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

Grant proposal: Economics of Transportation in the 21st Century

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1 Introduction

We propose to estimate the operating cost of the interstate highway system and investigate how this cost has changed over time. To accomplish this we rely on two main data sources. The first is disaggregated data describing the extent and condition of interstate highway system annually from about 1980 until 2008. The second is state-year data detailing expenditures on construction, resurfacing and maintenance. These data allow us to estimate the level and rate of change of the cost to construct and resurface a lane mile of interstate. Our data also describe the intensity with which each segment of the interstate network is used. Given an estimate of the rate at which pavement deteriorates with use, this leads to an estimate of the equation of motion of the quantity and quality of the Interstate highway network. We use this equation of motion to calculate the average and marginal cost of capital required to provide vehicle miles on the interstate.

These results are of interest for a number reasons. First, infrastructure policy in general and highway policy in particular are the topics of active policy debates. Our results provide a detailed description of the state of an important stock of infrastructure, and also of the cost to augment and maintain it. This has obvious relevance to policy.

Second, infrastructure is an important asset class and there has been some evidence that US productivity in infrastructure construction has been stagnant or declining over the past generation. Our investigation sheds light on this issue. Because the interstate highway system is constructed to similar standards everywhere and over time, it provides a useful special case for examining changes in the cost of infrastructure construction.

Third, the benefits of the interstate highway system have been the subject of much recent research. However, investigations of its cost have been rudimentary. To the extent that welfare analysis of the Interstate requires an evaluation of costs and benefits, we are filling the in costs half of this equation.

Finally, our estimates will give rise to a marginal capital cost of vehicle miles travelled. We compare this cost to the user fees generated by this travel. If we treat user fees as indicating revealed preferences for access to the interstate, then we can then assess the extent to which the provision of the interstate is optimal, given this willingness to pay.

2 Econometric model

We investigate two principal empirical quantities. The first is the extent of the interstate network in lane-miles measured at the state year level. The second is condition or quality of highway segments

as measured by the International Roughness Index (IRI), and recorded at the segment-year level.[1] Both quantities are reported in the Highway Performance Monitoring System (HPMS) data. These are the data on which, for example, Duranton and Turner (2012) is based, although the segment level data has not previously been exploited.

We will measure expenditure at the state-year level using the highway statistics series (e.g., US Federal Highway Administration (1985)). These are the same data as Brooks and Liscow (2018) rely upon in their investigation of highway construction costs.[2] However, as our study period is more recent than that of Brooks and Liscow (2018), we are able to exploit the greater detail reported in more recent highway statistics volumes.

We would like to estimate the price of a lane mile of interstate and the price to reduce the roughness of the interstate by one inch. Given the different resolution of the underlying extent and quality data, this requires two distinct econometric exercises.

To describe these econometric exercises, introduce the following notation. Our data are organized by state and year, and sometimes road segment. Index these attributes by $s \in \{1, ..., 48\}$, t and $j \in J$.

Let L_{jst} indicate lane miles of interstate highway for segment j in state s and year t. Similarly, let L_{st} indicate lane miles of interstate highway in state s and year t. Omitting subscripts for legibility, let Q indicate the quality of a length of interstate. Quality is measured in inches of suspension travel, so Q indicates the inches of suspension travel required to traverse a length of road. Define $q = Q/L$ to be inches of suspension travel per mile traveled along this road, that is, IRI. Here and throughout, we adopt the convention of using lower case letters to indicate per mile interstate attributes and uppercase to indicate aggregate attributes.

Let Y indicate total expenditure. We are also interested in three subclasses of expenditure, Y^L, Y^Q, and Y^M, where $Y = Y^L + Y^Q + Y^M$. These are; expenditure on new lane miles, expenditure on resurfacing, and expenditure on interstate maintenance that does not directly impact roughness or length. Let y, y^Q, y^L, y^M denote the corresponding per mile expenditures. Let Δ indicate first differences, so that $\Delta_t L_s = L_{st} - L_{st-1}$ indicates changes in lane miles.

To estimate p^L, we estimate the following equation,

$$\Delta_t L_s = A_0 + A_1 Y_{st}^L + \epsilon_{st} \tag{2.1}$$

This relates length to expenditure on new construction. In particular, $A_1 = 1/p^L$, so that this

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[1]IRI reports the number of inches of suspension travel per mile experienced by a typical car traversing a given mile of roadway.

[2]Note that the HPMS is *not* the same as the PR511 data on which Brooks and Liscow (2018) is also based. The HPMS is much more detailed and more recent.

equation leads to estimates of the inverse price of lane miles.[3]

We estimate the price of an inch of smoothness using the segment-by-year HPMS Sample data. For each year, the HPMS reports an indicator for each resurfaced segment. Denote this indicator by $\mathbb{1}_{jst}(q)$ and define it to take the value one if the segment j was resurfaced in year t, and zero otherwise. Also define $\mathbb{1}_{jst}(\sigma, \tau)$ as a state-year indicator. Finally, define L_{st}^Q as lane miles of interstate resurfaced in state-year (s, t).

We can now estimate the effect of resurfacing on roughness with the following equation,

$$\Delta_t q_{is} = A_2 \mathbb{1}_{ist}(q) + \sum_{\sigma, \tau} A_{\sigma\tau} \mathbb{1}_{ist}(\sigma, \tau) + \epsilon_{ist}. \tag{2.2}$$

Here, A_2 gives us the mean difference in roughness between a segment maintained in year t and state-year means of unmaintained segments. This regression yields large, precise estimates of the effect of resurfacing on roughness. Note that the terms $A_{\sigma\tau}$ describe the depreciation of an average segment in response to another year of use.

A_2 measures the change in roughness from resurfacing, inches per mile. We would like to know the price per inch to reduce roughness. One way to do this, would be to simply divide resurfacing expenditure per resurfaced mile by A_2. Rather than do this, we proceed by interacting the resurfacing indicator with state-year expenditure per resurfaced lane mile as follows,

$$\Delta_t q_{is} = A_2 \left[\mathbb{1}_{ist}(Q) \left(\frac{Y_{st}^Q}{L_{st}^Q} \right) \right] + \sum_{\sigma, \tau} A_{\sigma\tau} \mathbb{1}_{ist}(\sigma, \tau) + \epsilon_{ist}. \tag{2.3}$$

Since the left hand side of this equation is denominated in inches per mile, and the units of $\mathbb{1}_{ist}(Q) \left(\frac{Y_{st}^Q}{L_{st}^Q} \right)$ are dollars per mile, it must be that the units of A_2 are inches per dollar. That is, similarly to equation 2.2, $A_2 = 1/p^Q$.

The two equations, 2.1 and 2.3 are our main estimating equations and our empirical investigation will center around the estimation of variants of these equations. Note that equation 2.1 shows the rationale for estimating inverse prices rather than estimating prices directly. Doing it this way allows us to exploit all of the detail of our segment level data in 2.3. We formulate 2.1 with expenditure on the right for symmetry.

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[3] We are concerned that expenditure on lane miles may not be assigned to state-years at random. Implicitly, our first equation describes the way that expenditure is converted into the output, lane miles, and so it traces out a supply relationship. In fact, we observe the equilibrium choice of expenditure and the resulting output of length. This is a textbook simultaneity problem. To resolve it, following Leduc and Wilson (2013), we sometimes rely on lagged appropriations as an instrument for expenditure.

Figure 1: Quantity, Quality and prices over time

(a) Lane miles

(b) IRI

(c) Lane miles/10^6\$

(d) Inches of roughness/10^6\$
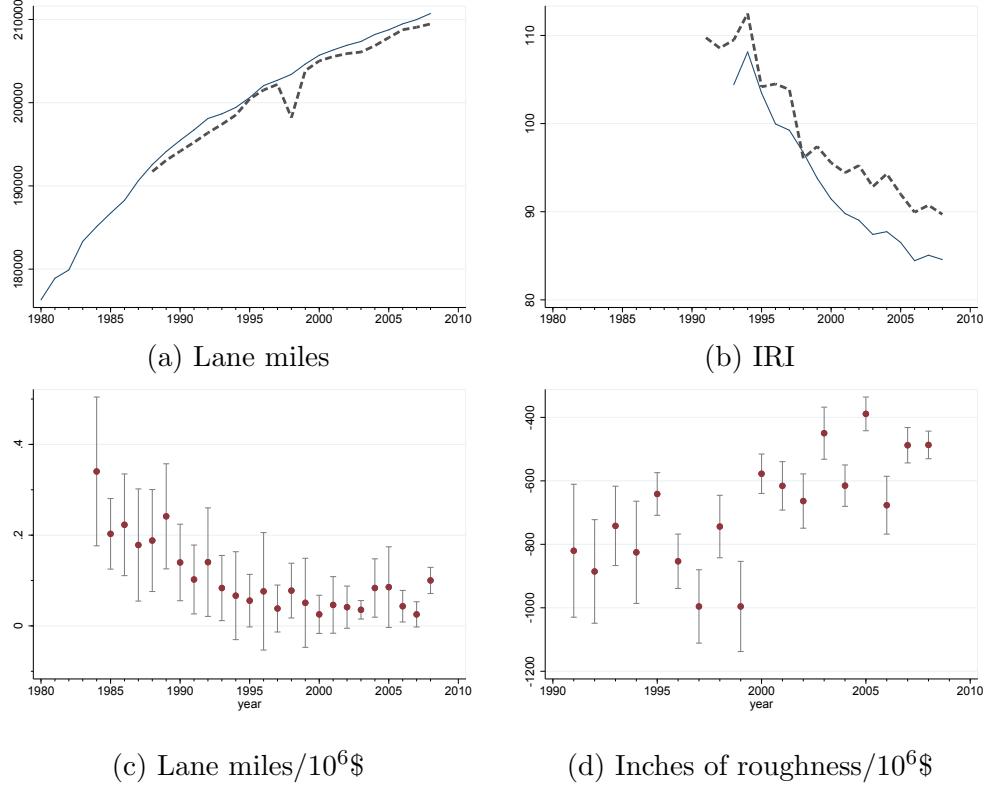
Note: (a) Total Interstate Lane Miles by year (miles). (b) Lane mile weighted IRI for the whole Interstate by year, (inches per mile). (c) Estimated lane miles per million dollars of construction expenditure. (d) Inches of roughness per million dollars of resurfacing expenditure.

3 Preliminary results

Figure 1 describes the basic features of our data. Panel (a) shows the about 20% increase in lane miles over our the 1980 to 2008 span of the HPMS. Panel (b) shows the decrease in lane mile weighted IRI over the 1992-2008 period when IRI data are available. The Federal Highway Administration considers roads to be in *good* or *acceptable* condition as their IRI value is below 95 or between 95 and 170 inches, respectively (US Department of Transportation, 2013). We see that the Interstate was smoother in 2008 than in 1992. Lane mile mean IRI declined from about 105 inches per mile to about 85.

Panel (c) describes mean lane miles per million dollars of construction expenditure by year. Around 1980, one million dollars purchased about 0.2 miles. This declined by about a factor of 4 by end of our sample. Panel (d) describes mean reductions in roughness per million dollars of resurfacing expenditure. This graph is somewhat noisier than is panel (c), but still shows a clear

trend. Around 1992, one million dollars of expenditure reduced roughness by about 800 inches. By 2008, this quantity was cut in half to about 400 inches per million dollars.

4   Conclusion

The data for this project is largely completed. We have two main tasks before us. The first is to understand why costs for construction and resurfacing have risen so rapidly. Over our study period, we observe that the interstate system became flatter, lower, closer to water, more exposed to union labor, more urban, more heavily used, more likely to be asphalt than concrete and thicker. Does any of these trends explain the trends in costs?

Second, we would like to calculate how the marginal cost of capital evolves over time. This rests on a further empirical result and on theory. First, we would like to know how road quality responds to use. In theory, our data allows us to estimate this, though we have not yet succeeded in doing so. Second, as figure 1 makes clear, calculating the cost of capital for a marginal vehicle mile will be subtle; the extent and quality of the network are improving, unit costs are increasing rapidly, and usage is increasing rapidly. In addition to providing estimates of the sorts of unit costs that we see in the bottom panels of figure 1, we intend to investigate how to aggregate this information into a marginal cost of capital. This exercise is underway. If we treat user fee revenue per vehicle mile traveled (which we can calculated from highway statistics data) as revealing information about the value of the interstate, then comparing this value to our estimate of the marginal cost of capital can provide a basis to estimate the welfare implications of marginal expansions or contractions of the highway network.

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