The Fast, the Slow, and the Congested: Urban Transportation in Rich and Poor Countries

Prottoy A. Akbar, Victor Couture, Gilles Duranton, Adam Storeygard

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Introduction: What we do

- Simulate 600 million Google Maps trips to produce travel speed indices for 1,358 cities.
- Document how urban travel speed rises with economic development.
- Develop a model to decompose the contribution of different city attributes in accounting for why richer countries are faster.

Introduction: What we find

- Urban travel is much faster in richer countries. SpeedGDP
  - Urban travel in the US is twice as fast as in Bangladesh.
  - Most speed variation is across countries, not within-country.
  - Country GDP per cap. explains more than 60% of cross-country speed variation.
- Decomposition to study why richer countries are faster:
  - Major impact: roads. Minor impact: land area
  - Effects through uncongested speed, not congestion. UncongestedGDP CongestionGDP

Introduction: Why this matters

- Cities exist to let people interact. Slow mobility limits those interactions.
- Urban transportation is a policy concern in every large city.
- Existing urban transportation data are extremely limited, especially in poor countries.

Creating an urban transportation database comparable across countries

1. We define city boundaries consistently worldwide.
2. We create trip samples within these cities using an app (Google Maps) available worldwide.
3. We use a price index methodology to ensure comparable baskets of trips in each city.
4. We create a dataset of city attributes from sources available worldwide (e.g, OSM).

Creating database: Delineating Cities

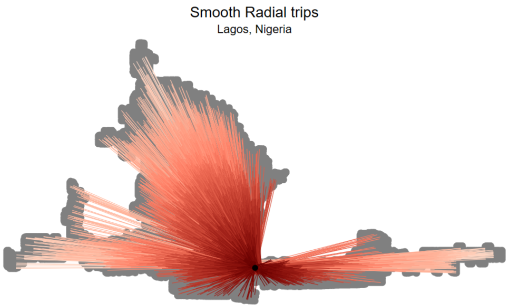
- City *points*: All 1,860 cities with projected 2018 population over 300,000 from UN World Urbanization Prospects
- City *boundaries*: Defined using GHS-SMOD 1-km layer circa 2015
  - Start with areas within 500m radius of 'built' (38m X 38m) pixels.
  - Merge secondary centers, separate attached primary centers, drop major mismatches etc. 1,795 cities remain.
- Drop countries without Google Maps (China, South Korea). 1,358 cities remain.

Creating database: Designing trips

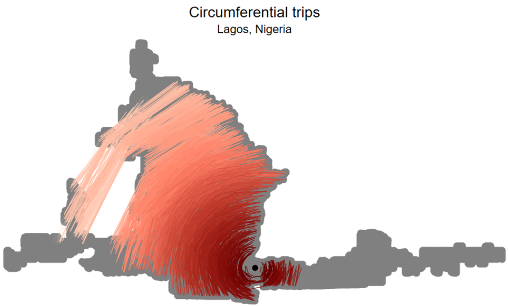
To obtain representative trips, we:

- Design trips that resemble actual trips.
- Use different design strategies and verify they lead to similar results.

Creating database: Illustration, trips for Lagos, Nigeria

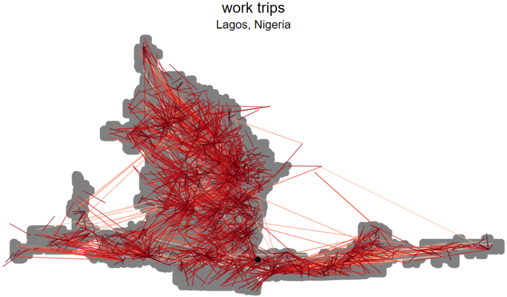


Radial trips

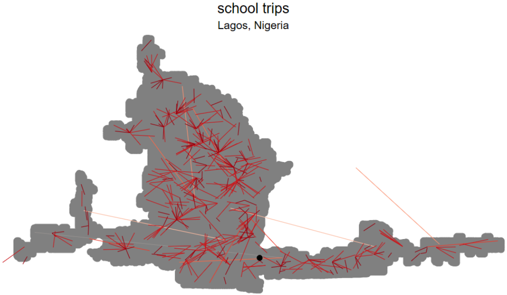


Circumferential trips

Creating database: Illustration, trips for Lagos, Nigeria



Trips to ‘work’



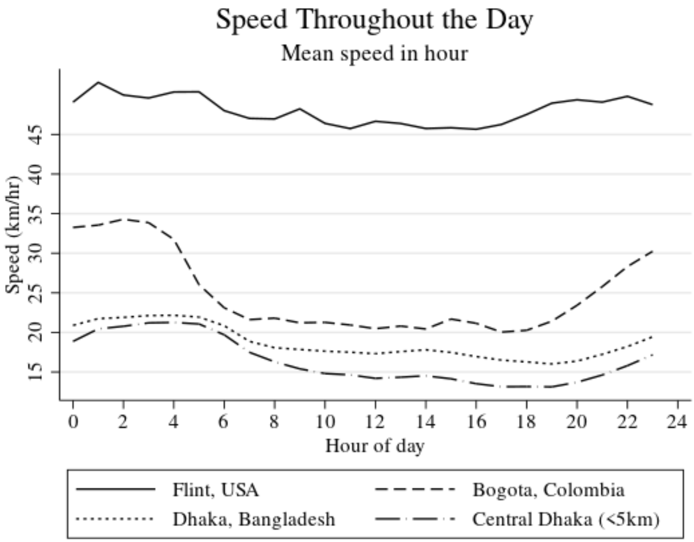
Trips to school

Combination of nearest and most popular according to Google

Creating database: Sampling trips

- About 20M trips in total and about 30 instances of each trip
  - at random times following a time/day distribution inspired by various travel surveys
- Simulated on Google Maps (website, GM)
  - 'real time traffic' motor vehicle trip instances
  - between June and November 2019
- For each trip instance and recommended GM route, we collect:
  - trip duration and length ($\Rightarrow$ speed)
  - duration in hypothetical state of no traffic ($\Rightarrow$ uncongested speed)
- For each trip, we collect the recommended route of one instance.

Creating database: Illustration, the Fast, the Slow, and the Congested



Limited to trips of length 5-10km.

Creating database: Assessing Google Maps' data quality

Context:

- GM is the most popular mapping/navigation app in the world.
- Relies on GPS pings from Android cellphones and other GM users.

  2.5 billion Android smartphones in May 2019.
- Worry: Poor cities may have fewer smartphones or receive less attention from Google.
  - We perform extensive quality checks to validate and clean our data.

Creating database: Computing a speed index in each city

- Objective: Produce speed indices that are comparable across world cities.
- Problem: Determinants of trip speed vary systematically across cities, e.g. trip distance, distance to the center, etc
- Solution (Couture et al., 2018, Akbar et al., 2021): Price index methodology
  - Each trip is a 'good'.
  - Speed is the (inverse) price of a trip in units of time.
  - Use a comparable basket of trips in each city.

Creating database: Computing a speed index in each city

Simple approach to go from trips i to a speed index for each city c:

$$speed\_outcome_i = \alpha X_i + speed\_index_{c(i)} + \epsilon_i \tag{1}$$

- We use three outcomes to estimate three indices:
  1. *log (real-time) speed* ⇒ speed index S_c
  2. *log uncongested speed* ⇒ uncongested speed index U_c
  3. *(log uncongested speed - log speed)* ⇒ congestion index K_c

- X: *trip distance*, distance to center, trip type, time of day, day of week, weather

- Property of OLS: $\hat{S}_c = \hat{U}_c - \hat{K}_c$

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Creating database: Fastest and slowest cities

	Fastest			Slowest		
Rank	City	Country	Index	City	Country	Index
1	Flint	United States	.47	Dhaka	Bangladesh	-.64
2	Greensboro	United States	.43	Lagos	Nigeria	-.58
3	Little Rock	United States	.43	Manila	Philippines	-.53
4	Wichita	United States	.42	Ikorodu	Nigeria	-.53
5	Huntsville	United States	.41	Kolkata	India	-.51
6	Lancaster-Palmdale	United States	.41	Bhiwandi	India	-.51
7	Victorville	United States	.40	Mumbai	India	-.45
8	Ogden	United States	.40	Phnom Penh	Cambodia	-.44
9	Lansing	United States	.40	Chittagong	Bangladesh	-.44
10	Knoxville	United States	.38	Bangalore	India	-.43
11	Visalia	United States	.38	Dar es Salaam	Tanzania	-.43
12	Khamis Mushayt	Saudi Arabia	.38	Kumasi	Ghana	-.43
13	Tulsa	United States	.38	Jakarta	Indonesia	-.43
14	Shreveport	United States	.37	Aba	Nigeria	-.42
15	Winston-Salem	United States	.37	Bihar Sharif	India	-.42
16	Port St. Lucie	United States	.37	Bacoor	Philippines	-.42
17	Youngstown	United States	.36	Arrah	India	-.42
18	Toledo	United States	.36	Mymensingh	Bangladesh	-.41
19	Fayetteville-Springdale	United States	.36	Lima	Peru	-.41
20	Rockford	United States	.36	Patna	India	-.41

Creating database: Most and least congested cities

	Most Congested			Least Congested		
Rank	City	Country	Index	City	Country	Index
1	Bogotá	Colombia	.21	Nazret	Ethiopia	-.17
2	Krasnodar	Russia	.19	Gondar	Ethiopia	-.17
3	Moscow	Russia	.18	Dire Dawa	Ethiopia	-.17
4	Bucharest	Romania	.17	Matadi	Congo (DRC)	-.17
5	Ulaanbaatar	Mongolia	.17	Potiskum	Nigeria	-.17
6	Manila	Philippines	.17	Mekele	Ethiopia	-.17
7	Bangkok	Thailand	.17	Birnin Kebbi	Nigeria	-.16
8	Bangalore	India	.17	Tshikapa	Congo (DRC)	-.16
9	Vladivostok	Russia	.15	Chitungwiza	Zimbabwe	-.16
10	Mexico City	Mexico	.15	Pointe-Noire	Congo	-.16
11	London	United Kingdom	.15	Saki	Nigeria	-.16
12	Lagos	Nigeria	.15	Ogbomosho	Nigeria	-.14
13	Mumbai	India	.14	Abakaliki	Nigeria	-.14
14	Yekaterinburg	Russia	.14	Baaqoobah	Iraq	-.13
15	Guatemala City	Guatemala	.14	Gombe	Nigeria	-.13
16	New York	United States	.14	Ondo	Nigeria	-.13
17	Delhi	India	.13	Bouake	Côte d'Ivoire	-.13
18	Sochi	Russia	.13	Nasiriyah	Iraq	-.12
19	Panama City	Panama	.13	Minna	Nigeria	-.12
20	Nairobi	Kenya	.13	Kasur	Pakistan	-.11

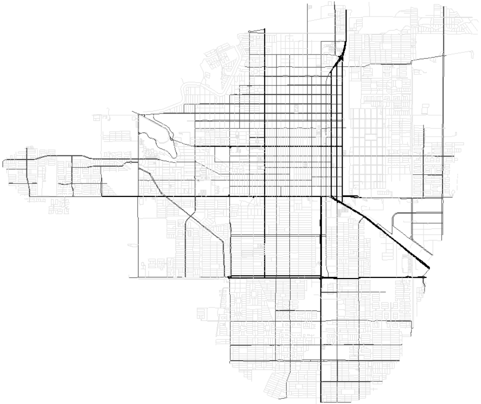
Creating database: Cities with fastest and slowest uncongested speed

	Fastest Uncongestd Speed			Slowest Uncongested Speed		
Rank	City	Country	Index	City	Country	Index
1	Flint	United States	.42	Ikorodu	Nigeria	-.53
2	Little Rock	United States	.39	Dhaka	Bangladesh	-.53
3	Greensboro	United States	.39	Aba	Nigeria	-.49
4	Victorville	United States	.38	Khulna	Bangladesh	-.44
5	Wichita	United States	.37	Lagos	Nigeria	-.43
6	Knoxville	United States	.36	Kolkata	India	-.43
7	Lancaster-Palmdale	United States	.36	Bhiwandi	India	-.41
8	Huntsville	United States	.36	Port-au-Prince	Haiti	-.41
9	Ogden	United States	.36	Bihar Sharif	India	-.41
10	Visalia	United States	.36	Mymensingh	Bangladesh	-.40
11	Tulsa	United States	.35	La Paz	Bolivia	-.40
12	Lansing	United States	.35	Dar es Salaam	Tanzania	-.39
13	Shreveport	United States	.35	Mombasa	Kenya	-.38
14	Bakersfield	United States	.35	Comilla	Bangladesh	-.38
15	Winston-Salem	United States	.34	Darbhanga	India	-.37
16	Windsor	Canada	.34	Bhagalpur	India	-.37
17	Memphis	United States	.34	Chittagong	Bangladesh	-.37
18	Grand Rapids	United States	.33	Quetta	Pakistan	-.37
19	Stockton	United States	.33	Arrah	India	-.37
20	Chattanooga	United States	.33	Dhanbad	India	-.37

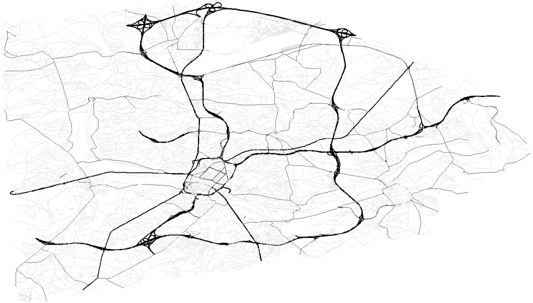
Creating database: Country income and six city attributes

- *Country Income*:
  - Country GDP per capita: *World Bank*, 2017 PPP $Int
- *City Size*:
  - Population: *WorldPop* (Population per 90m X 90m pixel)
  - Area: Our city boundaries
- *Infrastructure*:
  - Major Road Length: *OpenStreetMaps* sum of motorways, primary, secondary, tertiary roads
  - Griddiness: *OpenStreetMaps* share of road conforming to main grid orientation.
- *Topography:*
  - Water body length: *OpenStreetMaps*, sum of lakeshores, coastlines, river centerlines
  - Elevation Variance: *Google Maps API* measured at each intersection.
- Other attributes not shown.

Creating database: OSM Most and Least Griddy City



Panel A: Ciudad Obregon, Mexico



Panel B: Charleroi, Belgium

Mobility and Economic Development: City-level regressions

	Speed all	Speed all
log country GDP (pc)		0.13^{a}
		(0.022)
country FE	Y	N
Observations	1,190	1,190
R^2	0.71	0.44

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- Country FE explains $>$ 70% of speed variation across cities.
- Country GDP explains $\frac{0.44}{0.71}$ =62% of speed variation across countries.

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Model of how income affects urban travel speed

- Elements of the model:
  - Production function for travel and travel demand
  - Taxation to pay for roads
  - Endogenous land supply and population
- Model-based decomposition of impact of income on speed:
  - Contribution of city attribute to explaining speed-income relationship proportional to: *speed elasticity* × *income elasticity* of attribute.
  - Corresponds to exact empirical decomposition in Gelbach (2016).
- Structural interpretation of elasticities.
  - Compare to existing estimates from literature and introduce new parameters.

Why are richer countries faster?: Decomposing impact of GDP on Speed

		Speed index		GDP	Speed × Income
		Base	Full	Auxiliary	elasticities
	log country GDP (pc)	0.13[a]	0.055[a]		
		(0.022)	(0.012)		
City size	log population		-0.14[a]	-0.073	0.010
			(0.018)	(0.050)	(0.0070)
	log area		0.073[a]	0.24[a]	0.018[a]
			(0.022)	(0.059)	(0.0085)
Topo-	Elevation variance		-0.0025[a]	-0.10	-0.000
graphy			(0.00091)	(0.22)	(0.00057)
	Asinh water length		-0.082[a]	0.11[a]	-0.009[a]
			(0.021)	(0.026)	(0.0028)
Infra-	Asinh road length		0.062[a]	0.67[a]	0.042[a]
structure			(0.013)	(0.060)	(0.0081)
	Network griddiness		0.19[a]	0.032	0.006
			(0.057)	(0.025)	(0.0058)
	Observations	1,190	1,190	1,304	
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- Six city attributes explain $\frac{0.13-0.055}{0.13}$ =60% of why richer countries are faster
- Major roads explain a lot:
  - Large speed elast.× Very large income elast.
- Population doesn't explain:
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Decomposing impact of GDP on Uncongested Speed and Congestion

	Speed index		Uncongested speed		Congestion factor	
	Base	Full	Base	Full	Base	Full
log country GDP (pc)	0.13[a]	0.055[a]	0.15[a]	0.086[a]	0.018[a]	0.031[a]
	(0.022)	(0.012)	(0.018)	(0.010)	(0.0050)	(0.0052)
log population		-0.14[a]		-0.11[a]		0.035[a]
		(0.018)		(0.017)		(0.0050)
log area		0.073[a]		0.062[a]		-0.010
		(0.022)		(0.018)		(0.0078)
Elevation variance		-0.0025[a]		-0.0013		0.0012[a]
		(0.00091)		(0.0010)		(0.00039)
Asinh water length		-0.082[a]		-0.068[a]		0.014[c]
		(0.021)		(0.018)		(0.0072)
Asinh road length		0.062[a]		0.056[a]		-0.0063
		(0.013)		(0.012)		(0.0060)
Network griddiness		0.19[a]		0.13[a]		-0.054[a]
		(0.057)		(0.047)		(0.014)
Observations	1,190	1,190	1,190	1,190	1,190	1,190
R^2	0.44	0.70	0.62	0.75	0.10	0.48

Decomposing impact of GDP on Uncongested Speed and Congestion

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Urban crowding elasticity μ

Congestion elasticity θ

Population elasticity $-\mu - \theta$

Decomposing impact of GDP on Uncongested Speed and Congestion

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		(0.013)		(0.012)		(0.0060)
Network griddiness		0.19[a]		0.13[a]		-0.054[a]
		(0.057)		(0.047)		(0.014)
Observations	1,190	1,190	1,190	1,190	1,190	1,190
R^2	0.44	0.70	0.62	0.75	0.10	0.48

Urban crowding elasticity μ

Congestion elasticity θ

Population elasticity $-\mu - \theta$

Decomposing impact of GDP on Uncongested Speed and Congestion

	Speed index		Uncongested speed		Congestion factor	
	Base	Full	Base	Full	Base	Full
log country GDP (pc)	0.13[a]	0.055[a]	0.15[a]	0.086[a]	0.018[a]	0.031[a]
	(0.022)	(0.012)	(0.018)	(0.010)	(0.0050)	(0.0052)
log population		-0.14[a]		-0.11[a]		0.035[a]
		(0.018)		(0.017)		(0.0050)
log area		0.073[a]		0.062[a]		-0.010
		(0.022)		(0.018)		(0.0078)
Elevation variance		-0.0025[a]		-0.0013		0.0012[a]
		(0.00091)		(0.0010)		(0.00039)
Asinh water length		-0.082[a]		-0.068[a]		0.014[c]
		(0.021)		(0.018)		(0.0072)
Asinh road length		0.062[a]		0.056[a]		-0.0063
		(0.013)		(0.012)		(0.0060)
Network griddiness		0.19[a]		0.13[a]		-0.054[a]
		(0.057)		(0.047)		(0.014)
Observations	1,190	1,190	1,190	1,190	1,190	1,190
R^2	0.44	0.70	0.62	0.75	0.10	0.48

Urban crowding elasticity μ

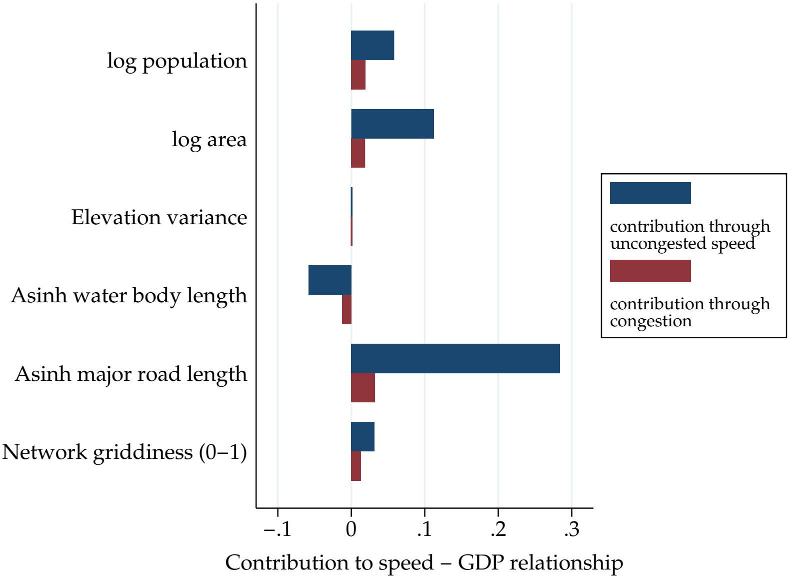
$-$

Congestion elasticity θ

$=$

Population elasticity $-\mu - \theta$

Why are richer countries faster?: Decomposing impact of GDP on Speed



Two more decompositions

- Why is United States so much faster than other rich countries? ▸▸ Table ▸▸ Figure
  - Model explains 83% of speed difference between US and rest of OECD.
  - US cities: Smaller pop (+), larger area (+), griddier network (+), more major roads (+)
  - Explanatory Power: City Size $>$ Infrastructure $\gg$ Topography
- Why is Bangladesh so much slower than other poor countries? ▸▸ Table ▸▸ Figure
  - Model explains 88% of speed difference between Bangladesh and other poor countries.
  - Bangladesh cities: More water bodies (-), more populous (-), fewer major roads (-)
  - Explanatory power: Topography $>$ City Size $>$ Infrastructure

Robustness: Impact of explanatory variables within and across countries

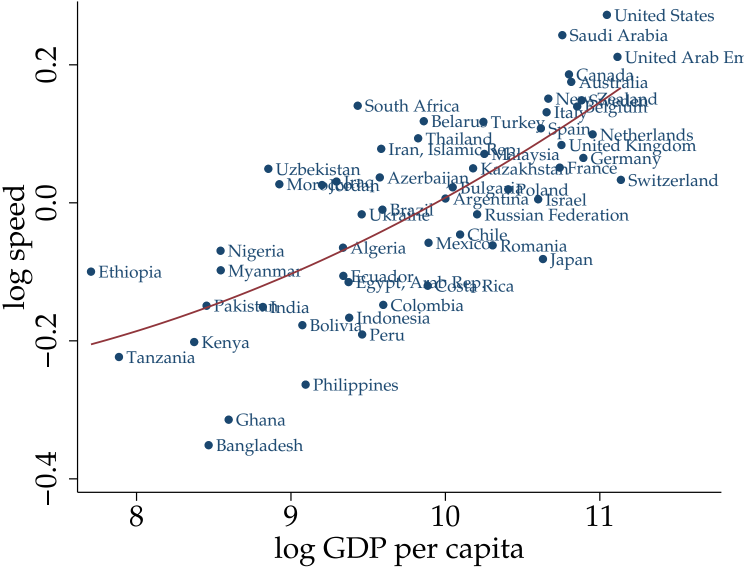
	Speed all	Speed all	Speed OECD	Speed Poor Countries	Speed US	Speed India
log country GDP (pc)	0.055[a]					
	(0.012)					
log population	-0.14[a]	-0.12[a]	-0.18[a]	-0.12[a]	-0.15[a]	-0.14[a]
	(0.018)	(0.016)	(0.026)	(0.013)	(0.021)	(0.019)
log area	0.073[a]	0.040[b]	0.085[a]	0.047[c]	0.099[a]	0.10[a]
	(0.022)	(0.016)	(0.019)	(0.025)	(0.024)	(0.025)
Elevation variance	-0.0025[a]	-0.0026[a]	-0.0024	-0.0028	-0.0017	-0.026[a]
	(0.00091)	(0.00094)	(0.0015)	(0.0017)	(0.0020)	(0.0066)
Asinh water body length	-0.082[a]	-0.055[a]	-0.055[a]	-0.069[c]	-0.064[a]	-0.15[a]
	(0.021)	(0.020)	(0.010)	(0.040)	(0.0095)	(0.030)
Asinh major road length	0.062[a]	0.052[a]	0.075[a]	0.051[a]	0.043[b]	0.053[a]
	(0.013)	(0.011)	(0.019)	(0.0074)	(0.020)	(0.018)
Network griddiness (0-1)	0.19[a]	0.15[a]	0.14[a]	0.28[a]	0.15[a]	0.25[b]
	(0.057)	(0.029)	(0.0075)	(0.028)	(0.025)	(0.10)
Country FE	N	Y	Y	Y	N	N
Observations	1,190	1,209	285	483	139	174
R^2	0.70	0.84	0.89	0.70	0.67	0.43
Within (Between) R^2		0.45 (0.57)	0.65 (0.64)	0.42 (0.52)		

Conclusion

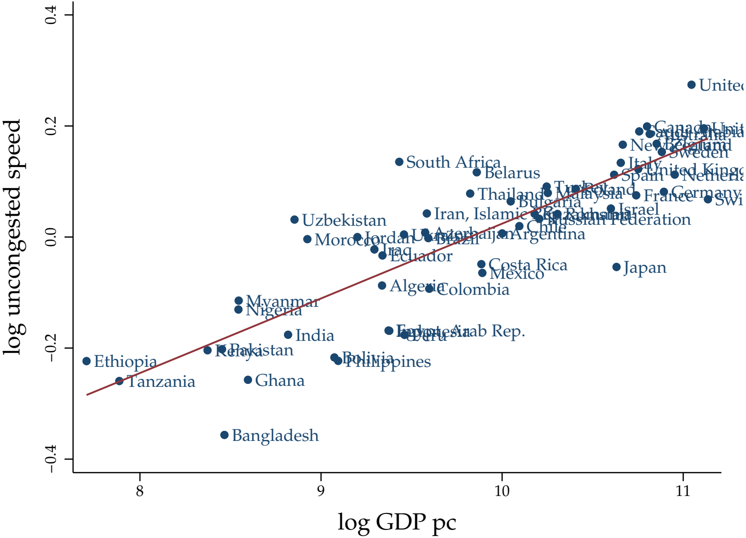
- We assemble an urban transportation database comparable across world cities.
- We identify robust correlates of urban travel speed within and across countries.
- We develop an urban model that decomposes the speed-income relationship into the contribution of city size, infrastructure, and topography.
- Policy implications:
  - Congestion policy won't close urban travel speed gap between rich and poor countries.
  - Economic development brings faster travel through road building and urban area expansion.
  - Infrastructure not always the main reason countries are fast or slow: e.g., Bangladesh constrained by challenging topography and large urban population.

Appendix: Speed vs.GDP pc, country

back



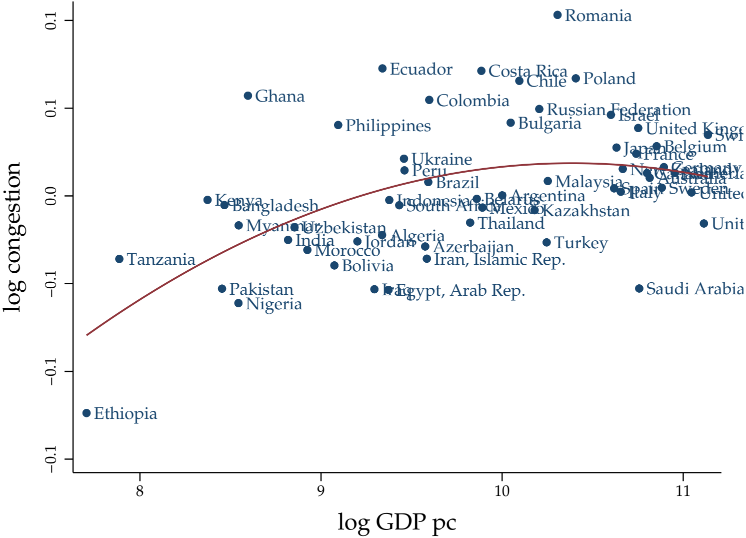
Appendix: Uncongested speed vs.GDP pc, country ⏩ back



Coefficient = 0.13 , R−squared = 0.71

Appendix: Congestion vs.GDP pc,country

back

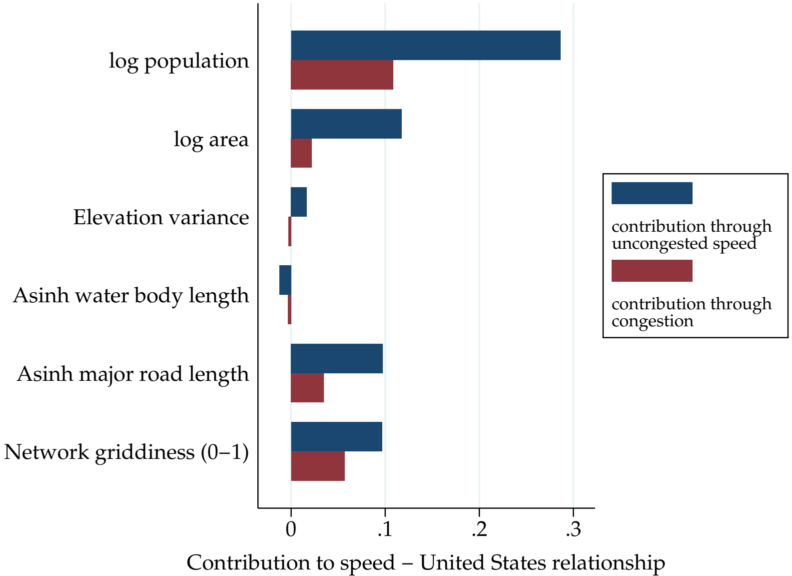


Coefficient = 0.02 , R−squared = 0.20

Appendix: Why is US faster than rest of OECD? back

	Speed index		Uncongested speed		Congestion factor		
	Base	Full	Base	Full	Base	Full	Auxiliary
United States	0.23[a]	0.038[c]	0.20[a]	0.057[a]	-0.031[a]	0.019[a]	
	(0.020)	(0.020)	(0.018)	(0.017)	(0.0053)	(0.0060)	
log population		-0.21[a]		-0.15[a]		0.056[a]	-0.44[a]
		(0.027)		(0.023)		(0.0053)	(0.10)
log area		0.087[a]		0.073[a]		-0.014	0.37[a]
		(0.030)		(0.024)		(0.015)	(0.088)
Elevation variance		-0.0036[b]		-0.0043[b]		-0.00070	-0.87
		(0.0014)		(0.0017)		(0.00055)	(0.53)
Asinh water body length		-0.038[c]		-0.030[b]		0.0083	0.094
		(0.021)		(0.014)		(0.0073)	(0.072)
Asinh major road length		0.093[a]		0.069[b]		-0.025[c]	0.32[a]
		(0.031)		(0.027)		(0.012)	(0.099)
Network griddiness (0-1)		0.13[a]		0.081[a]		-0.047[a]	0.27[a]
		(0.019)		(0.017)		(0.0040)	(0.0100)
Observations	285	285	285	285	285	285	286
R^2	0.52	0.83	0.60	0.82	0.15	0.66	

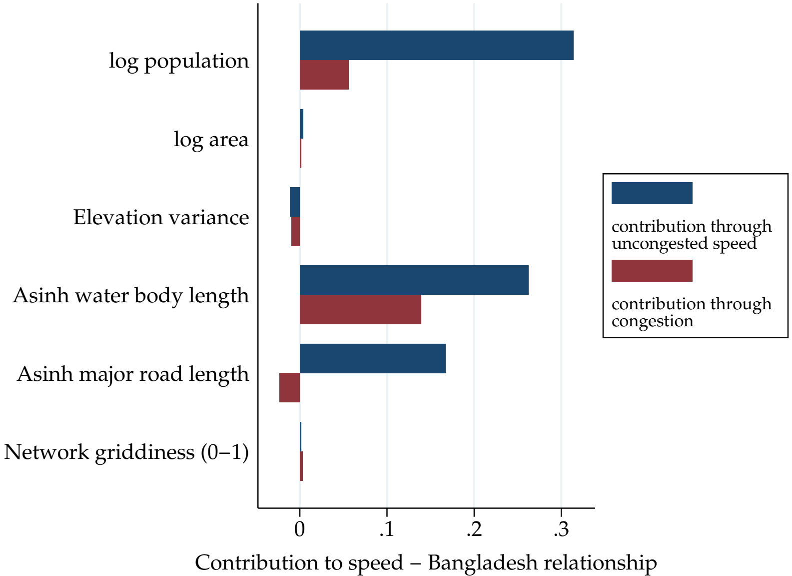
Appendix: Why is US faster than rest of OECD? back



Appendix: Why is Bangladesh slower than other poor countries? ▸▸ back

	Speed index		Uncongested speed		Congestion factor		
	Base	Full	Base	Full	Base	Full	Auxiliary
Bangladesh	-0.24[a]	-0.029	-0.22[a]	-0.048[b]	0.016[b]	-0.019	
	(0.023)	(0.035)	(0.022)	(0.021)	(0.0061)	(0.018)	
log population		-0.15[a]		-0.13[a]		0.023[a]	0.58[a]
		(0.016)		(0.015)		(0.0051)	(0.089)
log area		0.069[a]		0.049[b]		-0.019[b]	-0.018
		(0.025)		(0.021)		(0.0095)	(0.074)
Elevation variance		-0.0029[a]		-0.0016		0.0014[b]	-1.66[a]
		(0.0010)		(0.0013)		(0.00064)	(0.52)
Asinh water body length		-0.12[a]		-0.079[a]		0.042[b]	0.79[a]
		(0.031)		(0.023)		(0.017)	(0.028)
Asinh major road length		0.077[a]		0.090[a]		0.012[b]	-0.44[a]
		(0.0097)		(0.0071)		(0.0049)	(0.13)
Network griddiness (0-1)		0.100		0.034		-0.066[a]	-0.012
		(0.060)		(0.056)		(0.019)	(0.0086)
Observations	483	483	483	483	483	483	592
R^2	0.04	0.51	0.05	0.48	0.00	0.41	

Appendix: Why is Bangladesh slower than other poor countries? back



Appendix: Traffic color comparison for Annaba, Algeria ⏩ back