Driving and Population Density

(replaces previous version with Traffic Fatalities in title)

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Motivation: spatial patterns across the U.S.

- High population density locations have:
  - Less driving, more public transit use
  - More traffic congestion
  - Higher taxes
- No consistent pattern for per-capita incomes
- Drivers almost always in majority
- Simple model to help interpret

Model mechanism

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NEWS

Report: 98 Percent Of U.S. Commuters Favor Public Transportation For Others

Published November 29, 2000

WASHINGTON, DC–A study released Monday by the American Public Transportation Association reveals that 98 percent of Americans support the use of mass transit by others.

Traffic moves slowly near Seattle, WA, where a majority of drivers say they support other people using mass transit.

"With traffic congestion, pollution, and oil shortages all getting worse, now is the time to shift to affordable, efficient public transportation," APTA director Howard Collier said. "Fortunately, as this report shows, Americans have finally recognized the need for everyone else to do exactly that."

Of the study's 5,200 participants, 44 percent cited faster commutes as the primary reason to expand public transportation, followed closely by shorter lines at the gas station. Environmental and energy concerns ranked a distant third and fourth, respectively.

Median voter drives, but wants to fund public transit to reduce congestion

Related literature

- Urbanization/congestion/transportation (Duranton et al., 2011; Anderson, 2014; Duranton and Turner, 2018; Seidel and Wickerath, 2020; Basso et al., 2021; Akbar et al., 2023; Baum-Snow, 2007, 2010; Ostermeijer et al., 2022)
- Urban-rural differences in taxes, politics (Gethin et al. 2022)
- Public transit provision (Vickrey 1980)

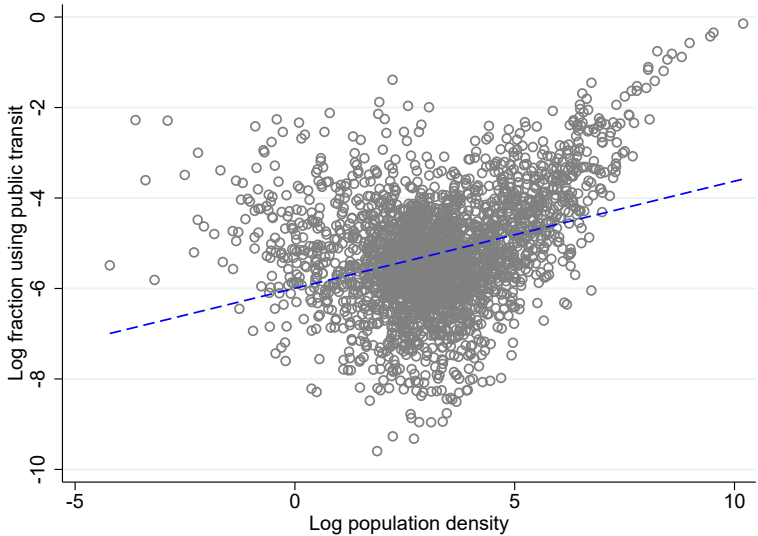
But few models linking these

U.S. Data

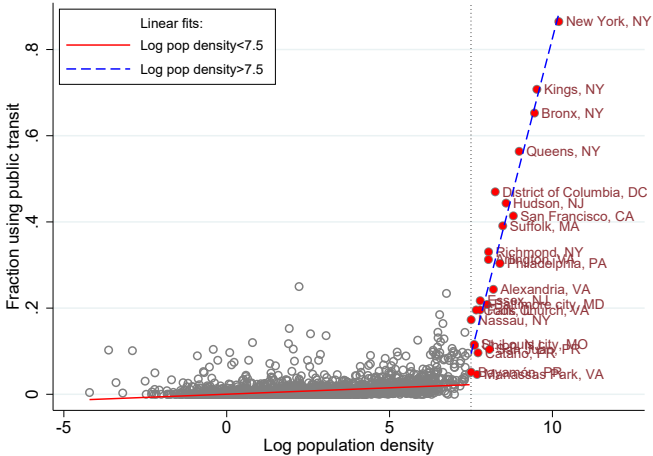
- Census data on population density
- Bureau of Economic Analysis data on personal incomes
- American Community Survey data on how people commute
  - (Here: ignore those who walk, work from home)
- Department of Energy data on vehicle use
- Bureau of Transportation data on congestion (city-level)
- Taxes
  - State-level on taxes from Tax Foundation
  - County-level property taxes (Bazzi et al. 2020)

Stylized Fact # 1:
Less per-capita driving in cities

Fraction using public transit



Fraction using public transit, non-logged



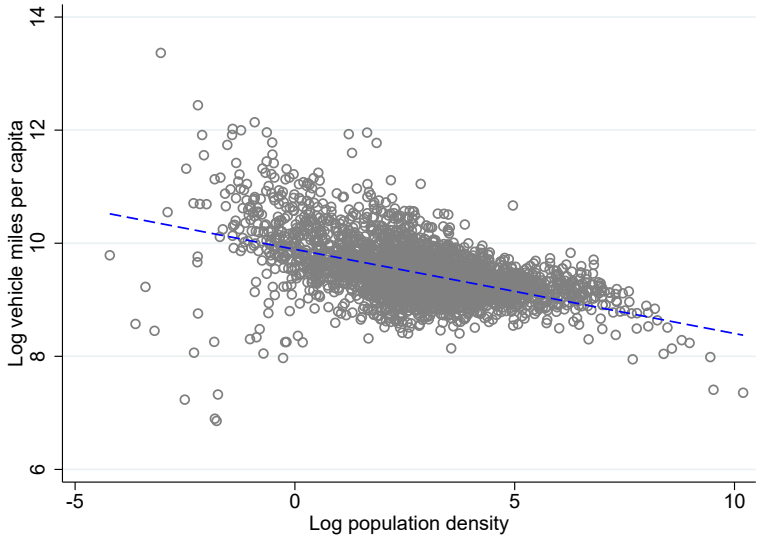
Notes: break at high density levels; public transit users rarely in majority

Logged fraction using public transit, regressions

	Dependent variable is the log fraction using public transit				
	(1)	(2)	(3)	(4)	(5)
Log population density	0.237***	0.197***	0.258***	0.241***	0.241***
	(0.019)	(0.019)	(0.019)	(0.022)	(0.044)
Log income per capita		1.278***	1.169***	0.469***	0.469**
		(0.131)	(0.134)	(0.149)	(0.219)
Log county area			0.216***	−0.095**	−0.095
			(0.035)	(0.047)	(0.077)
R^2	0.10	0.14	0.16	0.31	0.31
Number of obs.	2581	2432	2432	2432	2432
Fixed effects	None	None	None	State	State
Standard errors	Robust	Robust	Robust	Robust	Clustered

Notes: Ordinary least squares regressions. Robust standard errors are indicated in parentheses, except for column (5), which clusters on state. The unit of observation is a county. * indicates $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Vehicle miles traveled



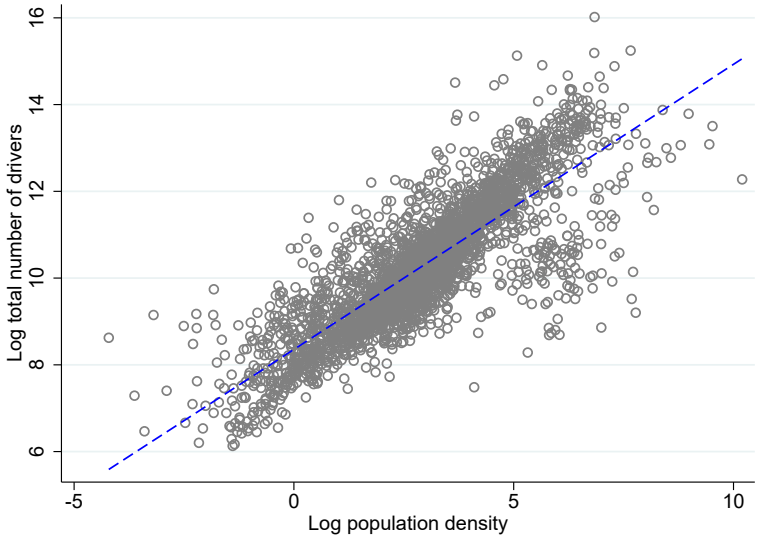
Vehicle miles traveled, regressions

	Dependent variable is log vehicle miles per capita				
	(1)	(2)	(3)	(4)	(5)
Log population density	-0.149^{***}	-0.169^{***}	-0.179^{***}	-0.216^{***}	-0.216^{***}
	(0.007)	(0.006)	(0.007)	(0.008)	(0.021)
Log income per capita		0.122^{***}	0.138^{***}	0.516^{***}	0.516^{***}
		(0.043)	(0.043)	(0.051)	(0.054)
Log county area			-0.038^{***}	-0.013	-0.013
			(0.014)	(0.017)	(0.023)
R^2	0.26	0.31	0.31	0.45	0.45
Number of obs.	3142	3055	3055	3055	3055
Fixed effects	None	None	None	State	State
Standard errors	Robust	Robust	Robust	Robust	Clustered

Notes: Ordinary least squares regressions. Robust standard errors are indicated in parentheses, except for column (5), which clusters on state. The unit of observation is a county. * indicates $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Stylized Fact # 2:
More congestion in cities

Total number of drivers

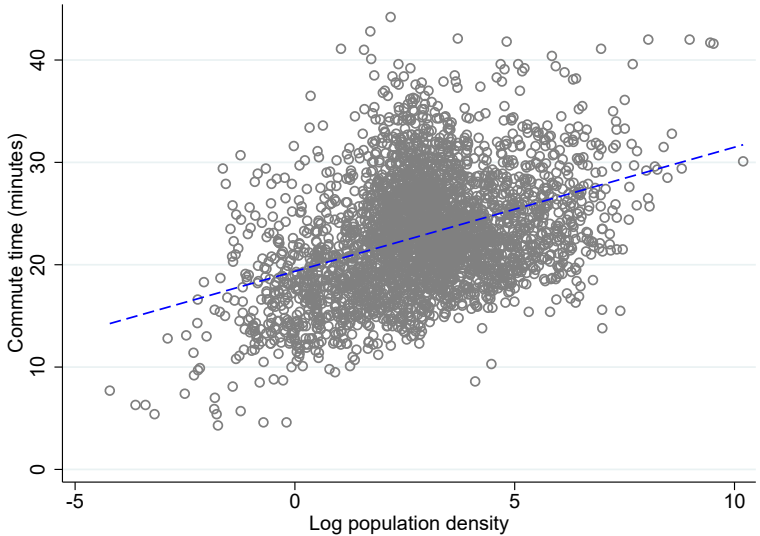


Total number of drivers, regressions

	Dependent variable is the log number of drivers				
	(1)	(2)	(3)	(4)	(5)
Log population density	0.657***	0.746***	0.992***	0.992***	0.992***
	(0.012)	(0.010)	(0.001)	(0.002)	(0.003)
Log income per capita		0.397***	−0.046***	−0.022	−0.022**
		(0.071)	(0.017)	(0.020)	(0.010)
Log county area			1.005***	1.020***	1.020***
			(0.003)	(0.007)	(0.013)
R^2	0.69	0.79	1.00	1.00	1.00
Number of obs.	3217	3052	3052	3052	3052
Fixed effects	None	None	None	State	State
Standard errors	Robust	Robust	Robust	Robust	Clustered

Notes: Ordinary least squares regressions. Robust standard errors are indicated in parentheses, except for column (5), which clusters on state. The unit of observation is a county. * indicates $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Commute time

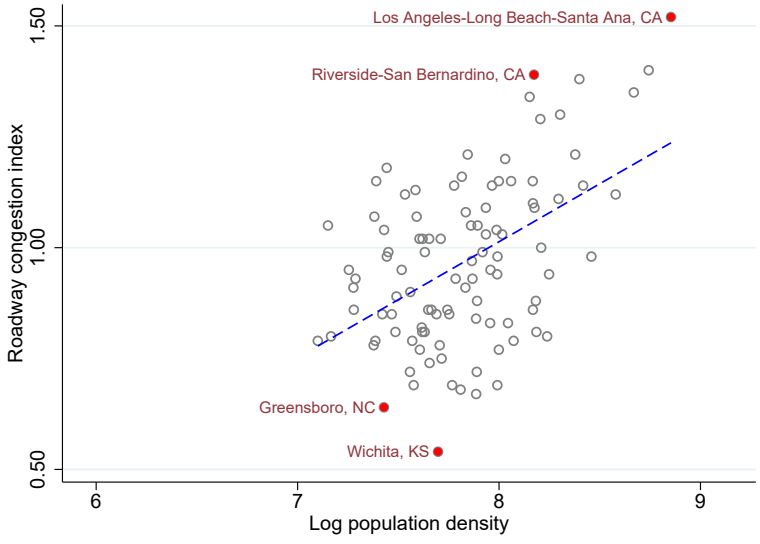


Commute time, regressions

	Dependent variable is log commute time				
	(1)	(2)	(3)	(4)	(5)
Log population density	0.062***	0.064***	0.052***	0.022***	0.022**
	(0.003)	(0.003)	(0.003)	(0.004)	(0.009)
Log income per capita		−0.305***	−0.285***	−0.179***	−0.179***
		(0.020)	(0.021)	(0.023)	(0.041)
Log county area			−0.047***	−0.044***	−0.044***
			(0.007)	(0.009)	(0.012)
R^2	0.18	0.22	0.24	0.37	0.37
Number of obs.	3217	3052	3052	3052	3052
Fixed effects	None	None	None	State	State
Standard errors	Robust	Robust	Robust	Robust	Clustered

Notes: Ordinary least squares regressions. Robust standard errors are indicated in parentheses, except for column (5), which clusters on state. The unit of observation is a county. * indicates $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Roadway Congestion Index



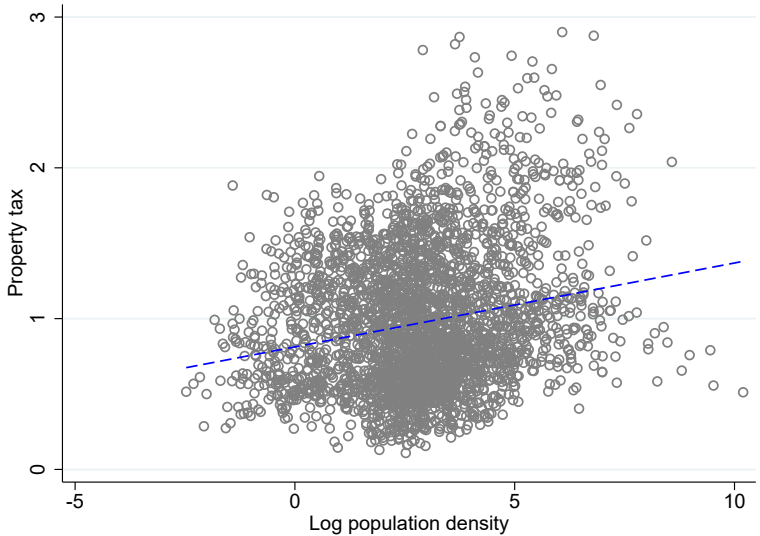
Roadway Congestion Index, regressions

	Dependent variable is the Roadway Congestion Index					
	(1)	(2)	(3)	(4)	(5)	(6)
Log population density	0.261***	0.226***	0.239***	0.293***	0.258***	0.110
	(0.049)	(0.051)	(0.042)	(0.086)	(0.094)	(0.071)
Log median income		0.211*	0.086		0.336	0.205
		(0.112)	(0.078)		(0.211)	(0.145)
Log area			0.099***			0.115***
			(0.017)			(0.023)
R^2	0.24	0.29	0.48	0.65	0.71	0.83
Number of obs.	101	101	101	101	101	101
Fixed effects	None	None	None	State	State	State
Standard errors	Robust	Robust	Robust	Robust	Robust	Robust

Notes: Ordinary least squares regressions. Robust standard errors are indicated in parentheses. The unit of observation is a city. * indicates $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Stylized Fact # 3:
Higher taxes in cities

Property taxes

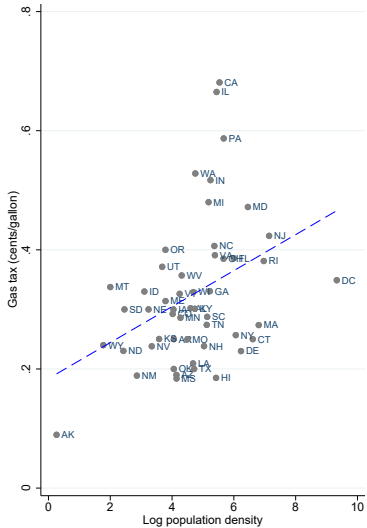


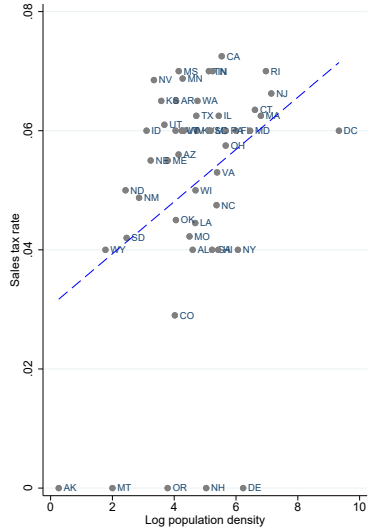
Property taxes, regressions

	Dependent variable is the log property tax rate				
	(1)	(2)	(3)	(4)	(5)
Log population density	0.054***	0.041***	0.043***	0.082***	0.082***
	(0.005)	(0.005)	(0.006)	(0.004)	(0.008)
Log income per capita		0.704***	0.700***	0.056	0.056
		(0.048)	(0.049)	(0.035)	(0.054)
Log county area			0.010	0.062***	0.062***
			(0.013)	(0.012)	(0.022)
R^2	0.03	0.13	0.13	0.83	0.83
Number of obs.	3094	3031	3031	3031	3031
Fixed effects	None	None	None	State	State
Standard errors	Robust	Robust	Robust	Robust	Clustered

Notes: Ordinary least squares regressions. Robust standard errors are indicated in parentheses, except for column (5), which clusters on state. The unit of observation is a county. * indicates $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Gas and sales taxes





Gas and sales taxes, regressions

	Dependent variable is the:					
	State sales tax rate			State gas tax (cents/gallon)		
	(1)	(2)	(3)	(4)	(5)	(6)
Log population density	0.030***	0.029***	0.063***	0.004**	0.005**	0.008***
	(0.009)	(0.009)	(0.018)	(0.002)	(0.002)	(0.003)
Log income per capita		0.056	0.182		−0.024	−0.011
		(0.152)	(0.151)		(0.022)	(0.024)
Log area			0.048**			0.005
			(0.021)			(0.003)
R^2	0.15	0.15	0.29	0.12	0.13	0.18
Number of obs.	51	51	51	51	51	51
Standard errors	Robust	Robust	Robust	Robust	Robust	Robust

Notes: Ordinary least squares regressions. Robust standard errors are indicated in parentheses. The unit of observation is a state. * indicates $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Summary of empirical patterns

Population density is associated with:

- Less driving per capita
- More traffic congestion
- Higher tax rates

Correlations with per-capita incomes less consistent

Drivers $>$ 50% almost everywhere

Model

Model

Ingrediants: Many locations with different population densities. Congestion externalities from driving. Heterogeneity in preferences for driving. Public transit = alt. mode of transport; pure public good funded by taxes, set by median voter

- L_i = population in location i (exogenous)
- z_i = fraction of population in location i who drive
- X = amount of space to drive on (exogenous, same across locations)
- $\eta_j \geq 1$ = agent j's preference for driving
  - $\eta_j \sim F(\eta_j) = 1 - \eta_j^{-\frac{1}{\delta}}; \delta < 1$
- $\frac{\eta_j X}{z_i L_i}$ = agent j's transportation consumption if driving

Model, cont'd

- y_i = income in location i (exogenous)
  - Net of other taxes than those funding public transit
- τ_i = tax rate in location i
- $P_i = (\tau_i y_i L_i)^\lambda$ = amount of public transit in location i (public good)
  - Assume $0 < \lambda < \delta < 1$: allows congestion, $z_i L_i$, to increase with L_i

Transportation consumption:

$$T_{ij} = \begin{cases} \frac{\eta_j X}{z_i L_i} & \text{if driving} \\ P_i & \text{if not driving} \end{cases}$$

Non-transportation consumption:

$$C_{ij} = \begin{cases} (1-\tau_i) y_i - D & \text{if driving} \\ (1-\tau_i) y_i & \text{if not driving} \end{cases}$$

D = fixed cost of driving

Utilities from driving/not driving

$$V_{ij}^{D} = \alpha \ln \left[(1-\tau_i)y_i - D\right] + (1-\alpha) \ln \left(\frac{\eta_j X}{z_i L_i}\right)$$

$$V_{ij}^{ND} = \alpha \ln \left[(1-\tau_i)y_i\right] + (1-\alpha)\lambda \ln \left(\tau_i y_i L_i\right)$$

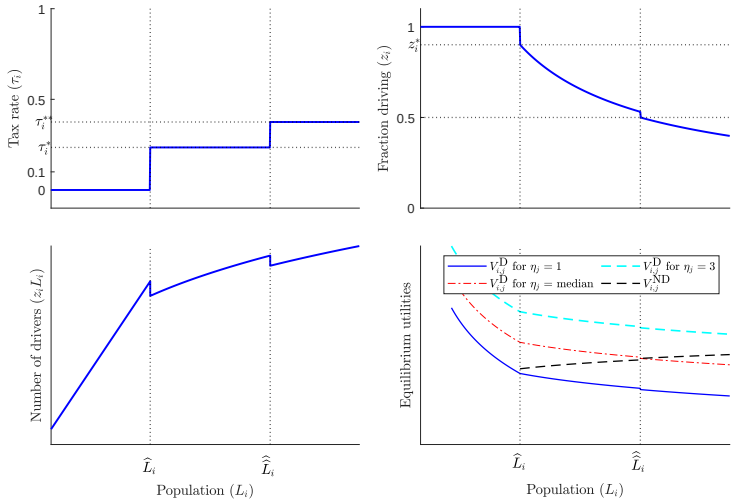
Equilibrium definition:

- Agents choose to drive or not drive
- Median voter sets τ_i

Equilibrium outcomes

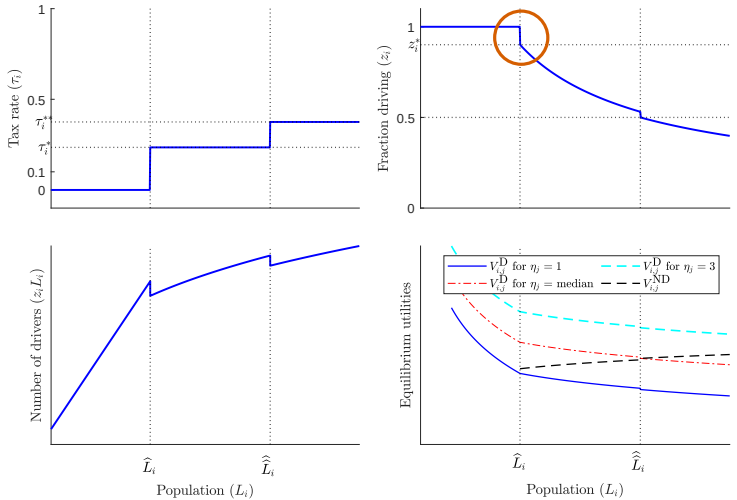
- If $L_i < \widehat{L}_i$
  - $z_i = 1$ and $\tau_i = 0$
  - $V_{ij}^D > V_{ij}^{ND}$: all drive, no funding for public transit
- If $\widehat{L}_i < L_i < \widehat{\widehat{L}}_i$
  - $1/2 < z_i < 1$, $\tau_i = \tau_i^* > 0$
  - $V_{ij}^D = V_{ij}^{ND}$ for some j: some do not drive, but median voter does; some public transit funding to ease congestion
- If $L_i > \widehat{\widehat{L}}_i$
  - $z_i < 1/2$ and $\tau_i = \tau_i^{**} > \tau_i^*$: median voter uses public transit

Quantitative illustration

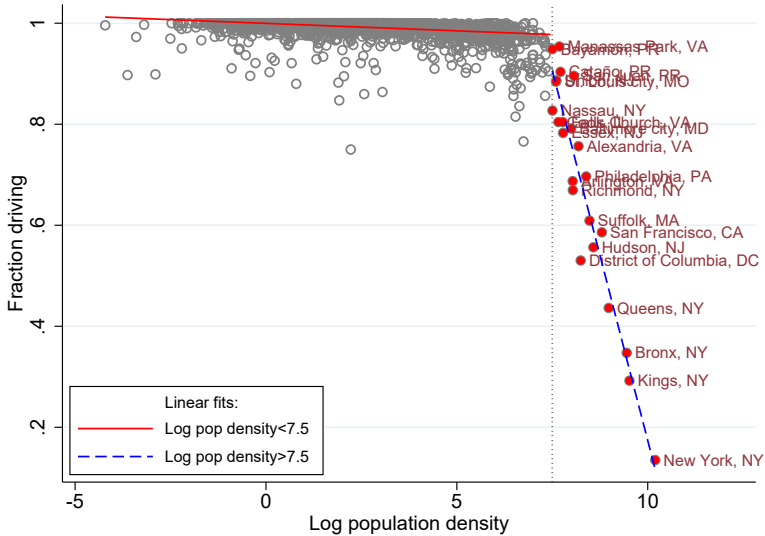


Quantitative illustration

Note kink/jump for z_i at $\widehat{L}_i$

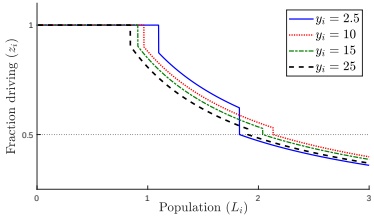


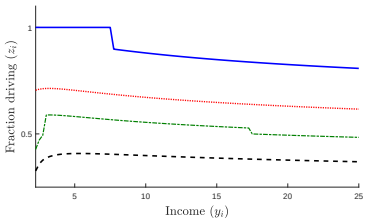
Comparing to data on fraction drivers (non-logged)

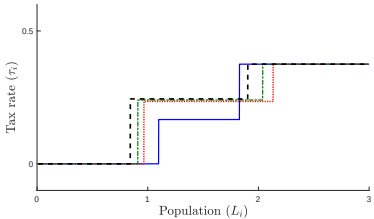


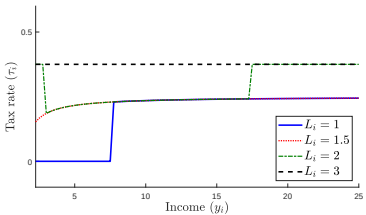
Varying incomes and population: examples

Smaller effects when varying per-capita incomes compared to pop. densities









Regressions on simulated data

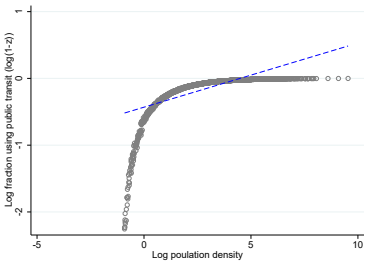
Simulate data with per-capita incomes and pop. densities as in data; run regressions on simulated data

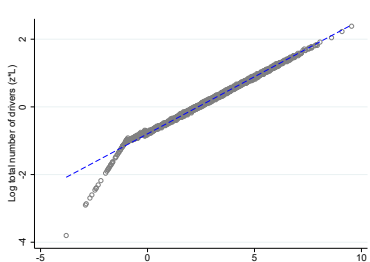
	Dependent variable is:					
	Log fraction using public transit ($\ln[1 - z_i]$)		Log total number of drivers ($\ln[z_i L_i]$)		Tax rate ($100 \times \tau_i$)	
	(1)	(2)	(3)	(4)	(5)	(6)
Log poulation density	0.093^{***}	0.093^{***}	0.335^{***}	0.338^{***}	0.125^{***}	0.124^{***}
	(0.003)	(0.003)	(0.002)	(0.002)	(0.010)	(0.010)
Log income per capita		0.005		-0.106^{***}		0.044
		(0.014)		(0.005)		(0.041)
R^2	0.49	0.49	0.99	0.99	0.20	0.20
Number of obs.	2949	2949	3000	3000	3000	3000
Standard errors	Robust	Robust	Robust	Robust	Robust	Robust

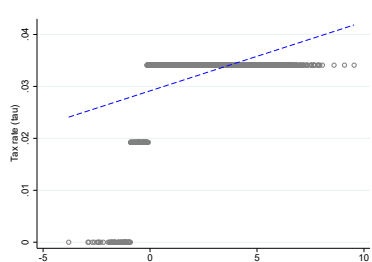
Notes: Ordinary least squares regressions. Robust standard errors are indicated in parentheses. * indicates $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

Plotting simulated data

Plots based on simulated data







Conclusion

- Some patterns across U.S. counties, states, cities
- High population density is associated with:
  - Less driving per capita
  - More traffic congestion
  - Higher tax rates
- Correlations with per-capita incomes less consistent
- Drivers $>$ 50% almost everywhere
- Proposed model qualitatively consistent with the facts