

# **The Fundamental Law of Highway Congestion: Evidence from the US**

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<http://www.pse.ens.fr/axes/convmedad.html>

## **Objective**

- Assess the effects of transportation infrastructure, roads and public transit in particular, on the total vehicle kilometers travelled.

## Main results

- The ‘fundamental law of highway congestion’ (Downs, 1962, 1992):  
Elasticity of highway VKT to highway lane kilometers is close to one.
- Because more highways lead to:
  - More individual driving.
  - Relocations.
  - More commercial driving.
- The demand for highway VKT is flat.

## **Transportation is important #1**

Very significant resources allocated to personal transportation:

- American household were spending 162 person minutes in passenger vehicles in 2001
- 10% increase since 1995

## **Transportation is important #2**

Numerous claims by advocacy groups:

- *American Road and Transport Builders Association* “adding highway capacity is key to helping to reduce traffic congestion”.
- *American Public Transit Association* “without new investment in public transit, highways will become so congested that they will no longer work”.

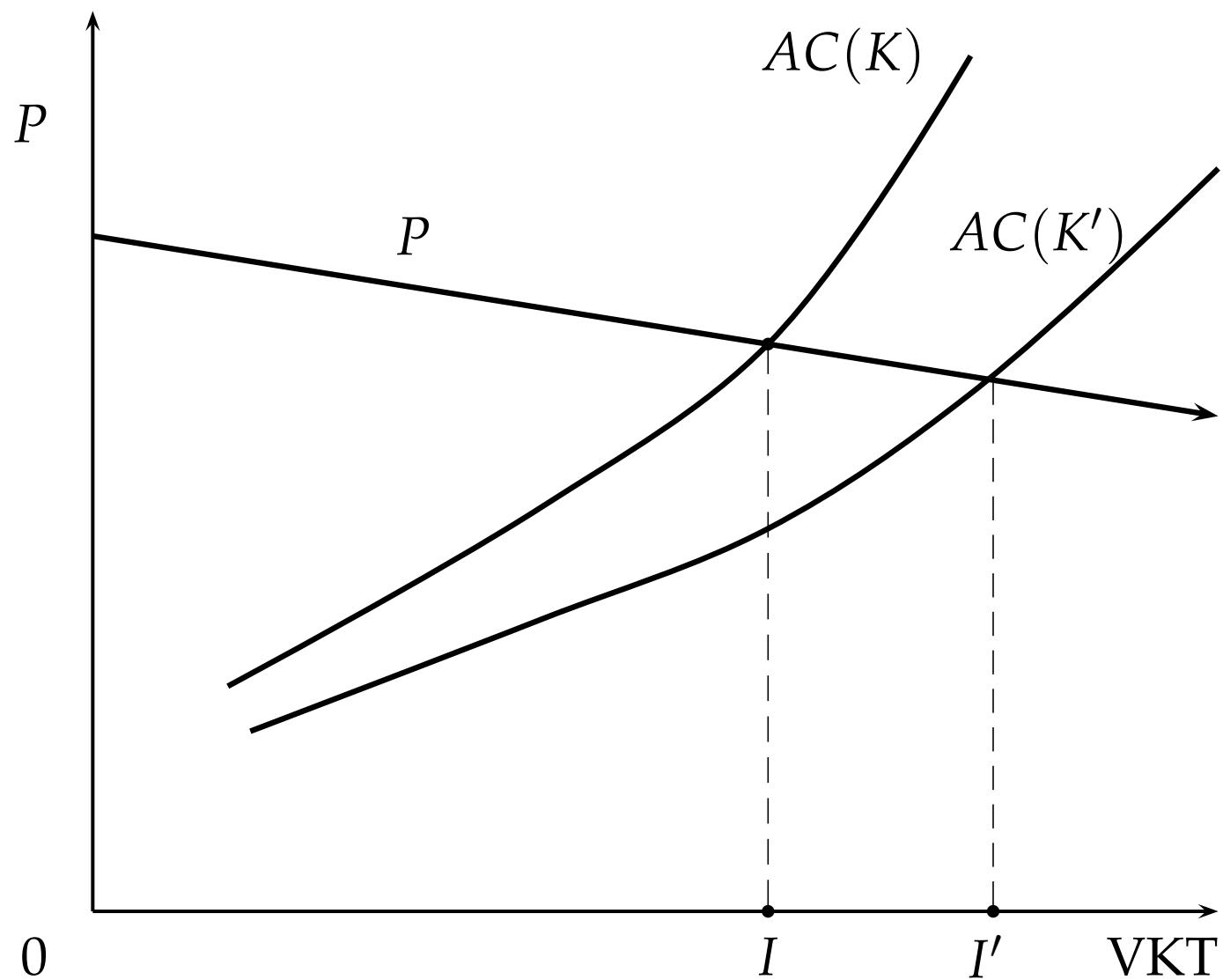
## **Transportation is important #3**

Road transport is a major source of carbon emission. The effects of changes in the road infrastructure need to be assessed in this light.

## Related literature

- Long tradition of analysis at the facility level (Jorgensen, 1947)
- Some work at the area level (Hansen and Huang, 1997, Fulton, Noland, Meszler, and Thomas, 2000, Noland, 2001, Cervero and Hansen, 2002, Cervero, 2003)
- Existing analysis at the area level differ in their findings and face three problems:
  - Data: coverage and resolution
  - Identification
  - Interpretation and welfare

# Theory



**Figure 1.** Equilibrium VKT.

- Determined at the city level
- $AC(\cdot)$  is an upward-sloping supply curve
- Shifts to the right with higher capacities
- Demand has 3 main components
- Equilibrium likely to be suboptimal
- Objective: estimate  $\rho_K^I$
- Meaning of a unitary elasticity

## **Traffic in US MSAs**

**Table 1.** Summary statistics for our main HPMS variables (averaged over MSAs).

Year:	1983	1993	2003
Mean daily VKT (highways,'000 km)	5,020 (10,705)	8,093 (16,229)	10,745 (20,709)
Mean daily VKT (all major roads,'000 km)		11,644 (25,091)	15,531 (32,156)
Mean AADT (highways)	4,828 (2,699)	7,194 (3,386)	9,409 (4,080)
Mean AADT (all major roads)		6,048 (2,801)	7,805 (3,537)
Mean lane km (highways)	744 (1,066)	829 (1,160)	871 (1,220)
Mean lane km (all major roads)		1,387 (1,931)	1,465 (2,023)
Mean lane km (highways, per 10,000 pop)	17.6 (15.4)	17.1 (13.3)	15.6 (11.8)
Mean lane km (all major roads, per 10,000 pop)		29.1 (21.4)	26.9 (19.1)
Number MSAs	228	228	228

## **The elasticity of VKT to lane kilometers**

**Table 2.** Interstate and Major Road VKT as a function of lane kilometers, OLS.

Year:	Interstate VKT												Major Road VKT	
	1983	1983	1983	1983	1993	1993	1993	1993	2003	2003	2003	2003	1993	2003
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
ln(lane km)	1.26 <sup>a</sup> (0.04)	0.91 <sup>a</sup> (0.06)	0.92 <sup>a</sup> (0.06)	0.89 <sup>a</sup> (0.06)	1.27 <sup>a</sup> (0.02)	0.67 <sup>a</sup> (0.05)	0.71 <sup>a</sup> (0.04)	0.70 <sup>a</sup> (0.04)	1.24 <sup>a</sup> (0.02)	0.64 <sup>a</sup> (0.05)	0.69 <sup>a</sup> (0.04)	0.70 <sup>a</sup> (0.04)	0.58 <sup>a</sup> (0.05)	0.54 <sup>a</sup> (0.05)
ln(pop)		0.44 <sup>a</sup> (0.04)	0.43 <sup>a</sup> (0.05)	1.03 <sup>a</sup> (0.37)		0.58 <sup>a</sup> (0.04)	0.54 <sup>a</sup> (0.04)	0.50 <sup>b</sup> (0.25)		0.57 <sup>a</sup> (0.04)	0.52 <sup>a</sup> (0.04)	0.45 (0.32)	1.04 <sup>a</sup> (0.22)	0.49 (0.34)
Elev. range			-0.055 (0.06)	-0.074 (0.05)			-0.037 (0.05)	-0.046 (0.05)			-0.027 (0.05)	-0.026 (0.05)	-0.040 (0.04)	-0.034 (0.04)
Ruggedness		6.25 <sup>c</sup> (3.38)	4.65 (3.18)			6.29 <sup>b</sup> (2.78)	4.09 (2.95)			5.43 <sup>c</sup> (2.78)	2.95 (3.02)	2.96 (2.41)	1.46 (2.75)	
Heating d.d.			-0.013 <sup>a</sup> (0.00)	-0.014 <sup>a</sup> (0.00)			-0.012 <sup>a</sup> (0.00)	-0.013 <sup>a</sup> (0.00)			-0.012 <sup>a</sup> (0.00)	-0.014 <sup>a</sup> (0.00)	-0.013 <sup>a</sup> (0.00)	-0.014 <sup>a</sup> (0.00)
Cooling d.d.			-0.017 <sup>c</sup> (0.01)	-0.026 <sup>b</sup> (0.01)			-0.019 <sup>a</sup> (0.01)	-0.024 <sup>b</sup> (0.01)			-0.021 <sup>a</sup> (0.01)	-0.024 <sup>a</sup> (0.01)	-0.025 <sup>a</sup> (0.01)	-0.024 <sup>a</sup> (0.01)
Sprawl		0.0059 <sup>c</sup> (0.00)	0.0063 <sup>c</sup> (0.00)			0.0035 (0.00)	0.0025 (0.00)			0.0022 (0.00)	0.0018 (0.00)	0.0042 <sup>c</sup> (0.00)	0.0027 (0.00)	
Census div.		Y	Y			Y	Y			Y	Y	Y	Y	
Hist. pop.			Y				Y				Y	Y	Y	
Socio-econ. char.			Y				Y				Y	Y	Y	
<i>R</i> <sup>2</sup>	0.86	0.92	0.94	0.94	0.86	0.94	0.95	0.96	0.87	0.94	0.96	0.96	0.97	0.97

All regressions include a constant. Robust standard errors in parentheses.

228 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

**Table 3.** Change in Interstate and Major Road VKT as a function of change in lane kilometers, OLS.

Period:	Interstate VKT										Major Road VKT	
	$\Delta_{93/83}$	$\Delta_{93/83}$	$\Delta_{93/83}$	$\Delta_{93/83}$	$\Delta_{93/83}$	$\Delta_{03/93}$	$\Delta_{03/93}$	$\Delta_{03/93}$	$\Delta_{03/93}$	$\Delta_{03/93}$	$\Delta_{03/93}$	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
$\Delta_{93/83} \ln(\text{lane km})$	1.09 <sup>a</sup> (0.06)	1.03 <sup>a</sup> (0.05)	1.09 <sup>a</sup> (0.06)	1.08 <sup>a</sup> (0.06)	0.85 <sup>a</sup> (0.08)							
$\Delta_{90/80} \ln(\text{pop})$	0.42 <sup>b</sup> (0.18)	0.51 <sup>a</sup> (0.16)	0.61 <sup>b</sup> (0.24)	0.71 <sup>b</sup> (0.30)	0.94 <sup>a</sup> (0.30)							
$\ln(\text{VKT 1983})$		-0.054 <sup>a</sup> (0.02)			-0.20 <sup>a</sup> (0.05)							
$\Delta_{03/93} \ln(\text{lane km})$					0.84 <sup>a</sup> (0.13)	0.79 <sup>a</sup> (0.13)	0.81 <sup>a</sup> (0.13)	0.80 <sup>a</sup> (0.13)	0.79 <sup>a</sup> (0.12)			
$\Delta_{00/90} \ln(\text{pop})$					0.35 <sup>a</sup> (0.10)	0.39 <sup>a</sup> (0.10)	0.32 <sup>b</sup> (0.14)	0.45 <sup>b</sup> (0.20)	0.46 <sup>b</sup> (0.20)	0.46 <sup>a</sup> (0.08)	0.46 <sup>a</sup> (0.17)	
$\ln(\text{VKT 1993})$						-0.026 <sup>a</sup> (0.01)			-0.036 (0.03)			
$\Delta_{03/93} \ln(\text{lane km MR})$										0.71 <sup>a</sup> (0.10)	0.72 <sup>a</sup> (0.11)	
Geography	Y	Y	Y			Y	Y	Y	Y			Y
Census div.	Y	Y	Y			Y	Y	Y	Y			Y
Socio-econ. char.	Y	Y				Y	Y	Y	Y			Y
Hist. Pop.	Y	Y				Y	Y	Y	Y			Y
N	128	128	128	128	128	117	117	117	117	117	155	155
R <sup>2</sup>	0.92	0.93	0.94	0.95	0.96	0.60	0.64	0.67	0.73	0.74	0.48	0.58

All regressions include a constant. Robust standard errors in parentheses.

*a, b, c*: significant at 1%, 5%, 10%

## Possible simultaneity of lane kilometers and VKT

Estimate:

$$\ln(I_i) = A_0 + \rho_K^I \widehat{\ln(K_i)} + A_2 X_i + \epsilon_i \quad (1)$$

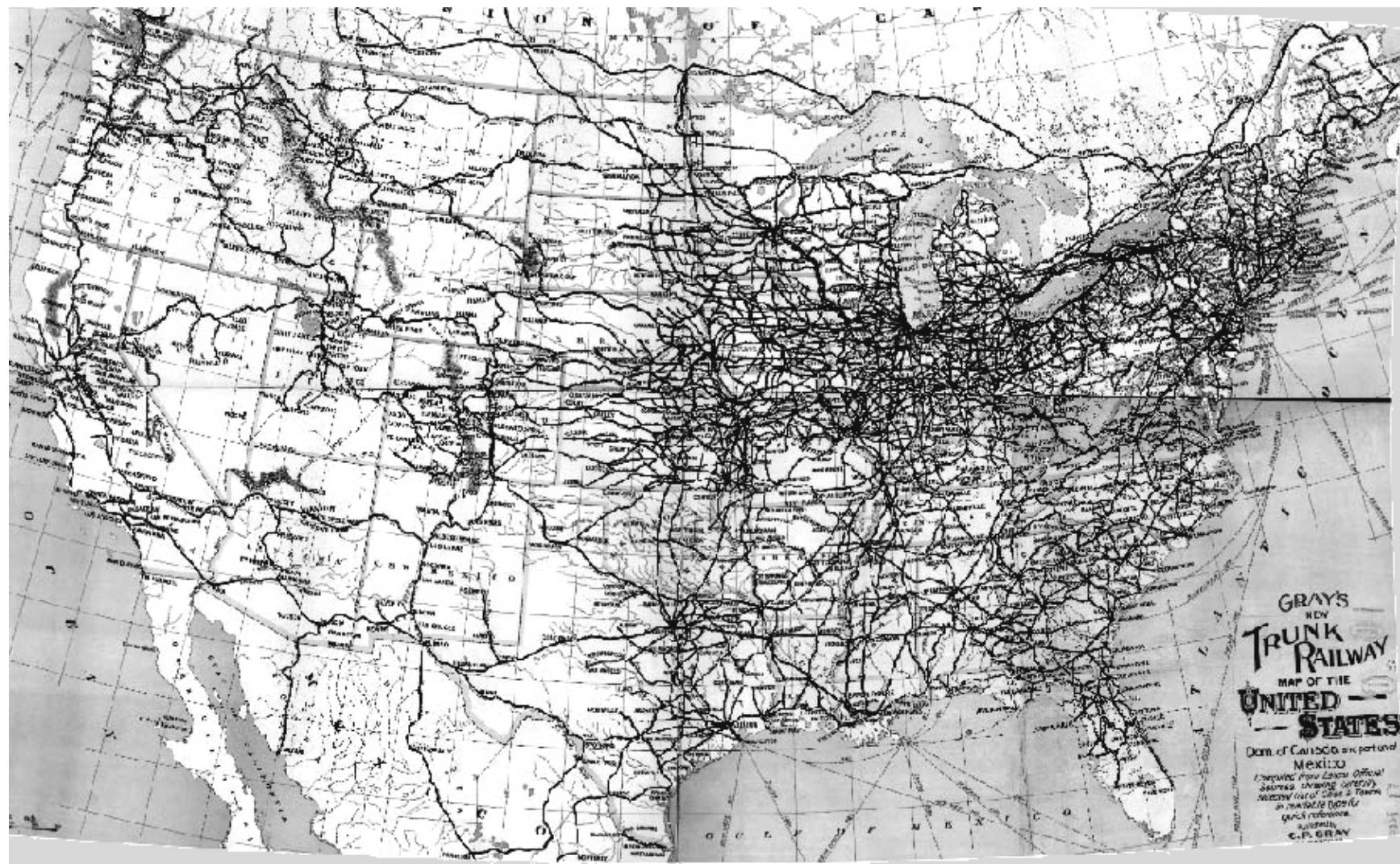
$$\ln(K_i) = B_0 + B_1 X_i + B_2 Z_i + \mu_i. \quad (2)$$

where  $Z = \{\log \text{ km of 1947 planned interstate highways, } \log \text{ km of 1898 railroads}\}$



**NATIONAL SYSTEM OF INTERSTATE HIGHWAYS**

SELECTED BY JOINT ACTION OF THE SEVERAL STATE HIGHWAY DEPARTMENTS  
AS MODIFIED AND APPROVED  
BY THE ADMINISTRATOR, FEDERAL WORKS AGENCY  
AUGUST 2, 1947



## **Relevance**

Old railroads and planned interstates predict contemporaneous  
interstates (Duranton and Turner, 2008)

**Table 4.** First stage: Interstate and Major Road km as a function of 1947 highway and 1898 rail, OLS.

Year:	Interstate												Major Road	
	VKT						VKT						1993	2003
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
ln(1898 rail)	0.21 <sup>b</sup> (0.09)	0.063 (0.05)	0.077 (0.06)	0.082 (0.07)	0.23 <sup>b</sup> (0.10)	0.067 <sup>c</sup> (0.04)	0.060 (0.04)	0.075 (0.06)	0.23 <sup>b</sup> (0.10)	0.085 <sup>b</sup> (0.04)	0.068 (0.04)	0.072 (0.06)	0.065 (0.04)	0.063 (0.05)
ln(1947 hwy)	0.30 <sup>a</sup> (0.04)	0.20 <sup>a</sup> (0.04)	0.16 <sup>a</sup> (0.04)	0.16 <sup>a</sup> (0.04)	0.29 <sup>a</sup> (0.04)	0.14 <sup>a</sup> (0.03)	0.11 <sup>a</sup> (0.03)	0.11 <sup>a</sup> (0.03)	0.29 <sup>a</sup> (0.04)	0.14 <sup>a</sup> (0.03)	0.12 <sup>a</sup> (0.03)	0.15 <sup>a</sup> (0.03)	0.054 <sup>a</sup> (0.03)	0.061 <sup>a</sup> (0.02)
ln(pop)	0.45 <sup>a</sup> (0.05)	0.55 <sup>a</sup> (0.05)	1.34 <sup>a</sup> (0.44)			0.55 <sup>a</sup> (0.03)	0.64 <sup>a</sup> (0.04)	0.14 (0.41)		0.55 <sup>a</sup> (0.03)	0.62 <sup>a</sup> (0.04)	0.17 (0.64)	0.35 (0.35)	-0.30 (0.60)
Geography	Y	Y				Y	Y			Y	Y	Y	Y	
Census div.	Y	Y				Y	Y			Y	Y	Y	Y	
Hist. pop.		Y					Y				Y	Y	Y	
<i>R</i> <sup>2</sup>	0.42	0.59	0.66	0.66	0.48	0.78	0.80	0.81	0.49	0.79	0.81	0.82	0.87	0.87
Partial <i>R</i> <sup>2</sup>	0.42	0.17	0.14	0.13	0.48	0.21	0.14	0.14	0.49	0.23	0.17	0.15	0.08	0.09
First-stage <i>F</i>	38.8	16.3	11.6	10.3	52.3	19.6	12.4	12.2	55.1	21.7	14.7	13.5	8.0	8.0

All regressions include a constant. Robust standard errors in parentheses.

228 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

## Exogeneity of planned interstates

- The 1947 Interstate plan was drawn:
  - To accommodate traffic *between* cities (and not within)...
  - ... for post-war America (and not forward-looking).
- Planned interstate km were proportional to 1947 population.
- Other city correlates at the origin of the 1947 plan that may drive contemporaneous traffic?  
Appropriate controls needed: geography and historical population

## **Exogeneity of old railroads**

- 19th century railroads were built:
  - In a very different economy,
  - For ‘short-run’ profit.
- Controls also matter

Two instruments with a different rationale allow for meaningful overidentification tests.

**Table 5.** Interstate and Major Road VKT as a function of lane kilometers, TSLS.

Year:	Interstate												Major Road	
				VKT						VKT			1993	2003
	1983 [1]	1983 [2]	1983 [3]	1983 [4]	1993 [5]	1993 [6]	1993 [7]	1993 [8]	2003 [9]	2003 [10]	2003 [11]	2003 [12]	[13]	[14]
ln(lane km)	1.41 <sup>a</sup> (0.04)	1.10 <sup>a</sup> (0.10)	1.20 <sup>a</sup> (0.12)	1.22 <sup>a</sup> (0.13)	1.35 <sup>a</sup> (0.05)	0.99 <sup>a</sup> (0.14)	1.16 <sup>a</sup> (0.18)	1.15 <sup>a</sup> (0.17)	1.27 <sup>a</sup> (0.05)	0.83 <sup>a</sup> (0.11)	0.95 <sup>a</sup> (0.13)	0.99 <sup>a</sup> (0.13)	1.07 <sup>a</sup> (0.23)	0.96 <sup>a</sup> (0.21)
ln(pop)	0.32 <sup>a</sup> (0.07)	0.22 <sup>b</sup> (0.10)	0.60 (0.44)		0.35 <sup>a</sup> (0.10)	0.19 (0.14)	0.31 (0.36)		0.44 <sup>a</sup> (0.08)	0.32 <sup>a</sup> (0.10)	0.42 (0.38)	0.73 <sup>b</sup> (0.30)	0.75 (0.47)	
Elev. range		-0.072 (0.07)	-0.088 (0.07)			-0.014 (0.07)	-0.030 (0.06)			-0.0081 (0.05)	-0.017 (0.05)	-0.085 (0.06)	-0.088 <sup>c</sup> (0.05)	
Ruggedness	7.92 <sup>c</sup> (4.12)	6.89 <sup>c</sup> (3.99)			7.07 <sup>c</sup> (3.79)	4.57 (3.55)			5.76 <sup>c</sup> (3.27)	3.35 (3.31)	7.22 <sup>b</sup> (3.67)	5.58 (3.55)		
Heating d.d.	-0.017 <sup>a</sup> (0.01)	-0.018 <sup>a</sup> (0.01)			-0.016 <sup>a</sup> (0.00)	-0.017 <sup>a</sup> (0.00)			-0.014 <sup>a</sup> (0.00)	-0.016 <sup>a</sup> (0.00)	-0.019 <sup>a</sup> (0.00)	-0.018 <sup>a</sup> (0.00)		
Cooling d.d.	-0.025 <sup>b</sup> (0.01)	-0.033 <sup>b</sup> (0.01)			-0.022 <sup>b</sup> (0.01)	-0.031 <sup>a</sup> (0.01)			-0.021 <sup>b</sup> (0.01)	-0.030 <sup>a</sup> (0.01)	-0.036 <sup>a</sup> (0.01)	-0.035 <sup>a</sup> (0.01)		
Sprawl	0.000720 (0.00)	0.00074 (0.00)			-0.0015 (0.00)	-0.0016 (0.00)			-0.00030 (0.00)	-0.00089 (0.00)	-0.00087 (0.00)	-0.0017 (0.00)		
Census div. Hist. pop.	Y	Y Y			Y	Y Y			Y	Y Y	Y	Y Y		
Overid	0.64	0.079	0.31	0.35	0.95	0.46	0.92	0.80	0.80	0.35	0.92	0.83	0.62	0.81
First stage F	38.8	16.3	11.6	10.3	52.3	19.6	12.4	12.2	55.1	21.7	14.7	13.5	8.03	7.98

All regressions include a constant. Robust standard errors in parentheses.

228 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Instruments are ln(1947 planned interstate km) and ln(1898 railroad km).

**Where does all the traffic come from?**

**Table 6.** Summary statistics for our main NPTS variables (averaged over individuals or hh).

Year:	1995	2001
<b>NPTS vehicle survey</b>		
Mean vehicle km (person)	12,435 (7,737)	12,202 (8,398)
Mean vehicle km (HH)	32,546 (19,672)	30,352 (20,198)
Mean vehicle km (vehicle)	19,560 (9,355)	17,573 (9,030)
<b>NPTS person survey</b>		
Minutes drive to work	22.4 (17.3)	21.3 (16.3)
Distance to work (km)	20.4 (21.6)	19.4 (20.2)
Speed to work	50.9 (21.1)	49.6 (22.1)
<b>NPTS trip survey</b>		
Total HH km	134.8 (119.9)	134.5 (160.9)
Total HH minutes	147.7 (132.7)	160.9 (133.9)
Mean HH km/h	48.4 (12.2)	43.9 (15.1)
Number MSAs	228	228

**Table 7.** Individual travel as a function of lane kilometers, OLS.

	Commute Distance			HH Daily VKT			HH Annual VKT		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
<b>1995:</b>									
ln(lane km 1995)	0.063 <sup>a</sup> (0.02)	0.072 <sup>a</sup> (0.02)	0.043 <sup>c</sup> (0.02)	0.24 <sup>a</sup> (0.07)	0.25 <sup>a</sup> (0.08)	0.16 <sup>a</sup> (0.03)	0.48 <sup>a</sup> (0.11)	0.39 <sup>a</sup> (0.10)	0.24 <sup>a</sup> (0.05)
ln(Pop. 1990)	0.045 <sup>a</sup> (0.02)	0.021 (0.02)	0.38 <sup>b</sup> (0.16)	-0.14 <sup>b</sup> (0.06)	-0.16 <sup>a</sup> (0.06)	0.39 (0.24)	-0.36 <sup>a</sup> (0.09)	-0.31 <sup>a</sup> (0.08)	0.46 (0.32)
N	18439	18233	18233	29352	27491	27491	31066	24519	24519
R <sup>2</sup>	0.03	0.08	0.08	0.02	0.23	0.25	0.01	0.39	0.40
<b>2001:</b>									
ln(lane km 2001)	0.10 <sup>a</sup> (0.03)	0.11 <sup>a</sup> (0.03)	0.079 <sup>a</sup> (0.02)	0.018 (0.04)	0.045 (0.03)	0.042 (0.03)	-0.00054 (0.05)	0.025 (0.03)	0.030 (0.03)
ln(Pop. 2000)	0.011 (0.02)	-0.011 (0.02)	0.13 (0.09)	-0.0018 (0.03)	-0.039 (0.03)	0.19 (0.12)	-0.063 (0.04)	-0.064 <sup>b</sup> (0.03)	0.072 (0.14)
N	36845	34243	34243	43707	39032	39032	46814	41777	41777
R <sup>2</sup>	0.04	0.08	0.09	0.00	0.25	0.26	0.01	0.39	0.39
<b>Other controls:</b>									
Sample demographics	Y	Y		Y	Y		Y	Y	
Geography		Y			Y			Y	
Census div.		Y			Y			Y	
Hist. Pop.		Y			Y			Y	

All regressions include a constant. Standard errors in parentheses, clustered by MSA.

*a, b, c:* significant at 1%, 5%, 10%.

**Table 8.** Changes in VKT, roads, and traffic as a function of their initial level, OLS.

	Change in VKT			Change in lane km			Change in daily traffic		
Period:	83-93	93-03	93-03	83-93	93-03	93-03	83-93	93-03	93-03
Roads:	I [1]	I [2]	MR [3]	I [4]	I [5]	MR [6]	I [7]	I [8]	MR [9]
Initial level	-0.15 <sup>a</sup> (0.06)	-0.020 <sup>a</sup> (0.01)	-0.0054 (0.01)	-0.19 <sup>b</sup> (0.09)	0.0064 (0.01)	0.0033 (0.01)	-0.14 <sup>a</sup> (0.03)	-0.08 <sup>b</sup> (0.04)	-0.02 (0.01)
<i>R</i> <sup>2</sup>	0.19	0.07	0.01	0.16	0.00	0.00	0.21	0.04	0.04

I denotes Interstates and MR all major roads.

All regressions include a constant. Robust standard errors in parentheses.

228 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

**Table 9.** Conditional convergence in daily traffic.

	Change in daily traffic								
Period:	83-93	93-03	93-03	83-93	93-03	93-03	83-93	93-03	93-03
Roads:	I	I	MR	I	I	MR	I	I	MR
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
	OLS	OLS	OLS	OLS	OLS	OLS	TSLS	TSLS	TSLS
Initial level	-0.15 <sup>a</sup> (0.03)	-0.10 <sup>a</sup> (0.04)	-0.030 <sup>b</sup> (0.01)	-0.17 <sup>a</sup> (0.03)	-0.13 <sup>a</sup> (0.04)	-0.035 <sup>b</sup> (0.02)	-0.17 <sup>a</sup> (0.03)	-0.19 <sup>a</sup> (0.06)	-0.062 <sup>c</sup> (0.03)
$\Delta \ln(\text{pop})$	0.40 <sup>a</sup> (0.13)	0.74 <sup>a</sup> (0.18)	0.35 <sup>a</sup> (0.09)	0.58 <sup>a</sup> (0.16)	0.95 <sup>a</sup> (0.22)	0.43 <sup>a</sup> (0.11)	0.92 <sup>b</sup> (0.42)	2.44 <sup>b</sup> (1.21)	0.96 (0.60)
Geography				Y	Y	Y	Y	Y	Y
Census div.				Y	Y	Y	Y	Y	Y
Initial Share Manuf.				Y	Y	Y	Y	Y	Y
$R^2$	0.22	0.11	0.12	0.42	0.25	0.20	-	-	-
First stage F							28.7	10.0	6.4

I denotes Interstates and MR all major roads.

All regressions include a constant. Robust standard errors in parentheses.

228 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Instrument is expected population growth based on initial composition of economic activity.

**Table 10.** log MSA share of trucking and warehousing employment as a function of log lane kilometers.

	1983				1993				2003			
	OLS [1]	OLS [2]	OLS [3]	TSLS [4]	OLS [5]	OLS [6]	OLS [7]	TSLS [8]	OLS [9]	OLS [10]	OLS [11]	TSLS [12]
ln(lane km)	0.12 <sup>a</sup> (0.05)	0.12 <sup>b</sup> (0.05)	0.13 <sup>b</sup> (0.05)	0.16 (0.19)	0.25 <sup>a</sup> (0.08)	0.24 <sup>a</sup> (0.08)	0.20 <sup>b</sup> (0.09)	0.14 (0.25)	0.16 <sup>a</sup> (0.06)	0.14 <sup>b</sup> (0.06)	0.15 <sup>b</sup> (0.07)	0.24 (0.17)
ln(Pop.)	1.00 <sup>a</sup> (0.04)	1.02 <sup>a</sup> (0.05)	1.54 <sup>a</sup> (0.43)	1.50 <sup>a</sup> (0.43)	0.87 <sup>a</sup> (0.06)	0.89 <sup>a</sup> (0.08)	1.13 <sup>b</sup> (0.45)	1.18 <sup>a</sup> (0.44)	0.88 <sup>a</sup> (0.04)	0.91 <sup>a</sup> (0.06)	2.93 <sup>a</sup> (0.64)	2.93 <sup>a</sup> (0.60)
Geography	Y	Y	Y		Y	Y	Y		Y	Y	Y	
Census div.	Y	Y	Y		Y	Y	Y		Y	Y	Y	
Socio-econ. char.	Y	Y			Y	Y			Y	Y		
Hist. pop.	Y	Y			Y	Y			Y	Y		
R <sup>2</sup>	0.83	0.85	0.88	-	0.80	0.83	0.87	-	0.85	0.88	0.91	-
Overid				0.98				0.80			0.88	
First-stage F				10.2				11.7			12.6	

All regressions include a constant. Robust standard errors in parentheses.

228 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Instruments are ln(1947 planned interstate km) and ln(1898 railroad km).

**Table 11.** 2003 truck interstate VKT as a function of lane kilometers.

	OLS [1]	OLS [2]	OLS [3]	OLS [4]	TSLS [5]	TSLS [6]
ln(lane km)	1.19 <sup>a</sup> (0.05)	0.90 <sup>a</sup> (0.14)	0.91 <sup>a</sup> (0.16)	0.78 <sup>a</sup> (0.16)	1.54 <sup>a</sup> (0.30)	1.73 <sup>a</sup> (0.48)
ln(pop)		0.27 <sup>b</sup> (0.13)	0.26 <sup>c</sup> (0.15)	-0.88 (1.98)	-0.23 (0.26)	-0.89 (1.97)
$R^2$	0.76	0.77	0.81	0.85	-	-
Overid					0.71	0.49
First stage F					11.6	4.9

All regressions include a constant. Robust standard errors in parentheses.

86 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Instruments are ln(1947 planned interstate km) and ln(1898 railroad km).

**Will public transport help reduce VKT?**

**Table 12.** Interstate and Major road VKT as a function of lane kilometers and bus service.

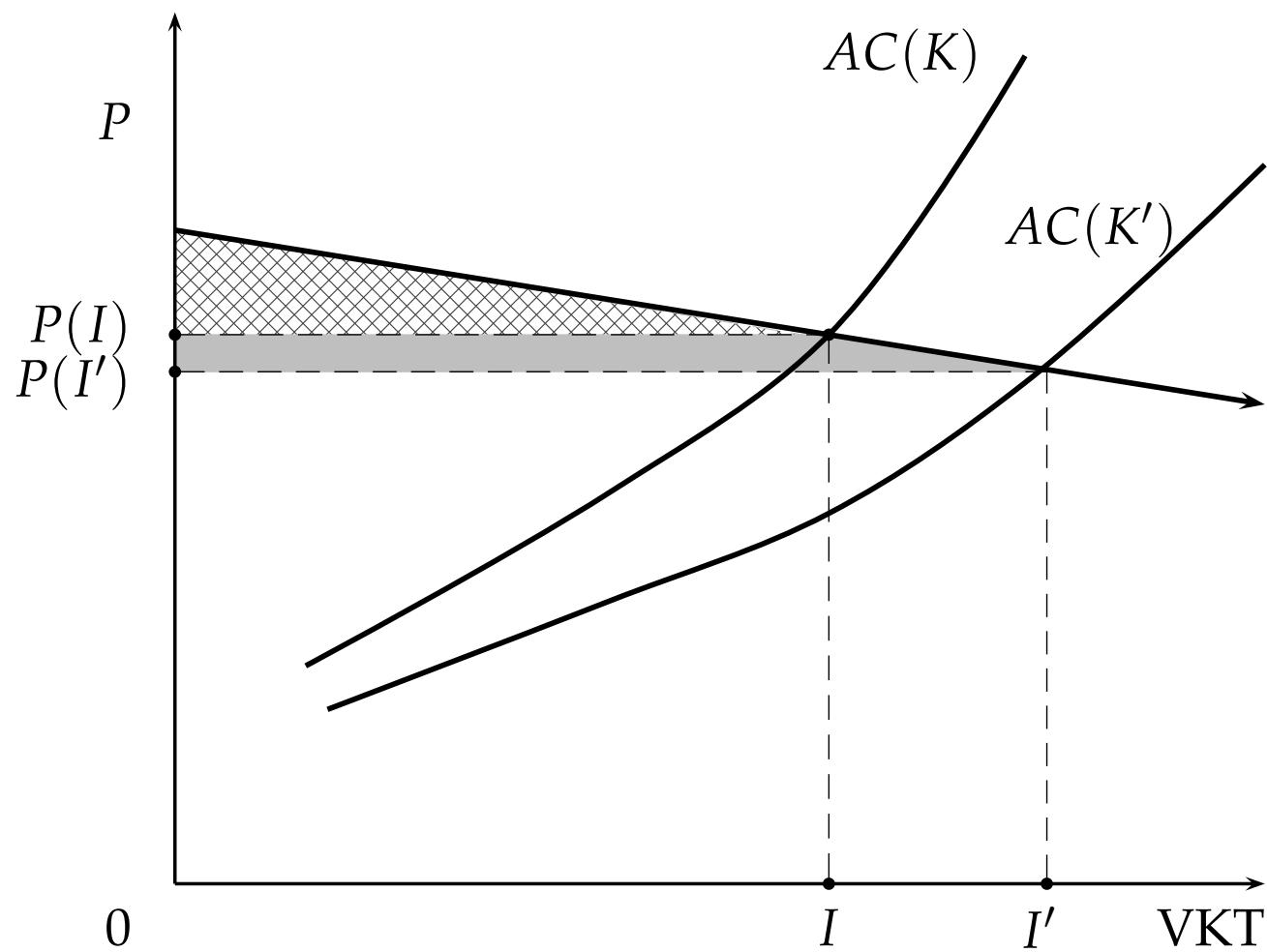
	1983				1993				2003			
	OLS [1]	OLS [2]	OLS [3]	LIML [4]	OLS [5]	OLS [6]	OLS [7]	LIML [8]	OLS [9]	OLS [10]	OLS [11]	LIML [12]
<b>Interstates:</b>												
ln(lane km)	0.91 <sup>a</sup> (0.06)	0.93 <sup>a</sup> (0.06)	0.90 <sup>a</sup> (0.06)	1.29 <sup>a</sup> (0.17)	0.67 <sup>a</sup> (0.05)	0.71 <sup>a</sup> (0.05)	0.72 <sup>a</sup> (0.04)	1.14 <sup>a</sup> (0.15)	0.64 <sup>a</sup> (0.05)	0.69 <sup>a</sup> (0.04)	0.70 <sup>a</sup> (0.04)	1.00 <sup>a</sup> (0.14)
ln(max bus)	-0.019 (0.02)	0.049 <sup>b</sup> (0.02)	0.053 <sup>b</sup> (0.03)	0.093 <sup>b</sup> (0.15)	-0.0079 (0.02)	0.033 <sup>c</sup> (0.02)	0.046 <sup>b</sup> (0.02)	0.17 <sup>c</sup> (0.10)	-0.038 <sup>c</sup> (0.02)	0.00017 (0.03)	0.022 (0.03)	0.16 (0.12)
ln(pop)		0.35 <sup>a</sup> (0.07)	1.03 <sup>a</sup> (0.36)	0.43 (0.53)		0.49 <sup>a</sup> (0.05)	0.43 <sup>c</sup> (0.25)	0.15 (0.39)		0.52 <sup>a</sup> (0.06)	0.41 (0.33)	0.15 (0.44)
R <sup>2</sup>	0.92	0.94	0.95	-	0.94	0.95	0.96	-	0.94	0.96	0.96	-
Overid				0.27				0.57				0.77
Kleibergen-Paap				5.41				4.18				4.82
<b>All Major Roads:</b>												
ln(lane km)					0.54 <sup>a</sup> (0.05)	0.58 <sup>a</sup> (0.05)	0.59 <sup>a</sup> (0.05)	1.11 <sup>a</sup> (0.22)	0.49 <sup>a</sup> (0.05)	0.53 <sup>a</sup> (0.05)	0.56 <sup>a</sup> (0.05)	1.03 <sup>a</sup> (0.23)
ln(max bus)					-0.011 (0.01)	0.013 (0.01)	0.015 (0.01)	0.086 (0.07)	-0.022 (0.02)	0.00044 (0.02)	0.0036 (0.02)	0.080 (0.09)
ln(pop)						0.50 <sup>a</sup> (0.05)	0.89 <sup>a</sup> (0.20)	0.49 <sup>c</sup> (0.39)		0.54 <sup>a</sup> (0.29)	0.52 (0.34)	0.66 (0.48)
R <sup>2</sup>					0.95	0.96	0.97	-	0.95	0.96	0.96	-
Overid								0.50				0.80
Kleibergen-Paap								4.24				9.02
<b>Other controls:</b>												
Geography	Y	Y	Y		Y	Y	Y		Y	Y	Y	
Census div.	Y	Y	Y		Y	Y	Y		Y	Y	Y	
Socio-econ. char.	Y				Y					Y		
Hist. pop.	Y	Y			Y	Y				Y	Y	

All regressions include a constant. Robust standard errors in parentheses.

228 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Instruments are ln(1947 planned interstate km), ln(1898 railroad km), and 1972 share democratic vote.

## **Welfare implications**



**Figure 2.** Second best surplus from change in VKT.

Assume:

- $K' = 1.01K$
- $\rho_K^{P(I)} = \frac{\partial \log P(I)}{\partial \log K}$

Then

- $I' \approx (1 + \rho_K^I / 100)I$
- $P(I') \approx \left(1 + \rho_K^{P(I)} / 100\right) P(I)$

Change in Welfare:

$$\begin{aligned}\Delta W_I &\approx \frac{I + I'}{2} \times [P(I) - P(I')] \\ &= - \left(1 + \frac{\rho_K^I}{200}\right) I \times \frac{\rho_K^{P(I)} P(I)}{100}.\end{aligned}$$

Using:  $\rho_K^{P(I)} = \rho_I^{P(I)} \times \rho_K^I$

Marginal highway welfare gain associated with an additional lane kilometer of highway:

$$\Delta w_I \approx -\rho_I^{P(I)} \rho_K^I P(I) \left(1 + \frac{\rho_K^I}{200}\right) \frac{I}{K}.$$

More highway km also affect driving on other roads:

$$\Delta w_O \approx -\rho_I^{P(O)} \rho_K^I P(O) \left(1 + \frac{\rho_K^O}{200}\right) \frac{O}{K},$$

Total marginal welfare gain from an additional lane kilometer of highway:  $\Delta w = \Delta w_I + \Delta w_O$ .

Too many terms cannot be estimated. But an upper bound for  $\Delta w$  is available:

- Assume  $\rho_K^I > \rho_K^O$
- From the data:  $O \approx 3 I$
- $\Rightarrow P(R) \approx [3P(O) + P(I)] / 4$
- $\Rightarrow \rho_I^{P(R)} \approx (3\rho_I^{P(O)} + \rho_I^{P(I)}) / 4$
- Assume  $P(O) > P(I)$
- Assume  $-\rho_I^{P(I)} > -\rho_I^{P(O)}$

$$\Delta w < \rho_K^I \frac{4I}{K} \left( 1 + \frac{\rho_K^I}{200} \right) P(R) \left( -\rho_I^{P(R)} \right).$$

With  $\rho_K^I = 1$ :

$$\Delta w < 4.02 \text{AADT} \times P(R) \left( -\rho_I^{P(R)} \right).$$

## Computing $P(R)$

Time-in-vehicle and vehicle-operating costs:

$$\rho_I^{P(R)} P(R) \equiv \rho_I^{TC(R)} TC(R) + \rho_I^{VOC(R)} VOC(R),$$

For  $TC(R)$ :

- Hours per kilometer for each MSA from NPTS
- MSA household income from census data
- Hours worked per household from the ATUS
- Adjustment factor of 50% and inflation to get 2008 figures
- Median MSA value:  $0.023 \text{ h/km} \times 20.20 \text{ \$/h}$  adjusted by 50% factor and inflation: \$ 0.26 per km

## **Vehicle operating costs**

Very small effects

**Table 13.** Time cost of traffic as a function of MSA VKT.

	Dependent variable: ln(hours per km) for commutes											
	[1] OLS	[2] OLS	[3] OLS	[4] OLS	[5] TSLS	[6] TSLS	[7] TSLS	[8] TSLS	[9] OLS	[10] OLS	[11] TSLS	[12] TSLS
<b>1995:</b>												
ln(I VKT)	-0.019 <sup>c</sup> (0.01)	-0.040 (0.03)	-0.047 <sup>c</sup> (0.03)	-0.081 <sup>a</sup> (0.03)	0.0032 (0.02)	0.0099 (0.05)	0.031 (0.05)	-0.0034 (0.06)				
ln(MR VKT)									-0.021 <sup>c</sup> (0.01)	-0.064 <sup>c</sup> (0.04)	0.0041 (0.02)	0.059 (0.10)
<i>R</i> <sup>2</sup>	0.04	0.19	0.24	0.33					0.04	0.24		
Overid					0.75 88.1	0.91 35.1	0.66 29.9	0.81 25.6			0.76 72.5	0.70 16.8
First-stage <i>F</i>												
<b>2001:</b>												
ln(I VKT)	-0.017 <sup>c</sup> (0.01)	-0.049 <sup>b</sup> (0.02)	-0.043 <sup>b</sup> (0.02)	-0.051 <sup>b</sup> (0.02)	-0.018 (0.01)	-0.080 <sup>b</sup> (0.04)	-0.041 (0.04)	-0.056 (0.05)				
ln(MR VKT)									-0.020 <sup>b</sup> (0.01)	-0.093 <sup>a</sup> (0.03)	-0.022 (0.02)	-0.084 (0.07)
<i>R</i> <sup>2</sup>	0.08	0.27	0.31	0.32					0.08	0.33		
Overid					0.17 88.0	0.045 32.0	0.32 26.2	0.24 24.6			0.19 72.2	0.40 15.2
First-stage <i>F</i>												
<b>Other controls:</b>												
Person charac.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Current pop.	Y	Y	Y		Y	Y	Y		Y	Y		Y
Geography	Y	Y	Y		Y	Y	Y			Y		Y
Census div.	Y	Y	Y		Y	Y	Y			Y		Y
Hist. pop.		Y	Y			Y	Y			Y		Y
Socio-econ. char.			Y				Y					

I denotes Interstates and MR all major roads.

All regressions include a constant. Robust standard errors in parentheses.

225 observations for 1995 and 227 for 2001. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Baseline value:  $\rho_I^{TC(R)} = -0.04$

## Calculations and highway costs

- MSA mean for the upper bound of  $\Delta w$ : \$ 152,000 per year
- Lowest values < \$30,000  
(Great Falls MT, Casper WY, Lawton OK)
- Highest values > \$400,000  
(Chicago, Miami, DC, San Francisco, West Palm Beach)

Costs:

- Maintenance: \$100,000 per lane km year (Duranton and Turner, 2008)
- Construction: between m\$ 3.64 and m\$ 11.96 per lane km depending on city size (Ng and Small, 2008)
- Cost of capital 5%
- Mean MSA annual cost: \$ 419,000

Sensitivity:

- With  $\rho_I^{TC(R)} = -0.08$ ,  
Upper bound  $\Delta w$  - costs = -116,000  
Only 30 MSAs with a positive difference
- With  $\rho_I^{TC(R)} = -0.12$ ,  
Upper bound  $\Delta w$  - costs  $\approx 0$

## Conclusions

- Fundamental law of traffic congestion:  $\rho_K^I \approx 1$
- Because more capacity leads to
  - More individual driving
  - In-migration
  - More commercial driving
- Public transportation provides no relief
- The demand for VKT is quite flat:

⇒ Congestion needs to be priced

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