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Can America Reduce Highway Construction Costs? Evidence from the States

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Can America Reduce Highway Construction Costs? Evidence from the States

Although infrastructure is a key input into economic growth, systematic evidence on its cost across time or place is very limited. In this paper, motivated in part by the difficulties in international comparisons, we focus on infrastructure for which we can consistently measure cost over time and space: the US Interstate system. Looking over the period of the build-out of the system from 1956 to 1993, we find that the 75th percentile state spent \$8.8 million more per mile than the 25th percentile state, relative to mean spending per mile of \$11.5 million (all dollar figures are 2016 dollars). If states spending over the median had limited their expenditure per mile to that of the median state, the Interstate system would have cost about 40 percent less to build. Even when we limit to costs within policymaker discretion, netting out pre-determined characteristics such as the slope of the terrain, a \$3.3 million per mile interquartile range persists. We then show that this cross-state variation exceeds that in other related public and private spending, and examine patterns of correlation that provide evidence of common cost drivers. We review the evidence that does exist on the root causes of infrastructure costs and test some of these hypotheses in our cross-state setting. Our empirical tests find limited evidence for any single driver of cross-sectional variation.

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Infrastructure—capital investment in roads, water, school facilities and sewerage—is a key input into economic growth (Munnell, 1992). Economic historians credit infrastructure investments with large increases in social welfare. For example, Beach et al. (2016) show that large-scale water purification in the US in the first part of the twentieth century decreased mortality and meaningfully increased human capital formation (see also Ferrie and Troesken (2008) and Cutler and Miller (2005)). Duranton and Turner (2012) find that the large capital investment in the Interstate system yielded broad-based increases in employment. And Allen and Arkolakis (2019) argue that large welfare gains are possible with improvements to selected segments of the Interstate system.

But these benefits are available only when we can build infrastructure at reasonable cost. Despite the importance of infrastructure, there is very limited evidence on how much individual pieces of infrastructure cost and on whether any particular components drive the bulk of costs. While there is contemporaneous coverage of specific instances of high cost infrastructure—New York City's new subways, Boston's Big Dig, or California's high speed rail are all particularly salient—without systematic evidence it is hard to evaluate whether these projects are well-publicized outliers or typical expenditures (Goldman, 2012; Barro, 2019b; Varghese, 2019).

The limited evidence in the literature suggests that costs are rising. Looking at the construction sector as a whole over the last 70 years, Swei (2018) finds limited evidence of real growth in materials prices, but substantial growth in labor costs. Brooks and Liscow (2020) find that the cost to build a mile of Interstate highway tripled between the 1960s and 1980s. Mehrotra et al. (2019) find that this trend continued for both new Interstate construction and Interstate maintenance from 1980 onward.

This increase in costs may explain the much decried state of US infrastructure. There is a general belief that the quality of US infrastructure is low. The American Society of Civil Engineers consistently gives US infrastructure a failing grade (American Society of

Civil Engineers, 2017). If per-unit infrastructure costs increase, even an equivalent amount of spending—and the US spent in 2016 about the same in real per capita terms as it did 1956—translates into quite a bit less physical capital to facilitate trade or improve human capital. Yet as a policy matter, we cannot simply return to the 1950s to procure low-cost infrastructure.

In this project, motivated in part by these difficulties of comparison, we focus on infrastructure for which we can consistently measure cost over time and space: the US Interstate system. Our goal is to highlight variation in cost. If some of this cost variation is due to policy choices in low-cost states that are replicable in high-cost states, this provides one route to lowering cost. New Interstate construction is particularly useful for analysis because a new mile of Interstate is at least uniformly defined over time and space. While all highway miles are certainly not exactly comparable, comparisons across different types of infrastructure, or even the same type of infrastructure at different levels of depreciation, are even more fraught. We focus on the 1956 to 1993 period, a period that saw the construction of over 90 percent of today's Interstate system.

In related work, we analyze the temporal variation in Interstate spending from 1956 to 1993 (Brooks and Liscow, 2020). We show that the US spent roughly $8.75 million 2016 dollars to build a new mile of interstate for first decade and a half of the program, from 1956 to 1969. After this, however, Interstate spending per mile starts a steady increase. By the 1980s, states spent roughly $25 million 2016 dollars to build a new mile of Interstate—roughly a tripling in costs. As neither labor nor materials prices increase in any meaningful way over the period, they do not explain the temporal increase.

Our related work also marshals multiple pieces of evidence to suggest that the rise of "citizen voice" drives at least some of these increased expenditures. We define "citizen voice" as an amalgam of changes in statutes, changes in judicial doctrine, and the rise of social movements, dating to the late 1960s and early 1970s, all of which combined to give individual citizens a greater ability to modify government behavior (Altshuler and Luberoff, 2003; Glaeser and Ponzetto, 2018). For example, the passage of the National Environmental Policy Act of 1969 gave individual citizens a cause of action to sue the government if they thought that the regulatory agency was not faithfully implementing the Act. In addition, we find that correlates of citizen demand for higher quality Interstates, such as income or education, are associated with higher costs only after the "citizen voice" tools for challenging government behavior appear.

In this paper we focus on whether there is economically meaningful cross-state variation in per mile Interstate spending. We find that there is—the interquartile range in spending per mile is an astonishing $8.8 million, relative to the mean of $10 million. If states spending over the median had limited their expenditure per mile to that of the median state, the Interstate system would have cost about $260 billion, or 40 percent less, to build.

We then isolate Interstate spending subject to policymaker discretion, by conditioning on pre-determined characteristics, such as changes in elevation along the route, that should drive costs.[2] When we restrict to this type of spending, cross-state geographic variation falls, but is far from eliminated. When we further limit analysis to the second period—after the rise of citizen voice—the ability of pre-determined characteristics to eliminate cross-state variation in costs declines.

We then look to clues for drivers of this geographic variation by looking at the correlation between Interstate spending and related private and public spending. We test whether key types of spending co-vary with Interstate cost per mile. Of all the types of spending we analyze, including private construction and overall public spending, Medicare spending per enrollee is the most strongly statistically related with spending per new Interstate mile net of geographic covariates. Each additional $1,000 of Medicare spending per capita (mean

[2]We deliberately use the word "policymaker" here to include both elected politicians and bureaucrats, both of whom have substantial power over spending decisions.

$5,650) is associated with an additional $3.4 million dollars in Interstate spending, or about 20 percent of mean spending per mile.

We then review the literature on the root causes of infrastructure cost increases and examine the relationship between some of these root causes and cross-sectional variation in Interstate spending per mile. Even in the second period (1970-1993), when citizen voice factors may be important, we see few strong correlations. Thus, the drivers of this cross-state spending remain something of a mystery.

To undertake these analyses, we use novel data on the cost of the US Interstate highway system from the Federal Highway Administration's *Highway Statistics* yearbooks that we assembled in Brooks and Liscow (2020). We combine these data with the date of mileage completion (Baum-Snow, 2007) to calculate spending per mile. As in Brooks and Liscow (2020), we use multiple spatial data sources to calculate population density, slope and wetlands and rivers by Interstate segment to control for the differential physical costs of constructing segments. Adding to our previous work, we also gather private spending on construction and healthcare, as well as public spending including Medicare, Medicaid and state and local government general spending.

This paper first presents background on the Interstate highway system, and then discuses the data we use. We follow with an analysis of the variation in spending per mile and the variation in spending per mile subject to policymaker control, along with tests for the validity of this measure. We continue with the correlation between Interstate spending and other relevant private and public spending. We then review the literature on the root causes of infrastructure cost changes. In the final empirical section, we test whether some of these cost drivers are related to Interstate spending per mile. The final empirical section asks whether higher spending per mile is related to better Interstate outcomes; we then conclude.

1 Interstate Construction

Though in plan since at least the 1940s, the Interstate System formally began with the Federal-Aid Highway Act of 1956. This Act authorized a roughly 41,000 mile system with an estimated completion before 1970 at a projected cost of 25 billion 1946 dollars, or 192 billion 2016 dollars. In reality, Interstate construction did not finish until the 1990s. The vast majority of miles were completed by 1993, the end of our study period. The total cost of the Interstate exceeded $504 billion 2016 dollars. (For details beyond this summary, see Brooks and Liscow (2020).) Interstate miles are present in all states.

The Interstate construction program was a federal-state partnership. For each new mile of Interstate—our focus in this paper—the federal government paid 90 percent of the cost; states bore the remaining ten percent.[3] In return for federal funding, states were required to build roads up to "Interstate standards." These standards meant two lanes in each direction, full control of access, a design that yielded a minimum speed of 50 miles per hour and that would support the projected traffic in 1975 (a requirement later changed to be projected traffic 20 years after completion). Although the government mandated a minimum standard, it would reimburse for quality above this minimum, subject to regulatory approval. The Interstate program was administered by state departments of transportation, which put projects out to bid. States varied in the bidding systems they used (Pietroforte and Miller, 2002, p. 429).

In practice, states had broad latitude in ordering the segments they built, and choosing how much to spend on each segment. However, the funding structure capped the amount states could spend in any one year. In each year of the program, the revenue available for highway spending came from the gas tax. The federal government split the gas tax revenue among states in proportion to the estimated cost of completion of remaining highway miles.

[3]There were some exceptions to 90 percent reimbursement for different types of specialized programs.

Thus, states had to choose between constructing quickly at lower spending per mile, or slowly at higher spending per mile.

The pace of construction slowed as the program aged. Most states built the bulk of their miles in the first two decades of the program; the 1950s and 1960s saw 60 percent of total miles constructed. States built another thirty percent of system mileage in the 1970s and the remaining ten percent in the 1980s and early 1990s.

2 Data

To investigate the variation in Interstate spending per mile across states, we collect four types of data. These are Interstate spending per mile; measures of pre-determined differences in construction costs; public and private spending by states; and key demographic covariates.

2.1 Spending per mile

To construct Interstate spending per mile, we need both the numerator—spending—and the denominator—miles. For annual Interstate spending, we digitize state level data from the US Department of Transportation's *Highway Statistics* yearbooks for years 1956 to 1993. These volumes report annual federal spending on new Interstate miles by state. The data appendix of Brooks and Liscow (2020) details how we adjust these data to account for small anomalies and issues due to two special rules on apportionment. Here and throughout, we adjust all dollar figures to 2016 dollars using the CPI-U.

For the denominator of spending per mile, we measure miles constructed by year of completion from Baum-Snow (2007). For each roughly one-mile segment of Interstate, we observe the exact location of that segment and the year in which the segment was completed.

Because spending is counted when it occurs and miles are counted when completed, the timing of spending usually pre-dates timing of completion of miles.[4] In this paper, we focus on either the entire time period—in which case there is no temporal mis-match—or two long time periods, in which case this issue is substantially lessened.

2.2 Pre-Determined Features

To account for pre-determined features that drive spending per mile and are outside of policymaker discretion, we rely on what researchers generally believe to be the three main drivers of physical construction costs (Balboni, 2019; Faber, 2014; Alder, 2019). The first is population density, with data from the Decennial Census (specific files as noted in the data appendix). We measure population density for each one-mile segment as the population density of the census tract in which the largest part of the segment falls, when tract data are available, or the population density of the county, when tract data are not available.[5] We use population density from the census year closest to the opening of each segment.[6] We create a state or state-period measure by taking a segment-weighted average.

The second physical feature relevant to Interstate cost is the slope of terrain. We measure the average state slope by first finding the average slope of land within 50 meters of each segment using USGS's National Elevation Map. We create a state or state-period measure of slope by taking the segment-length weighted average of all segment slopes for a state or state-period.

The final measure of pre-determined features is based on the length of the segment, in miles, that intersects wetlands or rivers. We define wetlands as the any of water types in the Cowardin classification system from the US Fish and Wildlife Service (2018) Wetlands

[4]In addition, we adjust spending to be a weighted average of the year the segment opens and the two years prior. See details in (Brooks and Liscow, 2020). We omit Alaska, Hawaii and the District of Columbia.

[5]The entire country is tracted only in 1990; from 1950 to 1980, tract data are available only for selected areas.

[6]For example, we attribute the 1960 census characteristics to segments opening from 1956-1964, and the 1970 census characteristics for segments opening 1965-1974.

Inventory. This definition includes rivers and any other large bodies of water. The final state or state-period measure is the average segment share in wetlands or rivers, weighted by segment length.

2.3 Public and Private Spending

We have several measures of private and public spending with which we correlate our Interstate construction cost measure. To compare Interstate spending to private spending, we use an index of private construction costs from R.S. Means, indexed to 100 in 1993, courtesy of Raven Molloy. Molloy collected these data for every five years from 1940 to 1980 and then annually 1981 to 2003. To measure construction wages, we use annual state-level construction payroll divided by number of construction employees from County Business Patterns (available periodically in the 1950s and 60s, then 1971 1993) to measure average annual construction wages per state. We also include private health insurance expenditures per enrollee in 2001 (the earliest year available) from the Centers for Medicare and Medicaid Services' "Health Expenditures by State of Residence, 1991-2014" (see Appendix for complete citation details). Private health insurance expenditures include expenditures by both the insurer and the insured.

We also compare Interstate spending to public spending. For Medicare and Medicaid, we use spending per enrollee from 1991, also from the Centers for Medicare and Medicaid Services' "Health Expenditures by State of Residence, 1991-2014."[7]

[7] In an appendix table we use a host of government spending measures from the Census of Governments (relying only on full censuses in 1967, 1972, 1977, 1982, 1987 and 1992). We use data on total state-wide local government expenditures (the sum of state and all local expenditures) and rely on the time-consistent compilation from Willamette University (Pierson et al., 2015). To avoid problems of differing state and local responsibilities, we aggregate all state and local government spending by state and year. These data do not include state-level accounts in 1967, so most of our data work relies on state-aggregate measures from 1972 onward.

2.4 Interstate Outcomes

To assess whether Interstate spending correlates with post-construction outcomes, we collect the number of accidents and fatalities per mile from the oldest relevant *Highway Statistics*, which is 1995. We also collect 2015 state maintenance spending per mile, again from *Highway Statistics*. We use later measures of maintenance expenditures so as to assess the long-run quality of Interstate construction.

See summary statistics for our main variables of interest in Table 1.

3 Documenting Cross-State Differences

With these data in hand, we now turn to documenting cross-state variation in Interstate spending per mile. We then create a measure of state spending per mile that reflects costs subject to policymaker discretion, omitting spending determined by pre-existing features, such as the slope of the terrain. Finally, to look for clues about potential drivers of cost, we assess whether spending due to policymaker choice covaries with other relevant public and private spending.

3.1 Absolute Spending

We begin with absolute spending in Figure 1, which shows how much states spend, on average, per new mile over the build-out of the Interstate system from 1956 to 2013. The average state spends $11.5 million per mile (this and all future figures are in 2016 dollars). The bars in the figure present deviations from this average. Delaware spent the most per mile of any state, at just over $50 million dollars per mile; the top three spenders also include New Jersey at over $30 million per mile, and Connecticut at just under $25 million per mile. North Dakota spent the least of any state per mile, at roughly $3 million per mile. Even excluding the top three spending states still leaves a $30 million per mile difference between the highest and lowest spending states.

The figure demarcates the four census regions in shades of purple. Western states tend to spend the least per mile; Northeastern states (and some states the Census denotes as South, but which may be more intuitively northeastern—Delaware and Maryland) are the highest spending ones. There are no Northeastern states in the bottom portion of the spending distribution.

This geographic variation is also visible in the top panel of Figure 3, which maps spending per mile by state for the entire period of construction. Unconditional spending per mile is highest in the Northeast and West Coast; states in these regions are mostly in the top quartile of spending per mile (the darkest purple).

3.2 Limiting to Spending Driven by Policymaker Choices

Some of this spending variation is surely due costs outside of state policymaker control. For example, construction costs in states with highways routed through more sloped land should be higher. Because we are interested in the scope of policy to potentially lower costs, our goal here is to isolate those costs that are within the purview of state policymakers. In other words, for example, we cannot make Colorado less hilly, but one could suggest that Colorado change its procurement rules. Thus, we want to purge spending related to the former and keep only spending related to the latter.

To disentangle spending within the grasp of policymaker choice from that determined by pre-existing features, we regress spending per mile on three key covariates, denoted G_s: average population density, average slope, and share of miles in wetlands or rivers of segments constructed (see data section for more specifics on the calculation of these measures). Approximations of cost in the engineering literature rely on these three covariates (Balboni, 2019; Faber, 2014; Alder, 2019). Recall that states were responsible for building highways on pre-determined routes. Thus, the slope, the extent of wetlands and water, and the surrounding population density of segments were federal choices that constrained the actions of state policymakers.

While this is a useful exercise, these covariates may "overcontrol" for the amount of pre-determined spending. For example, if areas with higher population density are more expensive places to build and furthermore prefer more spending on Interstates, our method removes spending related to both of these. This is despite the fact that our goal is to remove only the first. Thus, there are dueling concerns. Omitted variables may potentially yield residuals that are too big; alternatively, the variables we do include may yield residuals that understate the true variation in spending due to policymaker choice.

With these caveats in mind, we estimate

$$\text{spend per mile}_s = \beta_0 + \beta_1 G_s + \epsilon_s \tag{1}$$

where s indicates state. The dependent variable is spending on new Interstate miles in 2016 dollars. We use the estimated residual, $\hat{\epsilon}_s$, as our measure of spending within policymaker discretion. We weight all regressions by the number of Interstate miles built in a state so that the results approximate the average mile, rather than the average state.

Figure 2 presents these $\hat{\epsilon}_s$ residuals. By construction, they average to zero. A comparison of Figures 1 and 2 shows that the magnitude of the variation shrinks substantially. Instead of an almost \$50 million difference between the highest and lowest spending states (as in Figure 1), the difference falls to about \$25 million. Notably, Delaware—the highest spending state in the first graph—is now the lowest spending state, spending almost \$15 million fewer dollars per mile than the average state.[8]

The bottom panel of Figure 3 shows this residual spending in a state map. While Washington state and parts of the mid-Atlantic region remain in the top quartile of spending,

[8]Delaware has very few interstate miles, and many of these miles are adjacent to or are over water.

much of New England and the Northeast moves out of the top quartile of spending. In addition, much of the South now falls into the second highest quartile of spending per mile. The distribution also shows a fair amount of within-region heterogeneity in costs. For example, New York is in the bottom quartile, while most of its neighbors are in the top quartile. Louisiana is in the top quartile, while the rest of the South is in lower quartiles.

We begin by considering the relationship between raw and residual spending. Figure 4 plots each state's rank in the raw spending per mile distribution on the horizontal axis and the rank of the residual from Equation 1 on the vertical axis; points are the two letter state abbreviation and colors are by region. While the ranks are positively correlated, the strength of the correlation is moderate ($\rho = 0.3$).

Interestingly, the controls G_s change the ranks of high spending states more than the ranks of low spending states. There are virtually no states in the top left quadrant (unconditionally low, and conditionally high spending), but quite a few states in both the top right (high conditionally and unconditionally) and bottom right (high unconditionally, low conditionally) quadrants.

3.3 Evaluating the Isolation of Spending From Policymaker Discretion

These residual cost measures are of interest inasmuch as the variation we have isolated is truly just that spending within policymaker control. In this section, we stress test the distribution of these residuals and assess their persistence over time.

If the residuals from Figure 2 are spending within policymaker discretion, they should already omit pre-determined spending variation. If this is the case, changes in the specification should have little impact on the magnitude and distribution of their value. Table 2 tests this contention and reports the standard deviation, the interquartile range, and the difference between the 90th and 10th percentiles for the full period (first four columns) and the second half (last four columns). In the raw data (first row), the standard deviation in spending is $10.5 million 2016 dollars, or just slightly under mean spending over the entire period. The interquartile range and the 90-10 difference also reflect substantial variation.

These figures are even larger for the second period. The standard deviation of spending per mile across states from 1971 to 1993 is 16 million 2016 dollars, with an interquartile range of $14 million and 90-10 difference of $35 million.

The second row of Table 2 shows our preferred measure of spending within policymaker control, or residuals from a regression of spending per mile on slope, population density and water and wetlands. As we saw in the comparison of Figures 1 and 2, these pre-determined features do explain a substantial amount of the variation in the early years; the standard deviation for the full period falls from $10.5 to $4.4 million. Interestingly, when we consider just the 1971 to 1993 period, in which we hypothesize that a new cost regime has taken hold, the standard deviation of the residual is substantially closer to the unconditional standard deviation of raw spending ($10.2 for the residual versus $16.1). Relative to the full period, the interquartile range and particularly the 90-10 difference are larger.

The following rows test whether the residuals estimated in the second row change substantially as we include additional covariates. In the third row, we add controls for all the pre-determined characteristics squared and report results for the resulting residuals. Regardless of the time period, the variation in the residual changes very little, suggesting that the linear specification soaks up the bulk of the variation related to the pre-determined characteristics. In the next row we evaluate whether variation in the residual could be driven by variation in the number of lanes per highway across states. Ideally, our dependent variable would be spending per lane mile, but data on the initial number of lanes constructed are not available for the first part of our analysis period. Instead, we add a control for the average number of lanes per highway in a state. This adds no explanatory power to the regression—

the R^2 does not change—and the variation in the residuals is also virtually identical to the previous specification. This holds both for the full period and for the second half.

Alternatively, one might be concerned that these results are driven by a few high outliers, visible in both Figures 1 and 2. To assess the role of outliers, we drop the states with the two highest values of spending per mile and re-estimate Equation 1 using the covariates from the previous row. While the standard deviation and 90th-10th percentile difference both decline, the interquartile range is little changed, suggesting that the residuals for most observations are not driven a particular relationship between the covariates and the very largest observations.

Another way to test whether these residuals are driven by underlying state features or by temporal vagaries is to assess whether states' residuals persist over time. As we discussed above, in other work, we argue that there was a regime shift in spending that takes place around 1970. Because of this, the pre- and post-1970 correlation in residuals may be small. However, if state-specific factors such as procurement practices of industrial composition determine costs in the post-1970 regime, we should expect persistence in residuals within this latter period.

Figure 5(a) plots each state's residual rank from 1956 to 1970; the vertical axis plots the residual rank from 1971 to 1993. We use ranks, rather than absolute magnitudes, to visually abstract from large outliers. As the figure shows, this correlation is small and actually negative ($\rho = -0.03$), consistent with a regime change in Interstate spending.

The pattern post-1970 is strikingly different. Figure 5(b) uses the same scheme but reports ranks from 1971 to 1981 on the horizontal axis and 1982 to 1993 on the vertical axis. Here the correlation is positive ($\rho = 0.2$), as we would anticipate if underlying state features drive costs.

3.4 Spending Due to Policymaker Discretion and Related Private and Public Spending

Having created these residual measures of spending to reflect governance choices, we now turn to whether this residual variation is large or exceptional. We begin by comparing spending due to policymaker discretion with relevant private and public spending. The goal of this comparison is to illuminate possible common drivers of Interstate spending.

To effect this comparison, we estimate regressions of the form

$$\text{spend per mile}_s = \beta_0 + \beta_1 G_s + \beta_2 C_s + \epsilon_s. \tag{2}$$

The dependent variable is state Interstate spending per mile over the 1956 to 1993 period (or sometimes spending per mile from 1971 to 1993). As before, G_s is the vector of the three key pre-determined features as defined for Equation 1 above. We denote additional covariates as C_s. As in Table 2, we measure this residual variation in three ways: the standard deviation of the residuals; the difference between the 75th and 25th percentiles of the residual distribution; and the difference between the 90th and 10th percentiles of the residual distribution.

The first row in the top panel of Table 3 repeats the second row of Table 2 for comparison with the other results. The inclusion of pre-determined features explains about 85 percent of the variation in spending for the full period, as shown by the R^2 in column 3, and cuts the standard deviation of the residuals by more than half to \$4.4 million (column 4; relative to a mean of \$11.5 million per mile, see Table 1). The other measures of residual variation shrink by even larger shares.

The first row in the bottom panel of this table shows analogous figures for the second half of the period. In this later period, the variation across state is higher (standard deviation is \$16.1, rather than \$10.5) and the pre-determined covariates explain less of the overall spending (R^2 of 0.67 versus 0.84). The first row in each panel serves as the baseline to which we compare whether other spending explains a meaningful portion of spending due to policymaker discretion.

Our first additional covariate is private construction spending. This comparison to private costs tests whether Interstate spending per mile is higher in, for example, New Jersey or Connecticut because costs are generally higher in these states, or because of other factors specific to the Interstate.[9] If construction labor costs are generally higher in New Jersey, Interstate spending per mile should be related to private construction costs as they both include these higher labor costs. Said differently, if construction costs matter to both, a control for private construction costs in Equation 2 should substantially decrease the variation in the residual.

We measure construction cost via a constant quality index (see data section and appendix for greater details). The second row of the top part of the table shows that there is virtually no relationship between the variation in private construction spending and Interstate spending per mile for the 1956-1993 period—despite the fact that both operate in similar markets. This is consistent with the result in Brooks and Liscow (2020) that cross-state variation in labor costs explains none of the temporal increase in Interstate spending per mile. The coefficient on residential private spending construction costs is small and very imprecisely estimated; the measures of residual variance are barely changed by the addition of this additional covariate.

This finding is somewhat different in the 1971 to 1993 period; here construction costs are significantly and positively related to spending. With this greater variation in Interstate spending, we see more statistically strong relationships with both private and public spending. A two-unit increase in the private residential construction index (about one-third of

[9] Appendix Table 1 shows the coefficients of variation of all relevant variables; the only variable we analyze that has a higher coefficient of variation than Interstate spending per mile is Interstate maintenance per mile.

the interquartile range for this variable) is associated with $1 million additional Interstate spending per mile.

We can get at this same issue by evaluating whether, if highway spending varied across states in the same patterns as private construction costs, would there be any cross-state variation in Interstate spending left? We use a constrained regression to ask this question. We specify both the Interstate spending per mile and the construction cost index in logs so that no variation in excess of construction cost implies a coefficient of one. Estimating this log-log regression with the coefficient on private construction costs fixed at one, we find results very similar to the conclusions from Table 3. This restriction has very little impact on the remaining variance in spending subject to policymaker discretion.

Another private cost that varies substantially across space is health care. If the regulatory environment that drives health spending also drives Interstate spending, we would expect to see a large drop in the residual with the inclusion of private health care costs. These private health care costs are expenditures by individuals and insurance companies for health care, including premiums and health care expenses, as well as administrative expenses by health insurers. However, for the full period, we find an imprecise correlation between private health insurance expenditures per user from 2001 (the earliest available year) and spending due to policymaker discretion. Costliness of private care may speak to the regulatory environment in the state. However, we see no strong relationship between highway spending and private health insurance expenses, as standard errors are large.

In the 1971 to 1993 period, this relationship strengthens substantially. An additional $250 of in private insurance spending—the magnitude of the interquartile range—is associated with slightly more than $2 million more in Interstate spending per mile. This is about 14 percent of mean Interstate spending per mile. This is suggestive evidence that there may be common factors driving up both types of spending. However, the residuals change only modestly. For example, the standard deviation of the residual falls from $10.3 to $9.68.

Thus, there seem unlikely to be critical common drivers for these two types of spending.

With these mixed findings in hand, we now turn to public spending, which has different cost drivers than private spending and which may therefore suggest different cost drivers in Interstate spending. We start with spending on Medicare per enrollee. Medicare funding decisions are almost exclusively federal. States have no control over what or how much the system covers, nor do they bear any fiscal liability for the program. Yet there is local variation: federal decisions manifest locally through individuals' choices and hospital and health care provider choices. In addition, Medicare reimbursement rates vary regionally.

Although there is a near-vacuum in work on the geographic variation in highway costs, the geographic variation in Medicare has been studied intensely (see Wennberg and Gittelsohn (1973); Cutler and Sheiner (1999); Martin et al. (2007)). The most prominent strand of the literature, led largely by researchers at Dartmouth, argues that there is substantial unexplained variation in Medicare costs. In implementing these studies, researchers usually adjust spending for Medicare prices, so that the effects are driven by the quantity of procedures, rather than the price of procedures (Skinner and Fisher, 2010). Variation in prices is mechanical, because the federal government sets Medicare reimbursement rates. Quantity differences in healthcare, however, could be driven by, for example, different physician practice styles across the country.

The excellent overview in Congressional Budget Office (2008) divides the drivers of Medicare spending into four main categories: prices; health and illness status; regional preferences about the use of healthcare services; and residual variation. The summary of the literature suggests unsurprisingly that price is not a major driver. While this literature argues that regional variation in individual preferences for care is generally not a large driver, the report acknowledges that it is very difficult to measure regional preferences and that demographics' ability to explain preferences may be limited. This literature points out that the unexplained variation is large, and that addressing factors that cause the variation, such as physician practices, could yield large savings in the program.

A host of more recent work builds on these findings. For example, Gottlieb et al. (2010) analyze Medicare spending after adjusting for local price differences and find that utilization—not prices—drives Medicare spending. Finkelstein et al. (2016) also find an important role for place-based variation. They use patient migration to show that "40 to 50 percent of geographic variation in utilization is attributable to demand-side factors, including health and preferences, with the remainder due to place-specific supply factors." Similarly, Molitor (2018) shows that physicians change practice styles after moving and estimates that place can explain between 60 to 80 percent of physician practice differences.

In contrast, Sheiner argues that using state-level Medicare spending data—like the data we use in this paper—and a very limited set of state health status controls can explain a large amount of the cross-sectional variation in Medicare spending (Sheiner, 2014). She takes this as evidence that differing practice styles do not explain a large amount of variation in spending. Further, she is skeptical of the ability of geographic variation in Medicare spending to illuminate "inefficiencies in our healthcare system" (Sheiner, 2014, p. 1). Our work addresses part of this concern. If spending of multiple types is consistently high in some states, it may suggest key factors at work.

We correlate Interstate spending per mile with Medicare spending per enrollee as of 1991, the earliest year with digitized costs. Interestingly, Medicare spending is statistically significantly related to Interstate spending; it is also the only variable in the table that yields a notable decrease in Interstate spending residuals. For each additional $1,000 of Medicare spending—an amount slightly smaller than the interquartile range for this variable—a state spends an additional $1.3 million dollars to build an Interstate mile. This $1.3 million is roughly ten percent of the average state expenditure per mile. Comparing the final two columns of the table, it is clear that this stems from the explanatory power at the tails of the state spending distribution.

This relationship only strengthens in the second period. An additional $1,000 of Medicare spending—four-fifths of the interquartile range—is associated with an additional $3.4 million dollars in spending per mile, compared to an average of $15.2 million per mile. An additional $1,000 of local government spending—roughly three-fifths of the interquartile range—is associated with $1.1 million additional spending per mile. Medicare spending reduces the residual variation in the middle of the distribution (columns 4 and 5, standard deviation and interquartile range), whereas local government spending is more tied to reductions in residual variation at the tails of the distribution (column 6, 90-10 percentile difference).

Of all the variables we consider in this section, Medicare is the most strongly and significantly related to Interstate spending. To better understand the relationship with Medicare, Figure 6 shows the raw correlation between Interstate spending per mile from 1971 to 1993 on the horizontal axis and Medicare spending per enrollee on the vertical axis. The two series are clearly related, particularly at the high end of spending. The distribution of Medicare spending is substantially less skewed than the distribution of Interstate spending. The bottom panel shows this relationship, conditional on the geographic covariates; both axes present residuals.[10] The positive correlation remains, as does the much less symmetric distribution of Interstate spending.

We do not believe that Medicare spending drives Interstate spending. However, the correlation does suggest some common cost drivers. For example, the same institutional features that lead some states to consume large quantities of health services, such as second opinions, may also lead them to use more features, such as noise walls, on Interstates.

In contrast to Medicare, Medicaid decisions include substantial state discretion, subject to federal rules. States have some ability to choose who is covered, above certain minimum limits, and to expand the type of coverage. In form, the Interstate program is probably

[10]Because these regressions are weighted by miles constructed, the average of the points in the figures may not average to zero.

closer to Medicare, in the sense that states cannot limit coverage—if we analogize coverage to Interstate miles that the state must construct. However, states can provide Interstate quality above the minimum bar, as states can provide health care above a required minimum. for Medicaid.

However, the Medicaid program, with substantially more state discretion, has virtually no relationship with Interstate spending and makes no meaningful change to the residual variance. This lack of a meaningful relationship holds for the second period as well.

Finally, we evaluate whether general patterns of state fiscal behavior can explain Interstate spending. Perhaps states are high spending in all dimensions and Interstate spending is a reflection of this general pattern. To test this, we condition on overall state and local spending. To abstract from institutional differences in government organization across states, we use state aggregate spending.[11] This measure of total expenditure per capita is not statistically related to per mile Interstate spending; its inclusion actually slightly increases variation in the residuals. Therefore, if there is a common component that drives Interstate spending per mile and local government expenditure per capita, this component has little impact on local spending.

One might also hypothesize that particular categories of local spending, rather than public spending overall, might be related to Interstate spending and illuminate common cost drivers. In Appendix Table 3 we also consider the two key discretionary categories of local government, education spending and capital spending. Neither of these is statistically related to Interstate spending per mile, nor has either any appreciable impact on the residual variation.

While we have considered each spending covariate independently, this may mask some

[11] Because the digital Census of Governments does not have state governments in 1967, we make an additional measure that uses data from Census years (ending in 2 and 7) from 1967 to 1992, but excludes state governments; this is "Local (no state) exp per capita, $1,000s." Results with this measure are in Appendix Table 3.

interesting co-variation across spending types and with Interstate spending. Appendix Table 2 shows specifications with covariates standardized, so readers can compare their relative influence and specifications with all spending covariates entered jointly, both for the full period and the latter half. Regardless, Medicare per enrollee remains the category with the strongest and most precisely estimated relationship to Interstate spending per mile.

In sum, there is substantial cross-state variation in Interstate spending per mile. When we restrict to the variation within policymaker control, the variation is somewhat diminished but still economically meaningful. The geographic pattern of spending subject to policymaker discretion is most related to Medicare spending per enrollee, potentially highlighting a common cost mechanism.

4 Root Causes of Variation in Interstate Spending

While the relationship between Interstate spending per mile and Medicare spending per enrollee does not itself identify a mechanism, it hints at potential root causes. In this section, we review evidence on root cause drivers of infrastructure costs.

Unlike the attention given to health spending, outside of some popular press profiles, there has been very limited work on the geographic variation in infrastructure spending. *New York Magazine* profiled New York City's new transport infrastructure and found that for the same amount of money, New York gets "four new miles of tunneled LIRR [Long Island Rail Road] route and one new terminal station" while "London will get 14 miles serving seven stations" (Barro, 2019b).[12] The article provides examples of high labor costs—many hours worked, if not necessarily high hourly wages—and high costs of coordination across governments.

Equally eye-popping, Gordon and Schleicher (2015) find that the US leads the world in the cost of building new rail. These authors rule out a number of obvious suspects for

[12]Rosenthal (2019) presents a similar example in the *New York Times*.

these high costs: land, labor costs, and a decentralized system of infrastructure creation. The Reason Foundation also provides a state-level ranking of road spending, which highlights the declining quality of US road infrastructure, along with its increasing costs (see, for example Feigenbaum et al. (2019)).

The General Accountability Office was recently tasked by Congress to undertake an assessment of what makes American infrastructure costly relative to other advanced economies. Taken as a whole, the report punts, suggesting that no comparisons are possible until agencies do a better job collecting cost information (General Accountability Office, 2019; Barro, 2019a). Indeed, at a November 2019 Transportation Review Board convening that Brooks attended, a top Federal Highway Administration (FHWA) official acknowledged that while FHWA monitors spending, it does not keep track of costs on a per-project basis.

Broadly, there are many potential drivers of infrastructure costs. McKinsey Global Institute (2013) divides these drivers into seven categories. The first is technical explanations, including design standards, the type and location of projects, materials costs and economies of scale. We choose the Interstate system in part to abstract from some of these technical concerns: design standards are set nationally and to the extent that materials are a national market, our comparison is net of these costs. In Brooks and Liscow (2020) we find very little temporal variation in materials costs.

As the Interstate project drew to a close, the fixed costs may have grown relative to variable costs. While this is an issue for a temporal analysis, it matters for cross-state variation only if these fixed costs were relatively larger in some states. This seems possible, but none of our data can speak to this.

More generally, Flyvbjerg et al. (2004) examined 258 rail, bridge, tunnel, and road projects from around the world, and find that projects have grown larger over time. For bridges and tunnels, they find that larger projects are associated with high cost overruns, so a trend towards larger projects could be one reason that costs have grown. However, this only seems to hold true for bridges and tunnels. In their dataset, larger road projects (without bridges and tunnels) were not associated with higher cost overruns. In a study of cost overruns for Norwegian roads, Odeck (2004) found that overruns occur more frequently with smaller road projects. He attributes this finding to reduced economies of scale.

A second potentially important driver, also not relevant for our cross-state Interstate comparison, is funding source. Since the Interstate system follows a similar funding scheme across states, this is unlikely to be a major driver. In other types of projects, however, the funding may limit states' ability to make long-term commitments that lead to low-cost projects.

A third potential driver is the market structure of the construction industry, and the bidding and procurement practices of the government. If the construction industry is more concentrated in some states, this could yield higher bids and therefore higher costs. For the state of Indiana, Kishore and Abraham (2009, p. 2) note a decline in the average number of bids on road projects, from 4.2 in 2001 to 3.6 in 2005. They attribute the decline in bids to consolidation among contractors, increased work with repeat contractors, and frequent delays which discourage contractors from bidding on state projects in the future. Many other bidding and procurement practices—such as the mandatory choice of the low-cost bid, or Buy American provisions—are unique to US projects, but constant across states, so they cannot explain the variation we document here (Intueor Consulting, 2016; Davis, 2017).

Fourth, labor costs are a potential driver of spending. Over the last twenty years, construction productivity has been flat as overall productivity has increased (McKinsey Global Institute, 2013, p. 31). In the cross-state context, this could driven results if the change in productivity varies across state, which seems possible. Brooks and Liscow (2020) show that construction wages are roughly flat over time, so the price of labor does not explain the temporal increase in infrastructure cost. Further, labor's share of Interstate spending actually declines somewhat, suggesting that labor quantities are not a disproportionate cost driver.

All US states are subject to the Davis-Bacon Act of 1931 that requires the payment of "prevailing wages" on public projects. Findings on the role of Davis-Bacon in raising overall costs is mixed. In an early and influential study, Fraundorf et al. (1984) found that Davis-Bacon adds about 25 percent to overall construction costs for new, non-residential buildings. Dunn et al. (2005) found that the California prevailing wage law led to an increase of between 9 and 37 percent in the cost of building subsidized housing.

However, Azari-Rad et al. (2003) criticized the early findings of Fraundorf et al. (1984), pointing out that labor only accounts for a third of overall construction costs, making the 26 percent estimate seem implausible. In Azari-Rad et al. (2003)'s study of school construction costs, they found no statistically significant difference between the cost of constructing schools across states with and without labor agreements.

Duncan (2015) examined 10 years of Colorado road maintenance contracts. He compared projects built with federal money, which are subject to both Davis-Bacon and Disadvantaged Business Enterprise (DBE) requirements, to locally-funded projects. He found no difference in repaving costs, despite the different prevailing wage law and DBE requirements. He points out, however, that Colorado as a state has low rates of unionization in the construction industry, and thus Davis-Bacon may not substantially alter labor costs for highway contracts.

A fifth, oft-cited potential cause of high costs is the regulatory environment for large construction projects, including, but not limited to environmental regulation, litigation threat, and eminent domain costs. While all Interstate projects are subject to review under the National Environmental Policy Act of 1969 (NEPA), regional variation in enforcement—or enforcement via threat of litigation—is likely.

More generally, Brooks and Liscow (2020) show that the rise of "citizen voice," which dramatically shifted the regulatory environment by allowing affected citizens more direct sway over government decisionmaking because of new statutes, judicial doctrine and social movements, is consistent in timing and magnitude with the increase in infrastructure costs. In particular, proxies for economic and political power—income and housing prices—statistically explain much of the increase in Interstate costs, but only after 1970. Consistent with this, we see a pronounced rise, after 1970s, in ancillary structures that reduce local impacts (e.g., noise walls). We also see a notable increase post-1970 in politicians' joint discussion of environment and the Interstate, as measured by text from the *Congressional Record*.

By construction, environmental regulation is designed to raise project costs by forcing builders to internalize the negative externalities from their construction. The policy question is then whether these regulations increase costs above and beyond this internalizing of externalities. Hecht and Niemeier (2002, p. 354) made use of the fact that many projects in California receive categorical exemptions from NEPA requirements to estimate the costs of completing an environmental impact statement. They found that the cost of completing an environmental impact statement can come close to matching the rest of the costs associated with the initial project design phase. In addition to the direct costs of litigation, Todorovich and Schned (2012, p. 8) state that threat of litigation leads to expensive environmental impact statements which are overly technical.[13]

It is also possible that eminent domain costs could vary across states. Gordon and Schleicher (2015) identify the US., U.K., Australia, and New Zealand as common law countries with high infrastructure costs. They suggest that common law countries may provide property owners with particularly strong protections that drive up the cost of eminent domain. However, they also note that countries like Germany have both strong property rights protections and cheaper infrastructure costs, relative to the US. Brooks and Liscow (2020) note that the rise in construction costs in the US suggest that common law alone is not enough

[13]Cordes and Weisbrod (1979) show that a requirement to better compensate those harmed by Interstate construction led to meaningful changes in program implementation.

to increase costs because the US is and has always been a common law country, so some other factor must be driving costs. Brooks and Liscow (2020) also suggest that land costs do not drive the increase in Interstate spendingcosts, since share spent by states on land and planning declines over time.

In addition to these regulatory costs, other political institutions are a sixth potential driver of increased Interstate spending, including jurisdictional fragmentation and districted elections. Broadly, economists believe that institutions play a crucial role in determining state spending levels (see review in Besley and Case (2003)). Ideology also plays a role in spending decisions, and empirical work suggests that ideology plays a greater role as income increases (Pickering and Rockey, 2013). Brooks and Liscow (2020) find no relationship between changes in governmental fragmentation and changes in Interstate spending per mile.

Finally, project management is the seventh factor that could drive cost variation. There is a suggestion in the literature that these features are important, but no work has embarked on a quantitative classification. Many articles cite mismanagement as a major factor in delays and overruns. For example, Todorovich and Schned (2012, p. 5) attributes many delays in the NEPA process to administrative process bottlenecks, project management failings, or a lack of capacity among the agencies involved in the process.

A large number of factors can influence project management, including staff experience, institutional culture, and political will. Hecht and Niemeier (2002, p. 352) surveyed employees of the California Department of Transportation and found that less than 2 percent of employees felt like their agency would reward them for reducing the time or cost of a project. This included even simple rewards like recognition.

And these are merely the major drivers in a retrospective sense. Looking prospectively, Winston (2013) highlight a number of technology innovations—most important among them the driverless car—that have the potential to decrease cost.

5 Interstate Spending: Evidence on Root Causes and Consequences

While our data do not afford sufficient variation to identify causal effects, in this section we present correlations between some of the root causes from the previous section and Interstate spending per mile. We conclude by evaluating whether Interstate spending per mile is correlated with outcomes, such as accidents or maintenance spending.

5.1 Highway Costs and Potential Cost Drivers

As our literature review covers more cost drivers than we have degrees of freedom—we have only evidence from 48 states—we now turn to assessing the relationship between Interstate cost per mile and a few salient or well-measured potential cost drivers. As before, the dependent variable is spending per mile (in millions of 2016 dollars).

We focus here on the second period, 1970 to 1993, since that is where Interstate spending variation is larger (the analogous table for the full period is Appendix Table 4). We focus on demand for Interstate quality and on wages and politics. In Table 4 we report regressions where key variables enter individually (columns 1 and 3) as when all variables enter jointly (columns 2 and 4). To ease interpretation of levels, columns 1 and 2 show results for unstandardized variables; to ease relative comparisons, columns 3 and 4 report coefficients for standardized variables. In addition to the coefficient and standard error, we also report the standard deviation of the residuals and the interquartile range for the residuals, since our goal is to understand how much geographic variation remains. (We show the analogous version of these results for the full period in Appendix Table 4.)

The first two rows test a root cause not frequently discussed in the literature—that wealthier citizens prefer "more" highway, in the sense of having a safer, more durable, or less noisy main artery. We proxy for these demand factors with the share of people age 26 and above with a high school education and real median family income. While both variables have positive coefficients, indicating more spending in places with more educated populaces and higher income populations, neither of these factors is related in any sharp way with Interstate spending per mile.

The evidence presented in Brooks and Liscow (2020) suggests that wages do not drive cross-state variation, consistent with our finding here in the third set of rows of the table.[14] We use annual wages from the County Business Patterns data (see data appendix for details) and see a small, positive and imprecisely related relationship between wages and cross-state spending.

As discussed in Section 4, management, of lack thereof, could play a significant role in cost containment. The second-to-last set of rows in this table use a measure of the most pathological form of mismanagement: corruption. We measure corruption via an index from Boylan and Long (2003) who survey statehouse reporters to generate a cross-state measure of corruption. This measure is a normalized average of reporter responses and ranges between -2 and 2. While this measure of corruption is not individually related to highway spending per mile, in the joint estimation, we do find that states where reporters perceive more corruption have higher costs. A change in corruption equal to the interquartile range (0.68) yields an additional \$1.7 million dollars of spending per mile.

Political taste in willingness to spend public funds also seems likely. The final row in Table 4 looks at the impact of the Democratic presidential vote share (see appendix for construction details). Note that most of this period has a rather different political alignment than modern America: the South was largely Democratic, and the Northeast substantially more Republican. With this caveat in mind, we see than a 5.6 percentage point increase in the Democratic presidential vote share, a one standard deviation change, is related to a \$3.1

[14] Some findings from the cross-section here differ from results in Brooks and Liscow (2020). Here we rely on purely cross-sectional variation. Our other paper relies on within state changes, using a specification with state and period fixed effects. These two different sources of variation yield different conclusions.

million dollar increase in spending per Interstate mile.

5.2 How Does Spending Relate to Outcomes?

If states are spending more on Interstate highways but are in some sense "getting more"—safer or longer-lasting roads—the cross-state variation in governance choices make have fewer lessons for cost containment. In Table 5 we assess whether state spending is correlated with measurable highway outcomes. As in the previous table, the top panel covers the entire period, and the bottom panel the higher variance second period. The first two rows of each panel of the table repeat the first two rows of each panel of Table 3 for reference. Controlling for fatalities per hundreds of millions of vehicle miles traveled (VMT) has no additional explanatory power for the variance in state spending—it in fact raises the residual variation at the tails of the distribution. Accidents per 100,000 of VMT have similarly no relationship with Interstate spending per mile.

States that spend more money to build a new Interstate mile also spend more to maintain those miles, as measured by per mile maintenance costs per state in 2015. Each additional million dollar of maintenance per mile is associated with an additional $200,000 dollars of initial highway construction. Although this is a statistically significant relationship, the relationship accounts for very little of the residual variation in spending, either as measured by R^2 (84 to 85), or by the change in the standard deviation of the residuals (4.4 vs 4.5).

This pattern is similar when we limit the analysis to the second period, 1970 to 1993. States with higher highway maintenance expenditures are those that initially spent more per mile. This variation now does seem to explain some portion of the variation in the residual at the tails. However, unlike for the overall period, there is a negative and significant relationship between fatalities per vehicle mile traveled on Interstates and construction spending per mile. Reducing fatalities by the amount of the interquartile range—0.55 per 100 million vehicle miles traveled—is associated with $2.5 million dollars of additional Interstate spending per mile, or about 15 percent of the mean.

6 Discussion and Conclusion

In this paper, we show that the geographic variation in Interstate spending per mile is large. If states in the top half of the spending distribution had capped their spending at the median, the Interstate system would have cost 40 percent less to build. Put differently, the coefficient of variation in Interstate spending is 0.58—about four times that of Medicare per enrollee and twice that of Medicaid per enrollee. The high relative variance in Interstate spending per new mile remains even when we limit the analysis to spending within policymaker discretion, or costs net of pre-determined route features. While we have done our best to control for features that determine costs and are outside of policymaker control, it is still possible that we have failed to control for all such cost determinants. However, the variation in Interstate spending per mile net of policymaker discretion we estimate is very large. It is at least as economically meaningful as the variation in other categories of spending—Medicare and education—to which economists have devoted reams of papers.

In addition, we show that the geographic pattern in spending per Interstate mile is related, surprisingly, to spending per Medicare enrollee. An additional $1,000 dollars of Medicare spending is associated with an additional $1.3 million dollars of Interstate spending per mile, or about ten percent of the mean.

In Brooks and Liscow (2020), we show that temporal increases in the cost of constructing a new Interstate mile are driven by input quantities rather than prices. Our primary evidence for this conclusion is twofold: nationally, real prices for labor and materials change little from 1956 to 1993, and cross-state variation in labor prices is not correlated with Interstate costs. Our finding is very similar to the argument in the Medicare spending literature that it is quantities, rather than prices that drive variation in spending (see Gottlieb et al.

(2010), Finkelstein et al. (2016) and others). These results suggest that some common feature or features may drive "more" provision —both higher Medicare spending and higher infrastructure costs.

While we have no direct evidence on what these features are, we offer two speculative and related hypotheses. First, higher average incomes in a state, by increasing demand, could drive the provision of "more." This is consistent with Brooks and Liscow (2020), in which we show that increases in incomes and housing values statistically explain the entire increase in Interstate cost per mile over the period. We also show that costly features that mitigate the local costs of the Interstate, such as noise walls, are substantially more common in the citizen voice period. In healthcare, "more" could be more additional healthcare screenings, more appointments with specialists, or more luxurious hospital surroundings.

Second, and relatedly, states may differ in culture, which could be either the underlying preferences of state citizens or the institutions that aggregate those preferences, or both. This is consistent with some of the Medicare spending literature, which argues that higher spending is driven by a "culture of practice" (Gottlieb et al., 2010; Molitor, 2018). In the Interstate realm, this would be a "culture of production," where higher production costs could be due to state procurement practices, underlying preferences of state voters, or the state-specific market concentration of construction firms.

A central concern is whether additional spending delivers additional value. The Medicare spending literature generally finds that higher treatment costs are not associated with better health outcomes; see Chandra et al. (2011) and Fisher et al. (2003) among many others. The picture for Interstate highways is more nuanced. We find that more Interstate spending per mile is associated with fewer fatalities, but higher future maintenance. Lowered future fatalities given higher initial investment is consistent with more spending delivering higher quality. However, more initial Interstate spending is not associated with lower future highway maintenance. This could be because more initially expensive highway miles are also more expensive to maintain. Alternatively, this could be because states that initially choose high spending also choose make high spending for maintenance. Of course, a full analysis of quality requires a more holistic analysis that extends beyond the three factors we consider here.[15]

Any increase in the quality of US infrastructure depends crucially on managing per unit costs. Understanding what drives Interstate costs and the extent to which these costs justify benefits is crucial if we seek to spend more to improve the state of US infrastructure. What precisely drives infrastructure cost remains fertile ground for future research.

[15]While we find a correlation between Interstate spending per mile and Medicare spending per enrollee, we find no such relationship with Medicaid spending. This is consistent with an important role for income in generating spending. If higher income yields greater demand for spending, this means that it is the relatively wealthy who drive at least some of the spending increases. These relatively wealthy people are in the Medicare population. They are, however, by definition, not in the Medicaid population. This bolsters the case that part of the common driver of higher costs is higher income, or some institutional features that develop in the presence of higher income people.

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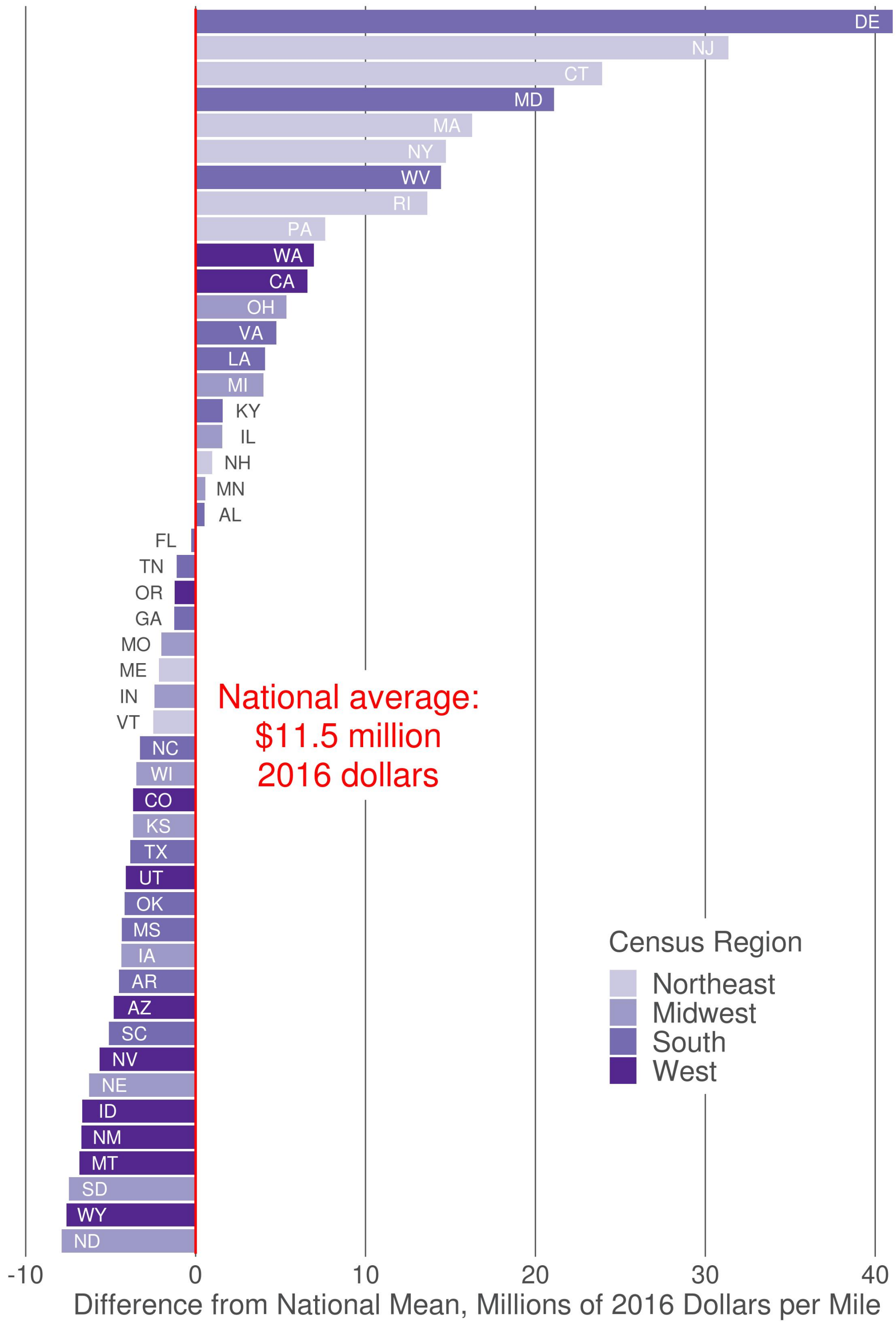
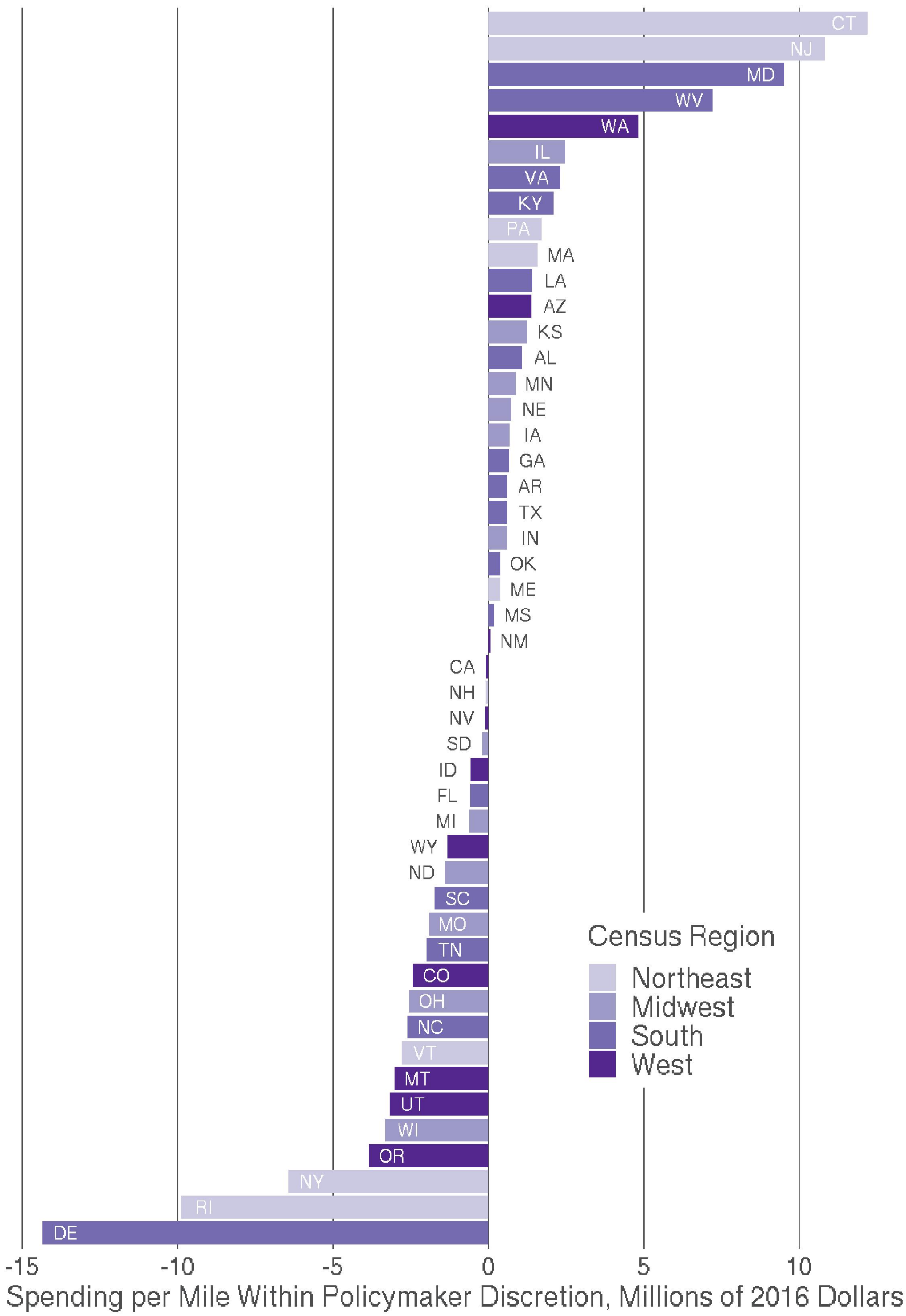
Figure 1: Interstate Spending per New Mile: Absolute Difference from National Average



Note: This figure presents deviations from national average Interstate construction spending per mile by state, 1956-1993. Here and everywhere else we omit Alaska, Hawaii and Washington, DC.

Figure 2: Interstate Spending per New Mile: Spending within Policymaker Discretion

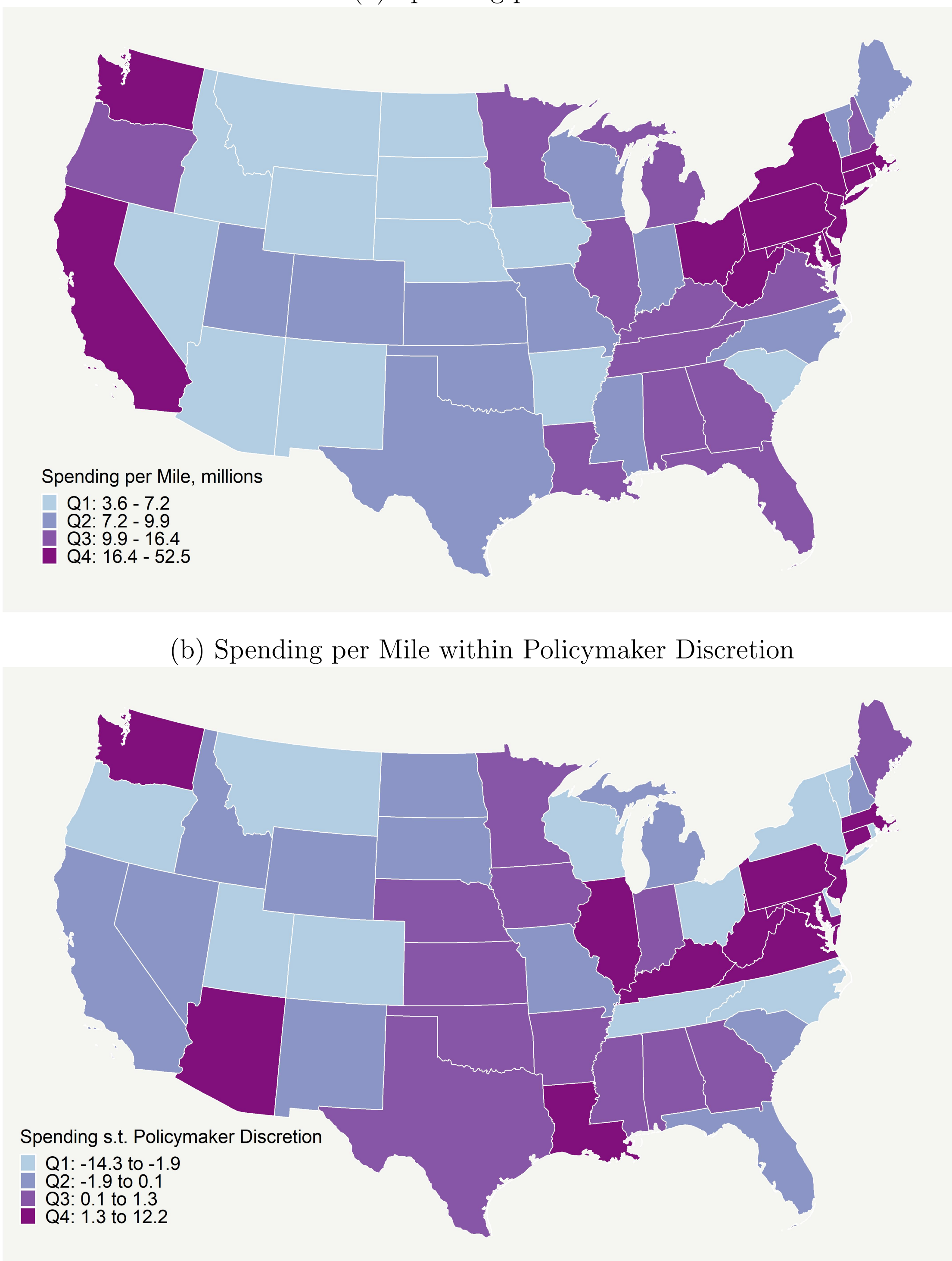


Note: This figure reports residuals from a regression of Interstate spending per mile, 1956 to 1993, on population density, slope and the extent of wetlands or rivers (see Equation 1 and surrounding text for details).

Figure 3: Geographic Pattern of Spending per Interstate Mile

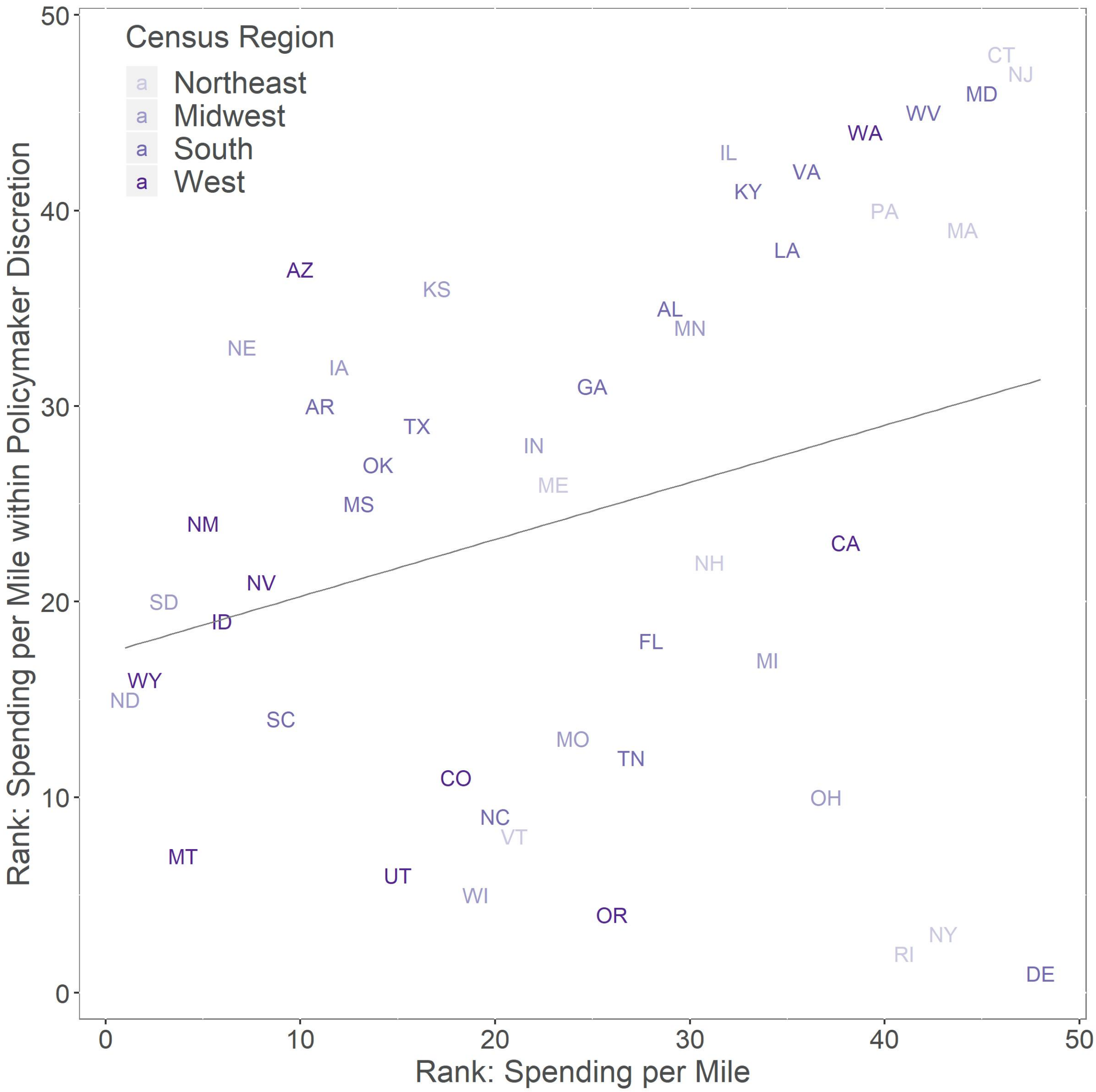
(a) Spending per Mile

(b) Spending per Mile within Policymaker Discretion



Note: Part (a) maps quartiles of Interstate spending per mile from Figure 1. Part (b) maps quartiles of Interstate spending per mile subject to policymaker discretion as in Figure 2.

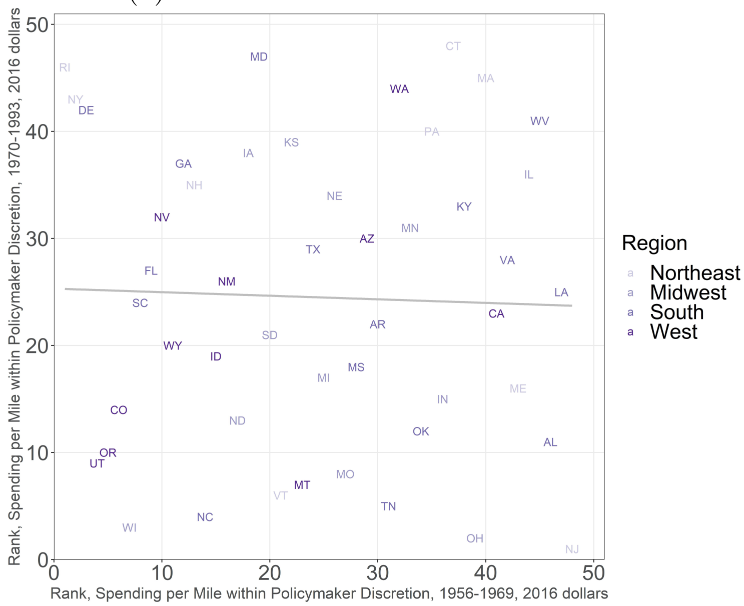
Figure 4: Rank-Rank Correlation: Raw Spending and Spending within Policymaker Discretion



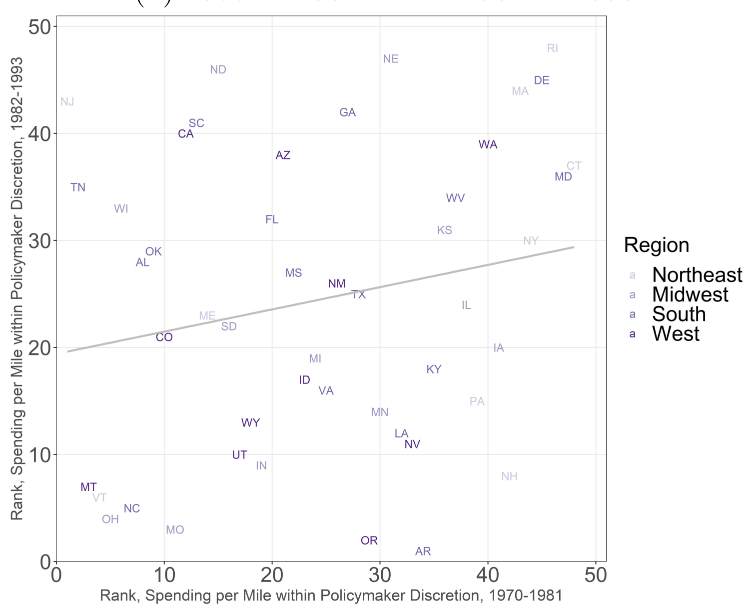
Note: This figure shows each state's rank (from 1 to 48) in Interstate spending per mile on the horizontal axis versus the state's rank in Interstate spending per mile subject to policymaker discretion on the vertical axis.

Figure 5: Correlation: State Rank, Spending per Mile Subject to Policymaker Discretion

(a) 1956 to 1969 versus 1970 to 1993



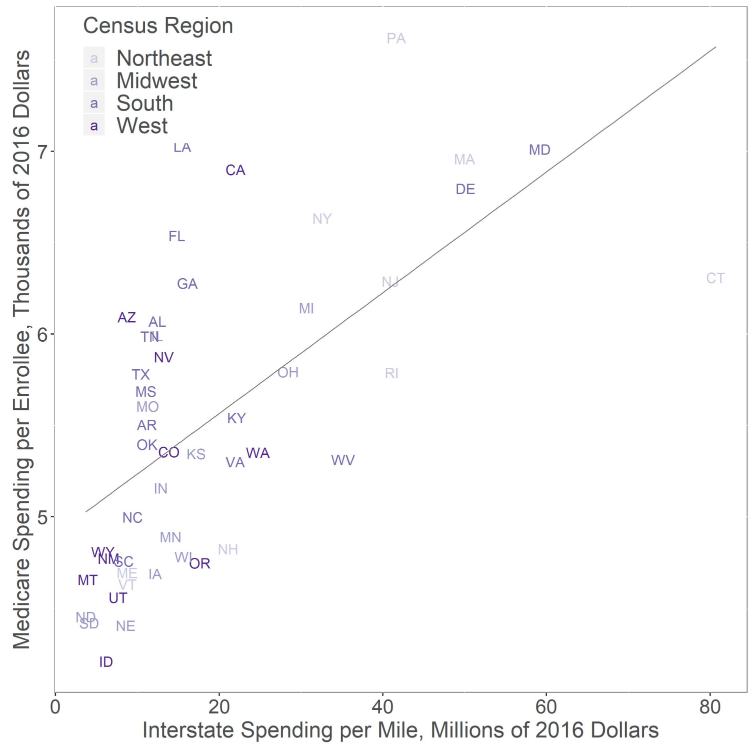
(b) 1970 to 1981 versus 1982 to 1993



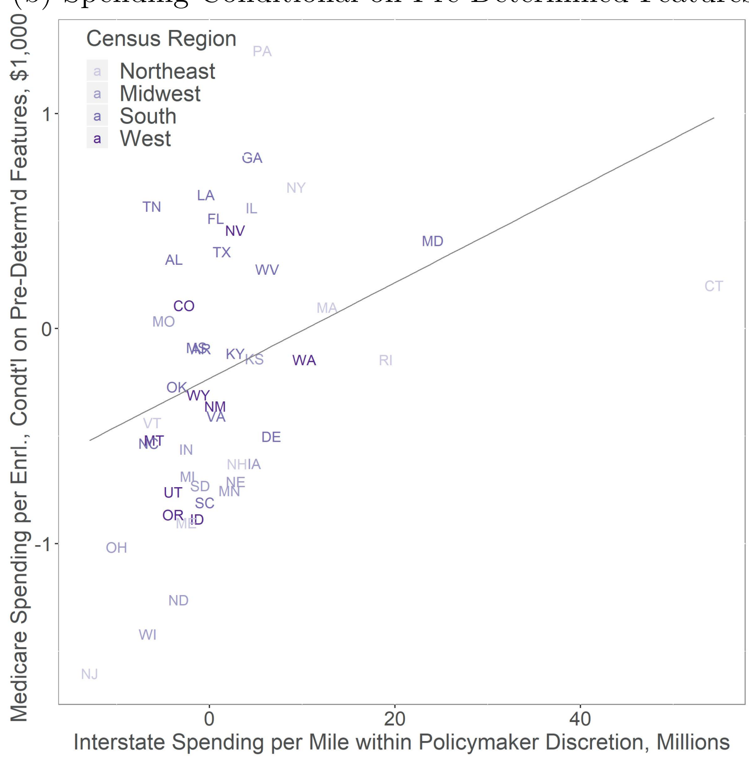
Note: This figure presents state ranks in spending per mile, conditional on preexisting features. The top panel of this figure shows these ranks before 1970 (horizontal axis) and 1970 onward (vertical axis). The bottom panel shows these ranks between 1970 and 1981 (horizontal axis) and 1982 to 1993 (vertical axis).

Figure 6: Correlation: Interstate Spending per Mile and Medicare Spending per Enrollee

(a) Raw Spending



(b) Spending Conditional on Pre-Determined Features



Note: The top panel of this figure shows the relationship between Interstate spending per mile after 1970 (horizontal axis) and Medicare spending per enrollee in 1991 (vertical axis; both in 2016 dollars). The bottom panel shows these two measures conditional on the three geographic covariates that we use throughout.

Table 1: Geographic Variation in Interstate and Other Local Spending

	Entire Cross-Section			Period 1: 1956 to 1969			Period 2: 1970 to 1993		
	Mean	Std. Dev.	Diff: p75 to p25	Mean	Std. Dev.	Diff: p75 to p25	Mean	Std. Dev.	Diff: p75 to p25
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Spending/Mile, $ millions	11.51	6.7	8.18	8.75	5.15	6.26	15.52	10.65	8.25
Private Spending									
Res. Const. Cost Index	31.53	4.93	5.83	19.83	1.7	2.12	48.55	5.66	5.84
Health Ins./Enrl., 2001, $1,000s	2.95	0.21	0.24	.	0.22	.	2.94	0.21	0.22
Public Spending, all $1,000s									
Medicaid per enrollee, 1991	6.01	1.93	2.17	.	1.93	.	5.97	1.91	2.44
Medicare per enrollee, 1992	5.65	0.83	1.27	.	0.83	.	5.65	0.83	1.32
Local Govt. Exp. per capita	6.5	1.31	1.8	.	1.3	.	6.94	1.34	1.58
Interstate Outcomes									
Fatalities per VMT, 1995*	0.86	0.4	0.55	.	0.41	.	0.88	0.39	0.53
Accidents per VMT, 1995*	3.71	1.95	2.17	.	1.93	.	3.73	1.97	2.36
Maint. per Mile, millions, 1995	5.73	4.27	4.92	.	4.2	.	5.92	4.35	5.52
Potential Root Causes									
Share High School Graduates	52.24	7.56	9.4	46.28	7.39	9.47	60.92	7.54	10.17
Median Family Income, $10,000s	5.49	0.8	1.29	5.17	0.86	1.31	5.96	0.76	1.23
Annual Construction Wages	43.22	7.53	10.44	42.04	7.73	12.14	44.93	7.85	12.87
Corruption Index	0.05	0.66	0.68	0.03	0.67	0.67	0.07	0.66	0.61
Democratic Pres. Vote Share	44.93	5.57	6.22	48.38	6.72	8.02	39.91	4.68	6.08

Note: *Fatalities are per 100 million vehicle miles traveled. Accidents are per 10,000 vehicle miles traveled (VMT). All rows contain 48 observations, with the exception of accidents, which has 47. We omit Alaska, Hawaii and Washington, DC. We weight all summary statistics by Interstate miles constructed in that state. Because of this, summary statistics for time-invariant variables, such as Medicaid spending in 1991, may vary slightly across the two time periods. "Residential construction costs" are an index where 1993 is 100. "Local government spending" is the total of all state and local government spending in the Census of Governments for all census years after 1967 (1967 does not report state-level information). The corruption index is from Boylan and Long (2003).

Table 2: Estimates of Spending Conditional on Pre-Determined Characteristics Robust to Specification Variation

	Full Period				Second Period: 1970 to 1993			
	R^2	Std. Dev.	Diff: p75 to p25	Diff: p90 to p10	R^2	Std. Dev.	Diff: p75 to p25	Diff: p90 to p10
Covariates	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Raw Data		10.51	9.41	23		16.08	14.32	35.43
+ pre-determ'd characteristics	0.84	4.37	3.25	8.16	0.67	10.23	8	16.4
+ characteristics squared	0.87	3.62	2.77	8.58	0.71	9.81	7.51	15.94
+ average number of lanes	0.87	3.63	2.78	8.58	0.71	9.76	7.53	15.97
+ without two highest obs.	0.88	2.98	2.66	4.91	0.79	5.66	6.98	14.04

Note: For variable definitions, please see note to Table 1. Columns 1 to 4 report figures for 1956 to 1993 and columns 5 to 8 figures from 1970 to 1993 only. The first row of this table presents summary statistics for the residual from a regression of spending per mile on a constant. The second row reports summary statistics for the residuals from the estimation of Equation 1. The third row reports summary statistics for the residuals from the previous estimation with the inclusion of a G_s^2 term. The fourth row reports summary statistics for residuals from an estimation that additionally includes the average number of lanes in a state. The final row has summary statistics from the same regression, but without the observations with the two highest values of spending per mile. All estimations have 48 observations except the last row which has 46.

Table 3: Relationship Between Interstate Spending Per New Mile and Public and Private Spending

	Coeff.	Std. Error	R^2	Residual Variation: Std. Dev.	Residual Variation: p75 - p25	Residual Variation: p90 - p10
	(1)	(2)	(3)	(4)	(5)	(6)
Interstate Spending per Mile: Entire Period, 1956-1993						
Pre-determ'd characteristics			0.84	4.37	3.25	8.16
Pre-determ'd characteristics and						
Private Spending						
Const. Spending, 1993 = 100	0.03	0.1	0.84	4.34	3.18	7.99
Health Insurance per User, 2001, $1000s	-0.34	1.99	0.84	4.38	3.27	8.02
Public Spending, all $1,000s						
Medicaid per enrollee, 1991	-0.23	0.22	0.84	4.42	3.67	8.17
Medicare per enrollee, 1991	1.29**	0.47	0.85	3.93	3.2	7.86
Local Govt. Exp per capita	-0.32	0.36	0.84	4.46	3.63	8.64
Interstate Spending per Mile: Second Period, 1970 - 1993						
Pre-determ'd characteristics			0.67	10.23	8	16.4
Pre-determ'd characteristics and						
Private Spending						
Const. Spending, 1993 = 100	0.51**	0.2	0.74	8.78	7.97	16.44
Health Insurance per User, 2001, $1000s	8.66*	4.99	0.7	9.68	7.27	14.62
Public Spending, all $1,000s						
Medicaid per enrollee, 1991	0.46	0.46	0.68	10.06	8.08	16.56
Medicare per enrollee, 1991	3.37**	1	0.72	9.69	7.06	15.59
Local Govt. Exp per capita	1.13**	0.57	0.69	10.06	7.67	14.13

Note: All rows contain 48 observations. *** Statistically significant at the 1% level. ** Statistically significant at the 5% level. * Statistically significant at the 10% level. All regressions are weighted by Interstate miles constructed. The first row in each panel reports a regression of Interstate spending per mile on a constant and the three pre-determined characteristics discussed in the text. All rows in each panel following "Geographic covariates and" report results from the estimation of Interstate spending per mile on geographic covariates and the named covariate (as in Equation 2).

Table 4: Spending per Mile and Potential Explanations, 1970 to 1993

	Unstandardized Variables		Standardized Variables	
	Variables Enter		Variables Enter	
	Individually	Jointly	Individually	Jointly
	(1)	(2)	(3)	(4)
Share High School Graduates	0.1	0.16	0.79	1.24
	(0.12)	(0.18)	(0.97)	(1.4)
residuals: standard dev.	10.1		10.1	
residuals: Q75 - Q25	7.57		7.57	
Real med. family inc., $10,000s	1.74	1.25	1.46	1.05
	(1.3)	(2.18)	(1.09)	(1.83)
	9.89		9.89	
	8.85		8.85	
Real construction wage	0.21	-0.07	1.55	-0.55
	(0.13)	(0.2)	(0.96)	(1.48)
	10.09		10.09	
	8.25		8.25	
Corruption Index	1.79	2.51*	1.27	1.79*
	(1.47)	(1.49)	(1.05)	(1.06)
	9.96		9.96	
	6.42		6.42	
Democratic Pres. Vote Share	0.44**	0.55**	2.39**	2.95**
	(0.2)	(0.24)	(1.09)	(1.28)
	9.82		9.82	
	15.49		15.49	
Overall				
Standard deviation of residuals		8.93		8.93
Diff: p75 to p25		6.62		6.62

Note: All specifications contain 48 observations. *** Statistically significant at the 1% level. ** Statistically significant at the 5% level. * Statistically significant at the 10% level. All regressions are weighted by Interstate miles constructed and use data from the 1970 to 1993 period. The first column in the table reports results for separate estimations of Equation 2. Below the standard error, we report the standard deviation of residuals and then interquartile range of the residual The second column report results from a regression when we include all covariates together. The final two rows report summary statistics for the residual from this regression. Columns 3 and 4 have a parallel organization but report results for variables standardized to mean zero standard deviation one to ease cross-variable comparisons.

Table 5: Relationship Between Spending Per Mile and Highway Outcomes

	Coeff.	Std. Error	R^2	Residual Variation: Std. Dev.	Residual Variation: p75 - p25	Residual Variation: p90 - p10
	(1)	(2)	(3)	(4)	(5)	(6)
Interstate Spending per Mile: Entire Period, 1956-1993						
Pre-determ'd characteristics			0.84	4.37	3.25	8.16
Pre-determ'd characteristics and highway outccome						
Fatalities per 100m miles of VMT	-1.39	1.04	0.84	4.23	3.64	8.38
Accidents per 1m miles of VMT	-0.05	0.22	0.83	4.41	3.18	8.28
Highway maintenance per mile, millions	0.21**	0.08	0.85	4.5	3.02	7.41
Interstate Spending per Mile: Second Period, 1970 - 1993						
Pre-determ'd characteristics			0.67	10.23	8	16.4
Pre-determ'd characteristics and highway outccome						
Fatalities per 100m miles of VMT	-4.51**	2.2	0.69	10.29	7.64	16.81
Accidents per 100,000 miles of VMT	0.26	0.46	0.66	10.23	7.85	15.13
Highway maintenance per mile, millions	0.44**	0.2	0.7	10.06	7.56	13.8

Note: All rows contain 48 observations, except for accidents which has 47. *** Statistically significant at the 1% level. ** Statistically significant at the 5% level. * Statistically significant at the 10% level. All regressions are weighted by Interstate miles constructed. The first row in each panel reports results from a regression of Interstate spending per mile on a constant and the three geographic covariates discussed in the text. All rows in each panel following "Pre-determined characteristics and" report results from the estimation of Interstate spending per mile on pre-determined characteristics and the named covariate (as in Equation 2).

Appendix Table 1: Coefficient of Variation: Interstate and Other Local Spending

	Entire Cross-Section			Second Period: 1970 to 1993		
	Mean	CV: Std. Dev./ Mean	Residual Std. Dev./ Mean	Mean	CV: Std. Dev./ Mean	Residual Std. Dev./ Mean
	(1)	(2)	(3)	(4)	(5)	(6)
Spending/Mile, $ millions	11.51	0.582	0.379	15.52	0.686	0.659
Private Spending						
Contruction. Cost Index	31.53	0.156	0.145	48.55	0.117	0.153
Health Ins./Enrollee., 2001, $1,000s	2.95	0.072	0.072	2.94	0.07	0.078
Public Spending, all $1,000s						
Medicaid per enrollee, 1991	6.01	0.32	0.311	5.97	0.321	0.32
Medicare per enrollee, 1992	5.65	0.146	0.152	5.65	0.146	0.117
Local Govt. Exp. per capita	6.5	0.201	0.208	6.94	0.193	0.187
Interstate Outcomes						
Fatalities per VMT, 1995*	0.86	0.469	0.543	0.88	0.445	0.408
Accidents per VMT, 1995*	3.71	0.525	0.478	3.73	0.529	0.403
Maint. per Mile, millions, 1995	5.73	0.745	0.661	5.92	0.735	0.899

Note: For variables, please see note to Table 1. This table presents coefficients of variation (standard deviation divided by mean, weighted by Interstate miles constructed) for Interstate spending per mile and other related or major public spending categories. The first set of three columns shows results for the entire period; the second set show results just for 1970 to 1993.

Appendix Table 2: Relative Relationship of Other Spending to Interstate Spending Using Standardized Variables

	Full Period		Years 1970 to 1993	
	Covariates Enter		Covariates Enter	
	Individually	Jointly	Individually	Jointly
	(1)	(2)	(3)	(4)
Const. Spending, 1993 = 100	0.16	0.51	2.88**	2.40**
	(0.47)	(0.53)	(0.86)	(0.86)
Health Insurance per User, 2001, $1000s	-0.07	0.09	1.78*	1.19
	(0.5)	(0.51)	(1)	(0.9)
Medicare per enrollee, 1991	1.06**	1.34**	2.78**	4.13**
	(0.49)	(0.64)	(1.07)	(1.27)
Medicaid per enrollee, 1991	-0.44	0.29	0.88	2.19**
	(0.43)	(0.54)	(0.95)	(1.06)
Local Govt. Exp per capita	-0.47	-0.81	1.39	-1.14
	(0.46)	(0.51)	(0.92)	(0.9)

Note: All regression contain 48 observations. *** Statistically significant at the 1% level. ** Statistically significant at the 5% level. * Statistically significant at the 10% level. All regressions are weighted by Interstate miles constructed. All variables in this table are standardized to mean zero, standard deviation one. The first column reports results for the full period. Each row in the first column is the coefficient from a separate regression of spending per mile on the named covariate and the three pre-determined characteristics. In the second column, covariates enter jointly. Columns 3 and 4 repeat this pattern, but for the 1970 to 1993 period.

Appendix Table 3: Correlation Between Spending per Mile and Additional Measures of Public Spending

	Coeff.	Std. Error	R^2	Residual Variation Std. Dev.	Residual Variation p75 - p25	Residual Variation p90 - p10
	(1)	(2)	(3)	(4)	(5)	(6)
Entire Period: 1956-1993						
Pre-determ'd characteristics			0.84	4.37	3.25	8.16
Pre-determ'd characteristics and public spending						
Local (no state) exp per capita, $1000s	-0.57	0.58	0.84	4.53	3.51	8.71
Primary & secnd. education per capita	-1.11	1.44	0.84	4.39	3.51	8.51
Capital outlays per capita, $1000s	0.07	1.88	0.84	4.37	3.23	8.11
Second Period: 1970 - 1993						
Pre-determ'd characteristics			0.67	10.23	8	16.4
Pre-determ'd characteristics and public spending						
Local (no state) exp per capita, $1000s	1.61*	0.82	0.69	10.22	8.01	14.92
Primary & secnd. education per capita	2.79	3.36	0.68	10.06	8.19	15.68
Capital outlays per capita, $1000s	5.36	3.51	0.69	10.18	7.99	14.97

Note: All rows contain 48 observations. *** Statistically significant at the 1% level. ** Statistically significant at the 5% level. * Statistically significant at the 10% level. All regressions are weighted by Interstate miles constructed. The first row in each panel reports a regression of Interstate spending per mile on a constant and the three pre-determined characteristics discussed in the text. All rows in each panel following "Geographic covariates and" report results from the estimation of Interstate spending per mile on geographic covariates and the named covariate (as in Equation 2).

Appendix Table 4: Spending per Mile and Potential Explanations, 1956 to 1993

	Unstandardized Variables		Standardized Variables	
	Variables Enter		Variables Enter	
	Individually	Jointly	Individually	Jointly
	(1)	(2)	(3)	(4)
Share High School Graduates	-0.04	-0.1	-0.28	-0.77
	(0.05)	(0.09)	(0.41)	(0.69)
residuals: standard dev.	4.37		4.37	
residuals: Q75 - Q25	3.48		3.48	
Real med. family inc., $10,000s	0.14	1	0.12	0.87
	(0.57)	(1.04)	(0.49)	(0.91)
	4.34		4.34	
	3.19		3.19	
Real construction wage	0.02	0.01	0.13	0.06
	(0.06)	(0.1)	(0.46)	(0.73)
	4.32		4.32	
	3.17		3.17	
Corruption Index	1	1.05	0.71	0.75
	(0.64)	(0.7)	(0.46)	(0.5)
	4.29		4.29	
	3.04		3.04	
Democratic Pres. Vote Share	0.03	0.03	0.18	0.17
	(0.09)	(0.11)	(0.61)	(0.7)
	4.34		4.34	
	8.26		8.26	
Overall				
Standard deviation of residuals		4.05		4.05
Diff: p75 to p25		3.5		3.5

Note: This table follows the same format as Table 4, but uses data are for the full 1956 to 1993 period.

7 Data Appendix

1. Interstate spending per mile

   See Data Appendix in Brooks and Liscow (2020).

2. Geographic Features

   (a) Population density

   We use tract population density, or county density when tract data are not available. See Brooks and Liscow (2020) for specific files.

   (b) Slope

   We measure the average slope within 50m of a segment using the Digital Elevation Map from USGS, purchased in 2018.

   (c) Wetlands

   We use the length, in miles, that the segment touches wetlands, defined as any of the types of wetlands classified by the Cowardin system, from US Fish and Wildlife Service (2018) National Wetlands Inventory dataset.

3. Public and private spending

   (a) Healthcare spending

   We measure Medicare spending per enrollee, Medicare spending per enrollee and private health insurance spending per enrollee from the Centers for Medicare and Medicaid Services' "Health Expenditures by State of Residence, 1991-2014." We specifically use Tables 23 ("Medicare Per Enrollee State Estimates by State of Residence"), 26 ("Medicaid Per Enrollee State Estimates by State of Residence"), and 29 ("Private Health Insurance Per Enrollee State Estimates by State of Residence").

   We download data from `https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/NationalHealthAccountsSt html`

   The Centers for Medicare and Medicaid Services define private health insurance in the National Health Expenditure Accounts as "Includes premiums paid to traditional managed care, self-insured health plans and indemnity plans. This category also includes the net cost of private health insurance which is the difference between health premiums earned and benefits incurred. The net cost consists of insurers costs of paying bills, advertising, sales commissions, and other administrative costs; net additions to reserves; rate credits and dividends; premium taxes; and profits or losses." See `https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/Downloads/quickref.pdf`

(b) State and Local expenditures

We use the 1967, 1972, 1977, 1982, 1987 and 1992 Censuses of Governments, as compiled by Wilammette University researchers Pierson et al. (2015).

These data do not contain state expenditures in 1967. Thus, to be time-consistent, we create a panel of spending per cenus year. Specifically, we data on total local (non-state) spending per capita per year, parks and recreation spending per capita per year, elementary and secondary education spending both per capita and per enrollee per year, and total education spending (which includes higher education and other small categories) per capita per year.

4. Other Interstate measures

(a) Highway maintenance

We rely on the 2015 *Highway Statistics* data. We create highway spending per mile using maintenance spending from Table SF-4 and maintenance mileage from table HM-10.

(b) Fatalities per Interstate Vehicle Miles Traveled, 1994

We use oldest available digital data on highway fatalities from Section 5 of *Highway Statistics, 1995*. Specifically, we use rely upon

- Total rural Interstate System fatalities and injuries, Table FI-6
- Total urban Interstate System fatalities and injuries, Table FI-7

Both tables also include vehicles traveled and are available at `https://www.fhwa.dot.gov/ohim/1995/section5.htm`. Fatalities are expressed per 100 million miles of vehicle travel.

(c) Lanes

Calculated from the Federal Highway Administration, Highway Performance Monitoring System, 2016.

5. Private construction spending

(a) Private residential construction costs

These data were assembled by Raven Molloy, who has generously shared them. Raven used city-level historical cost indexes from Company (2003). She matched the city names to Census place IDs, merged with city-level housing unit counts, and created state-wide averages. We use these state-wide averages. Costs are indexed and not in nominal dollars. Molloy uses these data in Saks (2008).

(b) Private health insurance spending

We measure private health insurance spending per enrollee from the Centers for Medicare and Medicaid Services' "Health Expenditures by State of Residence, 1991-2014." We use Table 29 ("Private Health Insurance Per Enrollee State Estimates by State of Residence").

We download data from https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/NationalHealthAccountsSt html

6. Demographics

   We use data on population from the Decennial Census. Specifically, we rely on the Census of Population and Housing for 1950 - 2000. We use state median family income[16], percent of adults over the age of 25 that have graduated high school, and median home values. All final variables are state-period averages weighted by miles.We use data on population from the Decennial Census.

7. Inflation adjustment

   We use the CPI-U from the Federal Reserve Bank of Minneapolis, downloaded from https://www.minneapolisfed.org/community/financial-and-economic-education/cpi-calculator-information/consumer-price-index-and-inflation-rates-1913.

8. Democratic presidential vote share

   We use data from 1956 to 1993. See Brooks and Liscow (2020) for full citation.

[16]Note that due to issues of data availability, we use mean family income for 1970.