Does the US have an Infrastructure Cost Problem? Evidence from the Interstate Highway System

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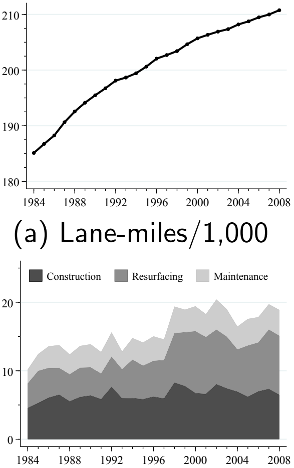
Trends in the interstate highway system



(a) Lane-miles/1,000 (b) IRI

(c) Expenditure/10^9 (d) AADT/10,000

Introduction I

- Expenditure and VMT about double as extent increases and pavement quality improves $\Longrightarrow$ cost decreasing?
- Construction cost of a lane mile or pavement quality increases $\Longrightarrow$ cost increasing?
- We need some theory. We pose the problem of managing the interstate as an optimal capital stock problem $\Longrightarrow$ 'user cost' is charge per vehicle mile that rationalizes investment.

Introduction II

- Results
  - Capital cost of lane miles contributes 100 times as much to user cost as the capital cost of pavement quality or depreciation.
  - The price of lane miles increased by about a factor of 2.5 from 1992-2008 and the price of pavement quality by about a factor of 2.
  - User cost fell by half from 1992-2008 because (1) interest rates fell from 4% to 1%, (2) VMT doubled. Things could have been different.
  - Increase in construction cost is not a composition effect. Increase in resurfacing costs is from materials costs. Stagnation/decline of infrastructure TFP is partial at most.
- Also, ... we have lots of work on the benefits of highways. We want to get better estimates of costs.

Literature

- Brooks and Liscow, unpublished, (2018). Estimate cost of miles 1950-1993. Find 4-fold increase mostly from 1970-1993. They suggest ‘citizen’s voice’. We find about a 2.5-fold increase 1992-2008, and larger for 1984-2008.
- Small and Winston AER (1978). The only other analysis of roughness. Much higher cost of resurfacing than we find.
- Smith et al. (1999a), Smith et al. (1999b), environmental regulation associated with higher costs per mile constructed (1990-1994)
- Keeler and Small, JPE (1978). Similar model, SF bay area, only. Less interested in dynamics.
- Allen and Arkolakis QJE (2014), Duranton and Turner RES (2012). ‘Steady state’ cost estimates.

Defining the 'cost of the interstate' (1)

We want τ_t to rationalize observed investment in lane miles and pavement quality.

$$V(L_0, q_0) = \max_{I_t^L, \imath_t^q} \sum_{t=0}^{\infty} \frac{\tau_t v(q_t^{-1}, L_t) - p_t^L I_t^L - p_t^q \imath_t^q L_t}{(1+r)^t}$$

$$\text{s.t. } L_{t+1} = L_t + I_t^L \quad (1)$$

$$q_{t+1} = q_t + \kappa \frac{v(q_t^{-1}, L_t)}{L_t} - \imath_t^q \quad (2)$$

$\tau_t \sim$ user cost of capital/user fee per vehicle mile.
$q_t,\ p_t^q \sim$ *IRI*
$L_t,\ p_t^L \sim$ lane miles
$v(q_t^{-1}, L_t) \sim$ VMT, CRS in q^{-1}, L_t
$r \sim$ time-varying real interest rate.
$\kappa \sim$ depreciation rate of q

Defining the 'cost of the interstate' (2)

- This is a standard optimal capital stock problem adjusted to describe the interstate.
- The value of travel is the subject of ongoing research. We make two simplifying assumptions about the objective
  - v CRS
  - linearity in user costs.

  These were the weakest assumptions we could find.
- It looks a lot like the FHA problem: the FHA gets gas taxes and pays for pavement quality and lane miles.
- In a steady state,

$$\tau = \left[rp^L L + rp^q qL + \kappa p^q v \right] / v.$$

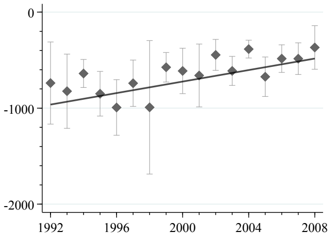
  This is the user fee that rationalizes given steady state quality and extent must offset the capital cost of lane-miles, the capital cost of keeping lanes miles at quality q, and offset depreciation, $\kappa \mathrm{VMT}$. N.B.: CRS makes this expression a lot simpler.
- The dynamic version is interesting, too.

Data

We rely on three main data sources:

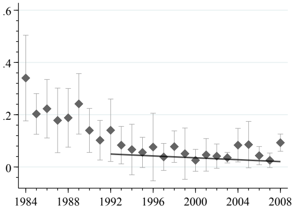
- *Highway Statistics*, state-year data on expenditure for construction, resurfacing and maintenance (1984–).
  - Construction: 'ROW', 'New Construction', 'Major Widening'.
  - Resurfacing: 'Reconstruction', 'Rehabilitation, Restoration and Resurfacing'.
  - Maintenance: signage, emergency services, snow removal, etc.
- *HPMS Universe* data, state-year data on lane miles for ALL interstate segments (1980-2008).
- *HPMS Sample* data, segment-year level data on IRI and resurfacing for a SAMPLE of interstate segments. (1992-2008)
- Various other, mostly GIS data sets, track system characteristics over time, e.g., proximity to water.
- We estimate p^q using segment-year level data, *HPMS Sample*$\times$*Highway Statistics*. We estimate p^L using state-year data, *HPMS Universe*$\times$*Highway Statistics*.

Resurfacing and the (inverse) price of IRI p_t^q over time



Inches of roughness per million dollars of expenditure $(1/p^q)$.
About 820 inches per million dollars in 1992, 490 in 2008.
Inverting, $p_{1992}^q = 1,200\$/\text{inch}$, $p_{1992}^q = 2,050\$/\text{inch}$. Solid line is linear fit we use in our calibration.

Inverse price of lane-miles, p_t^L, over time (1)

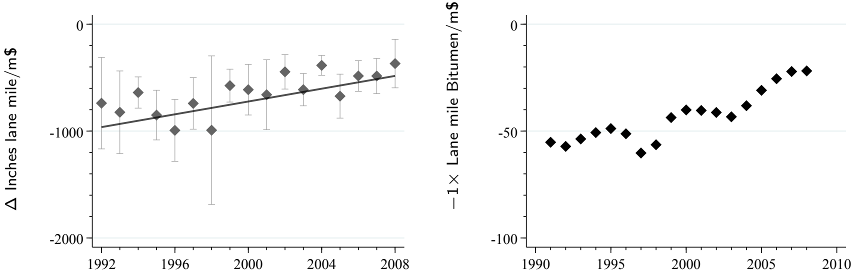


- Mean new lane miles per million of state expenditure $(1/p^L)$, by year.
- These are inverse prices. Solid line is linear fit we use in our calibration.

Why do p_t^q and p_t^L increase? I

- Over time, the network is: More urban/busier; flatter and lower; less exposed to unions; more exposed to wetlands; stronger (Structural # increases); and less likely to be concrete. Maybe prices are increasing because we are building and resurfacing different roads over time?
- For both p_t^q and p_t^L,
  - p_t^q and p_t^L are higher for urban roads, but urban premium declines. Shift to more urban roads does not explain trend.
  - p_t^q and p_t^L are higher in more union states, but union share and union premia decline. Changes in union exposure do not explain trends.
  - Proximity to water, elevation, grade, all affect level of p_t^q and p_t^L, but not trend.
  - Only structural number explains trend in p_t^q and p_t^L.

Why do p_t^q and p_t^L increase? II



Left: Inches of roughness per million dollars of expenditure $(1/p^q)$.

Right: Lane miles of asphaltic concrete per million \$ $(\times -1)$.

Increase in price of asphaltic concrete tracks increase in price of roughness.

Materials prices do not explain increase in the price of lane miles.

Calculate User Cost per VMT I

- Recall steady state expression for τ

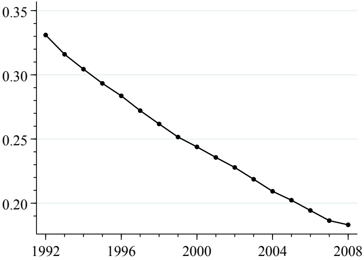
$$\tau = \left[r p^L L + r p^q q L + \kappa p^q v \right] / v.$$

- We observe L, q, v directly.
- r is the risk free rate, linear fit to 10 year treasury rate adjusted for inflation.
- We estimate p^q and p^L.
- κ from engineering books.

Calculate User Cost per VMT II

- Steady state expression for τ,

$$\tau = \left[rp^L L + rp^q qL + \kappa p^q \mathrm{VMT} \right] / \mathrm{VMT}.$$



- This shows how τ changes if we fix other variables in a particular year.
- Dynamic/Euler equations give much smaller and sometimes negative τ.

Calculate User Cost per VMT III

- Steady State expression for τ,

$$\tau = \left[rp^L L + rp^q qL + \kappa p^q \mathrm{VMT} \right] / \mathrm{VMT}.$$

- Let $o(k)$ denote a term of order 10^k, then we can evaluate the order of magnitude of the three terms in the numerator of τ,

$$\begin{aligned} rp^L L &\sim o(-2) \times o(7) \times o(5) = o(10) \\ rp^q qL &\sim o(-2) \times o(3) \times o(2) \times o(5) = o(8) \\ \kappa p^q \mathrm{VMT} &\sim 0(-6) \times o(3) \times o(11) = o(8). \end{aligned}$$

  Only the first term matters. This is the rental price for lane miles. It is the components of this term, p^L, r (and VMT). Quality and depreciation are not important determinants of user costs.

Sensitivity and Counterfactuals

		τ_{2007}	τ_{1992}	τ_{2007}/τ_{1992}
A.	Baseline	0.19	0.33	0.59
B. Counterfactuals	VMT_{92}	0.26	0.33	0.81
	p^L_{92}	0.09	0.33	0.27
	p^q_{92}	0.18	0.33	0.56
	r_{92}	0.51	0.33	1.60
C. Sensitivity	IV 92-08	0.06	0.15	0.40
	IV All	0.08	0.15	0.50
	Non parametric (Smooth)	0.07	0.14	0.50

Note: Values of τ in 1992, 2007, and percentage change between the two years. Panel A gives baseline values based on the same data and calculation as presented in the figure. Panel B considers four counterfactual cases identical to the baseline, except with a single variable held fixed. Panel C considers three cases identical to the baseline except for the technique used to estimate p^L.

Conclusion I

- Between 1994 and 2008, the price of IRI about doubled. This probably reflects increases in materials prices. This affects almost half of 2008 interstate expenditure.
- Between 1984 and 2008 the price of new construction increased by about a factor of 7. This may reflect hard to observe changes in construction or 'citizen's voice' (Brooks and Liscow, 2020).
- Composition effects are important for level effects, not for trend. The urban and union premia decrease.
- The steady state user cost of the interstate is declining. Interest rate decreases and VMT increases more than offset price increases. If interest rates go up, we have a problem.

Conclusion II

Does the US have an infrastructure cost problem?

- Prices relevant to 80% of the interstate budget are increasing rapidly.
- This is not strictly about 'construction costs'. The cost of resurfacing increases only because of materials costs.
- Overall, user costs decline. Increases in the price of new construction are not as important as the decline in interest rate and increase in VMT.
- Suggestive evidence indicates that new lane miles are changing in ways that we can't quite see. Do these (speculative) design changes pass a cost benefit test?
  - Early roads probably did not do enough externality mitigation (Brooks and Liscow 2020, Brinkman and Lin (2020)).
  - The interstate carries twice as much traffic through more urban places in 2008 than 1990. More externality mitigation makes sense.