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

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Introduction: What we do

- Simulate 600 million Google Maps trips to produce travel speed indices for 1,228 cities.
- Produce city-level travel speed indices comparable across countries
- 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

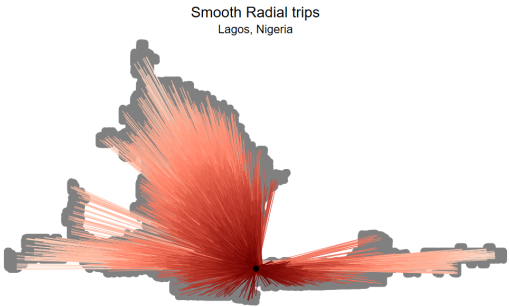
- City *points*: All 1,860 cities with projected 2018 population over 300,000 from UN World Urbanization Prospects
- City *boundaries*: Defined using GHS-SMOD 1-km layer circa 2015
  - Start with areas within 500m radius of 'built' (38m X 38m) pixels.
  - Merge secondary centers, separate attached primary centers, drop major mismatches etc. 1,807 cities remain.
- Drop countries without Google Maps (China, South Korea) and cities with population under 150,000 on *WorldPop*. 1,228 cities remain.

Creating database: Designing trips

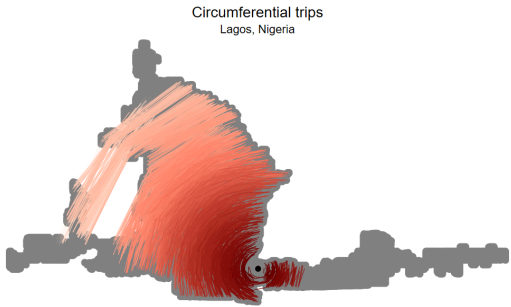
To obtain representative trips, we:

- 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

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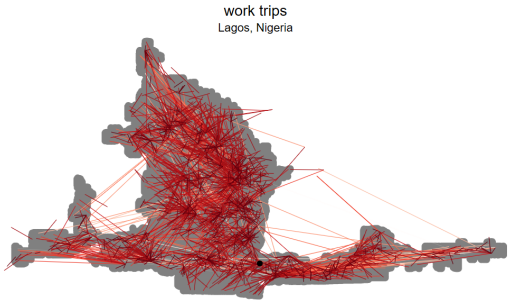
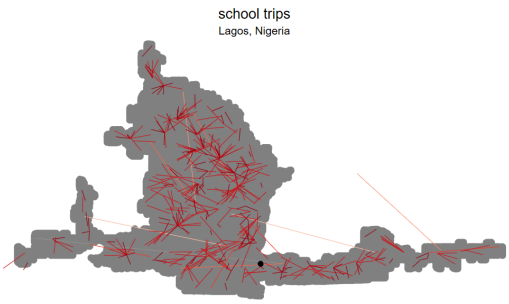


Trips to 'work'



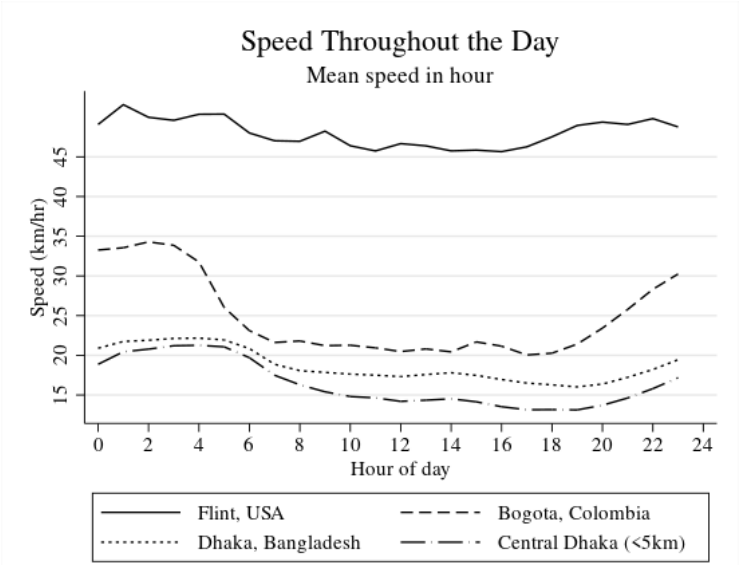
Trips to school

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)

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



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 drop:
  - countries with low variation in speeds across instances of the same trip. ´
  - 2 cities that Google identifies as having no traffic layer for.
  - 18 cities that we lack reliable income data.
  - 1,119 cities remain.

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:

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

- We use three outcomes to estimate three indices:
  1. *log (real-time) speed* $\Rightarrow$ speed index S_c
  2. *log uncongested speed* $\Rightarrow$ uncongested speed index U_c
  3. *(log uncongested speed - log speed)* $\Rightarrow$ 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	0.48	Dhaka	Bangladesh	-0.60
2	Greensboro	United States	0.45	Lagos	Nigeria	-0.54
3	Wichita	United States	0.44	Ikorodu	Nigeria	-0.51
4	Tulsa	United States	0.41	Manila	Philippines	-0.49
5	Lansing	United States	0.41	Bhiwandi	India	-0.48
6	Knoxville	United States	0.40	Kolkata	India	-0.47
7	Shreveport	United States	0.39	Arrah	India	-0.44
8	Memphis	United States	0.39	Phnom Penh	Cambodia	-0.43
9	Youngstown	United States	0.39	Mymensingh	Bangladesh	-0.43
10	Toledo	United States	0.38	Aba	Nigeria	-0.43
11	Port St. Lucie	United States	0.38	Bihar Sharif	India	-0.42
12	Rockford	United States	0.38	Chittagong	Bangladesh	-0.42
13	Dayton	United States	0.38	Mumbai	India	-0.41
14	Bakersfield	United States	0.37	Bacoor	Philippines	-0.41
15	Grand Rapids	United States	0.37	Dar es Salaam	Tanzania	-0.40
16	Stockton	United States	0.37	Kumasi	Ghana	-0.40
17	Montgomery	United States	0.36	Mombasa	Kenya	-0.40
18	Springfield, Missouri	United States	0.36	Aizawl	India	-0.39
19	Windsor	Canada	0.36	Bangalore	India	-0.39
20	Oklahoma City	United States	0.36	Shillong	India	-0.39

Creating database: Most and least congested cities

	Most Congested			Least Congested		
Rank	City	Country	Index	City	Country	Index
1	Bogotá	Colombia	0.21	Nazret	Ethiopia	-0.17
2	Krasnodar	Russia	0.19	Dire Dawa	Ethiopia	-0.17
3	Ulaanbaatar	Mongolia	0.18	Songea	Tanzania	-0.17
4	Bucharest	Romania	0.17	Gboko	Nigeria	-0.17
5	Moscow	Russia	0.17	Gondar	Ethiopia	-0.17
6	Bangkok	Thailand	0.17	Potiskum	Nigeria	-0.16
7	Manila	Philippines	0.16	Sikasso	Mali	-0.16
8	Bangalore	India	0.16	Ogbomosho	Nigeria	-0.14
9	Vladivostok	Russia	0.16	El Djelfa	Algeria	-0.14
10	Mexico City	Mexico	0.14	Oyo	Nigeria	-0.14
11	Lagos	Nigeria	0.14	Abakaliki	Nigeria	-0.13
12	London	United Kingdom	0.14	Morogoro	Tanzania	-0.13
13	Mumbai	India	0.14	Gombe	Nigeria	-0.13
14	Yekaterinburg	Russia	0.14	Nasiriyah	Iraq	-0.13
15	Guatemala City	Guatemala	0.14	Ondo	Nigeria	-0.12
16	Panama City	Panama	0.13	Bouake	Côte d'Ivoire	-0.12
17	Nairobi	Kenya	0.13	Safi	Morocco	-0.12
18	New York	United States	0.13	Katsina	Nigeria	-0.12
19	Santo Domingo	Dominican Republic	0.13	Minna	Nigeria	-0.12
20	Delhi	India	0.12	Ijebu-Ode	Nigeria	-0.12

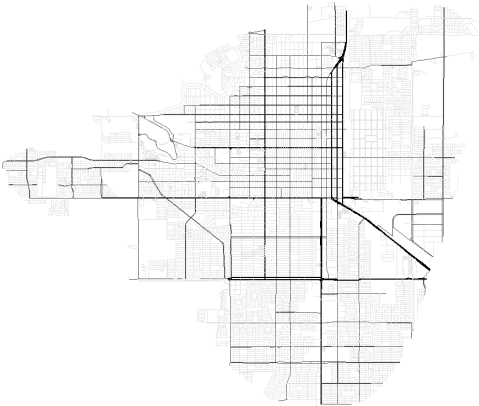
Creating database: Cities with fastest and slowest uncongested speed

	Fastest Uncongestd Speed			Slowest Uncongested Speed		
Rank	City	Country	Index	City	Country	Index
1	Flint	United States	0.43	Ikorodu	Nigeria	-0.52
2	Greensboro	United States	0.41	Dhaka	Bangladesh	-0.49
3	Wichita	United States	0.39	Aba	Nigeria	-0.49
4	Tulsa	United States	0.38	Khulna	Bangladesh	-0.43
5	Knoxville	United States	0.38	Mymensingh	Bangladesh	-0.41
6	Memphis	United States	0.37	Bihar Sharif	India	-0.41
7	Shreveport	United States	0.36	Bhiwandi	India	-0.40
8	Bakersfield	United States	0.36	Lagos	Nigeria	-0.39
9	Lansing	United States	0.36	Kolkata	India	-0.39
10	Hartford	United States	0.36	La Paz	Bolivia	-0.39
11	Grand Rapids	United States	0.35	Port-au-Prince	Haiti	-0.39
12	Youngstown	United States	0.35	Arrah	India	-0.38
13	Windsor	Canada	0.35	Mombasa	Kenya	-0.38
14	Montgomery	United States	0.35	Aizawl	India	-0.38
15	Corpus Christi	United States	0.35	Darbhanga	India	-0.37
16	Toledo	United States	0.35	Dar es Salaam	Tanzania	-0.37
17	Stockton	United States	0.34	Quetta	Pakistan	-0.36
18	Kansas City	United States	0.34	Chittagong	Bangladesh	-0.36
19	Fresno	United States	0.34	Comilla	Bangladesh	-0.35
20	Jacksonville, Florida	United States	0.34	Varanasi	India	-0.35

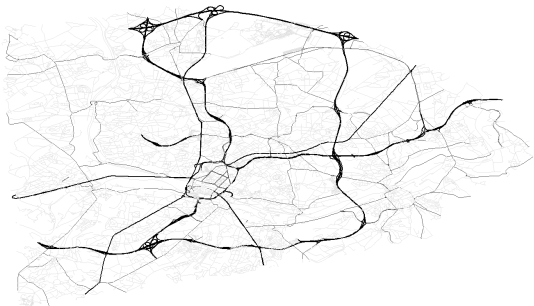
Creating database: Country income and six city attributes

- *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* queries of trips on walking mode.
- 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]
		(0.023)
country FE	Y	N
Observations	1,119	1,119
R^2	0.72	0.46

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- Country GDP explains $\frac{0.46}{0.72}$ =64% 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* $\times$ *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
		Base	Full	Auxiliary
	log country GDP (pc)	0.13^{a}	0.042^{a}	
		(0.023)	(0.011)	
City size	log population		-0.17^{a}	-0.10^{b}
			(0.018)	(0.042)
	log area		0.085^{a}	0.24^{a}
			(0.022)	(0.059)
Topo-graphy	Elevation variance		-0.0024^{b}	-0.10
			(0.00092)	(0.22)
	Asinh water length		-0.071^{a}	0.11^{a}
			(0.019)	(0.026)
Infra-structure	Asinh road length		0.080^{a}	0.67^{a}
			(0.012)	(0.060)
	Network griddiness		0.18^{a}	0.032
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Six city attributes explain $\frac{0.13-0.042}{0.13}$ =68% of why richer countries are faster:

- Denser cities are slower.
- Water bodies are an impediment, hilliness less so.
- Cities with more major roads or griddier networks are faster.

Cities in richer countries have:

- similar populations, elevation variance, and network griddiness.
- wider areas, a bit more water bodies and much more roads.

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- wider areas, a bit more water bodies and much more roads.

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	0.042^a	0.15^a	0.074^a	0.019^a	0.032^a
	(0.023)	(0.011)	(0.018)	(0.0090)	(0.0059)	(0.0067)
log population		-0.17^a		-0.13^a		0.040^a
		(0.018)		(0.015)		(0.0069)
log area		0.085^a		0.064^a		-0.021^b
		(0.022)		(0.019)		(0.0087)
Elevation variance		-0.0024^b		-0.0011		0.0013^a
		(0.00092)		(0.0010)		(0.00040)
Asinh water length		-0.071^a		-0.054^a		0.017^b
		(0.019)		(0.019)		(0.0083)
Asinh road length		0.080^a		0.076^a		-0.0040
		(0.012)		(0.013)		(0.0080)
Network griddiness		0.18^a		0.12^a		-0.058^a
		(0.057)		(0.046)		(0.015)
Observations	1,119	1,119	1,119	1,119	1,119	1,119
R^2	0.46	0.70	0.63	0.77	0.11	0.43

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	0.042^a	0.15^a	0.074^a	0.019^a	0.032^a
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		(0.018)		(0.015)		(0.0069)
log area		0.085^a		0.064^a		-0.021^b
		(0.022)		(0.019)		(0.0087)
Elevation variance		-0.0024^b		-0.0011		0.0013^a
		(0.00092)		(0.0010)		(0.00040)
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Network griddiness		0.18^a		0.12^a		-0.058^a
		(0.057)		(0.046)		(0.015)
Observations	1,119	1,119	1,119	1,119	1,119	1,119
R^2	0.46	0.70	0.63	0.77	0.11	0.43

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	0.042^a	0.15^a	0.074^a	0.019^a	0.032^a
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log population		-0.17^a		-0.13^a		0.040^a
		(0.018)		(0.015)		(0.0069)
log area		0.085^a		0.064^a		-0.021^b
		(0.022)		(0.019)		(0.0087)
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Network griddiness		0.18^a		0.12^a		-0.058^a
		(0.057)		(0.046)		(0.015)
Observations	1,119	1,119	1,119	1,119	1,119	1,119
R^2	0.46	0.70	0.63	0.77	0.11	0.43

Urban crowding elasticity μ

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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]	0.042[a]	0.15[a]	0.074[a]	0.019[a]	0.032[a]
	(0.023)	(0.011)	(0.018)	(0.0090)	(0.0059)	(0.0067)
log population		-0.17[a]		-0.13[a]		0.040[a]
		(0.018)		(0.015)		(0.0069)
log area		0.085[a]		0.064[a]		-0.021[b]
		(0.022)		(0.019)		(0.0087)
Elevation variance		-0.0024[b]		-0.0011		0.0013[a]
		(0.00092)		(0.0010)		(0.00040)
Asinh water length		-0.071[a]		-0.054[a]		0.017[b]
		(0.019)		(0.019)		(0.0083)
Asinh road length		0.080[a]		0.076[a]		-0.0040
		(0.012)		(0.013)		(0.0080)
Network griddiness		0.18[a]		0.12[a]		-0.058[a]
		(0.057)		(0.046)		(0.015)
Observations	1,119	1,119	1,119	1,119	1,119	1,119
R^2	0.46	0.70	0.63	0.77	0.11	0.43

Urban crowding elasticity μ

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Congestion elasticity θ

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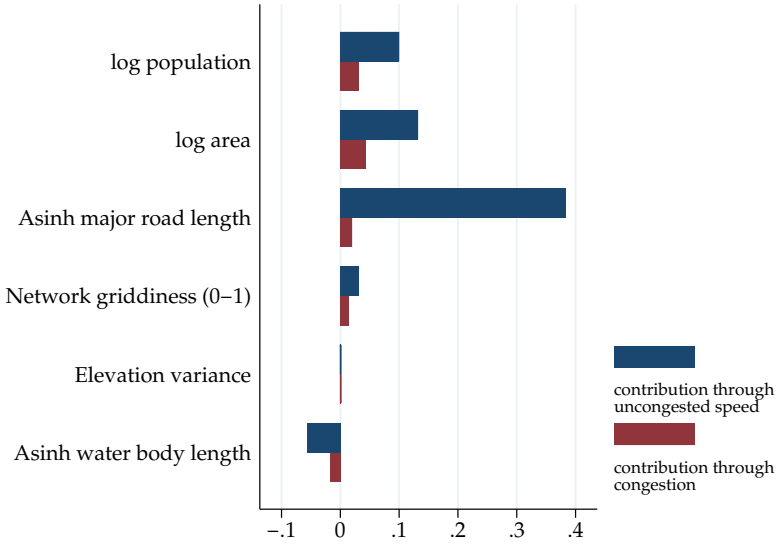
Population elasticity $\mu - \theta$

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 ≫ 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

Robustness: Impact of explanatory variables within and across countries

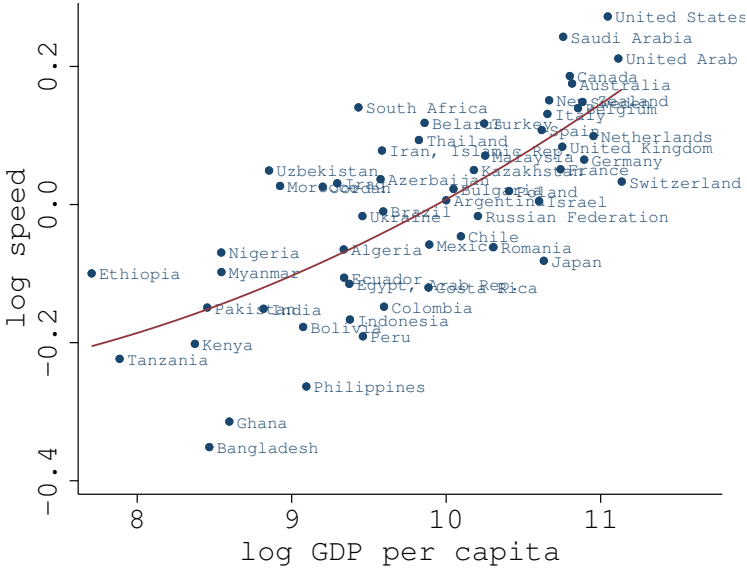
	(1) Speed all	(2) Speed all	(3) Speed OECD	(4) Speed Poor Countries	(5) Speed US	(6) Speed India
log country GDP (pc)	0.042^a					
	(0.011)					
log population	-0.17^a	-0.15^a	-0.19^a	-0.15^a	-0.17^a	-0.16^a
	(0.018)	(0.011)	(0.027)	(0.011)	(0.025)	(0.016)
log area	0.085^a	0.051^a	0.097^a	0.052^b	0.11^a	0.095^a
	(0.022)	(0.015)	(0.022)	(0.021)	(0.025)	(0.026)
Asinh major road length	0.080^a	0.076^a	0.085^a	0.070^a	0.052^b	0.072^a
	(0.012)	(0.0096)	(0.019)	(0.0094)	(0.025)	(0.016)
Network griddiness (0-1)	0.18^a	0.16^a	0.13^a	0.26^a	0.14^a	0.24^b
	(0.057)	(0.029)	(0.0099)	(0.027)	(0.027)	(0.10)
Elevation variance	-0.0024^b	-0.0022^b	-0.0020	-0.0035^b	-0.0012	-0.029^a
	(0.00092)	(0.00092)	(0.0016)	(0.0016)	(0.0019)	(0.0064)
Asinh water body length	-0.071^a	-0.040^b	-0.053^a	-0.045	-0.060^a	-0.11^a
	(0.019)	(0.017)	(0.010)	(0.029)	(0.0098)	(0.031)
Country FE	N	Y	Y	Y	N	N
Observations	1,119	1,119	265	425	121	173
R^2	0.70	0.85	0.90	0.62	0.66	0.49
Within (Between) R^2		0.45 (0.55)	0.62 (0.64)	0.41 (0.45)		

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.

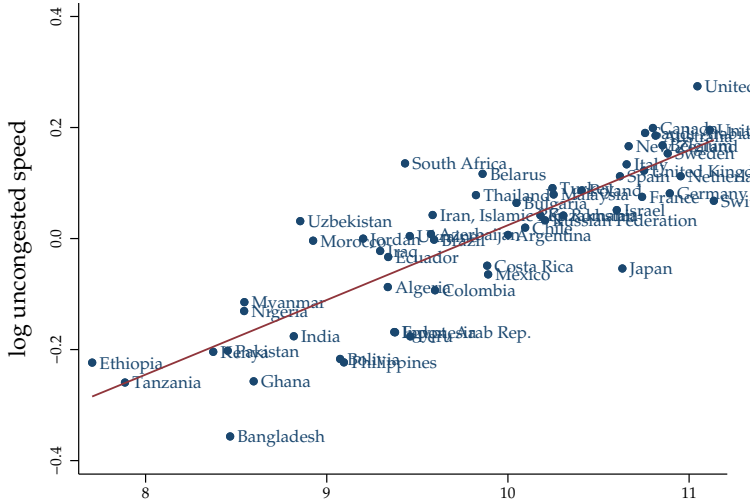
Appendix: Speed vs.GDP pc, country

back



Appendix: Uncongested speed vs.GDP pc, country

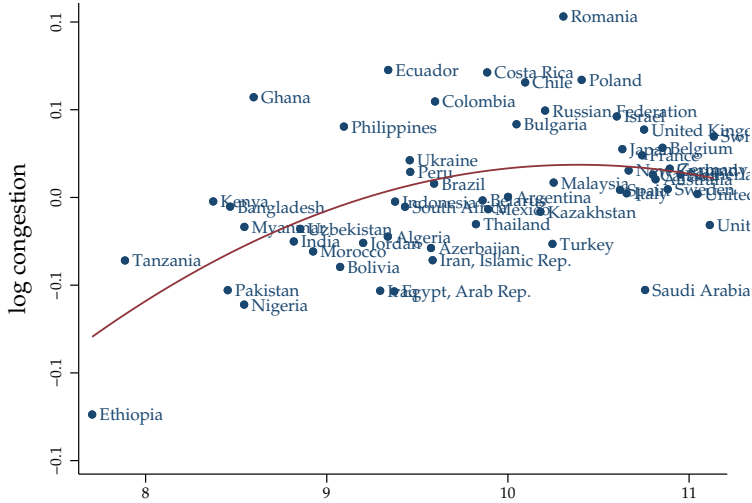
back



Coefficient = 0.13 , R−squared = 0.71

Appendix: Congestion vs.GDP pc,country

back



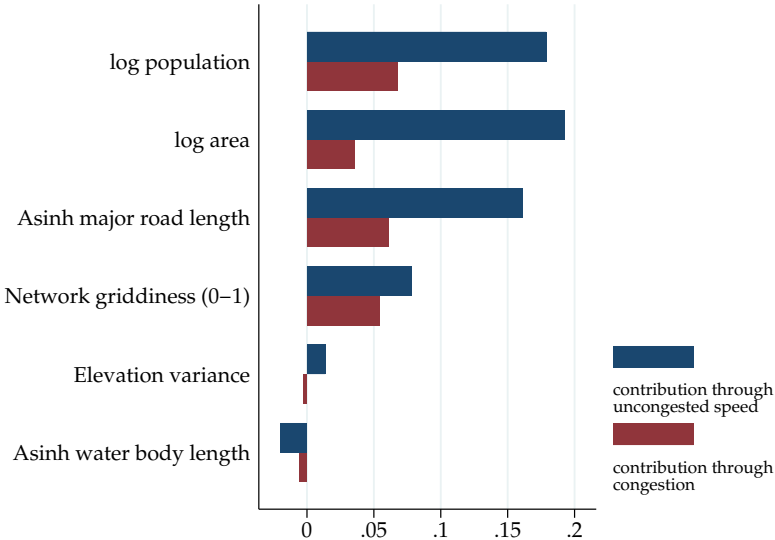
Coefficient = 0.02 , R−squared = 0.20

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



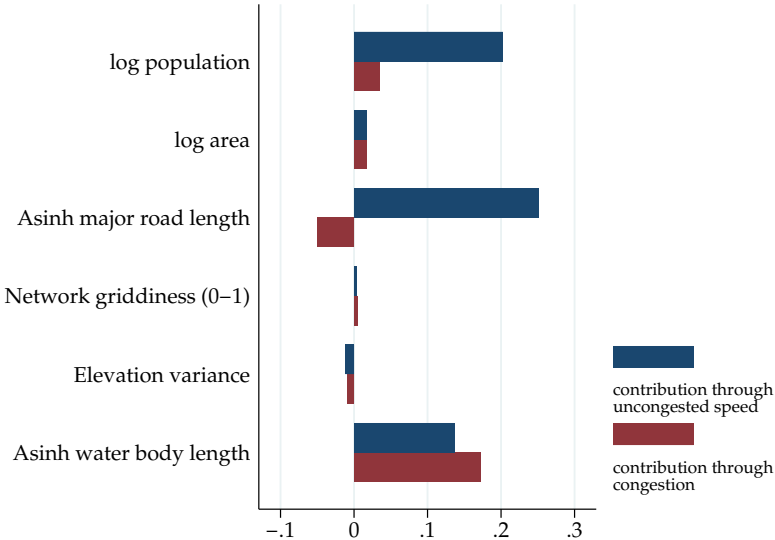
Appendix: Why is Bangladesh slower than other poor countries?

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: Robustness: Impact of explanatory variables within and across countries

back

	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)		

Appendix: Traffic color comparison for Annaba, Algeria

back