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The Fundamental Law of Road Congestion: Evidence from US cities

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Appendix to:
The Fundamental Law of Road Congestion: Evidence from US cities

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1. Description of data

A. *Consistent* MSA *definitions*

For each MSA in our sample we calculate population at each decennial census over the period 1920-2000. Since MSAs are defined as aggregations of counties, constructing these population series requires tracking changes in county boundaries over time. We did this using 2000 MSA definitions.

B. HPMS DATA

We rely extensively on the Highway Performance Monitoring System (HPMS) data for 1983, 1993, and 2003, and slightly on the HPMS data for 1995 and 2001. These data are collected and maintained by the US Federal Highway Administration in cooperation with many sub-national government agencies. Documentation is available in United States Department of Transportation, Federal Highway Administration (2005), United States Department of Transportation, Federal Highway Administration (2003*a*) and United States Department of Transportation, Federal Highway Administration (2003*b*).

The HPMS consists of two parts. The *Universe data* is supplied for most road segments in the interstate highway system and some other major roads and provides a description of each segment. The *Sample data* provides additional information about all segments in the Universe data, including an urbanized area code for segments falling in urbanized areas. For a sample of smaller urbanized area roads, the Sample data also provides all data fields that occur in the Universe and Sample data.

In general, each segment reported in the HPMS represents a larger set of similar roads, called a sample. Thus, each reported segment is associated with an expansion factor which relates the length of the segment described in the data to the length of the sample it represents. Since states are required to report information on every interstate highway segment, all interstate highway segments should have an expansion factor of one. In fact, the average expansion factor for these segments is about 1.5, so that states seem not to be in compliance with reporting requirements.[1] For non-interstate segments, principally smaller classes of roads, reporting requirements permit expansion factors of up to 100. In fact, a small number of larger expansion factors occur but

[1] In an earlier version of this paper, we used only the universe data which, consistent with mandated reporting requirements, does not report expansion factors. In the current version, we use expansion factors present in the sample data to adjust interstate segment length. Consequently, our estimates of interstate lane kilometers and VKT are higher than in our earlier version.

we exclude these segments from our sample. For urbanized area roads in the relevant classes, reporting rules require that the union of all samples be the set of all urbanized area roads. Loosely, urbanized area road segments are partitioned into sets of similar segments, and one segment from each set is reported in the HPMS sample data. In this sense, Sample data represents all urbanized road segments subject to reporting requirements.

For the interstate highway system the HPMS records number of lanes, length, AADT, and county. By construction, road segments do not cross county borders. For segments in urbanized areas, the HPMS also provides an urbanized area code. Since MSAs are county based units, these data allow us to calculate VKT for the urbanized and non-urbanized area interstate systems by MSA.

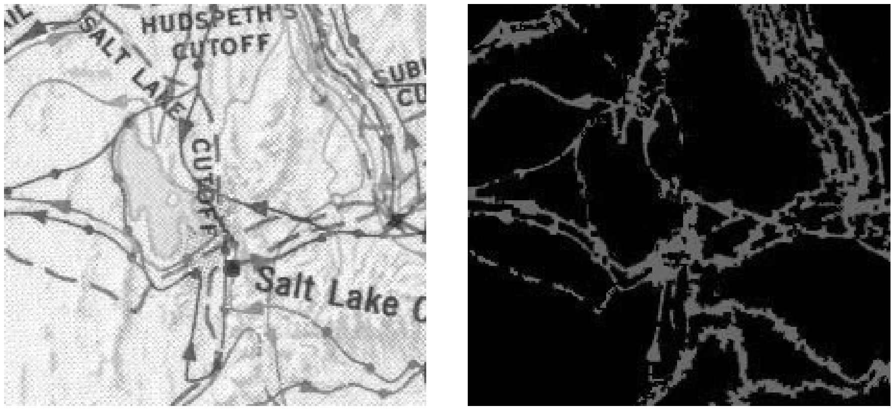
Within urbanized areas, the HPMS, not only describes the interstate highway system, but also all roads in the following functional classes: Principal arterial - Other freeways and expressways, Principal arterial - other, Minor arterial, Collector, Local. There is no mandated reporting of local roads, so they make up only a small share of the HPMS data and are excluded from our analysis. Our 'major roads' are defined as the union of the remaining classes. The definitions of these road classes are given in United States Department of Transportation, Federal Highway Administration (1989) and span about 20 pages. Loosely, a local road is one which is predominantly used to access addresses on that road, e.g., a residential street. Any road used principally to connect local roads (but not an interstate) falls in one of the larger classes that we consolidate into major roads.[2]

C. *Instruments*

Our measures of the 1947 interstate highway plan and the 1898 railroad network are taken from Duranton and Turner (2008) and are documented there. Further discussion of the 1947 highway plan is available in Michaels (2008) and Baum-Snow (2007).

While our exploration routes variable is new, Duranton and Turner (2008) experimented with a different formulation and found that it did not have much predictive ability. In this initial formulation of the exploration route data, we treated the exploration route map in exactly the same way as we did the 1947 highway plan and the 1898 railroad map. That is, all routes are treated in exactly the same way and receive exactly the same weight. In particular, this means that well used and important routes, such as the Oregon or Santa Fe trails, are given the same weight

[2] In an earlier version of this paper we used a different definition of major roads consistent with data on non-interstate roads available in the HPMS Universe data.



Appendix Figure 1: Right panel gives detail of original map of 1835-1850 exploration routes for a segment of the Oregon trail near Salt Lake City. Left panel shows incidence of exploration routes in same region. For this region, our measure of exploration routes is the count of grey pixels in the right panel.

as less successful routes. With this said, since the exploration routes map provides a line for each expedition it describes, even if this line is very close to the line for another expedition on the same route, the map does permit us to distinguish more intensively used routes from less. In particular, if we digitize the map and count all pixels assigned to any route, we have a measure of the intensity with which a region was used by explorers between 1835 and 1850. This is precisely what we did. Appendix figure 1 illustrates.

The share of the democratic vote in the 1972 presidential election is calculated from the General Election Data for the United States, 1950-1990, from the Inter-university Consortium for Political and Social Research (ICPSR).

D. *Geography*

Our data includes five measures describing the physical geography of an MSA taken from the data used by Burchfield, Overman, Puga, and Turner (2006). The particular measures of physical geography that we use are: elevation range within the MSA, the ruggedness of terrain in the MSA, heating degree days, and cooling degree days and 'sprawl' in 1992. Elevation range is the difference in meters between the elevation of the highest and lowest point in the MSA. Ruggedness is calculated by imposing a regular 90 meter grid on each MSA and calculating the mean difference in elevation between each cell and adjacent cells. Heating and cooling degree days are engineering measures used to assess the demand for heating and cooling. Sprawl is the measure of sprawl calculated in Burchfield *et al.* (2006) and measures the share of undeveloped land in the square kilometer surrounding an average structure. More detail about these variables is available in Burchfield *et al.* (2006) and at `http://diegopuga.org/data/sprawl/`.

E. *Employment*

To measure employment we use the County Business Patterns data from the US Census Bureau. These data are available annually from 1983 to 2003. We construct disaggregated employment data at the two digit-level (with 81 sectors) to investigate whether the supply of highways and other major roads affects the composition of economic activity and, in particular, employment in transportation-intensive sectors. Between 1983 and 2003, three different industrial classifications have been used in the US: the standard industrial classification (SIC) which remained unchanged at the two-digit level until 1997, the 1997 North American Industry Classification System (NAICS) from 1998 to 2002, and the 2002 NAICS for 2003. Using the same cross-walk as in Duranton and Turner (2008), we perform our employment regressions using SIC categories.

F. *Public transit infrastructure*

To comply with Section 15 of the Urban Mass Transportation Act, all public transit districts in the US submit annual reports to the federal government detailing their assets and activities over the course of the year. Our data for 1984 bus service comes from table 3.6, p3-308, of United States Department of Transportation, Urban Mass Transit Administration (September 1986). The section 15 reports are available in electronic form starting in 1984. While these reports do not assign transit districts to an MSA, they contain enough geographic information, e.g., zipcode, so that about 700 of the 740 transit districts that operate during 1984, 1994, or 2004 can be assigned to a non-MSA county or to an MSA.

With this correspondence constructed, we count all 'large buses' in each MSA at peak service for 1984. We use this daily average number of large buses operating at peak service in 1984 to measure an MSA's stock of public transit infrastructure. In our definition of large buses we include buses in the following Section 15 reporting classes: articulated bus; bus A (>35 seats); bus B (25-35 seats); bus C (<25 seats); double deck bus; motor bus; motor bus (private); street car; trolley bus.

G. ***Socio-economic characteristics:***

To measure MSA socio-economic characteristics, we use three data sources. The share of manufacturing employment is computed from the County Business Patterns for 1983, 1993, and 2003 to match the years of data for VKT and roadway. The 1980 segregation index is calculated from 1980 census tract level data and is based on the measure of housing segregation described in equation (3), p836 of Cutler and Glaeser (1997). Finally, the share of college educated workers, share of poor, and average earnings are computed using data from the 1980, 1990, and 2000 decennial censuses. From the education questions in these three censuses, we are able to build a consistent variable capturing the share of residents with some college education (or more) by MSA. The three censuses also contain a question about poverty which can be aggregated in the same way. Individual earnings are also aggregated in a similar fashion with the caveat that the bands and the top code differ across censuses.

2. Supplemental results

A. *Supplemental estimations providing direct evidence for the Fundamental Law of Road Congestion*

Appendix table 1 mirrors panel A of table 2 in the main text except that it uses only 192 MSAs instead of 228. These 192 MSAs are the same as those we use when running regressions using data for interstate highways and major roads in urbanized areas. The coefficients on lane kilometers are slightly below those of table 2 in the main text, but are still close to one.

Appendix table 2 is similar to table 2 in the main text, but restricts attention to OLS regressions and examines each decade separately. Panel A reports results for all interstate highways. Panels B, C, and D report results for the same regressions when using data for interstate highways in urbanized areas of MSAs, major roads in urbanized areas, and interstate highways within MSAs but outside urbanized areas. As for the results presented in the paper, in all specifications we find that the coefficient of the highway variable is positive, statistically different from zero, and close to one.

[t]

Appendix table 3 is similar to table 3 in the main text and reports results for regressions explaining changes in VKT with changes in lane kilometers of roads. However, unlike table 3 in the main

Appendix Table 1: VKT as a function of lane kilometers, pooled OLS, restricted sample.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Dependent variable: ln VKT for Interstate Highways, entire MSAs								
ln(IH lane km)	1.25[a]	0.72[a]	0.76[a]	0.76[a]	0.75[a]	0.96[a]	0.95[a]	0.94[a]
	(0.03)	(0.05)	(0.04)	(0.04)	(0.05)	(0.03)	(0.03)	(0.03)
ln(pop.)		0.54[a]	0.50[a]	0.51[a]	0.46[a]		0.32[a]	0.35[a]
		(0.04)	(0.04)	(0.04)	(0.12)		(0.11)	(0.11)
Elev. range			-0.030	-0.040	-0.025			
			(0.06)	(0.05)	(0.05)			
Ruggedness			5.64[c]	5.76[c]	4.20			
			(3.13)	(2.98)	(2.91)			
Heating d.d.			-0.013[a]	-0.014[a]	-0.015[a]			
			(0.00)	(0.00)	(0.00)			
Cooling d.d.			-0.016[b]	-0.017[c]	-0.019[c]			
			(0.01)	(0.01)	(0.01)			
Sprawl			0.0048	0.0052[c]	0.0033			
			(0.00)	(0.00)	(0.00)			
Census div.			Y	Y	Y			
Socio-econ. char.				Y	Y			Y
Hist. pop.					Y			
MSA fixed effects						Y	Y	Y
R^2	0.87	0.94	0.95	0.96	0.96	0.93	0.94	0.94

All regressions include a constant and year effects. Robust standard errors clustered by MSA in parentheses. 576 observations corresponding to 192 MSAs for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

text, appendix table 4 examines: interstate highways in urbanized areas of MSAs (panel A); major roads in urbanized areas (panel B); and interstate highways within MSAs but outside urbanized areas (panel C). Note that the boundaries of urbanized areas have changed over time so that the results here reflect both true changes in lane kilometers of roads and changes in boundaries. Coefficient estimates in this table are marginally lower than those presented in the main text, but still close to one.

Appendix table 4 is similar to table 3 in the main text, but examines the two cross-sections of first differences separately. This table reports results for six first difference specifications for the 1983-1993 period and six corresponding regressions for 1993-2003. Panel A reports results for all interstate highways. Panels B, C, and D report results for the same regressions when using data for interstate highways in urbanized areas of MSAs, major roads in urbanized areas, and interstate highways within MSAs but outside urbanized areas. These results are similar to those reported in table 3 of the main text. Recall that in panels B, C, and D, the boundaries of urbanized areas have changed over time and this may bias our estimates.

In appendix table 5, we perform a simple falsification exercise. We run the same six regressions as in columns 7-12 of appendix table 4 for changes in VKT between 1993 and 2003. In the first six columns we use changes in lane kilometers of interstate highways for 1983-1993 instead of (con-

Appendix Table 2: VKT as a function of lane kilometers, OLS by decade.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Year:	1983	1983	1983	1983	1993	1993	1993	1993	2003	2003	2003	2003
Panel A. Dependent variable: ln VKT for Interstate Highways, entire MSAs												
ln(IH lane km)	1.24^a	0.92^a	0.94^a	0.92^a	1.25^a	0.73^a	0.76^a	0.77^a	1.23^a	0.71^a	0.75^a	0.76^a
	(0.04)	(0.06)	(0.06)	(0.05)	(0.02)	(0.05)	(0.04)	(0.04)	(0.02)	(0.05)	(0.04)	(0.04)
ln(pop.)		0.43^a	0.42^a	1.01^a		0.54^a	0.51^a	0.46^c		0.53^a	0.49^a	0.39
		(0.04)	(0.05)	(0.37)		(0.04)	(0.04)	(0.25)		(0.04)	(0.04)	(0.35)
Elev. range			-0.057	-0.076			-0.027	-0.038			-0.026	-0.030
			(0.06)	(0.05)			(0.06)	(0.05)			(0.05)	(0.05)
Ruggedness			6.81^c	5.29			5.86^c	3.90			5.72^c	3.46
			(3.46)	(3.24)			(3.00)	(3.00)			(3.06)	(3.11)
Heating d.d.			-0.014^a	-0.015^a			-0.012^a	-0.013^a			-0.011^a	-0.013^a
			(0.00)	(0.01)			(0.00)	(0.00)			(0.00)	(0.00)
Cooling d.d.			-0.019^c	-0.027^b			-0.019^a	-0.022^b			-0.019^b	-0.020^b
			(0.01)	(0.01)			(0.01)	(0.01)			(0.01)	(0.01)
Sprawl			0.0059^c	0.0061^c			0.0033	0.0019			0.0021	0.0016
			(0.00)	(0.00)			(0.00)	(0.00)			(0.00)	(0.00)
Census div.			Y	Y			Y	Y			Y	Y
Hist. pop.				Y				Y				Y
Socio-econ. char.				Y				Y				Y
R^2	0.86	0.93	0.94	0.95	0.87	0.94	0.95	0.96	0.88	0.94	0.96	0.96
Panel B. Dependent variable: ln VKT for Interstate Highways, urbanized areas within MSAs												
ln(IHU lane km)	1.26^a	1.04^a	1.05^a	1.06^a	1.23^a	0.95^a	0.97^a	1.00^a	1.20^a	0.92^a	0.94^a	0.97^a
	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.04)	(0.02)	(0.03)	(0.03)	(0.04)
Panel C. Dependent variable: ln VKT for Major Roads, urbanized areas within MSAs												
ln(MRU lane km)	1.08^a	0.90^a	0.89^a	0.88^a	1.13^a	0.72^a	0.78^a	0.80^a	1.14^a	0.66^a	0.67^a	0.70^a
	(0.02)	(0.03)	(0.03)	(0.03)	(0.01)	(0.04)	(0.04)	(0.04)	(0.01)	(0.04)	(0.04)	(0.04)
Panel D. Dependent variable: ln VKT for Interstate Highways, outside urbanized areas within MSAs												
ln(IHNU lane km)	1.06^a	0.83^a	0.85^a	0.84^a	1.03^a	0.81^a	0.83^a	0.82^a	1.00^a	0.82^a	0.84^a	0.83^a
	(0.03)	(0.05)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)

The same regressions for different types of roads are performed in all four panels.
All regressions include a constant. Robust standard errors in parentheses.
228 observations for each regression in panel A and 192 in panels B-D. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Appendix Table 3: Changes in VKT as a function of changes in lane kilometers, OLS.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Panel A. Dependent variable: $\Delta \ln$ VKT for Interstate Highways, urbanized areas within MSAs										
$\Delta \ln$(IHU lane km)	0.97[a]	0.97[a]	0.94[a]	0.93[a]	0.90[a]	0.93[a]	0.94[a]	1.02[a]	0.89[a]	1.02[a]
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.02)	(0.03)	(0.10)
$\Delta \ln$(pop.)		0.22[b]	0.33[a]	0.55[a]	0.56[a]		0.33	0.15	0.53[a]	1.31[b]
		(0.09)	(0.08)	(0.11)	(0.15)		(0.20)	(0.12)	(0.20)	(0.56)
ln(initial IHU VKT)			-0.042[a]	-0.052[a]	-0.082[a]				-0.10[a]	-0.14[a]
			(0.00)	(0.01)	(0.02)				(0.02)	(0.05)
Geography				Y	Y	Y	Y			
Census div.				Y	Y	Y	Y			
Socio-econ. char.						Y	Y			
Hist. Pop.						Y	Y			Y
MSA fixed effects								Y	Y	Y
R^2	0.85	0.85	0.88	0.89	0.89	0.85	0.86	0.86	0.92	0.88
Panel B. Dependent variable: $\Delta \ln$ VKT for Major Roads, urbanized areas within MSAs										
$\Delta \ln$(MRU lane km)	0.87[a]	0.87[a]	0.87[a]	0.85[a]	0.66[a]	0.83[a]	0.83[a]	0.87[a]	0.64[a]	1.06[a]
	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.06)	(0.05)	(0.05)	(0.04)	(0.20)
Panel C. Dependent variable: $\Delta \ln$ VKT for Interstate Highways, outside urbanized areas within MSAs										
$\Delta \ln$(IHNU lane km)	0.95[a]	0.95[a]	0.94[a]	0.94[a]	0.93[a]	0.92[a]	0.92[a]	0.80[a]	0.69[a]	1.02[a]
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)	(0.07)	(0.06)

The same regressions for different types of roads are performed in all three panels.
All regressions include a constant and decade effects. Robust standard errors clustered by MSA in parentheses. 384 observations for each regression in Panels A-C. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Appendix Table 4: Changes in VKT as a function of changes in lane kilometers by decade, OLS.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Period:	83-93	83-93	83-93	83-93	83-93	83-93	93-03	93-03	93-03	93-03	93-03	93-03
Panel A. Dependent variable: $\Delta \ln$ VKT for Interstate Highways, entire MSAs												
$\Delta \ln$(IH lane km)	1.07[a]	1.07[a]	1.03[a]	1.06[a]	1.00[a]	0.93[a]	0.85[a]	0.86[a]	0.87[a]	0.85[a]	0.85[a]	0.85[a]
	(0.05)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
$\Delta \ln$(pop.)		0.36[a]	0.41[a]	0.49[a]	0.54[a]	0.55[a]		0.28[a]	0.34[a]	0.32[a]	0.40[a]	0.38[a]
		(0.13)	(0.12)	(0.18)	(0.16)	(0.20)		(0.09)	(0.09)	(0.11)	(0.11)	(0.14)
ln(initial IH VKT)			-0.057[a]		-0.069[a]	-0.14[a]			-0.032[a]		-0.035[a]	-0.057[a]
			(0.01)		(0.01)	(0.03)			(0.01)		(0.01)	(0.02)
Geography				Y	Y	Y				Y	Y	Y
Census div.				Y	Y	Y				Y	Y	Y
Socio-econ. char.						Y						Y
Hist. Pop.						Y						Y
R^2	0.88	0.89	0.91	0.91	0.92	0.94	0.66	0.68	0.72	0.71	0.74	0.75
Panel B. Dependent variable: $\Delta \ln$ VKT for Interstate Highways, urbanized areas within MSAs												
$\Delta \ln$(IHU lane km)	0.97[a]	0.96[a]	0.93[a]	0.96[a]	0.91[a]	0.91[a]	0.97[a]	0.96[a]	0.91[a]	0.96[a]	0.92[a]	0.92[a]
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Panel C. Dependent variable: $\Delta \ln$ VKT for Major Roads, urbanized areas within MSAs												
$\Delta \ln$(MRU lane km)	0.89[a]	0.89[a]	0.89[a]	0.89[a]	0.88[a]	0.68[a]	0.73[a]	0.68[a]	0.68[a]	0.72[a]	0.72[a]	0.64[a]
	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Panel D. Dependent variable: $\Delta \ln$ VKT for Interstate Highways, outside urbanized areas within MSAs												
$\Delta \ln$(IHNU lane km)	0.96[a]	0.96[a]	0.93[a]	0.92[a]	0.88[a]	0.88[a]	0.99[a]	0.98[a]	0.98[a]	0.97[a]	0.98[a]	0.98[a]
	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)

The same regressions for different types of roads are performed in all four panels.
All regressions include a constant and decade effects. Robust standard errors in parentheses.
456 observations for each regression in panel A and 384 in panels B-D. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Appendix Table 5: Changes in VKT as a function of changes in lane kilometers with lags, OLS.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Period:	93-03	93-03	93-03	93-03	93-03	93-03	93-03	93-03	93-03	93-03	93-03	93-03
Dependent variable: $\Delta \ln$ VKT for Interstate Highways, entire MSAs												
Δ_{03-93} ln(IH lane km)							0.85[a]	0.86[a]	0.87[a]	0.85[a]	0.85[a]	0.85[a]
							(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
Δ_{93-83} ln(IH lane km)	0.014	0.014	0.023	0.024	0.028	0.034	0.0040	0.0042	0.015	0.014	0.018	0.013
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Δ ln(pop.)		0.18	0.23	0.56[a]	0.64[a]	0.43[c]		0.28[a]	0.34[a]	0.31[a]	0.39[a]	0.39[a]
		(0.17)	(0.17)	(0.15)	(0.15)	(0.23)		(0.09)	(0.09)	(0.11)	(0.11)	(0.14)
ln(initial IH VKT)			-0.028[a]		-0.036[a]	-0.11[a]			-0.033[a]		-0.036[a]	-0.058[a]
			(0.01)		(0.01)	(0.03)			(0.01)		(0.01)	(0.02)
Geography				Y	Y	Y				Y	Y	Y
Census div.				Y	Y	Y				Y	Y	Y
Socio-econ. char.						Y						Y
Hist. Pop.						Y						Y
R^2	0.00	0.01	0.04	0.13	0.17	0.22	0.66	0.68	0.72	0.71	0.75	0.76

All regressions include a constant. Robust standard errors in parentheses.
228 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

temporaneous) changes for 1993-2003. In columns 7-12, we use both changes in lane kilometers of interstates for 1983-1993 and 1993-2003. Reassuringly, lagged changes in lane kilometers are never significant even though the effect is always precisely estimated. Furthermore, the coefficient on the change in roads for 1993-2003 is not affected by the presence of its lag.

In appendix table 6, we perform seven first difference regressions. These are similar to those in table 3 of the main text except that we instrument for the change in population. Following Bartik (1991) and others after him, we construct our instrument for MSA level population growth from the initial shares of sectoral employment in the MSA and the national growth rate of each sector during the study period. Interacting these quantities yields the MSA population growth that would occur if all MSA sectors grew at the national average rate with sectoral shares constant. To construct our population growth instrument we use employment data for each MSA and the entire US for two-digit sectors from the County Business Patterns.

Despite the strength of the instrument, the standard errors for the coefficient on population change are much larger than in OLS. The OLS range for this coefficient is between 0.3 and 0.5. When instrumenting the range is broader, from close to zero to above unity. We draw two conclusions from this table. First, there is a weak suggestion that the coefficient on population changes is above its OLS value when more controls are introduced. This is consistent with population migrating to MSAs where VKT increases more slowly, all else equal. Second, the coefficient on changes in lane kilometers of roads is unaffected by our instrumenting of population changes. This strongly

Appendix Table 6: Changes in VKT as a function of changes in lane kilometers instrumenting for population, TSLS.

	[1] TSLS	[2] TSLS	[3] TSLS	[4] TSLS	[5] TSLS	[6] TSLS	[7] TSLS
Dependent variable: $\Delta \ln$ VKT for Interstate Highways, entire MSAs							
$\Delta \ln$(IH lane km)	1.05^a	1.02^a	1.04^a	1.00^a	1.05^a	0.92^a	1.03^a
	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.03)
$\Delta \ln$(pop.)	0.093	0.34^b	-0.15	0.45	0.76^c	1.02^b	0.62^c
	(0.18)	(0.16)	(0.36)	(0.32)	(0.44)	(0.45)	(0.37)
ln(initial IH VKT)		-0.046^a		-0.057^a		-0.13^a	
		(0.01)		(0.01)		(0.02)	
Geography			Y	Y	Y	Y	
Census div.			Y	Y	Y	Y	
Socio-econ. char.					Y	Y	
Hist. Pop.					Y	Y	
MSA fixed effects							Y
First stage Stat.	63.3	54.3	32.1	29.2	24.9	23.9	20.1

All regressions include a constant and decade effects.
Robust standard errors in parentheses (clustered by MSA for columns 1-5).
456 observations corresponding to 228 MSAs for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.
Instrument for $\Delta \ln$(pop.) is expected population growth based on initial composition of economic activity.

suggests that even if population is endogenous, this does not affect our estimate for the highway elasticity of highway VKT.

Appendix table 7 is similar to table 4 in the main text, but performs regressions on each decade separately. Appendix table 7 reports results for four IV regressions performed separately for 1983, 1993, and 2003. Panel A examines all interstates while panel B reports results for interstate highways in the urbanized areas of MSAs. As with results presented in the main text, the coefficient on lane kilometers of highways is close to one.

We note that the overidentification test fails for three specifications for all interstates in 1983. This occurs because both 1947 planned interstates and 1898 railroads imply a coefficient for lane kilometers slightly above unity whereas 1835 exploration routes lead to a coefficient for lane kilometers slightly below unity. When using only 1947 planned interstates and 1898 railroads the coefficient on lane miles is 1.20 but when using 1835 exploration routes it is equal to 0.81. Similar but smaller differences are observed for 1993 and 2003. Since these results continue to confirm the Fundamental Law, this does not appear to pose problems for our identification strategy.

Appendix Table 7: VKT as a function of lane kilometers, IV by decade.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Year:	1983	1983	1983	1983	1993	1993	1993	1993	2003	2003	2003	2003
Panel A. TSLS estimation. Dependent variable: ln VKT for Interstate Highways, entire MSAs. Instruments: ln 1835 exploration routes, ln 1898 railroads, and ln 1947 planned interstates												
ln(IH lane km)	1.37^a	1.02^a	1.11^a	1.12^a	1.32^a	0.94^a	1.08^a	1.07^a	1.25^a	0.79^a	0.89^a	0.92^a
	(0.04)	(0.09)	(0.10)	(0.11)	(0.05)	(0.12)	(0.15)	(0.14)	(0.05)	(0.11)	(0.12)	(0.12)
ln(pop.)		0.37^a	0.29^a	0.83^b		0.40^a	0.25^b	0.30		0.47^a	0.37^a	0.42
		(0.07)	(0.08)	(0.39)		(0.09)	(0.12)	(0.35)		(0.08)	(0.10)	(0.38)
Elev. range			-0.064	-0.078			-0.013	-0.026			-0.012	-0.016
			(0.06)	(0.06)			(0.06)	(0.06)			(0.05)	(0.05)
Ruggedness			7.53^c	6.33^c			6.60^c	4.04			5.97^c	3.65
			(3.85)	(3.66)			(3.57)	(3.34)			(3.25)	(3.19)
Heating d.d.			-0.016^a	-0.018^a			-0.016^a	-0.018^a			-0.013^a	-0.016^a
			(0.01)	(0.01)			(0.00)	(0.00)			(0.00)	(0.00)
Cooling d.d.			-0.025^b	-0.034^a			-0.024^a	-0.033^a			-0.020^b	-0.029^a
			(0.01)	(0.01)			(0.01)	(0.01)			(0.01)	(0.01)
Sprawl			0.0027	0.0027			-0.00035	-0.00068			0.00081	0.000071
			(0.00)	(0.00)			(0.00)	(0.00)			(0.00)	(0.00)
Census div.			Y	Y			Y	Y			Y	Y
Socio-econ. char.				Y				Y				Y
Hist. pop.				Y				Y				Y
Overid.	0.36	0.034	0.092	0.084	0.70	0.28	0.40	0.42	0.81	0.20	0.42	0.49
First stage Stat.	27.6	12.2	8.55	6.68	45.2	16.7	10.2	8.79	42.8	14.5	10.0	7.88
Panel B. TSLS estimation. Dependent variable: ln VKT for Interstate Highways, urbanized areas within MSAs. Instruments: ln 1835 exploration routes, ln 1898 railroads, and ln 1947 planned interstates												
ln(IHU lane km)	1.31^a	1.22^a	1.27^a	1.23^a	1.25^a	1.06^a	1.14^a	1.11^a	1.20^a	0.92^a	1.01^a	1.02^a
	(0.03)	(0.11)	(0.13)	(0.13)	(0.04)	(0.13)	(0.14)	(0.12)	(0.03)	(0.08)	(0.10)	(0.11)
Overid.	0.37	0.12	0.33	0.16	0.50	0.53	0.37	0.54	0.60	0.42	0.70	0.63
First stage Stat.	28.7	6.98	6.65	6.03	31.0	10.00	7.95	6.92	33.5	9.19	7.56	5.66

All regressions include a constant. Robust standard errors in parentheses.
228 observations for each regression in panel A and 192 in panel B. *a*, *b*, *c*: significant at 1%, 5%, 10%.

B. *Supplemental estimations providing indirect evidence for the Fundamental Law of Road Congestion*

Appendix table 8 is similar to table 6 in the main text, but examines: urbanized area interstate highways (Panel A); non-urbanized area major roads highways (Panel B), and non-urbanized area interstate highways (Panel C). All estimations are consistent with the conclusion suggested by table 6 in the main text: the demand for VKT is highly elastic. Note that, unlike table 6 in the main text, appendix table 8 does not present IV estimations. This reflects the fact, mentioned previously, that our instruments do not generally have sufficient ability to predict all alternative classes of roads.

Appendix table 9 is similar to table 7 in the main text, but examines: urbanized area major roads (Panel A); urbanized area interstate highways (Panel B), and non-urbanized area interstate highways (Panel C). Remarkably, for each type of road, appendix table 9 suggests convergence in traffic levels. Note that, column 6 of appendix table 9 presents IV regressions in which we

Appendix Table 8: Time cost of driving as a function of VKT, pooled regressions, OLS.

	[1]	[2]	[3]	[4]	[5]	[6]
Dependent variable:	ln(hours per km) for commutes			ln(h. per km) for all household driving		
Panel A. Interstate highways, urbanized areas within MSAs.						
ln(IHU VKT)	0.0091	-0.047[a]	-0.046[a]	0.0057	-0.016[c]	-0.017[c]
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)
Personal char.	Y	Y	Y	Y	Y	Y
ln current pop.		Y	Y		Y	Y
Geography		Y	Y		Y	Y
Census div.		Y	Y		Y	Y
Hist. pop.			Y			Y
Observations	44805	44805	44805	18211	18211	18211
R^2	0.04	0.05	0.05	0.11	0.12	0.12
Panel B. Major roads, urbanized areas in MSAs.						
ln(MRU VKT)	0.016[b]	-0.016	-0.0038	0.011[b]	-0.011	-0.016
	(0.01)	(0.03)	(0.02)	(0.01)	(0.02)	(0.02)
Panel C. Interstate highways, outside urbanized areas and within MSAs.						
ln(IHNU VKT)	0.0094	-0.027[a]	-0.024[a]	-0.0017	-0.019[b]	-0.013
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)

All regressions include a constant and year effects. Robust standard errors clustered by MSA in parentheses. 192 MSAs represented in each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

instrument for population using the predicted population variable described earlier. Since we have one instrument and one endogenous dependent variable no over-identification test is possible.

Appendix table 10 presents estimations based on columns 2, 3, 4 and 9 of table 8 in the main text. However, unlike table 8 in the main text, appendix table 10 examines each of our three cross-sections individually. The results in appendix table 10 are consistent with those suggested by table 8 in the main text: the count of large buses in an MSA has at most a very small effect on total interstate VKT and on urbanized are interstate VKT. As in other regressions we continue to find road VKT elasticities of road lane kilometers close to one.

Appendix table 11 extends the results of table 8 in the main text to urbanized area major roads (Panel A) and non-urbanized area interstate highway (Panel B). These results strengthen the conclusions suggested by table 8 in the main text. In particular, changes in an MSA's stock of large buses has little effect on road VKT for any of the classes of roads that we examine. Note that we present a less extensive set of IV regressions in appendix table 11 than in table 8 of the main text. This reflects problems with instrument validity in regressions examining urbanized area major roads and non-urbanized area interstates.

Appendix table 12 is identical to table 8 in the main text, but measures an MSA's public transit

Appendix Table 9: Conditional convergence in daily traffic.

	[1] OLS	[2] OLS	[3] OLS	[4] OLS	[5] OLS, FE	[6] TSLS
Panel A. Dependent variable: Change in ln daily traffic (AADT) for Major Roads, urbanized areas within MSAs.						
Initial MRU AADT level	-0.16[a]	-0.21[a]	-0.36[a]	-0.55[a]	-1.26[a]	-0.40[a]
	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)
Δ ln(pop.)		0.42[a]	0.49[a]	0.31[a]		0.94[a]
		(0.06)	(0.08)	(0.09)		(0.31)
Geography			Y	Y		Y
Census div.			Y	Y		Y
Initial Share Manuf.				Y		Y
Hist. pop.				Y		
Socio-econ. char.				Y		
R^2	0.11	0.18	0.30	0.42	0.80	-
First stage Stat.						32.7
Panel B. Dep. var.: Change in ln daily traffic for Interstate Highways, urbanized areas within MSAs.						
Initial IHU AADT level	-0.16[a]	-0.18[a]	-0.23[a]	-0.28[a]	-1.07[a]	-0.24[a]
	(0.02)	(0.02)	(0.02)	(0.03)	(0.09)	(0.02)
Δ ln(pop.)		0.44[a]	0.62[a]	0.44[a]		1.10[b]
		(0.07)	(0.11)	(0.14)		(0.49)
R^2	0.27	0.33	0.40	0.44	0.77	-
First stage Stat.						34.0
Panel C. Dependent variable: Change in ln daily traffic (AADT) for Interstate Highways, non-urbanized areas within MSAs.						
Initial IHNU AADT level	-0.043[b]	-0.052[a]	-0.11[a]	-0.16[a]	-0.99[a]	-0.14[a]
	(0.02)	(0.02)	(0.02)	(0.03)	(0.05)	(0.03)
Δ ln(pop.)		0.36[a]	0.34[a]	0.16		0.99[b]
		(0.09)	(0.11)	(0.13)		(0.47)
R^2	0.14	0.18	0.31	0.38	0.80	-
First stage Stat.						34.7

All regressions include decade effects. Robust standard errors in parentheses (clustered by MSA).
384 observations corresponding to 192 MSAs for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.
Instrument for Δ ln(pop.) is expected population growth based on initial composition of economic activity.

network as the sum of the number of large buses and rail cars. Table 8 in the main text measures transit only as the count of large buses. The results presented in appendix table 12 are almost indistinguishable from those in table 8 of the main text.

C. *Supplemental estimations providing evidence for sources of* VKT

Appendix table 13 reproduces columns 1, 2, 3, and 5 of table 9 in the main text, but examines each cross-section independently. Appendix table 13 also expends table 9 in the main text by examining urban and non-urban interstate highways separately. The results presented in this table suggest that interstate truck VKT is probably more responsive to interstate lane kilometers than is all interstate VKT, and that major road truck VKT is probably less responsive to major road lane kilometers than is all major road VKT.

Appendix Table 10: VKT as a function of lane kilometers and buses, by decade.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
	OLS	OLS	OLS	LIML	OLS	OLS	OLS	LIML	OLS	OLS	OLS	LIML
Year:	1983	1983	1983	1983	1993	1993	1993	1993	2003	2003	2003	2003
Panel A. Dependent variable: ln VKT for Interstate Highways, entire MSAs												
ln(IH lane km)	0.92^a	0.95^a	0.93^a	1.20^a	0.73^a	0.76^a	0.78^a	1.11^a	0.71^a	0.75^a	0.77^a	0.93^a
	(0.06)	(0.06)	(0.05)	(0.14)	(0.04)	(0.04)	(0.04)	(0.16)	(0.05)	(0.04)	(0.04)	(0.14)
ln(bus)	-0.025	0.044^c	0.049^c	0.055	-0.012	0.031^c	0.046^b	0.14^c	-0.044^c	-0.0058	0.022	0.11
	(0.02)	(0.03)	(0.03)	(0.13)	(0.02)	(0.02)	(0.02)	(0.08)	(0.02)	(0.03)	(0.03)	(0.10)
ln(pop.)	0.48^a	0.34^a	1.01^a	0.13	0.56^a	0.46^a	0.39	0.017	0.59^a	0.50^a	0.35	0.20
	(0.06)	(0.07)	(0.36)	(0.28)	(0.05)	(0.05)	(0.25)	(0.22)	(0.05)	(0.06)	(0.36)	(0.21)
Geography		Y	Y	Y		Y	Y	Y		Y	Y	Y
Census div.		Y	Y	Y		Y	Y	Y		Y	Y	Y
Hist. pop.			Y				Y				Y	
Socio-econ. char.			Y				Y				Y	
R^2	0.93	0.94	0.95	-	0.94	0.95	0.96	-	0.94	0.96	0.96	-
Overid.				0.23				0.69				0.99
First stage Stat.				7.17				5.41				5.73
Panel B. Dependent variable: ln VKT for Interstate Highways, urbanized areas within MSAs												
ln(IHU lane km)	1.04^a	1.06^a	1.07^a	1.36^a	0.94^a	0.96^a	0.98^a	1.39^a	0.93^a	0.94^a	0.97^a	1.08^a
	(0.03)	(0.03)	(0.03)	(0.17)	(0.03)	(0.03)	(0.03)	(0.33)	(0.03)	(0.03)	(0.04)	(0.15)
ln(bus)	-0.015	0.054^b	0.059^b	0.020	0.0079	0.044^b	0.055^a	0.14	-0.022	0.0087	0.033	0.025
	(0.02)	(0.02)	(0.02)	(0.10)	(0.02)	(0.02)	(0.02)	(0.11)	(0.03)	(0.03)	(0.04)	(0.07)
ln(pop.)	0.36^a	0.23^a	1.04^a	-0.054	0.38^a	0.29^a	0.37	-0.35	0.40^a	0.32^a	0.55	0.15
	(0.05)	(0.06)	(0.39)	(0.29)	(0.05)	(0.05)	(0.34)	(0.49)	(0.05)	(0.06)	(0.46)	(0.20)
R^2	0.96	0.97	0.97	-	0.97	0.97	0.98	-	0.97	0.98	0.98	-
Overid.				0.79				0.97				0.93
First stage Stat.				6.39				1.92				3.48

All regressions include a constant. Robust standard errors in parentheses.
228 observations for each regression in panel A and 192 in panel B.
Instruments for buses and lane kilometers are ln 1898 railroads, ln 1947 planned interstates, and 1972 presidential election share of democratic vote. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Appendix Table 11: VKT as a function of lane kilometers and buses, pooled regressions.

	[1] OLS	[2] OLS	[3] OLS	[4] OLS	[5] OLS	[6] OLS	[7] LIML
Panel A. Dependent variable: ln VKT for Major Roads, urbanized areas within MSAs							
ln(MRU lane km)	1.05[a]	0.83[a]	0.84[a]	0.84[a]	0.89[a]	0.88[a]	1.23[a]
	(0.02)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.06)
ln(bus)	0.051[a]	-0.0034	0.013[c]	0.011	-0.0016	-0.011	-0.060[c]
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
ln(pop.)		0.31[a]	0.26[a]	0.33[a]		0.34[a]	
		(0.04)	(0.04)	(0.06)		(0.06)	
Geography			Y	Y			
Census div.			Y	Y			
Socio-econ. char.				Y			
Hist. pop.				Y			
MSA fixed effects					Y	Y	
R^2	0.97	0.98	0.99	0.99	0.95	0.95	-
Overid.							0.49
First stage Stat.							13.4
Panel B. Dependent variable: ln VKT for Interstate Highways, non-urbanized areas within MSAs							
ln(IHNU lane km)	0.93[a]	0.81[a]	0.84[a]	0.84[a]	0.97[a]	0.96[a]	1.33[a]
	(0.04)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.12)
ln(bus)	0.11[a]	-0.057[a]	0.0089	0.012	0.0031	-0.0045	-0.036
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.07)
ln(pop.)		0.39[a]	0.26[a]	0.35[a]		0.29[a]	
		(0.05)	(0.04)	(0.13)		(0.10)	
R^2	0.83	0.88	0.92	0.93	0.89	0.89	-
Overid.							0.25
First stage Stat.							8.62

All regressions include a constant and year effects. Robust standard errors clustered by MSA in parentheses. 576 observations corresponding to 192 MSAs for each regression.
Instruments for buses and lane kilometers are ln 1898 railroads, ln 1947 planned interstates, and 1972 presidential election share of democratic vote. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Appendix Table 12: VKT as a function of lane kilometers and all transit cars, pooled regressions.

	[1] OLS	[2] OLS	[3] OLS	[4] OLS	[5] OLS	[6] OLS	[7] LIML	[8] LIML	[9] LIML	[10] LIML
Panel A. Dependent variable: ln VKT for Interstate Highways, entire MSAs										
ln(IH lane km)	1.08[a]	0.82[a]	0.86[a]	0.86[a]	1.06[a]	1.06[a]	1.38[a]	0.95[a]	1.12[a]	1.22[a]
	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)	(0.07)	(0.11)	(0.14)	(0.18)
ln(transit)	0.13[a]	-0.027[c]	0.020	0.031[c]	0.024[a]	0.015[b]	-0.035	-0.079[c]	0.14	0.22
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.05)	(0.05)	(0.11)	(0.15)
ln(pop.)		0.52[a]	0.41[a]	0.27[b]		0.31[a]		0.51[a]	0.030	-0.24
		(0.05)	(0.05)	(0.12)		(0.10)		(0.12)	(0.24)	(0.33)
Geography			Y	Y					Y	Y
Census div.			Y	Y					Y	Y
Socio-econ. char.				Y						Y
Hist. pop.				Y						Y
MSA fixed effects					Y	Y				
R^2	0.90	0.94	0.95	0.96	0.94	0.94	0.86	-	-	-
Overid.							0.88	0.39	0.58	0.57
First stage Stat.							22.3	18.9	7.16	3.93
Panel B. Dependent variable: ln VKT for Interstate Highways, urbanized areas within MSAs										
ln(IHU lane km)	1.15[a]	0.98[a]	1.00[a]	1.02[a]	0.99[a]	0.99[a]	1.32[a]	1.09[a]	1.29[a]	1.30[a]
	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.05)	(0.14)	(0.20)	(0.21)
ln(transit)	0.083[a]	-0.0081	0.032[c]	0.042[b]	0.012	0.0072	-0.056	-0.074	0.065	0.089
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.04)	(0.05)	(0.09)	(0.09)
ln(pop.)		0.37[a]	0.27[a]	0.19		0.21[b]		0.34[c]	-0.11	-0.15
		(0.04)	(0.05)	(0.13)		(0.09)		(0.19)	(0.30)	(0.30)
R^2	0.96	0.97	0.97	0.98	0.95	0.95	-	-	-	-
Overid.							0.70	0.28	0.99	1.00
First stage Stat.							20.7	6.78	5.47	2.54

All regressions include a constant and year effects. Robust standard errors clustered by MSA in parentheses. 684 observations corresponding to 228 MSAs for each regression in panel A and 576 (192 MSAs) in panel B. Instruments for buses and lane kilometers are ln 1898 railroads, ln 1947 planned interstates, and 1972 presidential election share of democratic vote. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Appendix Table 13: Truck VKT as a function of lane kilometers, OLS by decade.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Year:	1983	1983	1983	1983	1993	1993	1993	1993	2003	2003	2003	2003
Panel A. Dependent variable: ln truck VKT for Interstate Highways, entire MSAs												
ln(IH lane km)	1.51[a]	1.44[a]	1.50[a]	1.38[a]	1.15[a]	0.84[a]	1.01[a]	1.00[a]	1.22[a]	0.94[a]	1.01[a]	1.11[a]
	(0.15)	(0.21)	(0.23)	(0.23)	(0.05)	(0.08)	(0.17)	(0.18)	(0.09)	(0.17)	(0.15)	(0.20)
ln(pop.)		0.095	0.011	-3.65[c]		0.32[a]	0.20	-0.15		0.28[a]	0.23[b]	1.97[c]
		(0.13)	(0.19)	(1.89)		(0.06)	(0.13)	(0.94)		(0.09)	(0.09)	(1.11)
Geography.			Y	Y			Y	Y			Y	Y
Census div.			Y	Y			Y	Y			Y	Y
Hist. pop.				Y				Y				Y
Socio-econ. char.				Y				Y				Y
R^2	0.47	0.47	0.55	0.64	0.52	0.54	0.59	0.63	0.58	0.60	0.67	0.69
Panel B. Dependent variable: ln truck VKT for Interstate Highways, urbanized areas within MSAs												
ln(IHU lane km)	1.24[a]	1.37[a]	1.35[a]	1.34[a]	1.10[a]	1.09[a]	1.10[a]	1.11[a]	1.01[a]	0.75[a]	0.80[a]	0.81[a]
	(0.09)	(0.23)	(0.21)	(0.23)	(0.05)	(0.21)	(0.19)	(0.21)	(0.03)	(0.06)	(0.07)	(0.08)
Panel C. Dependent variable: ln truck VKT for Major Roads, urbanized areas within MSAs												
ln(MRU lane km)	1.04[a]	0.73[a]	0.73[a]	0.76[a]	1.03[a]	0.21	0.41	0.30	1.07[a]	0.44[a]	0.50[a]	0.56[a]
	(0.04)	(0.11)	(0.09)	(0.09)	(0.06)	(0.24)	(0.29)	(0.30)	(0.03)	(0.09)	(0.09)	(0.10)
Panel D. Dependent variable: ln truck VKT for Interstate Highways, outside urbanized areas within MSAs												
ln(IHNU lane km)	1.05[a]	0.86[a]	1.00[a]	0.99[a]	1.09[a]	0.94[a]	1.03[a]	1.00[a]	1.06[a]	0.85[a]	0.89[a]	0.89[a]
	(0.06)	(0.09)	(0.08)	(0.08)	(0.06)	(0.09)	(0.08)	(0.09)	(0.06)	(0.08)	(0.09)	(0.10)

The same regressions for different types of roads are performed in all four panels.
All regressions include a constant. Robust standard errors in parentheses.
228 observations for each regression in panel A and 192 in panels B-D. *a*, *b*, *c*: significant at 1%, 5%, 10%.

As described in the main text, we also rely on County Business Patterns for 1983, 1993, and 2003 to describe commercial travel activity. These data provide county level information on employment in "Motor freight transportation and warehousing" (SIC 42), an indirect measure of commercial traffic.

Appendix table 14 presents the results of regressions predicting log MSA employment in trucking and warehousing for the 228 MSAs in our sample and pooling all three cross-sections. In all regressions, our dependent variable is the count of MSA employment in trucking an warehousing. In panel A the dependent variable of interest is all interstate highway lane kilometers. In columns 1-4 we conduct OLS regressions and in columns 5 and 6 we conduct instrumental variables estimations. In our first three OLS specifications we find a positive significant relationship between highway lane kilometers and trucking and warehousing employment. When we introduce an MSA fixed effect in column 4, the effect of roads on trucking and warehousing is not distinguishable from zero. In our IV estimates in columns 5 and 6 we find positive coefficients, that are not quite different from zero at standard confidence levels. Panel B of table 14 is similar to those in panel A but includes both urbanized and non-urbanized interstate highway lane kilometers as explanatory

Appendix Table 14: Trucking and warehousing employment as a function of ln lane kilometers.

	[1] OLS	[2] OLS	[3] OLS	[4] OLS	[5] TSLS	[6] TSLS
Panel A. Dependent variable: ln MSA trucking and warehousing employment as a function of all MSA interstate lane km						
ln(IH lane km)	0.16[a]	0.16[a]	0.14[a]	-0.018	0.23	0.21
	(0.05)	(0.05)	(0.05)	(0.04)	(0.15)	(0.15)
ln(pop.)	0.95[a]	0.96[a]	0.80[a]	0.47[b]	0.90[a]	0.93[a]
	(0.04)	(0.06)	(0.23)	(0.20)	(0.11)	(0.12)
Geography		Y	Y			Y
Census div.		Y	Y			Y
Socio-econ. char.			Y			Y
MSA fixed effects				Y		
R^2	0.82	0.84	0.87	0.47	-	-
Overid.					0.098	0.52
First stage Stat					15.7	10.9
Panel B. Dependent variable: ln MSA trucking and warehousing employment as a function of MSA interstate lane km in urbanized and non urbanized areas						
ln(IHU lane km)	0.17[a]	0.096[b]	0.093[c]	-0.082		
	(0.05)	(0.05)	(0.05)	(0.05)		
ln(IHNU lane km)	0.095[c]	0.14[a]	0.11[b]	0.057		
	(0.05)	(0.05)	(0.05)	(0.09)		
ln(pop.)	0.79[a]	0.85[a]	0.87[a]	0.53[b]		
	(0.06)	(0.07)	(0.29)	(0.22)		
R^2	0.83	0.84	0.87	0.48		

All regressions include a constant and year effects. Robust standard errors clustered by MSA in parentheses. 456 observations corresponding to 228 MSAs for each regression in panel A and 384 (192 MSAs) in panel B. Instruments in panel A are ln 1835 exploration routes, ln 1898 railroads, and ln 1947 planned interstates. *a*, *b*, *c*: significant at 1%, 5%, 10%.

variables. We see that coefficients on urbanized interstate highway lane kilometers are similar to panel A, but the effect of non-urbanized interstate highway lane kilometers is uniformly positive, larger than urbanized interstate, and generally different from zero at standard confidence levels. This suggests that trucking and warehousing employment is more sensitive non-urban interstate.[3] Table 14 does not report IV in panel B because we are not able to instrument for the two road variables simultaneously. As a check, appendix table 15 reproduces the estimations in Panel A of appendix table 14 in each of our cross-sections. These results are consistent with those reported in appendix table 14.

Appendix table 16 presents estimations corresponding to those presented in table 11 in the main text but examines each cross-section individually. Appendix table 17 presents the results of first difference regression corresponding to those presented in table 11 in the main text. These supplemental results confirm the results of table 11 in the main text. In particular, individual

[3]This finding is broadly consistent with Michaels (2008), who finds that earnings in trucking and warehousing in rural counties also increases with increases in nearby interstate highways.

Appendix Table 15: ln MSA trucking and warehousing employment as a function of ln lane kilometers.

	1983				1993				2003			
	OLS	OLS	OLS	TSLS	OLS	OLS	OLS	TSLS	OLS	OLS	OLS	TSLS
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
ln(IH lane km)	0.12^a	0.12^a	0.12^b	0.17	0.25^a	0.25^a	0.20^b	0.28	0.20^a	0.15^b	0.15^b	0.35^b
	(0.04)	(0.04)	(0.05)	(0.14)	(0.07)	(0.08)	(0.08)	(0.20)	(0.05)	(0.06)	(0.06)	(0.15)
ln(pop.)	1.00^a	1.01^a	1.58^a	0.98^a	0.87^a	0.87^a	1.06^b	0.84^a	0.85^a	0.90^a	2.99^a	0.73^a
	(0.04)	(0.05)	(0.43)	(0.11)	(0.06)	(0.08)	(0.46)	(0.17)	(0.04)	(0.06)	(0.62)	(0.13)
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^2	0.83	0.85	0.88	-	0.80	0.83	0.87	-	0.85	0.88	0.91	-
Overid.				0.52				0.24				0.20
First stage Stat.				8.55				10.2				10.0

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 interstates and ln 1898 railroads.

Appendix Table 16: VKT as a function of lane kilometers for different roads, OLS by decade.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
Year:	1983	1983	1983	1983	1993	1993	1993	1993	2003	2003	2003	2003
Panel A. Dependent variable: ln VKT for Interstate Highways, urbanized areas within MSAs												
ln(IHU lane km)	1.17^a	1.07^a	1.11^a	1.11^a	1.06^a	0.98^a	1.00^a	1.01^a	1.00^a	0.97^a	0.99^a	0.99^a
	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
ln(MRU lane km)	0.15^a	-0.074	-0.11^c	-0.11^c	0.26^a	-0.17^c	-0.14	-0.081	0.29^a	-0.24^a	-0.21^b	-0.11
	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.09)	(0.09)	(0.08)	(0.04)	(0.08)	(0.09)	(0.08)
ln(IHNU lane km)	0.0035	-0.062	-0.087^b	-0.10^a	-0.048	-0.095^a	-0.096^a	-0.12^a	-0.038	-0.10^a	-0.099^a	-0.094^a
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
ln(pop.)		Y	Y	Y		Y	Y	Y		Y	Y	Y
Geography.			Y	Y			Y	Y			Y	Y
Census div.			Y	Y			Y	Y			Y	Y
Socio-econ. char.				Y				Y				Y
Hist. pop.				Y				Y				Y
R^2	0.96	0.96	0.97	0.98	0.96	0.97	0.97	0.98	0.97	0.98	0.98	0.98
Panel B. Dependent variable: ln VKT for Major Roads, urbanized areas within MSAs												
ln(IHU lane km)	0.032	-0.033	-0.045^c	-0.036	0.019	-0.047^c	-0.051^a	-0.060^a	-0.027	-0.053^a	-0.043^b	-0.054^a
	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
ln(MRU lane km)	1.03^a	0.87^a	0.87^a	0.84^a	1.10^a	0.74^a	0.80^a	0.81^a	1.15^a	0.68^a	0.68^a	0.73^a
	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)
ln(IHNU lane km)	0.068^a	0.024	0.021	0.010	0.023	-0.016	-0.010	-0.019	0.036	-0.020	-0.016	-0.013
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
Panel C. Dependent variable: ln VKT for Interstate Highways, outside urbanized areas within MSAs												
ln(IHU lane km)	0.10^a	0.015	0.038	0.046	-0.0067	-0.092^b	-0.077^b	-0.060	-0.033	-0.066	-0.052	-0.039
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)
ln(MRU lane km)	0.14^a	-0.067	-0.031	-0.045	0.26^a	-0.21^a	-0.083	0.019	0.30^a	-0.28^a	-0.15	-0.053
	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.08)	(0.08)	(0.08)	(0.06)	(0.10)	(0.11)	(0.10)
ln(IHNU lane km)	0.88^a	0.82^a	0.84^a	0.83^a	0.86^a	0.81^a	0.84^a	0.83^a	0.87^a	0.81^a	0.83^a	0.83^a
	(0.05)	(0.05)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)

The same regressions for different types of roads are performed in all four panels.
All regressions include a constant. Robust standard errors in parentheses.
192 observations for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

Appendix Table 17: Change in VKT as a function of change in lane kilometers for different roads, pooled OLS.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Panel A. Dependent variable: Δ ln VKT for interstate highways, urbanized areas within MSAs										
Δ ln(IHU lane km)	0.96[a]	0.95[a]	0.90[a]	0.94[a]	0.89[a]	0.92[a]	0.87[a]	0.81[a]	0.81[a]	0.82[a]
	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)
Δ ln(IHNU lane km)	0.039	0.036	0.024	0.033	0.026	0.026	0.027	-0.011	-0.0076	-0.0074
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)	(0.04)
Δ ln(MRU lane km)	-0.032	-0.033	-0.0073	-0.026	-0.0098	-0.014	-0.016	0.026	0.028	0.030
	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
Δ ln(pop.)		0.25[a]	0.36[a]	0.42[a]	0.56[a]	0.37[b]	0.52[a]		0.13	0.21
		(0.09)	(0.08)	(0.12)	(0.12)	(0.16)	(0.16)		(0.25)	(0.22)
ln(initial VKT)			-0.042[a]		-0.050[a]		-0.076[a]			
			(0.00)		(0.01)		(0.02)			
Geography				Y	Y	Y	Y		Y	Y
Census div.				Y	Y	Y	Y		Y	Y
Socio-econ. char.						Y	Y		Y	Y
Hist. Pop.						Y	Y		Y	Y
MSA fixed effects									Y	Y
R^2	0.79	0.80	0.83	0.81	0.84	0.84	0.85	0.75	0.75	0.77
Panel B. Dependent variable: Δ ln VKT for interstate highways, outside urbanized areas within MSAs										
Δ ln(IHU lane km)	-0.0017	-0.0098	-0.016	-0.026	-0.032	-0.034	-0.037	-0.088[a]	-0.087[a]	-0.089[a]
	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Δ ln(IHNU lane km)	0.97[a]	0.96[a]	0.95[a]	0.96[a]	0.94[a]	0.96[a]	0.94[a]	0.97[a]	0.97[a]	0.95[a]
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Δ ln(MRU lane km)	-0.019	-0.020	-0.011	-0.010	0.00041	-0.014	-0.0048	0.018	0.019	0.027
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
R^2	0.76	0.77	0.77	0.79	0.80	0.80	0.81	0.79	0.79	0.81
Panel C. Dependent variable: ln VKT for Major Roads, urbanized areas within MSAs										
Δ ln(IHU lane km)	-0.027	-0.036	-0.036	-0.036	-0.037	-0.042	-0.027	-0.046	-0.045	-0.045
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.02)	(0.04)	(0.04)	(0.04)
Δ ln(IHNU lane km)	0.029	0.025	0.025	0.026	0.025	0.027	0.016	-0.0076	-0.0051	-0.020
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.04)
Δ ln(MRU lane km)	0.81[a]	0.81[a]	0.81[a]	0.81[a]	0.81[a]	0.80[a]	0.63[a]	0.74[a]	0.74[a]	0.75[a]
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)
R^2	0.78	0.79	0.79	0.80	0.80	0.81	0.85	0.76	0.76	0.77

All regressions include a constant and period effects. Robust standard errors clustered by MSA in parentheses. 384 observations corresponding to 192 MSAs for each regression. *a*, *b*, *c*: significant at 1%, 5%, 10%.

cross-sections and the time series variation in our data confirm that an extension of one our classes of roads has very little impact on VKT on the others.

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