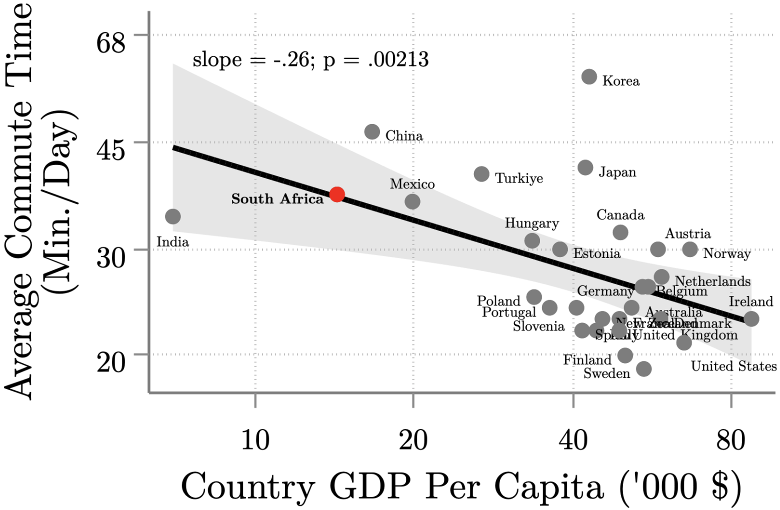
Subways or Minibuses?

Privatized Provision of Public Transit

Lucas Conwell

August 2023

Long Commutes in Lower-Income Countries



Typical Recommendation: Formal “Bus Rapid Transit”

Sources: ODA Ltd.; Creamer Media’s Engineering News

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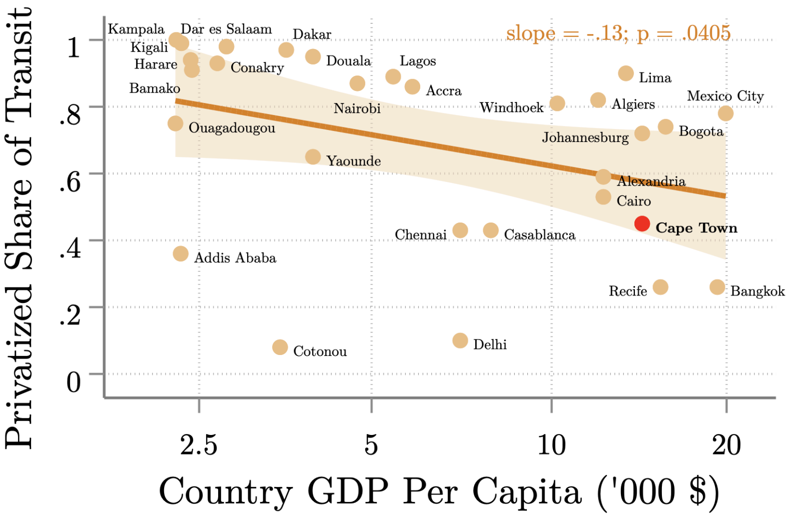
The Limits of Bus Rapid Transit: A Cape Town Case Study

Why BRT isn't right for every city.

- Bloomberg

Privatized Shared Transit



This Paper: Subways vs. Minibuses

- Model of privatized shared transit
  1. Minibuses enter + match with passengers ⇒ wait times
  2. Commuter home + work + mode choice [time + quality]

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- **Data**, newly-collected
  1. **Matching:** buses + passengers [ID: demand shocks w/i 44 routes]
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  1. **Social Planner:** optimally ↑ fares on high-wage, amenity routes
  2. **Station Security:** greatest *net* gains

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↓

commute time/quality + relocation + environmental

▸ Literature

Minibus Entry $\nrightarrow$ Lower Passenger Wait Times

1. **Off-bus wait**
   avg. $\approx$ 9 min.

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   > *Queues, especially during certain times of the day are impossibl[y long].*
   > -“Pros Cons of Minibus Taxis” on Medium

Minibus Entry $\nrightarrow$ Lower Passenger Wait Times

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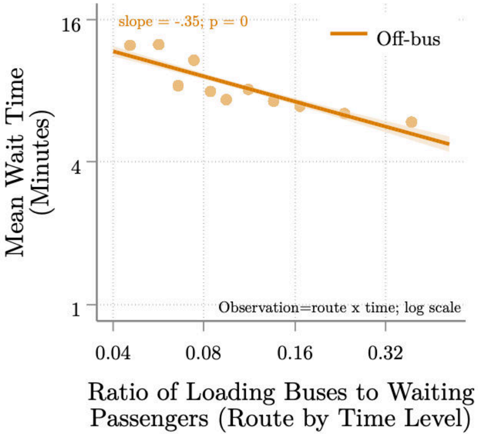
> *One…inefficient practice…is that minibus taxis generally only leave when they are full.* -World Bank (2018)

1. Off-bus wait
   avg. ≈ 9 min.

2. On-bus wait
   avg. ≈ 3 min.



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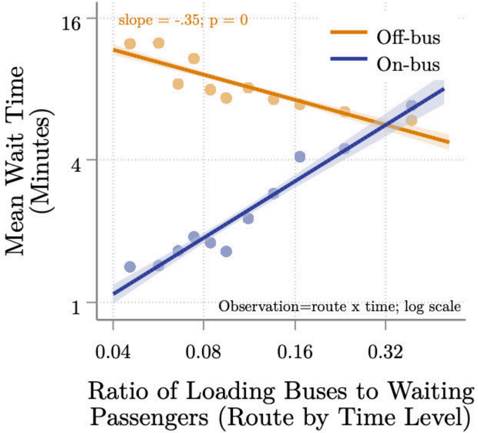

▸ Context ▸ Security

Today's Talk

Model

Data and Estimation

Transport Policies

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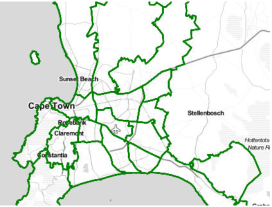
Model Overview

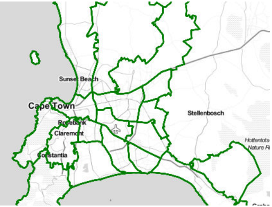


Environment

Time: continuous

Geography: I locations

Emissions costs
external, mode-specific



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Minibuses

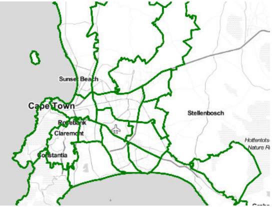
Entry at cost
∀ origin-destination

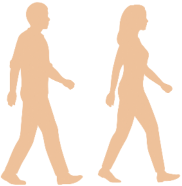
Fares: exogenous

Matching: frictional
with passengers

Trips: multiple

Model Overview





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Entry at cost
$\forall$ origin-destination

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with passengers

Trips: multiple

Commuters

Skill: heterogeneous
$g \in \{\text{low}, \text{high}\}$

Choice:

1. Home i [amenity θ_i^g]
2. Work j [wage ω_j^g]
3. Mode $m \in$
   - minibus
   - formal transit
   - car

▸ Market Structure ▸ Commuter Mode Choice ▸ Equilibrium

A Minibus Trip

1. Load passengers s.t. frictional matching process ▸ Why matching?

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A Minibus Trip

1. **Load** passengers s.t. frictional matching process ▸ Why matching?
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3. **Collect** fares τ_{ijM} [calibrated to data] ▸ Data
4. **Travel** to j, operating cost χ per distance Δ_{ij}
5. **Arrive** at rate d_{ij} and end work "shift" with $\Pr = g\overbrace{(\text{trip time})}^{(+)}$

▸ Profits

Minibus-Passenger Matching

- **Matching function** for each route *ij*:

$$\mathscr{M}_{ij} \equiv \mu_{ij} p_{ij}^{\alpha} b_{ij}^{\beta} \quad \Big\} \begin{array}{l} \mu_{ij} = \text{matching efficiency} \\ p_{ij}, b_{ij} = \text{passengers, buses} \end{array}$$

⇒ Passenger **boarding** (λ_{ij}) and bus **loading** (ι_{ij}) rates

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$\Rightarrow$ Passenger **boarding** (λ_{ij}) and bus **loading** (ι_{ij}) rates

- Minibus passengers' **expected wait time** [$\mu_{ij} = 1$ and CRS]:

$$\underbrace{\frac{1}{\lambda_{ij}}}_{\text{off-bus}} + \underbrace{\frac{1}{2}\frac{\overline{\eta}}{\iota_{ij}}}_{\text{on-bus}} = \underbrace{\left(\frac{p_{ij}}{b_{ij}}\right)^{\beta}}_{\text{boarding externality}} + \underbrace{\frac{\overline{\eta}}{2}\left(\frac{b_{ij}}{p_{ij}}\right)^{1-\beta}}_{\text{filling externality}}$$

Social Planner Optimum via Minibus Fares + Taxes

Social Planner Problem

$$\max_{\boldsymbol{b}_{ij},\boldsymbol{\pi}^g_{ijm}} \left\{ \sum_g \underset{\substack{\uparrow \\ \text{expected} \\ \text{commuter utility}}}{N^g \overline{W}^g} + \underset{\substack{\uparrow \\ \text{minibus} \\ \text{profits}}}{\Pi} - \underset{\substack{\uparrow \\ \text{emissions} \\ \text{costs}}}{E} \right\} \text{ s.t. } \begin{matrix}\text{matching} \\ \text{technology.}\end{matrix}$$

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Optimal Minibus Fares

Assume $\alpha + \beta = 1$ and $\mu_{ij} = 1$.

$$\tau^*_{ijM} \propto \underbrace{\chi\Delta_{ij}}_{\text{operating costs}} + \underbrace{\overline{\psi}g\left[\overline{\eta}^{\beta}\left(\frac{2\beta}{1-\beta}\right)^{1-\beta} + \frac{1}{d_{ij}}\right] b_{ij}^{*\phi}}_{\text{net boarding} - \text{filling externality}}$$

Today's Talk

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Transport Policies

Data Collection

❶ Minibus Station Counts

- **Loading process** [M-F 6-10:00]
  - bus arrival/departure
  - waiting passengers
- **Sample**: $N = 44$ routes
  2-stage, stratified by bus entry

Data Collection

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❷ Stated Preference Surveys

Over Commute Modes

Q1.1	Option 1.1.1	Option 1.1.2
Cost	R18.00	R6.00
Travel Time	50 Minutes	50 Minutes
Security	Security at taxi rank	No security at taxi rank
Driver Behaviour	Adheres to speed limit	Exceeds speed limit
Bus Loading	Enough seats for all passengers	Overloaded: more passengers than seats

1. New: minibus options
   - 5 randomized **choice sets**
   - 2 minibus options/set
   - **Sample** ($N = 526$) ▸ vs. pop.
     at mall, minibus stations
2. **Existing:** other modes

Estimation

1. Station Counts ⇒ **Matching Function** ▸ Details

$$\log \iota_{ijt} = \hat{\alpha} \log p_{ijt} + \left(\hat{\beta} - 1\right) \log b_{ijt} + \overline{\mu}_{ij} + \overline{\mu}_{it} + \epsilon_{ijt}$$

ID Strategy: assume CRS ⇒ IV for $\log\left(\frac{p_{ijt}}{b_{ijt}}\right)$ = commuters in i leaving at t

Estimation

1. Station Counts ⇒ Matching Function ▸ Details

$$\log \iota_{ijt} = \hat{\alpha} \log p_{ijt} + \left(\hat{\beta} - 1\right) \log b_{ijt} + \overline{\mu}_{ij} + \overline{\mu}_{it} + \epsilon_{ijt}$$

ID Strategy: assume CRS ⇒ IV for $\log \left(\frac{p_{ijt}}{b_{ijt}}\right)$ = commuters in i leaving at t

2. Stated Preference Survey ⇒ Demand ▸ Details

ID Strategy: exogenously-varied attributes

- Low rate of time preference r
- High minibus utility costs κ_M^g
- Security = most-valued quality improvement.

▸ All parameters ▸ Validation

Today's Talk

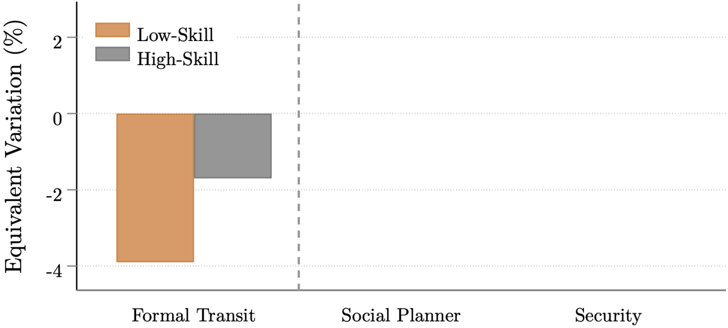
Model

Data and Estimation

Transport Policies

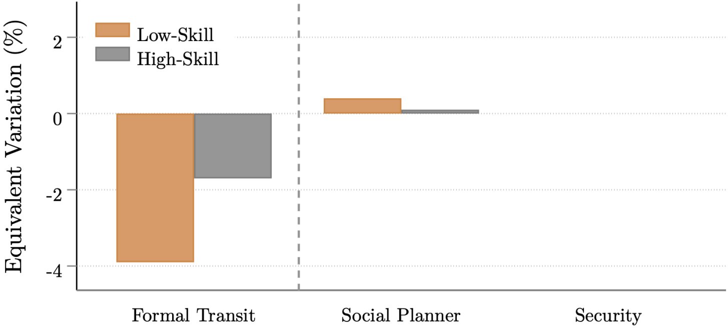
Comparing Policies [Net Welfare Gains]

1. *MyCiti* Formal Bus Rapid Transit [existing]
   Monetary costs: construction + operations, via lump-sum tax.



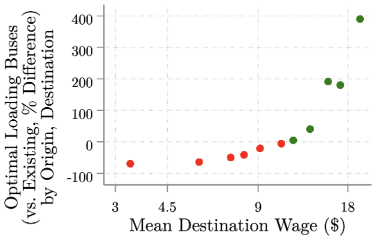
2 Social Planner Optimum

Optimal Minibus Fares + Mode-Specific Commuter Taxes



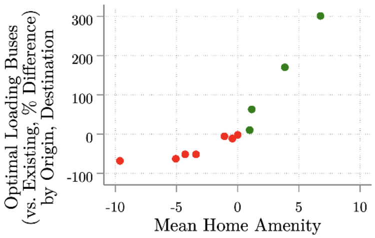
Wages

[at destination]



Amenities

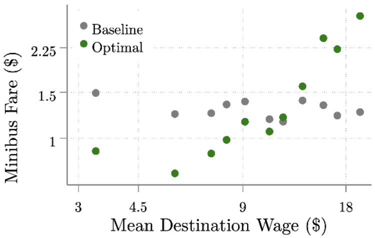
[at origin]



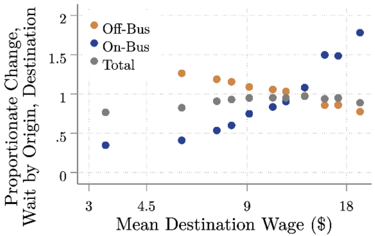
➋ Social Planner: Optimal Minibus Fares → Access High Wages

↑ Fares on High-Wage Routes

[vs. status quo]



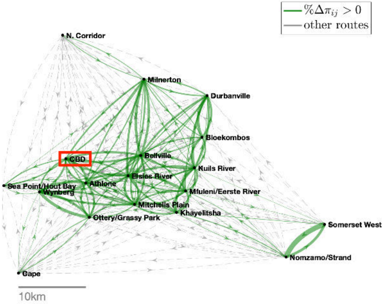
↓ Off-Bus Waits



➋ Social Planner: Spatial Reallocation

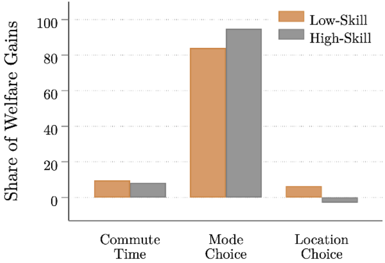
↑ Suburb to Suburb Commutes

[Δ Home-Work Flow > 0]



Reallocation Benefits Low-Skill

[Decomposition of Gains in %]



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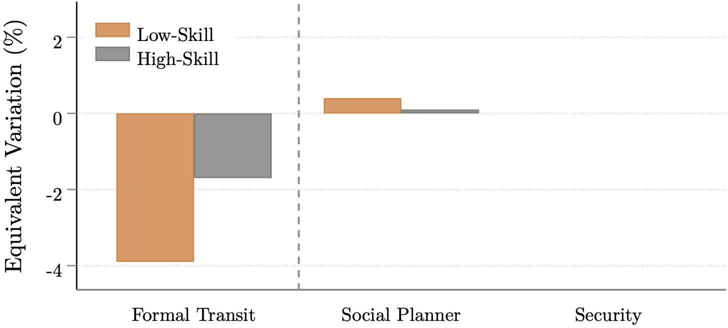
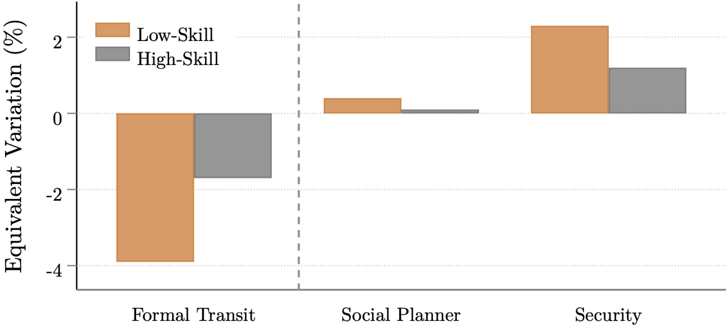


Comparing Policies [Net Welfare Gains]

3 **Minibus Station Security:** ↓ utility cost by stated pref. effect
Monetary costs: guard wages covered with lump-sum tax.



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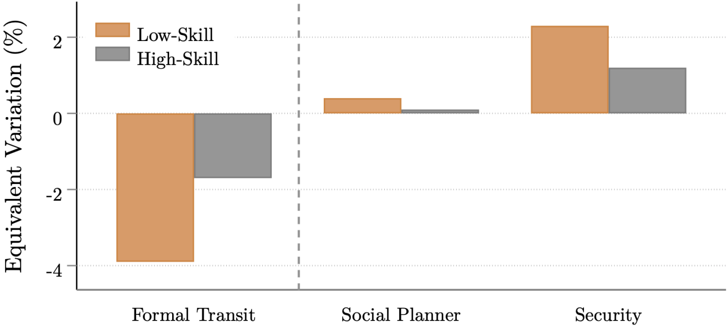


⇒ **Optimized minibuses:** low-cost **solution** to { long commutes, spatial misallocation, emissions.

Literature

- Public transit and (developing-country) cities

  Glaeser, Kahn, Rappaport '08; Ahlfeldt, Redding, Sturm, Wolf '15
  Heblich, Redding, Sturm '20; Balboni, Bryan, Morten, Siddiqi '20
  Tsivanidis '22; Severen '23; Warnes '21, Zarate '23

  $\Rightarrow$ **Privatized transit.**

- Road congestion and optimal networks

  Duranton and Turner '11; Kreindler '22; Fajgelbaum and Schaal '20
  Allen and Arkolakis '22; Almagro, Barbieri, Castillo, Hickok, Salz '23
  Barwick, Li, Waxman, Wu, Xia '22; Brancaccio, Kalouptsidi, Papageorgiou, Rosaia '22
  Kreindler, Gaduh, Graff, Hanna, Olken '23; Akbar, Couture, Duranton, Storeygard '23

  $\Rightarrow$ **Optimal minibus entry.**

- Methodology
  - Matching $\Rightarrow$ **Observe passengers *and* buses.**

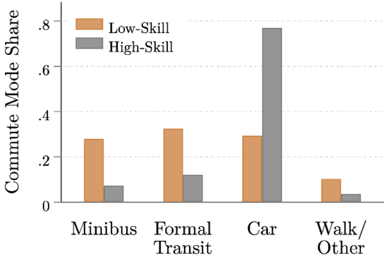
    Brancaccio, Kalouptsidi, Papageorgiou '20; Castillo '22
  - Stated preference $\Rightarrow$ **Plausible context.**

    Ameriks, Briggs, Caplin, Shapiro, Tonetti '20; Andrew and Adams-Prassl '23

Back

Minibuses in Cape Town

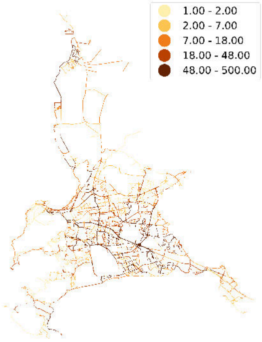
- **Large market share**
  $\frac{1}{3}$ of low-skill commuters
- **Small firms** avg. < 2 buses
  $\frac{1}{2}$ informal
- Enter specific **route** s.t. fee
  = origin $\times$ destination
- **Fares:** distance-based
  set by gov't + route "association."



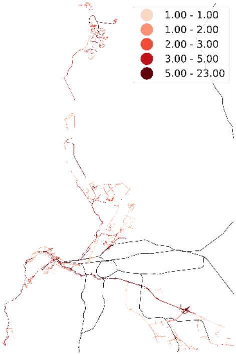
Cape Town Transit Networks: # Routes

Minibus

Golden Arrow Bus



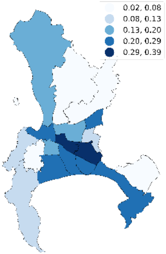
BRT + Metrorail



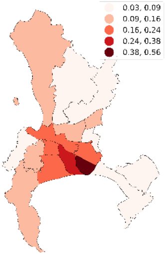
Back

Mode Shares by Home Location

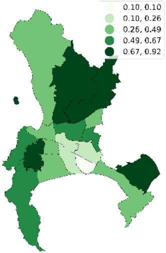
Minibus



Formal Transit

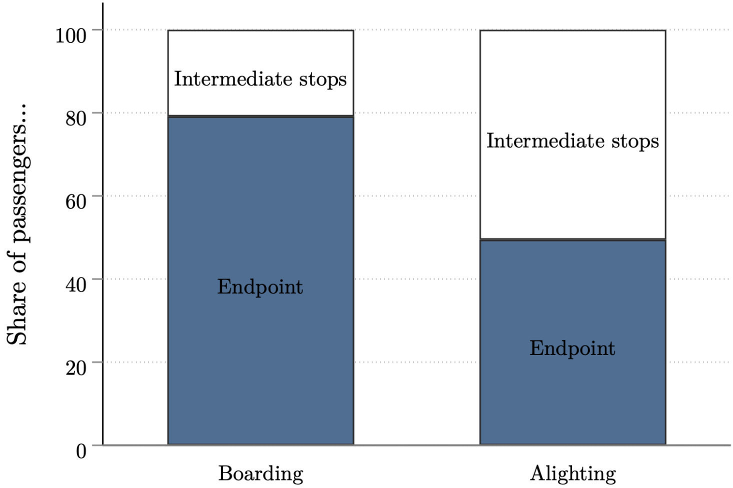


Car



Back to context

Most Boardings/Alightings at Endpoints



▸ Back

Association Entry Restrictions: No Consensus

Free entry at cost?

[Associations'] main income derives from owners' membership fees. . . it is ***in [their] interest to have as many members as possible***" - Schalekamp (2017)

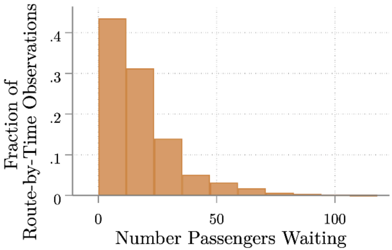
Most associations are still taking on new members and going out on recruitment drives to ***encourage new members to join****. These new members pay an exorbitant amount of money to join the association* - City of Cape Town Operating Licence Strategy (2014)

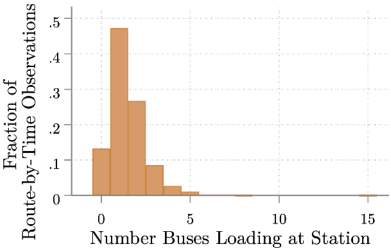
Cartel-like quantity controls?

Taxi associations prevent entry by other operators through a number of different means, not all of which are used by every association... ***Entry deterrence and cartel price setting*** *make owning a taxi extremely lucrative on many routes.* - World Bank (2018)

Back

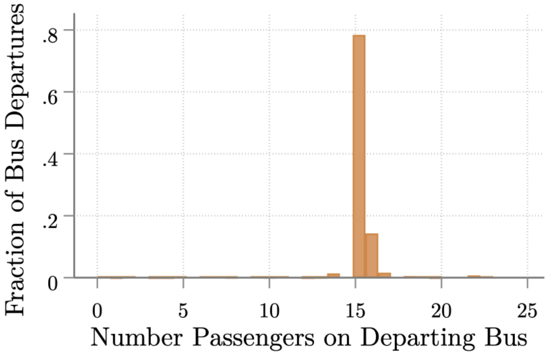
Long Passenger Lines + Multiple Buses Loading





Back

Minibuses: 15-Passenger + Depart When Full



▸ Restrictions ▸ Back

Legal Restrictions on Minibus Size

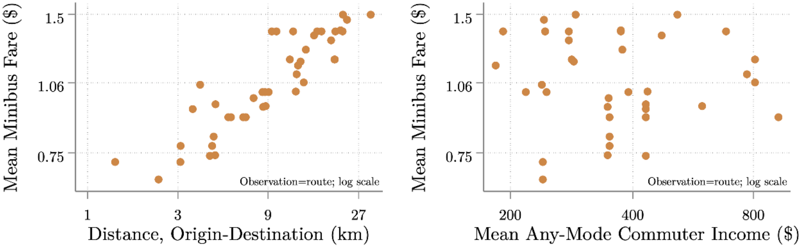
The [National Land Transport Act] specifies the vehicles…to be used for non-contracted PT purposes. - City of Cape Town Comprehensive Integrated Transport Plan (2018)

Table 6 2: Approved vehicle types, capacities and number of legal OLs issued

Type of Vehicle	Seating Capacities including the Driver	Current OLs per vehicle group
Sedan	5	205
Avanza (8 +1)	9	400
Minibuses (15+1)	16	9 500 to 10 100
Midi-buses (16<35)	35	negligible
Buses	35 +	**n/a**

◂ Back to context ◂ Back to fact

Fares ↑ with Distance, not Ability to Pay



Why? City considers "cost to the user" in route approvals

▸ Details ▸ Fares vs. entry ▸ Back to context ▸ Back to trip ▸ Back to market

City of Cape Town: New Route Approvals

Considerations and recommended procedure for new minibus-taxi routes

⋮

- *The potential for conflict with existing associations and members*
- *Existing travel patterns*
- *Existing public transport network coverage*

⋮

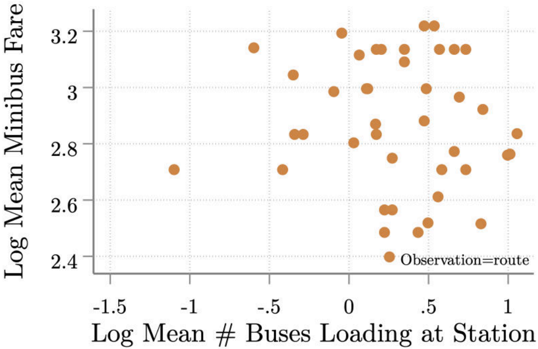
- ***Cost to the user (portion of monthly income spent on public transport)***

⋮

- City of Cape Town Operating Licence Strategy (2014)

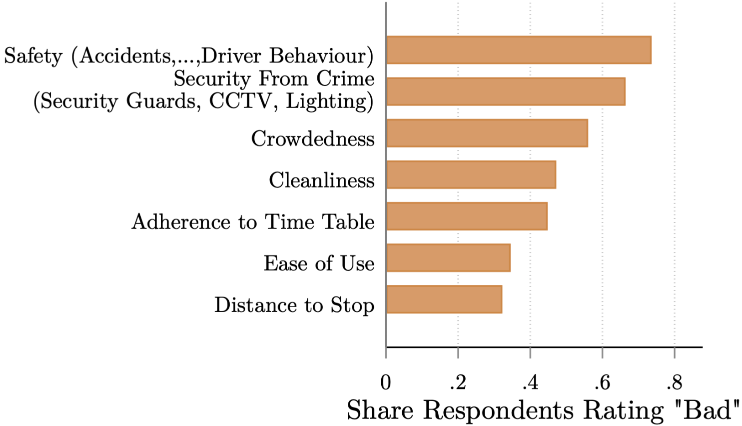
◂ Back to context ◂ Back to fact ▸ Back to market

Route-Level Fares Versus Bus Entry



Back to fact

Security = Major Rider Complaint



⇒ Counterfactual: station security guards. Back

Minibus Market Structure on each route ij

- **Entry cost**, increasing in mass of loading buses b_{ij}

$$\overline{\psi} b_{ij}^{\phi}$$

- **Multiple trips** during effectively finite "work shift"

- **Fares** exogenously calibrated ▸ Evidence

$$\tau_{ijM} \equiv h\Big(\underbrace{\overline{\Delta}_{ij}}_{\text{distance}}\Big)$$

▸ Back

Minibus Profits on route ij

$$\Pi_{ij} \equiv \underbrace{\left[\overline{\eta}\tau_{ijM} - \chi\Delta_{ij}\right]}_{\text{per-trip net revenue}} \underbrace{\frac{1}{g\left(\frac{\overline{\eta}}{\iota_{ij}} + \frac{1}{d_{ij}}\right)}}_{E[\#\text{ trips}]} - \overline{\psi} b_{ij}^{\phi}$$

- Per-trip net revenue $\overline{\eta}\tau_{ijM} - \chi\Delta_{ij}$
- Expected total trip time $\frac{\overline{\eta}}{\iota_{ij}} + \frac{1}{d_{ij}}$
- Entry cost $\overline{\psi} b_{ij}^{\phi}$

Back to trip

Commuters: Choose Home + Work + Mode

- **Example**: minibus choice utility for home i, work j

$$\overline{U}^g_{ijM} = \underset{\substack{\uparrow \\ \text{amenity}}}{\theta^g_i} + \underset{\substack{\uparrow \\ \text{wage}}}{\omega^g_j} - \overset{\substack{\text{rate of time pref.} \\ \downarrow}}{r}\omega^g_j \left(\underset{\substack{\uparrow \\ \text{off-bus wait}}}{\frac{1}{\lambda_{ij}}} + \underset{\substack{\uparrow \\ \text{on-bus wait}}}{\frac{1}{2}\frac{\overline{\eta}}{\iota_{ij}}} + \underset{\substack{\uparrow \\ \text{travel time}}}{\frac{1}{d_{ij}}} \right) - \underset{\substack{\uparrow \\ \text{mode utility cost}}}{\kappa^g_M} - \underset{\substack{\uparrow \\ \text{fare}}}{\tau_{ijM}}$$

Gumbel shock, shape $\nu \Rightarrow$ choice Pr. $\pi^g_{ijM} \equiv \exp\left(\frac{\overline{U}^g_{ijM}}{\nu}\right) / \sum_{i,j,m} \exp\left(\frac{\overline{U}^g_{ijm}}{\nu}\right)$.

- **Policies,** e.g. security $\Rightarrow \kappa^g_M$.

▸ Other Modes ▸ Back

Commute Utility: Other Modes

- **Formal transit:** travel $\rightarrow$ arrive at rate d_{ijF}

$$\underset{}{\overline{U}^g_{ijF}} = \underset{\substack{\uparrow \\ \text{amenity}}}{\theta^g_i} + \underset{\substack{\uparrow \\ \text{wage}}}{\omega^g_j} - r\omega^g_j \underset{\substack{\uparrow \\ \text{travel} \\ \text{time}}}{\left(\frac{1}{d_{ijF}}\right)} - \underset{\substack{\uparrow \\ \text{utility} \\ \text{cost}}}{\kappa^g_F} - \underset{\substack{\uparrow \\ \text{fare}}}{\tau_{ijF}}$$

- **Car:** travel $\rightarrow$ arrive at rate d_{ij}

$$\overline{U}^g_{ijA} = \underset{\substack{\uparrow \\ \text{amenity}}}{\theta^g_i} + \underset{\substack{\uparrow \\ \text{wage}}}{\omega^g_j} - r\omega^g_j \underset{\substack{\uparrow \\ \text{travel} \\ \text{time}}}{\left(\frac{1}{d_{ij}}\right)} - \underset{\substack{\uparrow \\ \text{car cost}}}{\tau_A}$$

▸ Back

Equilibrium

Equilibrium

A vector $\{\mathbf{b}, \boldsymbol{\pi}, \boldsymbol{\lambda}, \boldsymbol{\iota}\}$ *satisfying (i) free entry, (ii) 3 sets of choice probability equations, (iii) boarding as well as (iv) loading rate equations.*

Welfare

$$\Omega \equiv \sum_g N^g \nu \log \left[\sum_{i,j,m} \exp\left(\underbrace{\overline{U}^g_{ijm}}_{\uparrow \text{ commute utility}} \right)^{1/\nu} \right] + \underbrace{\Pi}_{\substack{\uparrow \\ \text{rebated minibus} \\ \text{profits + entry costs}}} - \underbrace{E}_{\substack{\uparrow \\ \text{emissions} \\ \text{costs}}}$$

Back

Station Counts ⇒ Matching Function

- Estimate **bus loading rate** equation in logs ▸ Histograms
  across 44 routes (ij) × 48 5-min. periods (t)

$$\log \iota_{ijt} = \hat{\alpha} \log \left(p_{ijt} / b_{ijt} \right) \underbrace{+ \overline{\mu}_{ij} + \epsilon_{ijt}}_{\text{matching efficiency}}$$

Parameter	OLS *route+origin-time FE*	IV *route FE*
α	0.645 (0.0264)	0.841 (0.106)
β	0.435 (0.043)	0.159 (0.106)

Note: Robust standard errors in parentheses, clustered at origin level.

- **Threat to ID:** matching efficiency shocks over t *w/i same origin i*
  ID Strategy: assume CRS ⇒ IV for $\underbrace{\log \left(\frac{p_{ijt}}{b_{ijt}} \right)}_{2022} = \underbrace{\text{commuters}}_{2013}$ in i leaving at t

▸ Back

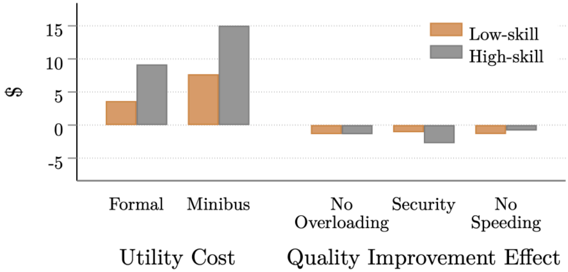
Stated Preference Survey $\Rightarrow \kappa_m^g, r, \nu$

- Estimate **multinomial logit** [model-implied] ▸ Details

  ID Strategy: exogenously-varied attributes

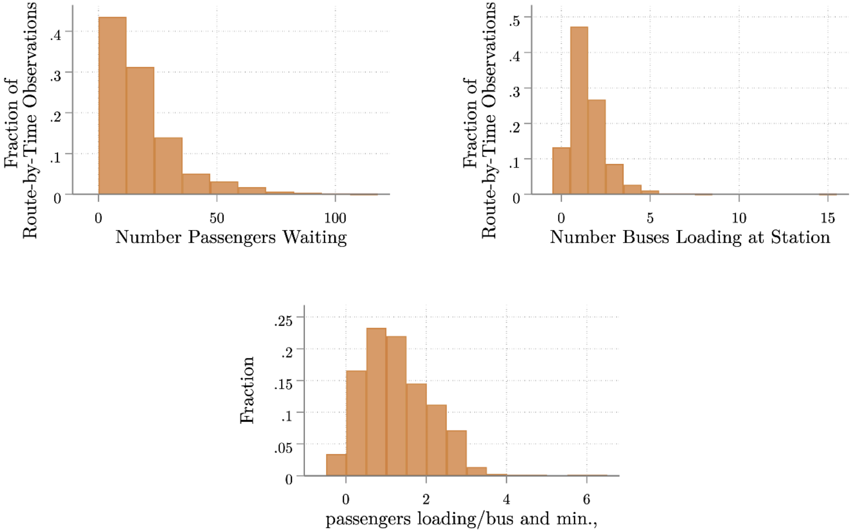
Parameter	Estimate
r	0.001
commuter rate of time pref.	(0.0004)
ν	4.76
Gumbel pref. shock shape	(1.26)

Note: Robust standard errors in parentheses



▸ Predictions ▸ Heterogeneity ▸ Sample vs. pop. ▸ Sample robustness ▸ Back

Matching Estimation: Distributions of Variables



ι_{ij}

▸ Back

Estimated Parameters

Parameter	Description	Value
Externally Calibrated		
I	Number Locations	18
N^g	Commuter Populations	
d_{ij}	Road-Based Destination Arrival Rate	
d_{ijF}	Formal Destination Arrival Rate	
τ_{ijF}	Formal Fare	
τ_A	Car Commute Cost	5.2
δ_0	Minibus Shift Length	240
δ_1	Minibus Inverse # Trips	0.01
χ	Per-km. Operating Cost	0.06
Δ_{ij}	Route Driving Distance	
χ^e_M	Minibus CO2-equiv./km.	0.06
χ^e_F	Formal CO2-equiv./km.	0.04
χ^e_A	Car CO2-equiv./km.	0.55
ς	Social cost of carbon	0.0485
Minibus Supply ▸ ϕ ▸ Γ_1		
α	Passenger Elasticity	0.84
β	Bus Elasticity	0.16
ϕ	Entry Cost Elasticity	0.602

Parameter	Description	Value
Γ_0	Fare Intercept	2.23
Γ_1	Fare Distance Slope	0.29
Stated Preference		
r	Commuter Rate of Time Pref.	0.001
ν	Gumbel Shape	4.76
κ^l_M	Low-Skill Minibus Util. Cost	7.7
κ^h_M	High-Skill Minibus Util. Cost	15
κ^l_F	Low-Skill Formal Util. Cost	3.6
κ^h_F	High-Skill Formal Util. Cost	9.2
Internally Calibrated ▸ $\overline{\psi}, \overline{\eta}, \mu$		
$\overline{\psi}$	Minibus Entry Cost Intercept	3.1
$\overline{\eta}$	Minibus Capacity	6.2
μ	Minibus Matching Efficiency	0.2
Model Inversion		
θ^g_i	Amenities	
ω^g_j	Wages	

▸ Back

Entry Congestion Estimation

- **Station counts** yield route-level average
  - loading buses b_{ij}
  - bus loading time $\overline{\eta}/\iota_{ij}$
  - travel time $1/d_{ij}$
- **Estimate** ϕ across $N = 43$ routes using free entry:

$$\log b_{ij} = \zeta_0 + \frac{1}{\phi} \log \left\{ 1 + \exp \left[-\delta_1 \left(\frac{\overline{\eta}}{\iota_{ij}} + \frac{1}{d_{ij}} - \delta_0 \right) \right] \right\} + X_{ij}\zeta + \varepsilon_{ij}.$$

$$\Rightarrow \hat{\phi} = 0.602\ (0.326)$$

▸ Back to parameter table

Fare Function Estimation: Γ_1

- **Onboard tracking data** yield route-level average
  - fare τ_{ijM}
  - straight-line distance $\overline{\Delta}_{ij}$
- **Estimate Γ_1** using $\log \tau_{ijM} = \Gamma_0 + \Gamma_1 \log \overline{\Delta}_{ij} + \epsilon_{ij}$.

Parameter	(1) log mean fare
Γ_1	0.292***
	(0.0232)
Constant	2.231***
	(0.0591)
Observations	43
R-Squared	0.798

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Back to parameter table

Internal Calibration

Moment			Parameter		
Description	*Data*	*Model*	*Description*		*Value*
Median Loading Buses/ Waiting Passengers	0.09	0.09	$\overline{\psi}$	Entry Cost Intercept	3.1
Median Bus Loading Time	4	4	$\overline{\eta}$	Minibus Capacity	6.2
Median Off-Bus Passenger Wait Time	7.18	7.18	μ	Matching Efficiency	0.2

▸ Back to parameter table

Multinomial Logit: Choice Probability

Pr. individual i in group g chooses alternative l in choice set c:

$$\pi_{icl}^{g} = \frac{\exp\left[\zeta_{m(c,l)}^{g} + \sum_z \beta_z^g q_{cl}(z) + \beta_{\text{time}}\omega_i \left(w_{cl} + t_{cl}\right) + \beta_{\text{fare}}\tau_{cl} + \beta_{\text{resid}} w_{cl}\tau_{cl}\right]}{\sum_{l'} \exp\left(U_{icl'}^{g}/\nu\right)}.$$

- $\zeta_{m(c,l)}^{g}$ = group-mode fixed effect $\Rightarrow \kappa_m^g$
- $q_{cl}(z)$ = indicator: quality improvement z in set c, alternative l
- ω_i = personal income
- w_{cl} and t_{cl} = wait and travel time
- τ_{cl} = fare

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Stated Preference Sample

Variable	*Stated Pref. Samples* Own	City-Run	*Data* Cape Town
Share Auto Owners	0.448	0.581	0.561
Share Female	0.458	0.494	0.458
Share College-Educated	0.295	0.228	0.190
Median Monthly Personal Income [bin]	$182-$364	$182-$364	$182-$364
Median Age	35	39	39
Commute Mode Shares of...			
Minibus	59.56	22.56	23.55
Formal Transit	19.61	27.69	22.81
Auto	12.11	40	39.40
Share Using Minibuses > 1x/week	0.951	0.635	
N	413	407	

Back to data Back to estimation

Stated Preference Robustness

Parameter	Skill	Baseline	Intermodal Sample Only	Commute Mode-Weighted
r		0.001	0.0014	0.0011
commuter rate of time pref.		(0.0004)	(0.0007)	(.0005)
ν		4.76	6.83	5.84
Gumbel pref. shock shape		(1.26)	(2.73)	(1.99)
κ_M	*Low*	7.68	10.61	9.25
minibus (baseline) utility cost		(1.56)	(3.54)	(2.55)
	High	15.03	21.16	18.3
		(3.55)	(7.82)	(5.67)
κ_F	*Low*	3.63	4.53	4.14
formal utility cost		(0.51)	(1.08)	(0.80)
	High	9.17	12.5	10.96
		(1.89)	(4.20)	(3.05)
N Respondents		820	546	820

Note: Robust standard errors in parentheses

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Stated Preference Robustness

Parameter	Skill	Baseline	Intermodal Sample Only	Commute Mode-Weighted
ξ_{security}	*Low*	-1.09	-2.13	-1.55
effect of security on κ_M		(0.39)	(1.06)	(0.69)
	High	-2.75	-4.91	-5.1
		(0.84)	(2.29)	(1.86)
$\xi_{\text{no overloading}}$	*Low*	-1.38	-2.02	-1.26
effect of no overloading on κ_M		(0.437)	(1.01)	(0.596)
	High	-1.39	-1.25	-1.43
		(0.543)	(1.28)	(0.83)
$\xi_{\text{no speeding}}$	*Low*	-1.36	-3.03	-2.12
effect of no speeding on κ_M		(0.44)	(1.38)	(0.85)
	High	-0.825	-1.86	-0.582
		(0.465)	(1.39)	(0.73)
N Respondents		820	546	820

Note: Robust standard errors in parentheses

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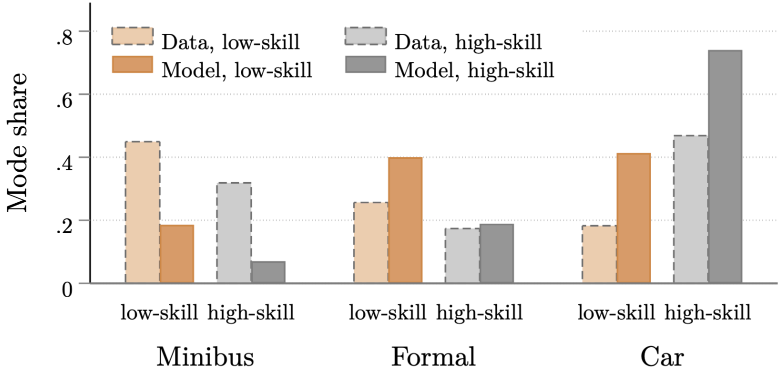
Stated Preference Respondents: Predicted Mode Shares



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Stated Preference: Effect Heterogeneity

Dimension	r *rate of time pref.*	*Mode Utility Cost* κ_M *minibus*	κ_F *formal*	*Effects on Minibus Utility Cost* $\lvert\xi_{\text{overload}}\rvert$ *no overload.*	$\lvert\xi_{\text{security}}\rvert$ *security*	$\lvert\xi_{\text{speed}}\rvert$ *no speed.*
Female	+	-	-		-	
College	+	+	+		+	
Age>45	+		-		+	+

Note: (+) indicates larger effect magnitude, (-) smaller. Only effects significant at 5% level displayed.

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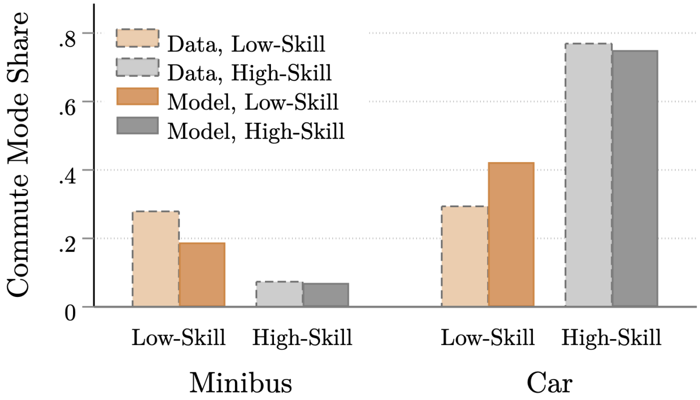
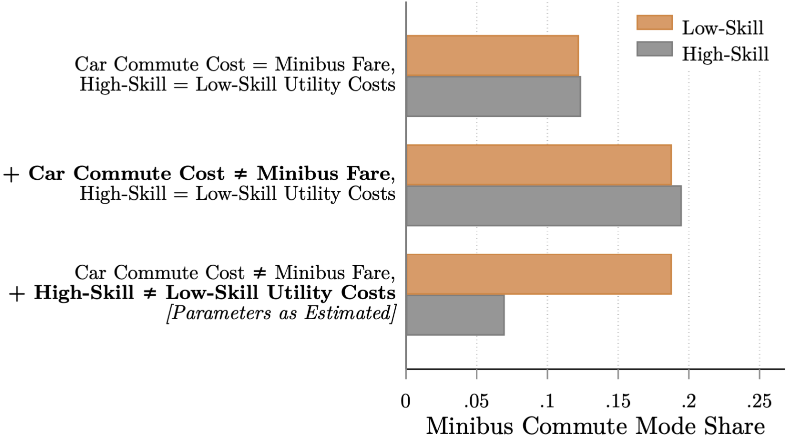
Only Low-Skill Use Minibuses ⇐ Due to Utility Costs



▸ Decomposition ▸ O-D mode choice pr. ▸ Network ▸ Matching ▸ Back

Why Don't the Rich Use Minibuses?



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Validation: Mode Choice by Origin-Destination-Skill

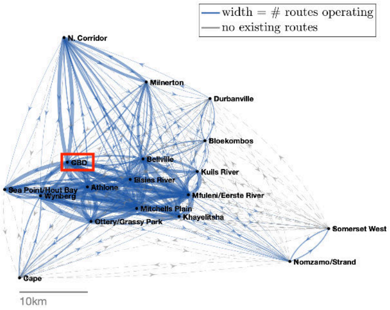
	Minibus	Car
Variables	Mode Share, Data	Mode Share, Data
Mode Share, Model	1.209***	0.992***
origin×destination×skill	(0.153)	(0.0814)
Constant	-0.00558	0.0335
	(0.0208)	(0.0493)
Observations	507	507
R-squared	0.106	0.230

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

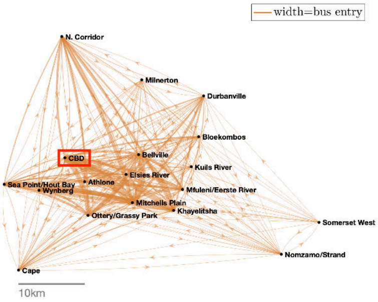
▸ Back

Minibus Network

Data



Model



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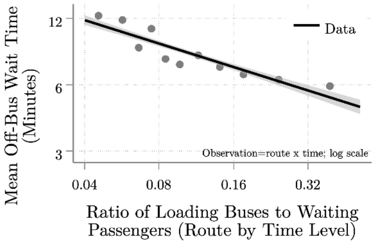
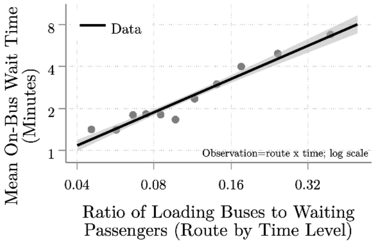
Opposing Matching Externalities

Boarding



Filling



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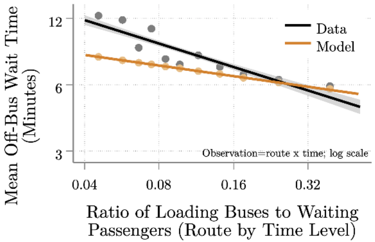
Opposing Matching Externalities

Boarding



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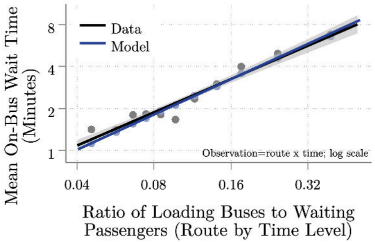

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