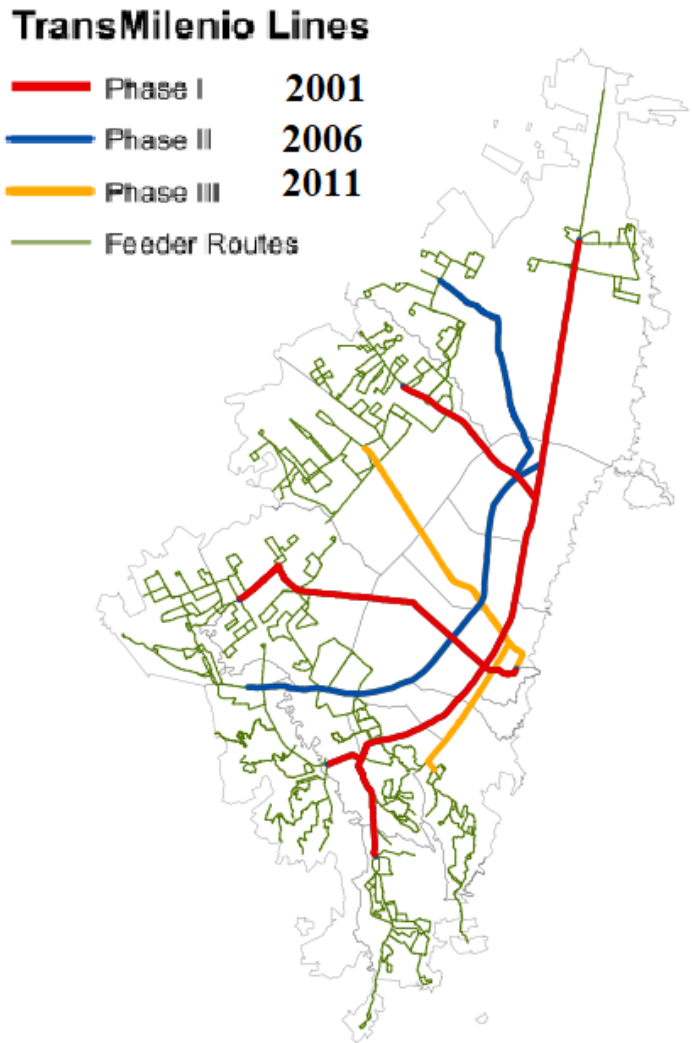
Paper Motivation

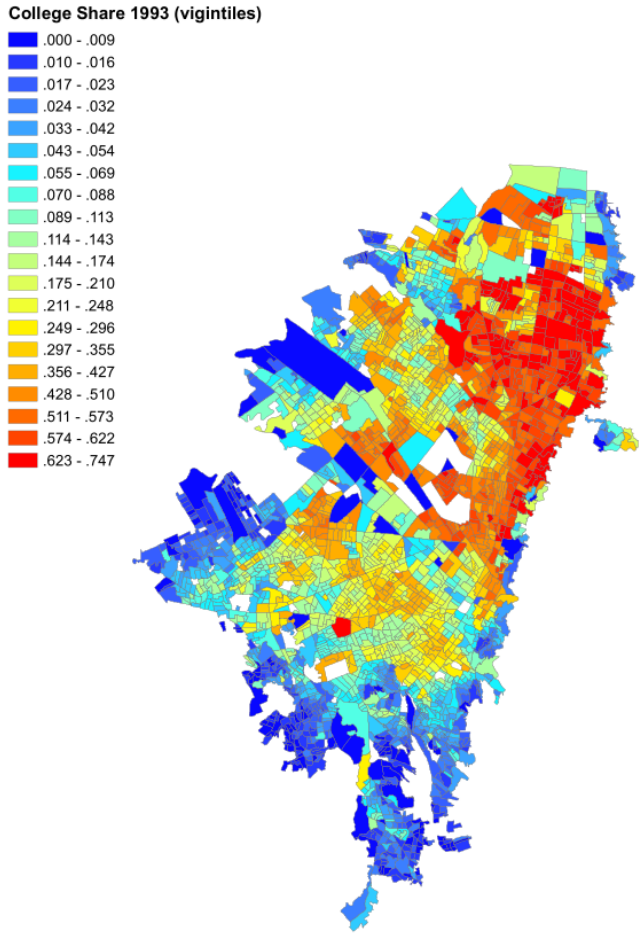
- Transit system is a key determinant of a city spatial structure
  - City-dwellers live, work and consume in different locations
  - US workers spent on average 8% time commuting
- Changes in commuting network may involve large general equilibrium effects
  - Commuters switch transit modes, congestion
  - Workers and firms sort into new locations
- Distributional effects of changes in transit system may go both ways
  - Low-income workers rely more on public transit
  - Gentrification and wages adjustments may benefit educated workers

Paper Structure

- Tsivanidis develops a general reduced-form approach based on gravity commuting models
- Focus on changes in a price-index called Commuter Market Access (CMA)
- Paper proposes a GE model with heterogeneous workers to study redistribution
- Estimation relies on development of Bus Rapid Transit (BRT) in Bogota

Bogota Bus Rapid Transit Development





Commuting in Bogota

Mode	Bus	Car	Walk	TM
Panel A: Commute Shares				
1995	0.74	0.17	0.09	
2005	0.66	0.17	0.07	0.11
2011	0.46	0.16	0.19	0.19
2015	0.48	0.15	0.16	0.21
Panel B: Commute Speeds (kmh)				
1995	16.31	25.37	8.20	
2005	12.88	15.65	6.53	16.88
2011	10.49	14.02	7.95	13.08
2015	10.37	12.95	6.36	13.04

Before and After TransMilenio

(a) Previous bus lanes, Avenida Caracas (Sur)

(b) TransMilenio Station, Avenida Caracas (Norte)

Baseline Model of Transit

- **Geography:** Location i characterized by amenities $\bar{u}_i$, productivities $\bar{A}_i$, housing supply (H_{Ri}, H_{Fi})
- **Preferences:** Worker lives in i, works in j, enjoys amenities and splits income between consumption and housing
- **Iceberg costs:** Commuting from i to j discounts wages to $\frac{w_j}{d_{ij}}$

$$\underbrace{U_{ij}(\omega)}_{\text{indirect utility}} = u_i . \underbrace{r_i^{\beta-1}}_{\text{residential rent}} . \frac{w_j}{d_{ij}} . \underbrace{\epsilon_{ij}(\omega)}_{\text{prod shock}}$$

Gravity Equation of Commuting

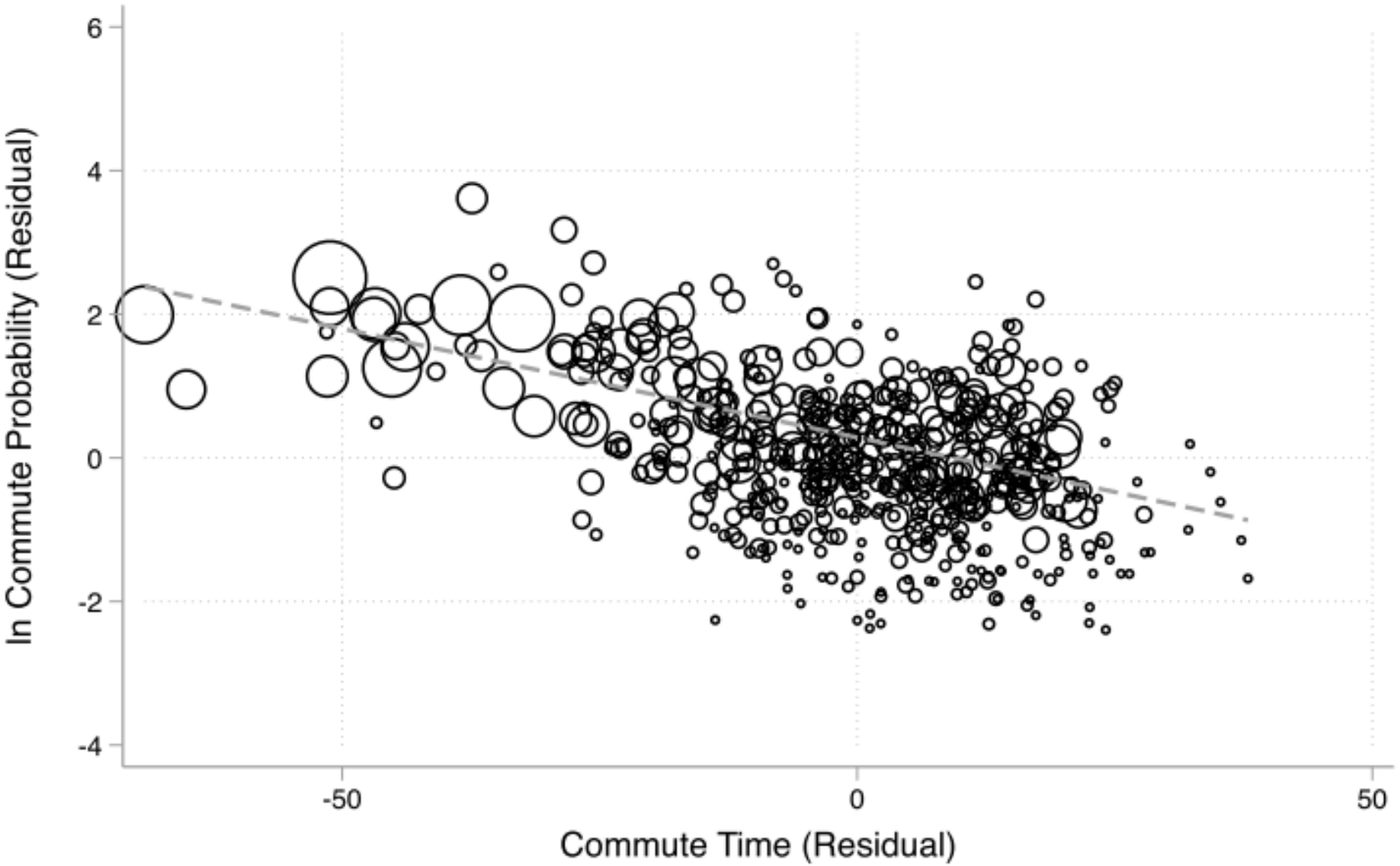
- Idiosyncratic productivity Fréchet distributed $\epsilon \sim \exp(-T\epsilon^{-}\theta)$
- Bilateral commuting flows L_{ij} can be obtained as

$$L_{ij} = \int_{\epsilon_{ij}} \mathbb{P}\left(u_i r_i^{\beta-1}.\frac{w_j}{d_{ij}}\epsilon_{ij} > u_{i'} r_{i'}^{\beta-1}.\frac{w_{j'}}{d_{i'j'}}\epsilon_{i'j'} \forall (i',j') \neq (i,j)\right) f(\epsilon_{ij}) d\epsilon_{ij}$$

- Computing the integral yields the gravity of commuting flows

$$L_{ij} \propto \frac{(u_i r_i^{\beta-1})^{\theta} w_j^{\theta}}{d_{ij}^{\theta}} \propto \gamma_i \delta_j \kappa_{ij}$$

Robust Fact: Fit of Gravity



Commuter Market Acces (CMA)

- Solving for residents $L_{Ri} = \sum_j L_{ij}$ and employment $L_{Fj} = \sum_i L_{ij}$ yields

$$L_{Ri} \propto (u_i r_i^{\beta-1})^{\theta} \underbrace{\sum_j \left(\frac{w_j}{d_{ij}}\right)^{\theta}}_{\text{RCMA } \Phi_{Ri}}$$

$$L_{Fj} \propto w_j^{\theta} \underbrace{\sum_i (\frac{u_i r_i^{\beta-1}}{d_{ij}})^{\theta}}_{\text{FCMA } \Phi_{Fj}}$$

- Residents value neighbourhoods close to workplaces paying high wages
- CMA also solve $\Phi_{Ri} = \sum_j d_{ij}^{-\theta} \frac{L_{Fj}}{\Phi_{Fj}}$ and $\Phi_{Fj} = \sum_i d_{ij}^{-\theta} \frac{L_{Ri}}{\Phi_{Ri}}$

Deriving Reduced From Equations

- Using average Income in i proportional to $\Phi_{Ri}^{\frac{1}{\theta}}$, residential market clearing yields:

$$r_{Ri} H_{Ri} \propto (1-\beta) L_i \Phi_{Ri}^{\frac{1}{\theta}}$$

- To match sorting patterns, introduce amenities spillovers $u_i = \bar{u}_i L_{Ri}^{\mu} U$

- Taking log and first difference of L_{R_i} definition and the equation for rental market clearing

$$(1-\theta\mu_U)\Delta \log L_{Ri} + \theta(1-\beta)\Delta \log r_{Ri} = \Delta \log \Phi_{Ri} + \theta \Delta \log \bar{u}_i \quad (1)$$

$$\Delta \log r_{Ri} - \Delta \log L_{Ri} = \frac{1}{\theta}\Delta \log \Phi_{Ri} - \Delta \log H_{Ri} \quad (2)$$

Reduced-form Framework

- Close model with firms using labor and land in to produce in each location
- Symmetrically, introduce agglomeration economies $A_i = \bar{A}_i L_{Fi}^{\mu_A}$

$$\begin{bmatrix} \Delta \log L_{Ri} \\ \Delta \log r_{Ri} \\ \Delta \log L_{Fi} \\ \Delta \log r_{Fi} \end{bmatrix} = A_R \Delta \log \Phi_{Ri} + B_F \Delta \log \Phi_{Fi} + e_i$$

- Changes in CMA contain what workers and residents care about when making commuting decisions
- Tsivanidis provides a formula linking First Order Approximation of Welfare changes to RCMA

Endogeneity Concerns

- Error e_i contains changes in unobserved amenities $\bar{u}_i$ and productivities $\bar{A}_i$
- Urban Endogeneity Problem: Φ contain changes in population counts likely correlated with unobserved amenities
  - Use residual changes in CMA not due to population changes
- Transportation Endogeneity Problem: government may decide where to build new routes based on productivity changes
  - Engineering instrument: use changes in CMA predicted by least cost route
  - Historical route: use changes in CMA predicted by old Bogota Tramway

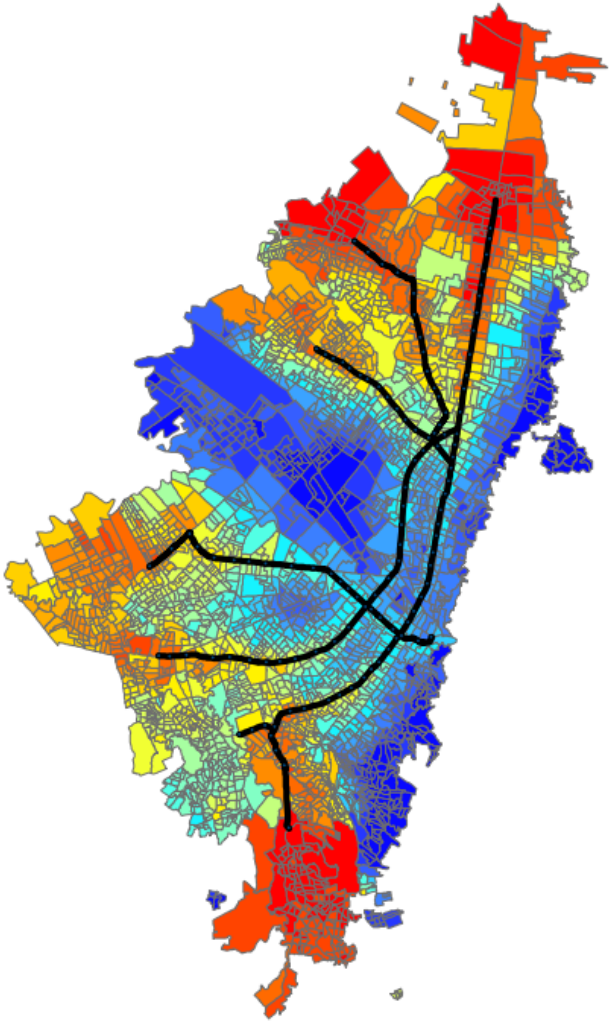
OLS and IV Results

Table 3: IV Results: Main Outcomes

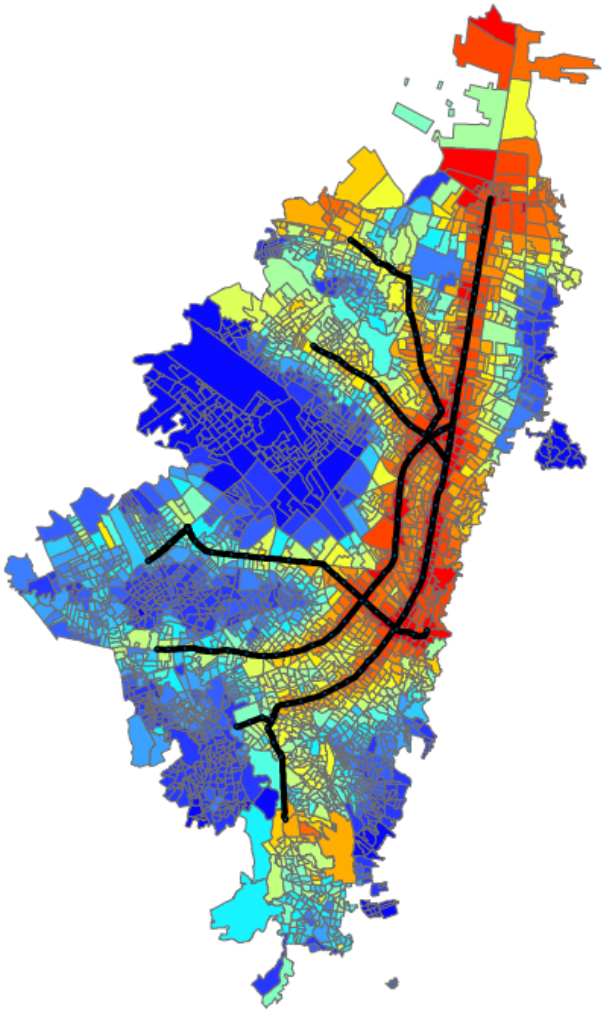
	(1) OLS	(8) IV All
Panel A: Residents		
ln(Res Floorspace Price)	0.386***	0.401***
	(0.067)	(0.096)
N	1,943	1,943
F-Stat		337.54
Over-ID p-value		0.09
ln(Residential Pop)	0.213**	0.243*
	(0.102)	(0.139)
N	1,997	1,997
F-Stat		769.49
Over-ID p-value		0.95
Panel B: Firms		
ln(Comm Floorspace Price)	0.211**	0.245*
	(0.097)	(0.142)
N	1,884	1,884
F-Stat		535.07
Over-ID p-value		0.97
ln(Establishments)	0.939***	0.742
	(0.295)	(0.505)
N	1,724	1,724
F-Stat		208.62
Over-ID p-value		0.04

Change in Commuter Market Access due to BRT

(a) Resident CMA



(b) Firm CMA



Why Heterogeneity may Matter

- Baseline model ignores that high and low skill workers are not perfect substitutes in production
- As a workplace becomes more productive, it may benefit more qualified workers
- Educated workers are generally thought to benefit more from amenities spillovers
- Low-income workers are hurt more by increases in rents

Full Model of City Structure

- Consider the previous model, but introduce in addition
- Two workers groups, high and low-skill, imperfect subs. in production
- Stone Geary preferences for housing (non-homotheticity)
- Option to purchase a car and commuting choices
- Multiple sectors in production

Results: Welfare Gains and Distributional Effects

	Average Welfare	Inequality
First Order Approximation (CMA)	0.937	-0.230
First Order Approximation (VTTS-Model)	1.308	-0.172
General Equilibrium	1.628	0.085