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Urban transportation in emerging cities

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Congestion, mobility, and accessibility in emerging cities

The current state of the debate:

- Very little academic interest outside of congestion
- A traditional policy focus on mobility that ignores accessibility
- A new academic focus on accessibility that often negates mobility

This is clearly undesirable

Accessibility, mobility, and congestion in emerging cities

What I want to do:

- Rekindle interest in urban transportation in emerging cities
- Propose an integrated framework to think about accessibility, mobility, and congestion consistently
- Show that we can make progress by combing simple economics with novel sources of data

Roadmap

- The importance of urban transportation in emerging cities and the transportation wedge
- Redefining the mobility vs. accessibility debate
- Mobility and accessibility in Indian cities
- A focus on congestion

Urban transportation matters

The benefits from cities and urbanization

- Cities make workers and firms more productive
- Cities allow residents to consume a greater variety of goods at a lower price
- Cities allow residents to enjoy urban amenities

But for this, city residents need to be able to “go places”

Urban transportation matters

Extremely large investments are involved

- Transportation represents more than 20% of World Bank commitments
- A kilometer of subway costs at least 100 m$
- Roadway expansion plans may involve the conversion of 5 to 10% of urban land

Urban transportation matters

Urban households allocate considerable monetary resources to be able to move around

- US households devote 17.5% of their expenditure to transportation
- French households devote 13.5% of their expenditure to transportation
- Colombian households spend 9% of their income on transportation

Urban transportation matters

Urban households allocate considerable time resources to be able to move around

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Urban transportation matters

In a typical US metropolitan area:

- A traveler takes 4.2 trips per day
- Each trip is on average 12.8 kilometers long and takes 17.5 minutes
- Reported travel speed is 38.5 km/h and overwhelmingly by car

In Bogota, Colombia:

- A traveler takes 2.7 trips per day
- Each trip is on average 10.9 kilometers long and takes 38.2 minutes
- Reported travel speed is 17.1 km/h and car and taxi are only about a quarter of all trips

Mobility

- Historically, urban transportation has been managed by transportation planners
- Mobility has been their key concern
- Mobility is essentially the speed at which one can travel from O to D
- Mobility is ‘easily’ measurable
- To accommodate a growing demand, increasing capacity is usually the answer

Accessibility

- When traveling from O to D, the relevant measure is not speed but the total cost of reaching a destination (time, monetary, and other)
- Accessibility is essentially the ease of reaching a destination
- Accessibility is hard to measure, be it because the choice of a destination is endogenous
- "Accessibility" is usually managed by land-use planners with little consideration of mobility, sometimes in opposition to mobility

Accessibility and mobility

For a given trip:

- Start with a simple relationship:

$$\text{total cost} = \text{distance} \times \text{cost per unit of distance}$$

- To simplify, we only consider the time element:

$$\text{duration} = \text{distance} \ / \ \text{speed} \qquad \text{or:}$$

$$-\log \text{duration} = -\log \text{distance} + \log \text{speed} \qquad \text{or:}$$

$$\text{time accessibility} = \text{distance accessibility} + \text{mobility}$$

- In turn, we can decompose mobility:

time accessibility = distance accessibility
+ free mobility
+ congestion factor

Measuring accessibility and mobility in cities

This is a real data challenge

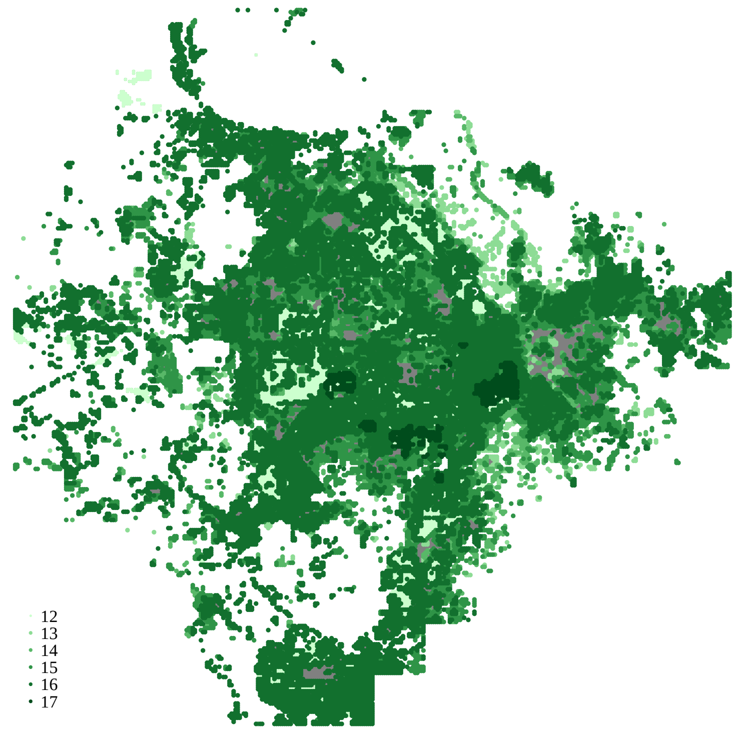
- Ideally, we need a very large, precise, sample of trips taken by travelers everywhere
- Transportation surveys are scarce and sparse (and often lack key elements and their reliability is questionable)
- Road censors are also problematic: we need to know about trips
- Recent alternative: "counterfactual" trips using mapping/navigagtion websites/apps
- Key limitation: these are not real trips and thus may not be representative of actual travel

Measuring accessibility and mobility in cities

- Use Google Maps in 154 large Indian cities
- Delineate these cities using light nights (DN>34)
- Four trip design strategies:
  - Radial trips
  - Circumferential trips
  - Gravity trips
  - Trips to “remarkable places”
- These strategies aim to mimic actual trips in key dimensions (length, destinations, etc) or some idealized travel behavior
- Data collection to be extended to many more cities in the world

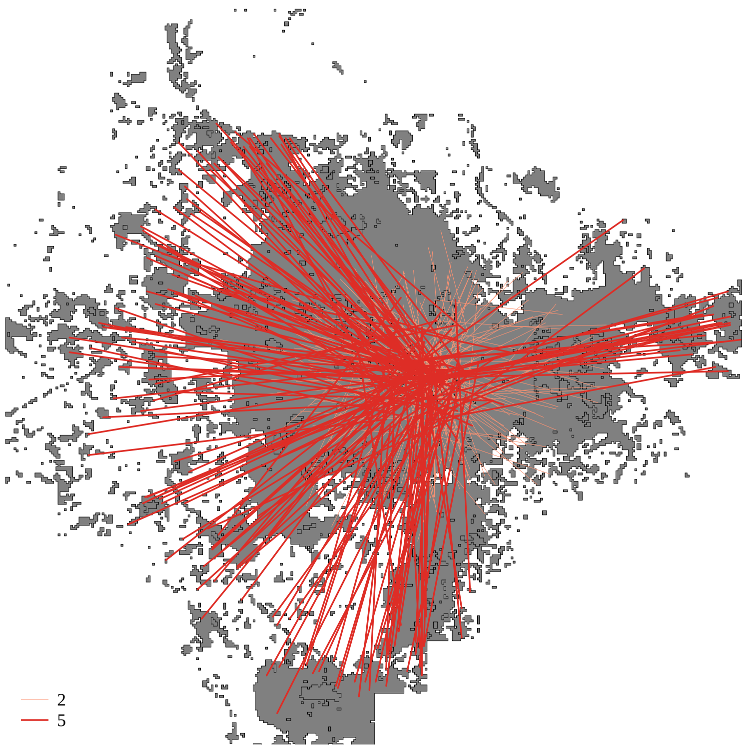
Illustration, Jamnagar in Gujarat

Google Maps representation

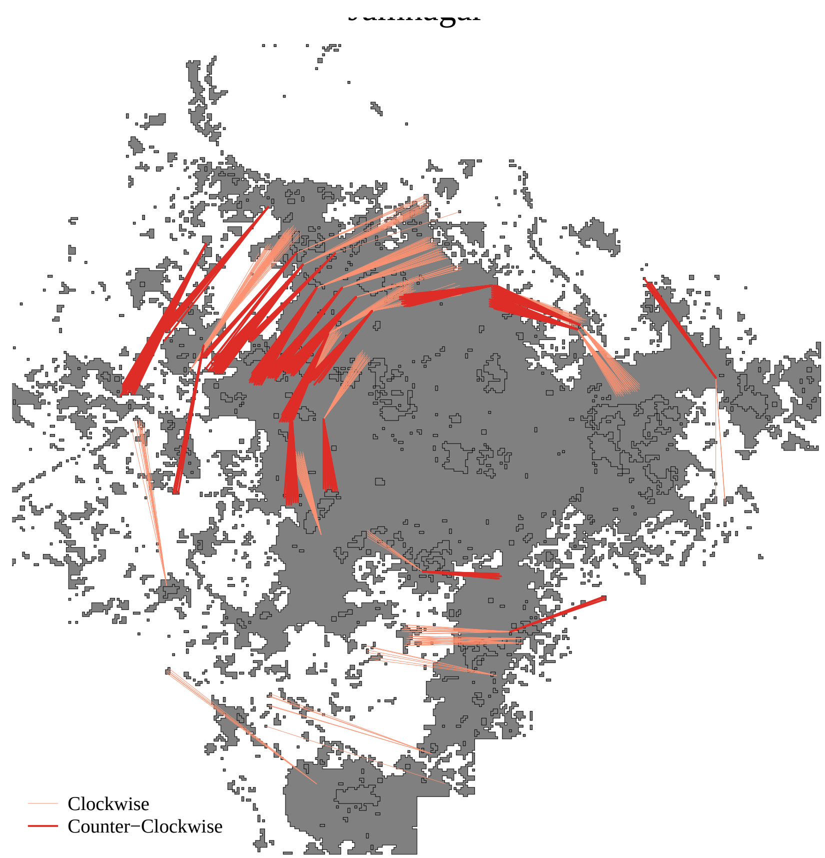


Lighted built-up areas

Illustration, Jamnagar in Gujarat

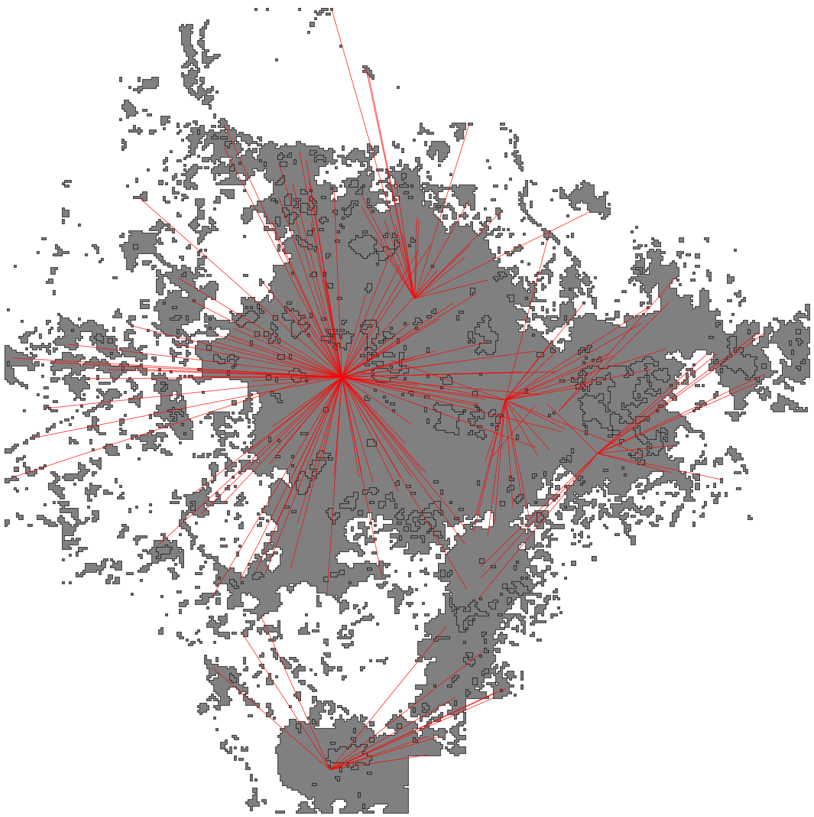


Radial trips

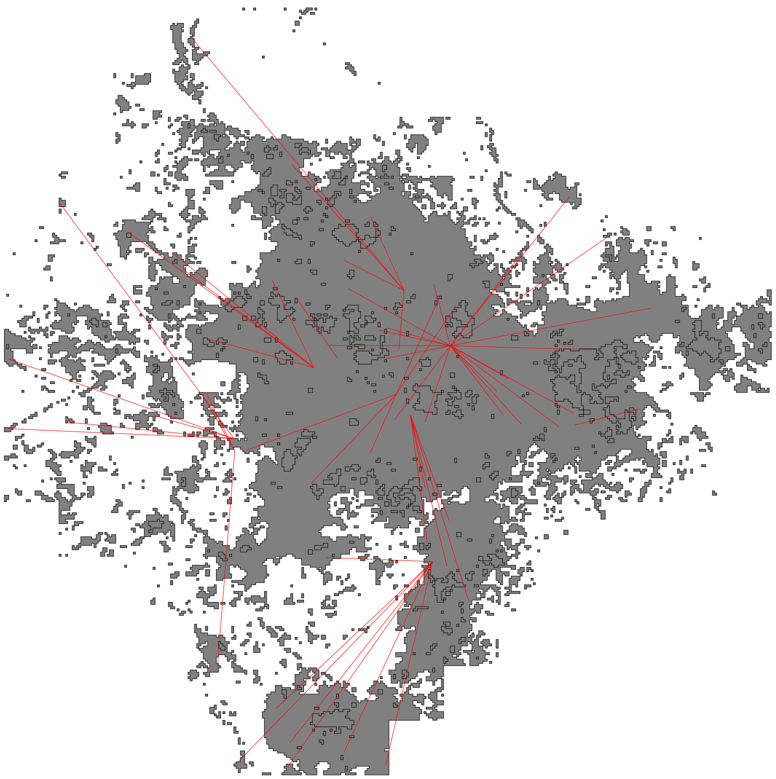


Circumferential trips

Illustration, Jamnagar in Gujarat



Trips to the mall



Trips to the hospital

Trip sampling

- We defined about $15\sqrt{\text{population}}$ trips per city
- Each trip was sampled about 10 times in the Fall of 2016
- In total: about 22 million observations
- For each trip we know: duration, duration in absence of traffic, length, effective length, origin, destination, city, day, time of day

Some descriptive statistics: trips

			percentile:						
	Mean	St. dev.	1	10	25	50	75	90	99
Speed	22.1	7.2	11.5	14.7	17.1	20.6	25.5	31.6	45.8
Duration	19.9	17.6	4	7	9	14	23	40	93
Duration (no traffic)	17.2	14.0	4	6	9	13	20	33	93
Trip length	8.2	10.0	1.3	1.9	2.9	4.7	8.9	17.9	53.9
Effective distance	5.4	7.0	1.0	1.2	1.8	2.9	5.5	12.0	39.6

Some descriptive statistics: cities

	Mean	St. dev.	Min.	Max.
Population ('000), 2011	1,319	3,023	18	23,888
Metropolitan population ('000), 2015	1,538	3,169	307	25,703
Population growth 1990-2015 (%)	105	65	31	399
Total area (km^2)	236	413	5.91	3568
Total road length (km)	1,384	3,442	10	32,513
Motorways (km)	43.6	64.4	0	437
Primary roads	43.9	77.1	0	481
Share households with car access (%)	9.99	5.76	2.33	31.5
Share households with motorcycle access (%)	41.3	11.7	5.83	73.4
Mean daily earnings ($)	4.91	1.93	2.00	12.28

Some descriptive statistics: trips in cities

	Mean	St. dev.	Min.	Max.
All trips	24.4	3.82	16.2	34.9
Radial trips	22.2	3.83	14.8	32.8
Circumferential trips	20.6	3.24	14.3	29.5
Gravity trips	22.6	3.43	14.7	30.9
Trip to remarkable places	27.0	6.10	16.6	42.0
All trips, unweighted by distance	21.8	2.96	15.7	31.4
All trips in absence of traffic	26.8	4.51	16.3	38.1
All trip, effective speed	16.4	2.77	11.60	24.0

Estimating accessibility and mobility in cities

- We estimate the following regressions:

$$\log Y_i = \alpha X_i' + FE_{c(i)} + \epsilon_i$$

- For Y, we use:
  - Trip duration ($\times -1$) for time-accessibility
  - Trip length ($\times -1$) for distance-accessibility
  - Trip speed for mobility
  - Trip speed in absence of traffic for free mobility
  - Trip speed in absence of traffic / trip speed for the congestion factor
- In X we include: time of day, day of week, weather, type of destination (for accessibility), distance to center, and trip length and trip type (for mobility)

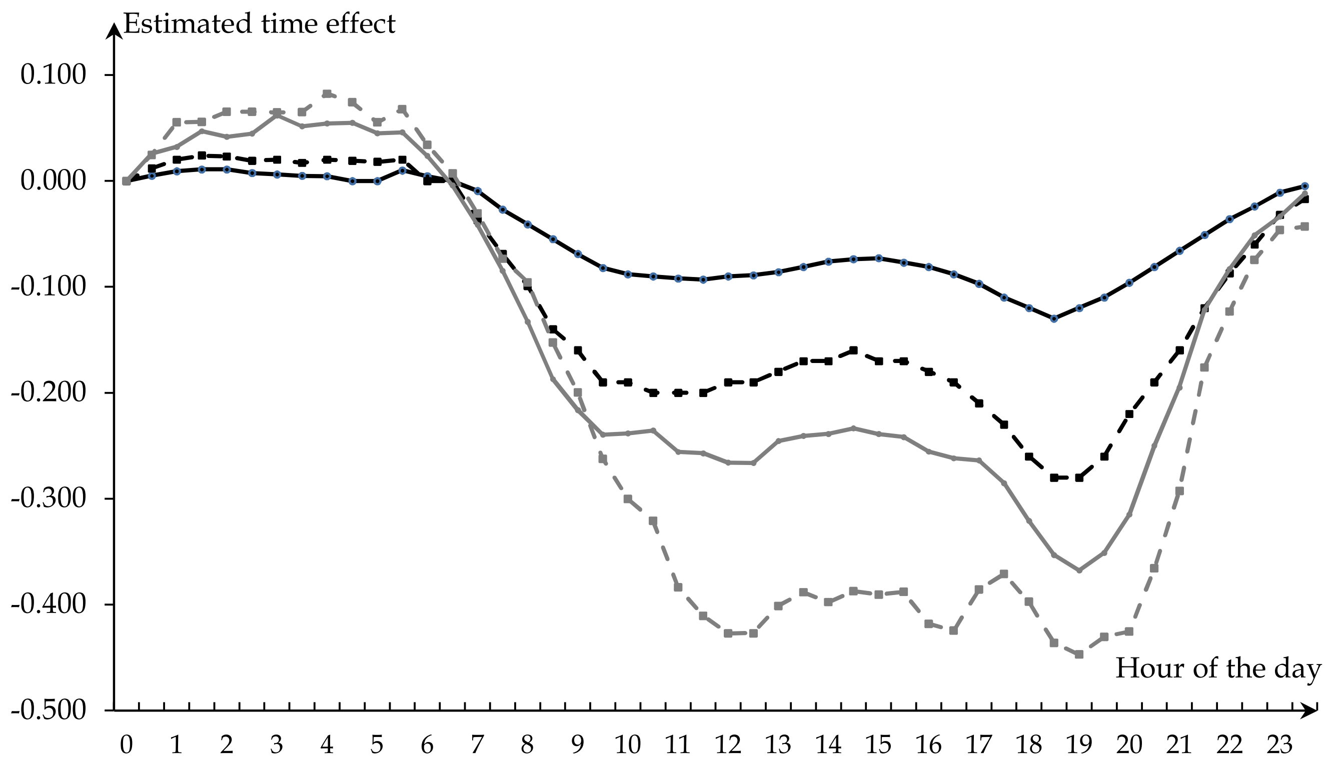
Estimating accessibility and mobility in cities

- Obviously many variants are possible depending on:
  - What is included among the controls
  - Which sample of trips is considered (weekend or not, specific hours of the day, etc)
- We can allow coefficients to vary across cities and estimate Laspeyres and Paasche type indices
- We can weight slower trips more
- For congestion we can use alternative measures, etc

Mobility in cities: some results

- Longer trips and trips further away from the center are faster
- Minimal differences between different types of trips
- Mild evidence of positive effects of bad weather
- Interesting time of day patterns

Time of day effects



Mobility in cities: some results

- Standard deviation of city fixed effects: 0.11
- The fastest city is twice as fast as the slowest
- These differences are much larger than among US metropolitan areas

Who's slow?

Rank	City	State	Index
1	Kolkata	West Bengal	-0.33
2	Bangalore	Karnataka	-0.25
3	Hyderabad	Andhra Pradesh	-0.25
4	Mumbai	Maharashtra	-0.24
5	Varanasi (Benares)	Uttar Pradesh	-0.24
6	Patna	Bihar	-0.23
7	Bhagalpur	Bihar	-0.22
8	Delhi	Delhi	-0.22
9	Bihar Sharif	Bihar	-0.19
10	Chennai	Tamil Nadu	-0.18
11	Muzaffarpur	Bihar	-0.16
12	Aligarh	Uttar Pradesh	-0.15
13	English Bazar (Malda)	West Bengal	-0.15
14	Darbhanga	Bihar	-0.15
15	Gaya	Bihar	-0.14
16	Allahabad	Uttar Pradesh	-0.13
17	Ranchi	Jharkhand	-0.13
18	Dhanbad	Jharkhand	-0.12
19	Akola	Maharashtra	-0.12
20	Pune	Maharashtra	-0.12

Who’s fast?

Rank	City	Index	
1	Ranipet	Tamil Nadu	0.35
2	Bokaro Steel City	Jharkhand	0.28
3	Srinagar	Jammu and Kashmir	0.26
4	Kayamkulam	Kerala	0.23
5	Jammu	Jammu and Kashmir	0.23
6	Thrissur	Kerala	0.19
7	Palakkad	Kerala	0.16
8	Chandigarh	Chandigarh	0.16
9	Alwar	Rajasthan	0.15
10	Thoothukkudi	Tamil Nadu	0.15

Mobility in cities: how robust

- Results are highly robust to the exact estimation procedure, hours of the days being considered, and type of trips
- Exception: the correlations between our preferred index and measures of mean speed are lower because means do not condition out trip length
- Laspeyres-type indices are more fragile because they require wild out of sample predictions

Accessibility in cities: some results

For distance accessibility

- Standard deviation of city fixed effects: 0.20 to 0.29
- The distance ratio between the extremes is 2.7 to 4.0

For time accessibility

- Standard deviation of city fixed effects: 0.14 to 0.22
- The distance ratio between the extremes is 2.2 to 2.6

Who's least time accessible?

Rank	City	State	Index
1	Kolkata	West Bengal	-0.56
2	Mumbai	Maharashtra	-0.45
3	Delhi	Delhi	-0.45
4	Bokaro Steel City	Jharkhand	-0.42
5	Asansol	West Bengal	-0.41
6	Hyderabad	Andhra Pradesh	-0.40
7	Dehradun	Uttaranchal	-0.39
8	Mathura	Uttar Pradesh	-0.36
9	Dhanbad	Jharkhand	-0.36
10	Guntur	Andhra Pradesh	-0.36
11	Chandrapur	Maharashtra	-0.35
12	Vijayawada	Andhra Pradesh	-0.35
13	Bangalore	Karnataka	-0.33
14	Aligarh	Uttar Pradesh	-0.32
15	Begusarai	Bihar	-0.32
16	Chennai	Tamil Nadu	-0.31
17	Bhagalpur	Bihar	-0.30
18	Allahabad	Uttar Pradesh	-0.29
19	Jalandhar	Punjab	-0.27
20	Gulbarga	Karnataka	-0.26

Who's most time accessible?

Rank	City	State	Index
1	Anantapur	Andhra Pradesh	0.40
2	Anand	Gujarat	0.39
3	Kannur	Kerala	0.39
4	Latur	Maharashtra	0.39
5	Hubli-Dharwad	Karnataka	0.37
6	Brahmapur	Orissa	0.37
7	Nizamabad	Andhra Pradesh	0.36
8	Davangere	Karnataka	0.35
9	Palakkad	Kerala	0.35
10	Bhilwara	Rajasthan	0.34

Decomposing mobility

We can decompose mobility into free mobility and a congestion factor

- Free mobility and the congestion factor factor fully explain mobility by construction
- Free mobility explains 70% of the variance of mobility
- The congestion factor explains 15% (and this is broader than just too many vehicles travelling)
- Cities that are intrinsically faster are also more congested
- The congestion factor has more explanatory power during peak hours and in large cities
- Still poor mobility appears to be driven by intrinsic poor mobility rather than overcrowded roads for the most part

Decomposing time accessibility

We can also decompose time-accessibility into distance accessibility and mobility

- Distance accessibility and mobility explain most of time accessibility in practice
- Mobility explains 21% of the variance of time accessibility
- Distance accessibility explains 81% (and this is broader than just too many vehicles travelling)
- Distance accessibility are essentially uncorrelated

Explaining accessibility and mobility

We now try to explain free mobility, the congestion factor, distance accessibility, and time accessibility with a range of city level characteristics

- Population worsens free mobility and congestion and improves distance accessibility. The resulting effect on time accessibility is small
- Area improves free mobility, has little effect on congestion, and worsens distance accessibility. The resulting effect on time accessibility negative

Explaining accessibility and mobility

- Primary roads improve free mobility, do little to the congestion factor, improve distance accessibility. The resulting effect on time accessibility is large
- The explanatory power of roads is small
- Vehicles are strongly positively associated with free mobility, have a large negative effect on congestion, and are positively associated with distance accessibility. The overall association with time accessibility is positive

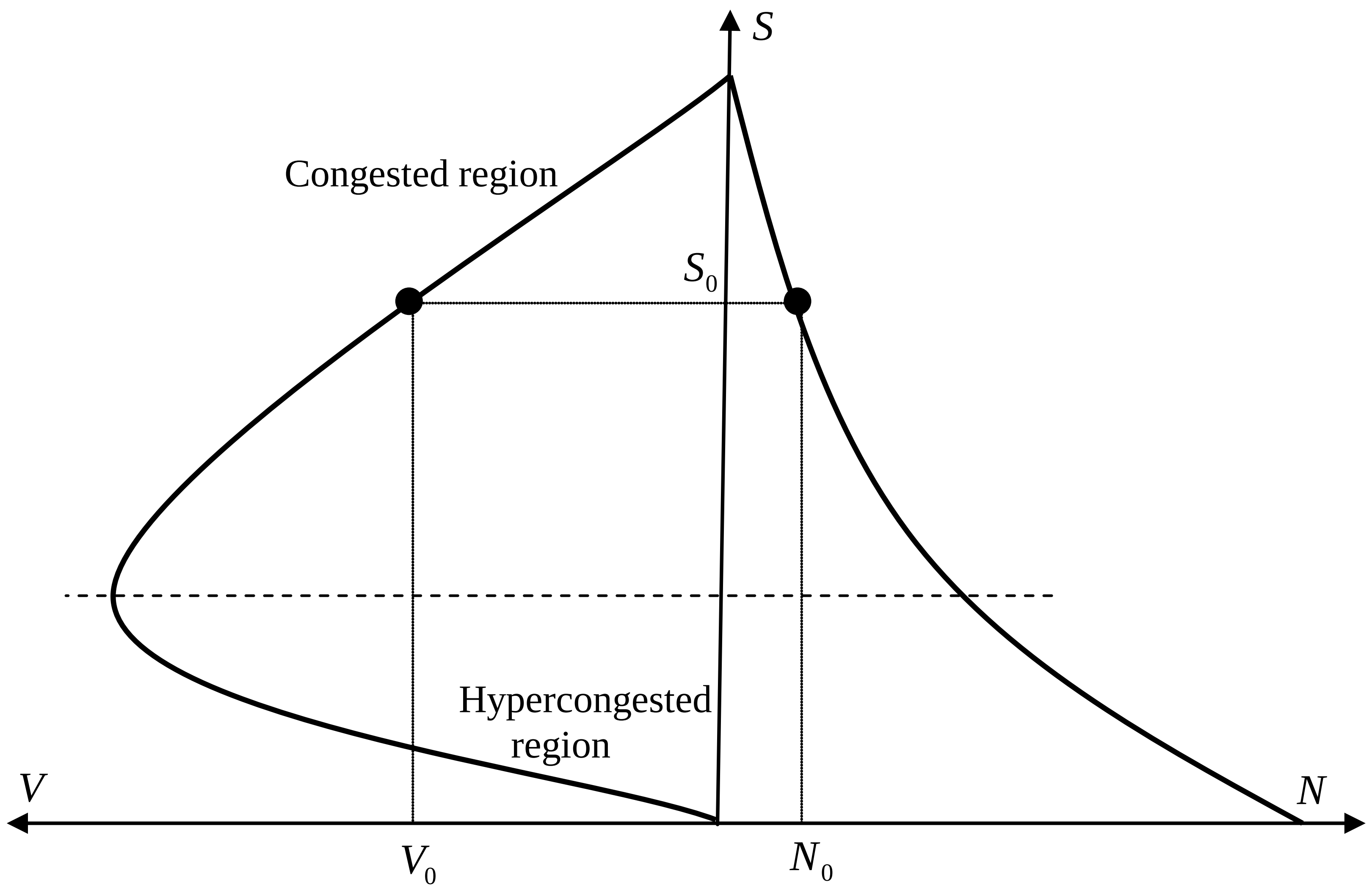
Some more speculative conclusions

- There is tremendous heterogeneity in mobility and accessibility across India
- Congestion matters but maybe not as much as we think
- There is general mobility problem in Indian cities
- More roadway allows people to go places but it has only a small effect on mobility
- The organisation and the management of the roadway is perhaps more important than its sheer quantity
- The roadway in Indian cities appears to serve many purposes beyond motorized travel. Specializing the roadway for motorized travel entails both costs and benefits

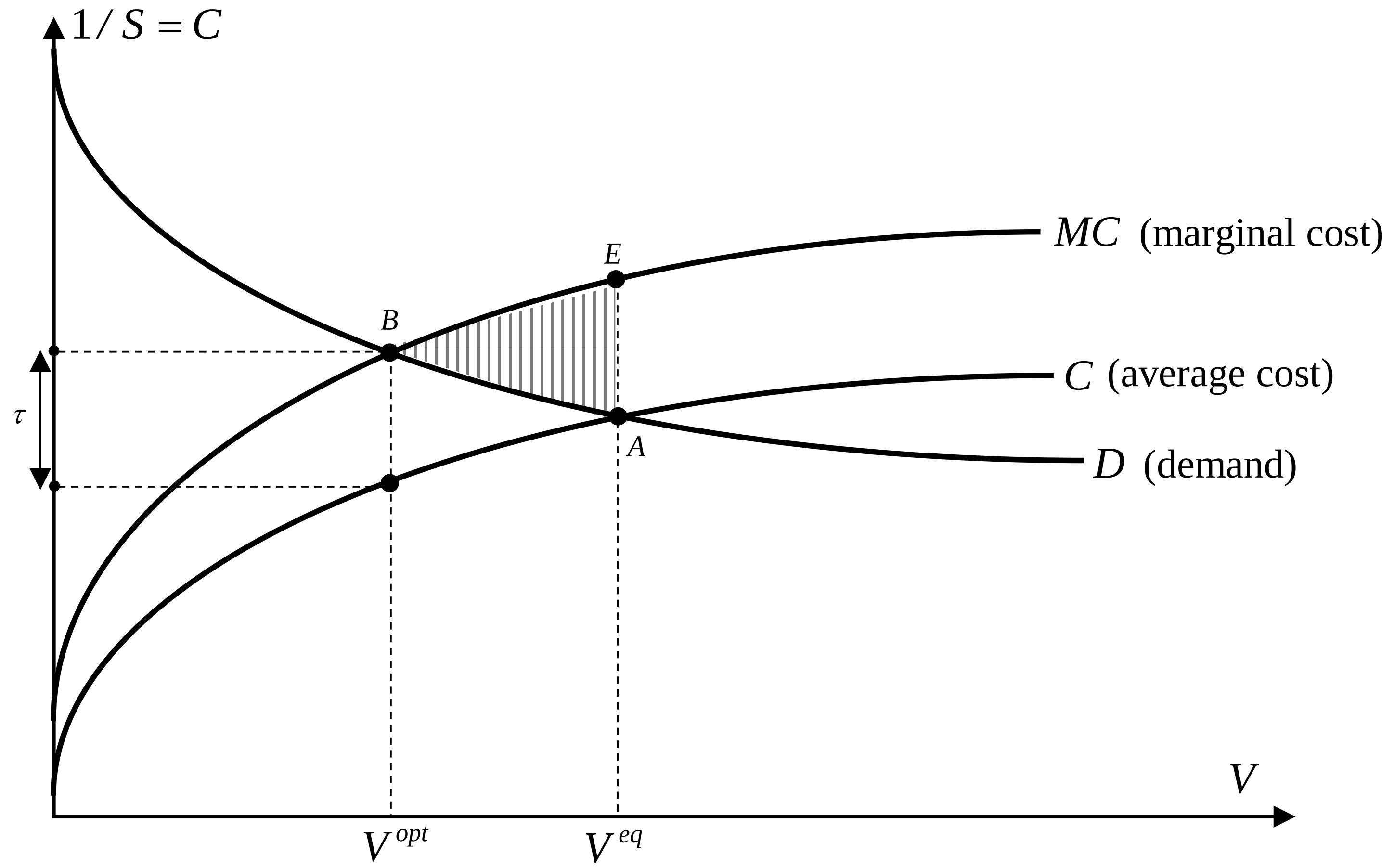
More on congestion

- Because of data limitations, congestion is anything that slows down traffic relative to free mobility
- We know what congestion does to mobility but cannot provide a measure of its welfare costs
- For this we need more data

The fundamental diagram of traffic congestion



The supply and demand of travel (ignoring hypercongestion)



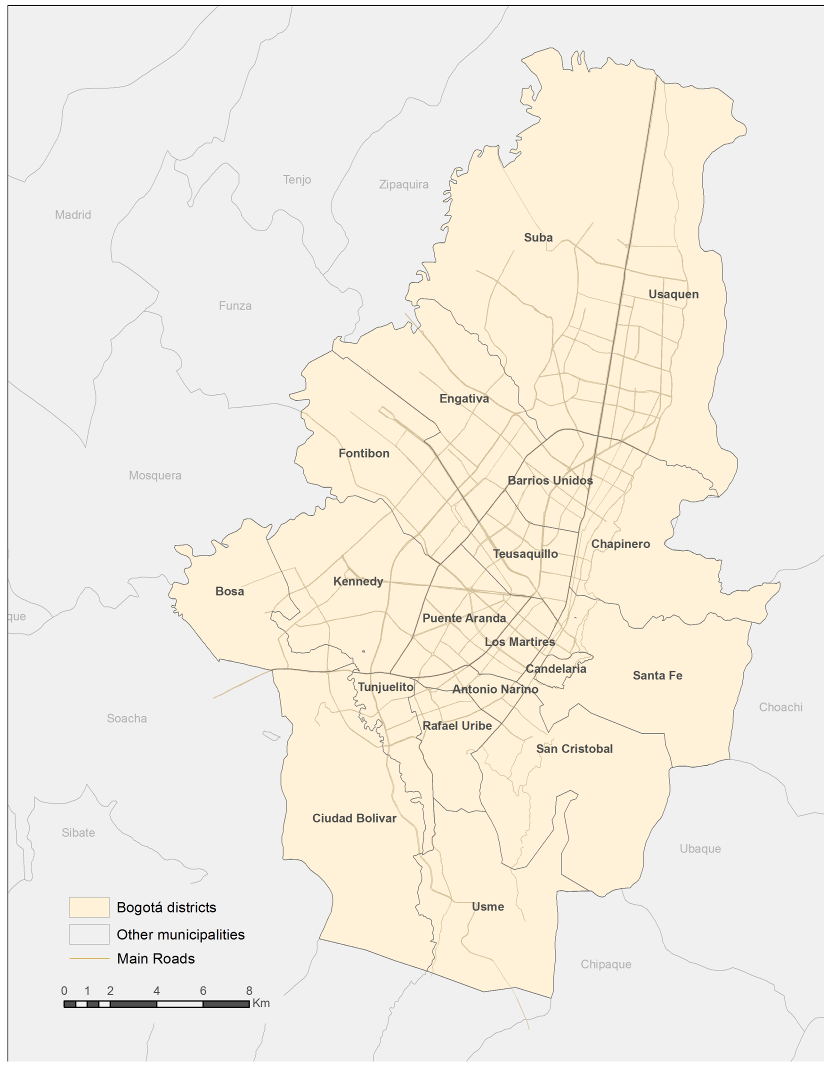
The social of congestion

- To compute the deadweight loss of congestion
  - We need to know about supply (cost)
  - We need to know about demand
  - We need to know about the distortion
- The distortion is easy: travelers pay the average cost of travel, not the marginal cost
- For demand, we know about travel conditions when travelers choose to travel and when they choose not to
- This requires both actual and counterfactual travel data: the Bogota transportation survey and Google Maps

Colombia


Providencia
San Andrés
Caribbean Sea
Barranquilla
Santa Marta
Riohacha
Cartagena
Valledupar
Sincelejo
Panama
Montería
Cúcuta
Venezuela
Turbo
Bucaramanga
Quibdó
Medellín
Yopal
Manizales
Pereira
Pacific Ocean
Ibagué
Bogotá
Armenia
Buenaventura
Villavicencio
Palmira
Cali
Neiva
Popayán
Colombia
Tumaco
Florencia
Pasto
Ecuador
Brazil
Population
100,000 - 200,000
200,001 - 500,000
500,001 - 1,000,000
1,000,001 and above
Peru
0 50 100 200 300 400
Km

Bogotá


Tenjo
Zipaquira
Madrid
Funza
Mosquera
Soacha
Sibate
Choachi
Ubaque
Chipaque
Suba
Usaquen
Engativa
Fontibon
Barrios Unidos
Teusaquillo
Chapinero
Kennedy
Bosa
Puente Aranda
Los Martires
Candelaria
Santa Fe
Tunjuelito
Antonio Narino
Rafael Uribe
San Cristobal
Ciudad Bolivar
Usme
Bogotá districts
Other municipalities
Main Roads
0 1 2 4 6 8
Km

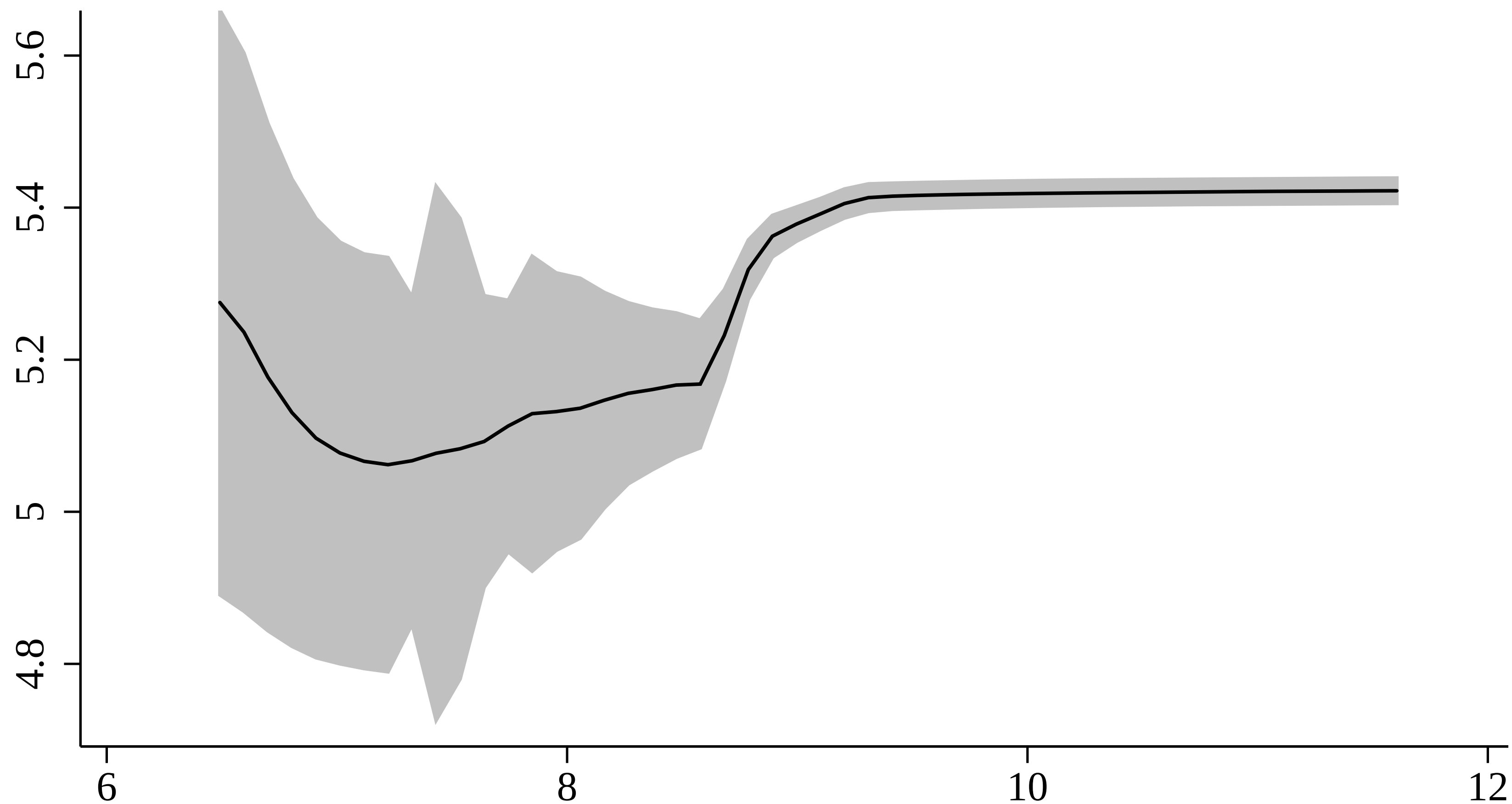
The Bogota transportation survey

- Travel diary from 2011 (similar to US NHTS or the French Enquête Transport)
- 16,157 households representing about 100,000 trips, 65,000 unique OD pairs
- Reports origin, destination, time of departure, time of arrival, purpose, mode, etc
- Day of the week trips

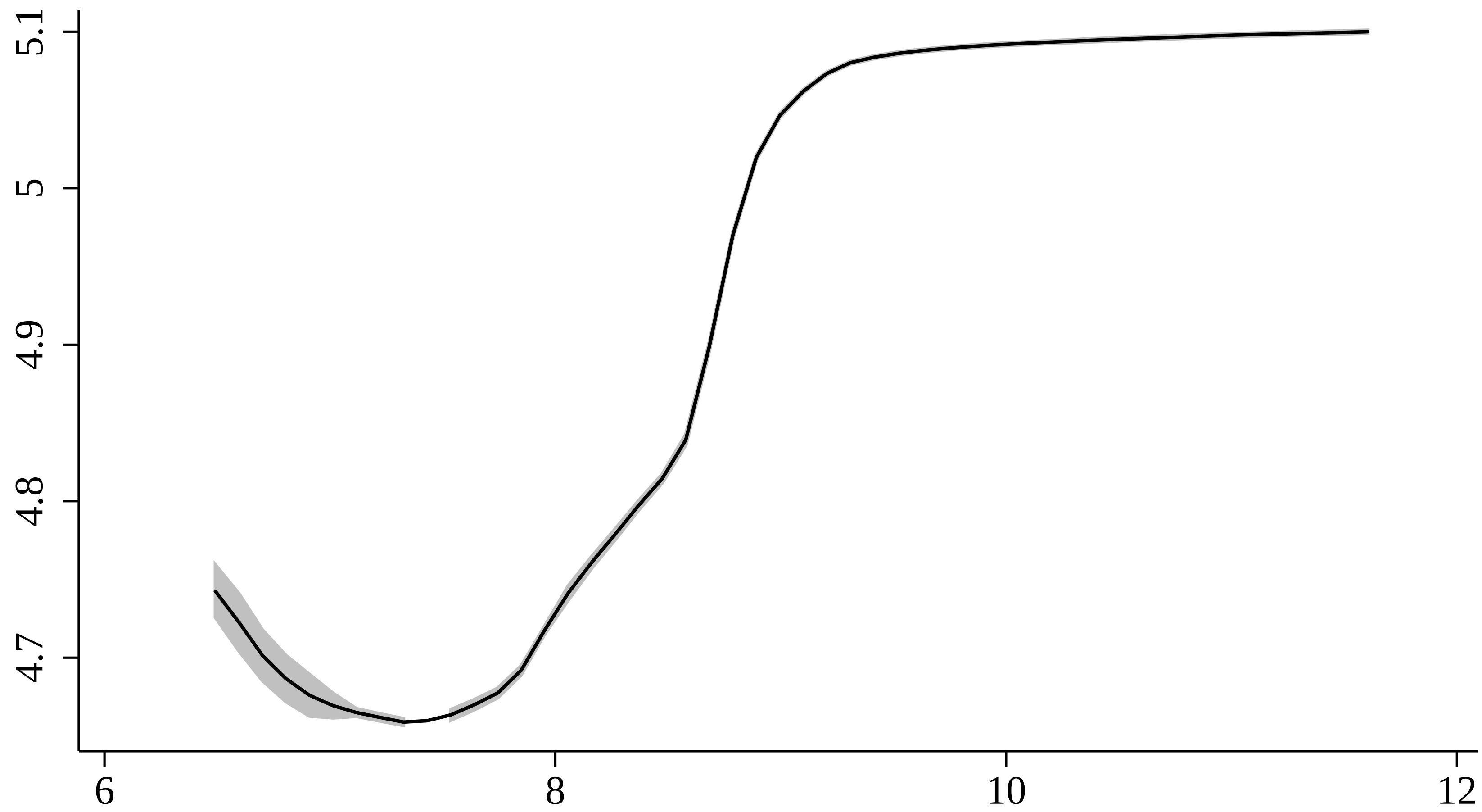
Estimating travel supply

- Regress the time cost of travel on the number of travelers controlling for trip and traveler characteristics
- Worry: simultaneous determination of the time cost of travel and number of travelers
- Shocks lead travelers to stay home, get stuck, take an alternative mode of transport, or re-route their trip
- Some of these shocks like the weather are observable
- To avoid biases from re-routing, we need to consider entire areas
- Use counterfactual travel times and number of travelers instead of actual ones

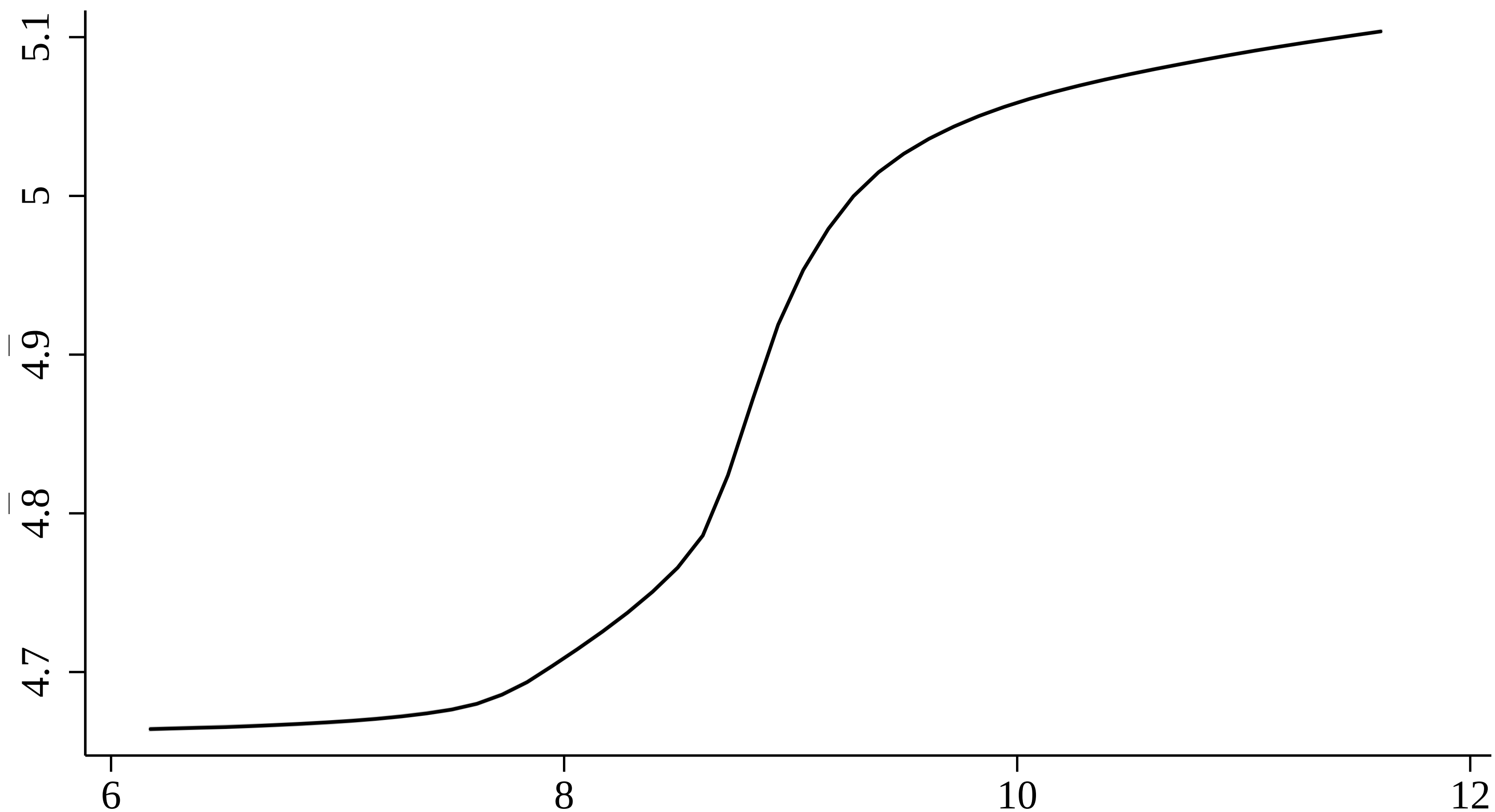
Actual times cost on all trips



Counterfactual time costs on all trips at stated times



Counterfactual time costs on all trips at all times



Estimating travel supply

- Our preferred estimate indicates an elasticity of the time cost of travel with respect to the number of travelers of 0.06 on average and 0.20 at the steepest
- This is a small number
- The existence of local streets puts a ceiling on the time cost of travel

Estimating travel demand

- We want to estimate the propensity to travel on a trip given the time cost of that trip
- We want to account for the fact that demand is stronger at certain hours of the day
- In practice we regress whether a traveler travels on a trip as a function of the time cost of travel for that trip, trip and traveler characteristics
- This yields an individual demand for travel time that we can aggregate and transform into an aggregate demand for kilometers traveled
- The main worry is that individual travel demand will be correlated with aggregate travel demand
- We can reduce the problem by imposing specific intercepts by

time of the day and sub-areas

- If we underestimate the elasticity of travel demand, we can obtain an upper bound by assuming a flat demand curve

Estimating travel demand

- We estimate a demand elasticity of about -1.2 to -1.8
- The elasticity varies during the day but not sensitive to the exact estimation used

Computing the deadweight loss of congestion

- The wedge on the supply side is about 6%
- With the estimated demand elasticity, the amount of excess driving is of the same magnitude or smaller
- That means a loss 'triangle' of about 0.2% or less - this is negligible
- Even with a supply wedge of 30% and a demand elasticity of 20, the loss is still only about 12% of travel time
- The problem is again a lack of capacity and slow traffic more than congestion narrowly defined

The road forward

- transit
- more big data
- streets and networks
- traffic management policies
- environmental issues
- self driving vehicles