INFRASTRUCTURE COSTS

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There is widespread consensus that US infrastructure quality has been on the decline. In response, politicians across the ideological spectrum have called for increased infrastructure spending. Although the cost of infrastructure determines how much physical output each dollar of spending yields, we know surprisingly little about these costs across time and place. We help to fill this gap by using data we digitized on the Interstate highway system—one of the nation's most valuable infrastructure assets—to document spending per mile over the history of its construction.

We make two main contributions. First, we find that real spending per mile on Interstate construction increased more than threefold from the 1960s to the 1980s. The increase does not appear to come from states building "easy" miles first, since the increase is roughly unchanged conditional on pre-existing observable geographic cost determinants. Second, we provide suggestive evidence of the determinants of the increase in spending per mile. Increases in per unit labor or materials prices are inconsistent with the pattern of the increase. But increases in income and housing prices explain about half of the increase in spending per mile. We find suggestive evidence that the rise of "citizen voice" in government decision-making caused increased expenditure per mile.

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1. Introduction

The United States spends a huge amount—more than $400 billion per year—on infrastructure (CBO 2015). There is broad agreement that infrastructure is a crucial input into economic growth. Yet there is widespread concern about the decline in quality of US infrastructure (ASCE 2017). Politicians across the ideological spectrum have responded with calls for increased infrastructure spending.

The cost of infrastructure determines how much physical output such new spending would yield. Unfortunately, there is a widespread belief that the US now gets less per dollar of infrastructure spending—both less than it used to, and less relative to other countries (Long 2017; Smith 2017; Beyer 2014). For example, Gordon and Schleicher (2015) argue that recent transit projects are more expensive in the US than in the rest of the world. However, there is little credible evidence on how even US infrastructure costs have changed over time. Much of the cutting edge in this area consists of *New York Times* exposés and blog posts (Rosenthal 2017; Levy 2013). The issue of infrastructure costs is particularly important as calls for increased infrastructure spending are sometimes coupled with prescriptions—such as proposed curtailment of environmental review processes—to address higher perceived costs (Friedman 2020).

The lack of scholarship on infrastructure costs is likely attributable to several factors. With so many political, legal, and economic differences across countries, international comparisons are difficult. Even domestic comparisons across time and space face a bedeviling challenge due to the diversity of infrastructure investments. Further, the combination of economic, technical, historical, and legal background knowledge required to understand infrastructure spending and its potential drivers is a strong deterrent to research. As well, granular data on infrastructure spending are limited.[1] And the issue of different types of infrastructure built in different types of places creates additional challenges.

One concern with rising infrastructure costs is that they might reflect inefficiencies, such as corruption, excessive bureaucracy, excess markups, and the like. However, as noted, we have little systematic evidence on whether infrastructure costs have increased, partly because of the difficulty of dealing with the selection of infrastructure built over time. A rise in costs may also capture many other things that do not stem from inefficient infrastructure provision, such as

[1] Many researchers have used detailed state department of transportation bid data. Unfortunately, these are quite difficult to standardize nationally, and we are aware of no project that has done so. Furthermore, these data are bids, rather than realized spending, and the difference between the two is economically meaningful. Swei (2018) uses macro data on infrastructure broadly defined and argues that a Baumol-type cost disease is increasing costs from the interwar period to the present.

rising input costs or a change in demand for the quality of these public goods. In this paper we provide evidence on the evolution of infrastructure costs in the US, using a unique setting that looks at roughly the same infrastructure good over time. We also investigate mechanisms that drive this spending increase.

In particular, we document and analyze spending on new construction of the US Interstate Highway System during the second half of the twentieth century.[2] Interstate highway construction is of particular interest because it is one of the largest infrastructure projects in American history (Erickson 2012; Davis 2016). Like many other forms of infrastructure, it was built with significant federal funding. Because the total number of Interstate miles was fixed, state discretion was largely limited to highway design (within federal standards) and construction implementation. In addition, and usefully for our analysis, Interstate highways are a relatively uniform product across space and time, particularly in comparison with other big-ticket items such as mass transit or airports. This relative uniformity simplifies comparisons across time and space. At the same time, there is rich potential for geographic variation because states were responsible for Interstate construction (as in Chetty et al. 2014).

To find and analyze the cost of each new Interstate mile, we digitize annual state-level spending data from 1956 to the present. Along with Leff Yaffe (2019), we are the first to use more than a few years of these data[3] and to combine these data with the number of Interstate miles completed in each year (Baum-Snow 2007). We combine these spending per mile ("cost") data with numerous other sources to measure the geographic, political, and legal determinants of costs. While the spending data are at the state level, we observe the precise location of Interstate segments by date of completion, which allows us to undertake some more granular analysis.

We make two main contributions. First, we document Interstate costs over time and reveal a dramatic increase in spending per mile of constructed Interstate. In real terms, states spent approximately three times as much to construct a highway mile in the 1980s as they did in the early 1960s. This substantial increase persists even controlling for pre-existing geographic determinants of Interstate costs. In other words, the bulk of the cost increase is not due to highway planners leaving the "hardest" sections until last, at least in ways captured by observable features. Our results complement existing "construction cost" indices produced by the Department of Transportation (DOT) and private parties that show relatively little increase in

[2] In a current working paper, Mehrotra et al. (2020) analyze costs in a later period of Interstate construction. While we focus more on cost drivers, Mehrotra et al. use the granularity of more modern data to understand how these costs relate to vehicle miles traveled and other quality measures.
[3] Smith, Haefen, and Zhu (1999) use the data from 1990-1994.

price for an ostensibly constant basket of construction inputs (Appendix Figures A1 and A2).[4] In contrast, our measure includes both price and quantity changes and shows a large increase. Furthermore, we show that, so far as the limited international evidence allow, the US's dramatic cost increase and high level of costs are unique in the world.

Our second contribution is to shed light on which hypotheses about cost drivers explain the increase over time. We have three main results here. First, increases in real per unit input prices for labor and materials move very little over the period and therefore do not drive much of the cost increase. This result suggests that increases in the quantity of highway inputs, rather than increases in input prices, drove the increase in costs. Second, the increase in real median per capita income and housing prices over the period statistically accounts for just over half of the increase in expenditures per mile over the period. This suggests that greater demand for more expensive Interstate highways as households' resources increase—because wealthier people are either willing to pay for more expensive highways, or more effective at voicing their interests in the political process—plays an important role.

Third, we discuss evidence consistent with a potentially important role for the rise of "citizen voice" in increasing costs during the late 1960s and early 1970s. We define "citizen voice" as a combination of social movements, legislation, and judicial doctrine that significantly expanded the opportunity for citizens to influence government behavior directly to reflect their concerns. The most important piece of evidence here is that the increase in land use litigation explains about a quarter of the increase in costs. As well, income's relationship to costs is five times stronger in the post-1970 era; income has no statistically significant relationship to costs before 1970. These results suggest an important institutional change in the relationship between income and cost.

We also consider other plausible explanations for which the evidence is either mixed or for which we have no data.

Our work complements a large literature that concludes that enlarging transportation networks enhances growth. This literature focuses primarily on the benefits, rather than the costs. Economists find that the creation of the US Interstate highway system generated economic

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[4] In these appendix figures, we show how our measure increases much more than the Department of Transportation Bid Price Index and the Bureau of Labor Statistics producer price index for Streets and Highways (BHWY). (In 2003, DOT started producing the National Highway Construction Cost Index (NHCCI), but that measure again just used prices, not quantities (FHWA 2019).) We also compare our measures to the privately produced non-transportation-specific Craftsman Building Cost Index and the Engineering News-Record Construction Cost Index, neither of which shows the increase we demonstrate. The Craftsman index is for one square foot of construction, but it resembles a price index and shows similar trends to the other indices. See Appendix A for sources.

growth (Duranton and Turner 2012; Duranton et al. 2014; Leff Yaffe 2019).[5] The conclusion that highway infrastructure creates economic growth extends to Great Britain (Gibbons et al. 2019), Spain (Holl 2016), and China (Faber 2014; Baum-Snow et al. 2017). Using costs based on engineering estimates, Allen and Arkolakis (2014) examine the net welfare benefits of highways. They conclude that the construction of the Interstate system increased social welfare. In contrast to this literature, which investigates the cost of infrastructure only inasmuch as it is useful as a comparison to its benefits, we focus directly on determinants of cost.

Our work also relates to an industrial organization literature that examines how procurement methods impact infrastructure costs. While this literature is very broad, extending to public-private partnerships and auction schemes, one strand focuses directly on government procurement and highway construction. Due to the difficulties of harmonizing data across states, these papers usually focus on procurement and spending within a state. For example, Bajari et al. (2014) use data from California to show that firms' plans for renegotiation after the initial bid add seven to fifteen percent to the costs of highway paving. Bolotnyy and Vasserman (2019) use similar data from Massachusetts to assess whether the state's system of scaling auctions is welfare-enhancing relative to lump-sum auctions. In contrast, our focus is on overall costs over the course of decades across the country, and we consider a variety of possible explanations for the patterns we document.

This paper is organized as follows: Section 2 describes the history of the Interstate system. Section 3 describes our data. Section 4 documents the large increase in spending per mile over time. Section 5 tests hypotheses for this increase. Section 6 concludes.

2. The Interstate System

In this section we discuss four key points of institutional background necessary to understand states' ability to make choices about Interstate construction. These are, in turn, route determination, construction timing, funding structure, and federal construction requirements.

Route determination. The bulk of highway system routing was determined at a high level in the 1940s and early 1950s, predating significant federal government funding. The Federal-Aid Highway Act of 1944 established plans for a 40,000-mile National System of Interstate and Defense Highways spanning the United States. Subject to a Federal Highway Administration

[5] Mechanisms for growth include knowledge spillovers (Agarwal et al. 2008), productivity (Fernald 1999; Holl 2016), and factor complementarities (Michaels 2008). See also Holtz-Eakin and Schwartz (1995) on productivity spillovers.

(FHWA) approval process, states chose the final, precise routes, which were typically similar, though not necessarily identical, to those routes planned in the late 1940s and early 1950s.[6]

Plans aside, there was little progress on Interstate construction until 1956. That year, the Federal-Aid Highway Act of 1956 made major appropriations and extended the planned system by roughly 1,000 miles, for a total of 41,000 miles. Thus, by the time the federal government significantly funded construction, many of the major decisions over route existence and location were complete. Over the 20 years following 1956, roughly 2,000 additional funded miles were designated as part of the Interstate system, along with roughly 6,000 unfunded ones (e.g., those already existing in 1956 or those funded by tolls and thus ineligible for funding), producing today's roughly 49,000-mile system (FHWA 2017b). We analyze funded miles through 1993.

Timing. Though Interstate construction lasted for over 40 years, most miles were constructed in the 1960s and 1970s—54 and 31 percent, respectively. This pattern is clear in Appendix Figure A4, which shows the total number of miles opened by year.[7] Almost all states did some construction in each of the 1950s, 60s, 70s, and 80s; just under half did any in the 1990s. Rather than starting at one end of a highway and continuing along the route, most Interstates were built in pieces, with those pieces eventually connecting to complete the throughway (Michaels 2008). This pattern suggests substantial discretion afforded to the states in the timing and ordering of construction. We defer to Section 4.B our discussion how states choose to order construction.

In 1956, the FHWA's predecessor estimated that the network would cost $25 billion in federal funds, or $192 billion in 2016 dollars, and that it would be completed in 1970, after thirteen years of construction (DOT 1958, p. 7). In the end, it totaled over $504 billion (2016 dollars) in federal spending, and construction took over forty years (DOT [1958-1991]).[8]

Funding. Funding for the system was overwhelmingly federal. Thus, at the state level, decisions about highway funding were largely about how to spend federal dollars, rather than raising state revenue for these investments. The 1956 Highway Act set the federal government contribution for new highway construction at 90 percent of the cost of the Interstate system, with the remaining 10 percent to be borne by the states.[9]

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[6] Appendix Figure A3 shows an early map of the planned routes.

[7] Appendix Figure A5 maps the miles opened in each decade with a wide line; thin lines indicate miles opened in previous decades.

[8] Based on periodic DOT *Interstate Cost Estimates* that we inflate to 2016 dollars. See data appendix.

[9] In states where more than five percent of total land area was comprised of "unreserved [federally owned] public lands and nontaxable Indian lands," the federal government paid up to half of the remaining ten percent of Interstate

Broadly speaking, there was no cap on the total amount a state could spend to construct an approved Interstate highway route, so long as the state could cover the upfront costs and secure FHWA approval over successive Congressional appropriations. In any given year, a state's receipt of funds was limited by the state's cost estimates for remaining miles and the amount of federal funds authorized and appropriated for that year. From a total cost perspective, a state could spend more on an Interstate simply by building it more slowly, on the assumption that Congress would continue to authorize revenue for the Highway Trust Fund. This funding structure was specific to new construction, which is the subject of our analysis.[10] Additional highway funding details are in Appendix C.

Construction requirements. Finally, in exchange for the receipt of Interstate construction funds, states were required to construct according to federal "Interstate standards." In general, Interstates had to have at least two lanes in both directions,[11] full control of access, minimum design speeds of 50-70 mph, minimum lane widths, and adequate capacity to support the traffic volume expected for 1975 (a requirement that was later changed to the volume expected 20 years from project completion).[12] Tolls were prohibited on federally funded miles.[13] Congress also applied the 1931 Davis-Bacon Act to Interstate construction, requiring that Interstate construction laborers be paid the prevailing wages of the project area (Weingroff 1996). States were allowed to spend Interstate funds on right-of-way acquisition.

3. Data

One of our primary contributions is to marshal data that describe the long-run trajectory of Interstate expenditure per mile by state over time. In this section, we discuss the highway spending data we collect and give a brief overview of the many other sources we have paired with these data. Full details are in Appendix A.

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construction costs (23 U.S.C. §120(a)(1)). Ten to thirteen western states benefited from this additional funding, with Nevada, Arizona, and Utah receiving roughly 95 percent reimbursement (Lewis 1982; FHWA 1992). To account for this difference among states, we scale back our observed federal spending in proportion to the additional reimbursement.

[10] In some limited cases, states were able to use small amounts of Interstate funds on non-Interstate projects; we adjust for this in our data construction.

[11] See more detail in Appendix D.

[12] See AASHO (1956) and AASHTO (1991).

[13] Some of the roads incorporated into the system were toll roads. While they were designated as part of the Interstate System and counted towards the 41,000-mile limit, they were ineligible for federal Interstate construction funds (FHWA 2018).

3.A Highway Mileage and Spending

To measure highway mileage over time, we use Baum-Snow (2007)'s digital map and his digitization of the *Form PR-511 Database* maintained by the FHWA. These mileage data are available as one-mile geocoded "segments" of Interstate and include each segment's opening date.[14] To pair these data with the state-level spending data, in most analyses we aggregate this mileage to the state level.

We complement these mileage data with our digitization of spending at the state level from 1956-onward from the Federal Highway Administration's *Highway Statistics* (FHWA [1956-1995]). With minor exceptions, this spending is on new construction. New construction includes land acquisition and right of way, preliminary engineering, and physical construction. It excludes maintenance, resurfacing, and other post-construction categories of spending.[15] Isolating spending to only new construction is a major feature of the analysis, as it allows us to study all spending on a fairly uniform unit: a newly constructed mile of Interstate highway.

We observe state-level expenditures in the year that the federal government reimburses states for obligated expenditures—typically the year in which the state spent the money. We observe miles, however, in the year the segment opened to the public. This generates a mismatch between the two data series, including 437 state-year observations (24 percent of observations) with expenditures but no opened miles. All else equal, this mismatch yields a decline in spending per mile over time, since spending predates full mileage completion.

To more closely align the timing of spending with the timing of miles opened, we evaluate the relationship between miles opened in year *t* and spending in year *t* and other nearby years. We use this relationship to produce an adjusted measure of Interstate expenditure, in which we associate a mile constructed in year *t* with 45 percent of spending from year *t*, 38 percent from year *t*-1, and 17 percent from year *t*-2 (see Appendix Table A1 for results and complete specification). With this adjustment based on a two-year lag and raw data beginning in 1956, our data series begins in 1958. This reallocated spending measure is our primary measure of spending throughout the analysis.

After this cleaning, there are a substantial number of state-year observations with spending but no miles opened, yielding an undefined measure for spending per mile. To

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[14] These data contain over 98 percent of the system's funded mileage built by 1993 (FHWA 1998a). We exclude Hawaii and Alaska, for which opening year is not recorded in our data. We also exclude the District of Columbia, due to its status as the lone exclusively urbanized jurisdiction.

[15] As we explain in Appendix B, we make small adjustments using auxiliary data from *Highway Statistics* and elsewhere to account for these minor exceptions (small amounts of money that, in some cases, could be used for non-Interstate purposes).

ameliorate this problem, we group years into "periods." Our primary period length is six years, which evenly divides our 36 years of data. Our mutually exclusive six-year periods start with 1958-1963 and end with 1988-1993.

3.B. Covariates

We combine these state-level (and sometimes segment-level) data on spending per mile with data from many sources to assess the drivers of spending increase. In the interest of brevity, we describe our general approach to these covariates here and leave full citation details for Appendix A. We collect three types of covariates. The first is physical and human geographic covariates that drive the cost of highway construction, principally slope (USGS 2015), water and wetlands (US Fish and Wildlife Services 2018), and population density (Decennial Census, see Appendix A.1 for full Census citations). The second type is data on additional potential drivers of cost changes, including wages (King et al. 2010), incomes (Decennial Census), institutions (e.g., U.S. Census Bureau 1963), and other variables. Finally, we collect data on the physical features of highway construction, such as structures (FHWA 2016a; FHWA 2017a) and highway "wiggliness" (FHWA 2016a), that could determine cost increases.

When gathering and assembling covariates, we start with the covariate's smallest available geographic level, and we associate each Interstate segment and opening year with this covariate. We then average this covariate across all segments that open within a particular state and period. For example, for population density, our state-period measure is the average population density of segments completed in a given six-year period. We measure a segment's the population density (and any other Decennial Census demographic variable) as the population density of the tract in which the segment falls, as of the closest Census year to the segment's opening date. When tract data are not available, we use county data.[16]

4. Documenting Interstate Highway Costs over Time and Space

We now turn to our first main contribution: documenting the dramatic increase in the per mile cost of building the Interstate system from 1956 to 1993. We show that the bulk of this increase persists even controlling for human and physical geographic construction cost determinants. Next, we date the timing of the increase, present a decomposition method to explain its drivers, and explore the physical manifestations of the increased spending. We conclude the section by considering whether the cost increase in the US is a uniquely domestic or an international phenomenon.

[16] The census tracted the nation gradually from the 1930s on, usually from the most urban areas outwards.

4.A. Highway Cost Increases Dramatically, 1956-1993

We first examine whether our raw data show an increase in the cost of an Interstate mile over time. We do so by estimating per mile spending as a function of six-year period fixed effects. The coefficients on these period effects report the average spending across states in an unrestricted way in each period:

$$\frac{spending}{miles}_{sp} = \beta_0 + \beta_{1,p}\, period_p + \varepsilon_{sp}. \tag{1}$$

We index states by *s* and six-year periods by *p*. Here and throughout, the six-year periods are 1958-1963, 1964-1969, 1970-1975, 1976-1981, 1982-1987, and 1988-1993. Spending per mile is total Interstate spending in state *s* in period *p* divided by total miles completed in period *p*, expressed in 2016 dollars. Throughout, we deflate all nominal figures using the CPI-U. In this and all subsequent regressions, we weight by mileage opened in a given state-period. We do this to produce results that roughly describe the average Interstate mile, rather than the average state.[17] We cluster standard errors by state. Coefficients $\beta_{1,p}$ report the average difference in spending per Interstate mile for period *p* relative to average spending in 1958-1963. (Appendix Figure A6 shows raw annual figures.)

We report these coefficients with the blue line in Figure 1 and in the first column of Table 1. (Find summary statistics for all variables in Appendix Table A2.) The figure clearly shows an increase in spending per mile over time. The first period, from 1958 to 1963, had an average cost of $8.5 million. In the mid-1980s, the federal government spent an additional $16 million more per mile, or three times as much to build a highway mile as it did in the initial two periods of the 1950s and 1960s. For all periods 1970-onward, this additional spending per mile is statistically significantly greater than that in the initial period.

4.B Can Human and Physical Geography Explain the Cost Increase?

An increase in spending is less concerning if highway miles are increasingly built in locations where construction is physically costlier. Here we evaluate whether this is the case. We distinguish the physical costliness and time-invariant features on which we focus here from other sources of change, which we analyze in Section 5.[18]

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[17] When we do not weight by miles completed, coefficients on the period fixed effects for 1970-onward are roughly double the size of what we present in Figure 1 below.

[18] Here and throughout, we rely on cross-state variation to identify the correlation between covariates and spending per mile. We document the overall cross state variation Appendix Figure A7. Appendix Figure A8 shows the change in state spending per mile pre- and post-1970, and Appendix Figure A9 presents an analogous figure with controls for geographic characteristics. Appendix Figure A10 maps those costs. We discuss the cross-state variation in detail in Brooks and Liscow (2020).

We first present quantitative evidence on the importance of physical costliness on the magnitude of the cost increase over time and then review the qualitative evidence on whether states delayed costlier Interstate segments. For our quantitative assessment, we modify Equation (1) to include state fixed effects (I_s) and geographic covariates ($\mathcal{G}_{sp}$), estimating

$$\frac{spending}{miles}_{sp} = \beta_0 + \beta_{1,p}\, period_{\,p} + \beta_2\, \mathcal{G}_{sp} + \beta_3\, I_s + \varepsilon_{sp}. \quad (2)$$

The highway literature, citing the engineering literature, singles out three key factors as driving the physical costliness of construction: presence of water ("water" includes rivers and wetlands), population density, and slope (Balboni 2019; Faber 2014; Alder 2016). With these data, we calculate state-period measures of human and physical geography, $\mathcal{G}_{sp}$, as the mean across segments that open in a given state and period. For example, our measure of slope for state *s* in period *p* is the average slope of highway segments built in state *s* in the six-year period *p*. Because these controls are specific to the miles completed, they vary over time. We standardize these (and all covariates, unless otherwise noted) to simplify comparisons of relative magnitude.

It is also possible that there are time-invariant state-specific attributes, such as a state's flood likelihood or government institutions, that impact costs. If states vary in both these attributes and the quantity of miles they construct over time, these attributes could drive changes in the estimated period fixed effects. To rule this out, we include state fixed effects, I_s.[19]

Regardless of specification, the inclusion of geographic covariates and state fixed effects has remarkably little impact on the estimated period coefficients. We report these results in Table 1. Column 2 includes state fixed effects, and it reports that the estimated period fixed effects are barely different from the unconditional period fixed effects in the first column. Column 3 adds our three geographic covariates. This inclusion yields a slightly larger cost increase in the 1970-1975 period and slightly smaller cost increases thereafter. The coefficients on the geographic covariates show that all these variables are associated with increased cost. However, their lack of impact on the period fixed effects suggests that they do not display a strong temporal pattern.

The final column of Table 1 includes both the state fixed effects and geographic covariates. With this inclusion, we see estimated period coefficients again quite similar to the unconditional result in column 1. Figure 1 reports these estimated coefficients in green, with 95

[19] Changes in federal Interstate standards could also drive spending. With the exception of increased capacity requirements, we know of no large changes in federal Interstate construction standards that increased spending per mile. After an extensive search, we are unaware of any other substantial changes in design standards required by federal Interstate guidelines that could have led to substantially higher costs over time. However, we cannot rule out the possibility that the accretion of many small changes aggregated to a substantial impact. See full details in Appendix D.

percent confidence intervals in light green. This green line is barely distinguishable visually from the blue line reporting the unconditional period effects (column 1). When we test whether each pair of period coefficients is statistically different, we find that the pairs are statistically indistinguishable.

There is no reason to view these cost increases as inevitable. Moreover, there are at least two reasons to expect that measured costs might actually decline over this period. First, the mismatch between spending and mileage in our data pushes miles forward relative to spending. All else equal, this makes a larger denominator in later periods and therefore biases costs toward lower per mile spending in later periods. Second, many cost-decreasing technical innovations in highway construction have occurred since 1956. Construction equipment has become more sophisticated, and building materials have improved. For example, by the 1980s, the use of high-strength steel reinforcement—initially introduced in other types of construction in the 1960s—reduced bridge reinforcement costs during construction by 30 percent (National Research Council 1984, p. 26). Laser-guided survey and excavation equipment have also improved construction productivity (Yates 1988, p. 71).

Given that the available quantitative evidence suggests that changes in human and physical geographic determinants did not drive the cost run-up, we now turn to the qualitative evidence on whether states delayed the construction of more expensive mileage. At the beginning of Interstate construction in the mid-1950s, state policymakers believed that they would finish the system in about thirteen years. As a result, they rushed as many segments as possible into construction with no regard to potential resistance because "no one anticipated the urban battles ahead," as noted by Department of Transportation highway historian Richard Weingroff (Brinkman and Lin 2019, p. 9). As Brinkman and Lin (2019, p. 9) note in "Freeway Revolts!," "Which projects were completed first often depended more on the ability of the state highway department to staff up quickly, its experience in right-of-way acquisition or designing (pre-Interstate) freeways, and the pipeline of previously completed plans." Thus, the historical record suggests that at the Interstate's inception, state officials were not particularly selective in ordering Interstate segments.

Furthermore, careful readings of the historical record suggest that, if anything, states were likely to build segments perceived as most costly earlier, rather than later. Brinkman and Lin (2019) focus on metropolitan areas and show that indicia of costs actually decline, rather than increase, over time. For example, highway segments constructed in the 1970s were in areas with about five percent lower population density than those constructed in the 1950s.

Campbell and Hubbard's (2016) analysis of rural Interstate construction also suggests that earlier constructed segments were likely to be more physically costly. They write that "construction tended to proceed first in areas where through traffic was causing problems: in traffic corridors, and on highway segments within corridors, where through traffic was causing existing roads to be congested. Construction then progressed to other areas, connecting completed segments until all the highways in the state were complete" (p. 10). Thus, the historical record suggests that, if anything, states built more difficult segments first. If highway officials attempted more physically difficult miles first, as this narrative suggests, our estimates of temporal increase are biased downward.

4.C. Dating and Quantifying the Increase

Given this evidence of a substantial cost increase, we now turn to defining a summary measure for the increase, for purposes of our analysis. To do so, we must define a time at which the cost increase begins and a method for evaluating correlates of the increase.

To the first point, we turn to the data to date the start of the spending increase. Unfortunately, our short panel is poorly suited to standard time series tests for trend breaks (see Bai and Perron (1998)) to which researchers usually appeal. Since that test is unsuitable, we turn to other tests that complement the evidence we do have.

First, our flexible estimation of period fixed effects finds higher costs relative to the initial period of 1958-1963 only from 1970-onward (the third through the sixth six-year periods). Second, the historical record clearly notes the period of the late 1960s as a rupture along many dimensions in the relationship between the government and the governed, including in the area of infrastructure (Altshuler and Luberoff 2003). We discuss the judicial, statutory and civil society changes that occur in Section 5.C below.

Finally, we use our annual state-level spending data—on which we rely cautiously, given the caveats in the data section—to estimate the timing of any trend break in the spending per mile series, as in Lafortune et al. (2018). We estimate

$$\frac{spending}{miles}_{st} = \alpha_0 + \alpha_1 time_t + \alpha_2((time_t * 1\{time > T\}) + \alpha_3 G_{st} + I_s + \varepsilon_{st} \quad (3)$$

for each $t > 1959$ in our sample. The subscript *s* denotes state *s* and *t* denotes year *t* in {1958,1993}. We specify the variable $time_t$ as the year, entering linearly. Thus, the coefficient α_2 reports whether, for years *time* > *T* onward, the trend of the spending per mile series differs from the overall time trend in spending per mile. We find evidence of a statistically significant incremental increase in trend only when *T* is 1969 or 1970, with the largest value of α_2 in 1970 (see results in Appendix Figure A11).

Thus, putting these pieces of evidence together, our focus for the rest of the analysis is on the difference in the level of spending per mile pre-1970 and 1970-onward. Relative to changes in trend, changes in levels are easier to interpret, and they are of the most direct policy interest. Changes in trends may also be of interest, but they are more difficult to interpret and require more data to estimate. For these reasons, and given the limits of our data, we focus on the average change in the level of spending per mile before and after 1970.

Our goal going forward is to explore the determinants of this change. The Oaxaca-Blinder (OB) decomposition is a natural framework for examining the role of covariates in explaining an observed difference (Oaxaca 1973). Specifically, we decompose the change in spending per mile into an "explained" portion attributable to pre-period coefficients and changes in covariates, and another portion attributable to the post-period mean and changes in coefficients. Let β_q be the coefficient from a regression of covariates X on spending per mile in period q, where q is either the "before" period (the two periods before 1970) or the "after" period (the four periods from 1970-onward). The change in spending is therefore

$$\frac{spending}{miles}_{after} - \frac{spending}{miles}_{before} = \beta_{before}\left(\bar{X}_{after} - \bar{X}_{before}\right) + \bar{X}_{after}\left(\beta_{after} - \beta_{before}\right). \quad (4)$$

The first term in Equation (4), $\beta_{before}\,(\bar{X}_{after} - \bar{X}_{before})$, explains the change in cost due to the change in the average value ($\bar{X}_q$) of correlates of costs, given the impact of the before-period coefficients. The second term measures the remainder of the change as a function of the after-period covariates and the change in coefficients before and after.

Comparing the before versus after periods, the overall change in spending per mile is $6.8 million. This result is, by construction, the same as the miles-weighted difference in the unconditional period indicators in Table 1, column 1, before and after 1970. Figure 2 presents this difference to be explained in the first horizontal bar in grey. This is an OB decomposition with only the constant as a covariate.

The second row of Figure 2 presents the decomposition results where the covariates are state fixed effects; the purple part of the bar is the portion of the change explained by changes in covariates multiplied by before-period coefficients. The figure shows that the composition of states explains just under eight percent of the overall spending increase. (For exact numbers, see Appendix Table A3i. For coefficients, see Appendix Table A4i.) Similarly, the third row shows that changes in the geographic covariates also explains roughly ten percent of the overall cost increase. The most comprehensive way to understand the role of these covariates is to include them all together, since the order of covariate inclusion can substantially change the results.

Including both state indicators and geographic covariates fails, on net, to explain any of the cost increase: these factors together explain negative two percent of the difference.

4.D Findings Robust to Variations in Covariates and Sample

We show in Appendix Table A5 that this cost increase is robust to variations in specification and sample choices. The table reports little variation in the portion of the variation explained by changes in covariates when we control for polynomials of the geographic covariates,[20] include the share of miles through different types of ecoregions (U.S. Forest Service 2007), or include a measure of the share of miles in urban areas (Decennial Census). Ideally we would measure a cost per lane mile, but we do not observe lanes at the time of construction. When we condition on the number of lanes as of 2016 (FHWA 2016a), we observe a qualitatively similar cost per mile increase.

The particular specification of geographic factors therefore does not seem to explain the temporal increase. Yet one might still be concerned that some features of our sample—the unbalanced panel, the large increase in the final period, one particular region, or our periodization into six-year groups—drive it instead. The second half of Appendix Table A5 shows that none of these decisions materially impacts the overall cost increase, nor the amount of the difference explained by covariates.

4.E. Evolution of Highway Attributes

As Interstate costs increase over time, it is possible that these cost increases result in physical indicia. Here we test whether such indicia increase over time, using the four measures of highway construction within the scope of state discretion that we could gather.[21]

The first measure is noise walls (FHWA 2017a). We observe noise walls only as a national aggregate and for all US highways, not just Interstates. For this series, the bottom right chart in Figure 3 shows a time pattern that parallels what we see for overall Interstate costs: the US built almost no noise walls before the early 1970s; after 1974, the number of square feet of noise walls built annually increases roughly linearly.

[20] We have also calculated segment-level cost as in Balboni (2019), Alder (2016), and Faber (2014). Conditional on this cost approximation, our results are qualitatively unchanged. Our results are similarly unchanged conditional on share of miles built in areas with steep slopes.

[21] These measurable attributes are only a subset of all costly Interstate attributes. Furthermore, because many attributes are substitutes for one another—such as a bridge and a depressed highway—it is likely that unmeasured features describe useful variation not captured by measured attributes.

We observe three other measures of capital at the segment level. Specifically, we measure the share of a one-mile highway segment with a ramp[22] or an elevated highway (FHWA 2016a)[23] and the ratio of a one-mile segment's true distance to its as-the-crow files distance, which we call "wiggliness" (formally, tortuosity) (Baum-Snow 2007; FHWA 2016a). (See Appendix A for details on data construction.)

Figure 3 plots these three series and shows that all three measures increase over our period of analysis. Comparing the 1970-onward era to the pre-1970 era, the share of Interstate miles with an elevated highway rises by 28 percent, and the wiggliness of Interstate miles grows by 17 percent.[24] Because the temporal path of ramps is quite different—a sustained decrease, followed by a sustained increase—we find little overall difference in the levels before and after 1970. However, Figure 3 clearly shows a sustained upward trend in the share of Interstate miles with ramps from the late 1970s-onward, and this sustained increase holds conditional on geographic controls. (See Appendix Figure A12 for a version of Figure 3 with geographic controls; this chart looks qualitatively similar to the figures without controls.[25])

4.F. US Costs Versus the Rest of the World

Putting the overall cost increase we document into an international context helps to understand whether these costs are specific to the US, as many have argued (Levy 2021), or instead one example of a more general worldwide cost increase. While assembling consistent data on US costs is difficult, finding international data with both a cost numerator and a distance denominator is even more challenging. The international data we have gathered are primarily from developing countries, leaning heavily on a World Bank compilation. (See complete details on all international sources in Appendix C.) In contrast to the US information on the entire system, these data are typically for single projects. Furthermore, most data are quite recent, with only two datapoints before 1990.

[22] Ramps (e.g., offramps and onramps) connect an Interstate to another highway or road and may be built to increase commerce or avoid protected areas (FHWA 2016b).
[23] FHWA's definition of an elevated highway is broad: any structure that goes over something else and is at least 20 feet long.
[24] To calculate change in wiggliness, we subtract one from wiggliness and then calculate the change in this measure. We measure the percentage change relative to the pre-1970 mean. When we use wiggliness conditional on the geographic variables from the OB decomposition, we find an increase of 6 percent. (Here we regress wiggliness on the OB geographic covariates, re-center the residuals at the unconditional mean, subtract one from this result, and then follow the same procedure as for unconditional wiggliness.) Similarly, we find a 10 percent increase in elevated highways when we limit variation to that not explained by the geographic variables from the OB decomposition (as before, we regress elevated highways on the OB geographic covariates, find residuals, and re-center the residuals at the unconditional mean).
[25] The time trends look similar when also controlling for an indicator of whether the Interstate miles were built in a dense area. Results are available upon request.

With these caveats in mind, Appendix Figure A13 shows that US costs in later periods are outliers. We found no country in any period—including recently—that spent as much per mile as the US did in the mid-1980s and early 1990s. Indeed, we found not even one single project that cost as much per mile. This evidence suggests that the phenomenon we document is specific to the US context. Although our data stop in 1993, other work suggests that rising costs have continued to be a US-specific phenomenon. Mehrotra et al. (2020) produce a US data series starting roughly at the end of ours for the few remaining Interstate miles and shows only more increases. Furthermore, unlike the US data, the international data show no upward trend in costs.

5. Explanations: What Drives the Infrastructure Cost Increase?

In the remainder of our paper we explore potential causes of the increase in per mile Interstate spending, focusing on a variety of commonly stated potential drivers of infrastructure costs (e.g., McKinsey Global Institute 2013). In this section, again using the Oaxaca-Blinder decomposition, we show that input prices appear to play little role, while rising income and housing values statistically explain about half of the increase. We also propose the "citizen voice" hypothesis as one explanation and review evidence in light of this theory. Finally, we consider additional possible explanations subject to limited data availability, or with available data that seem unable to explain the cost increase.

5.A. Input Prices Do Not Appear to Be Primary Drivers of Costs

Rising prices of labor, materials, or land are straightforward explanations for an increase in Interstate spending per mile. For example, a sustained increase in the price of concrete would drive up Interstate costs. To assess the importance of changes in input prices, we turn again to the decomposition method. Instead of using spending per mile as the dependent variable, as in Section 4, we now use spending per mile conditional on our three geographic covariates. This residual spending is our object of interest: spending that physical and human geography do not explain.

This change in spending per mile conditional on geography—that is, the residuals from a regression of spending per mile on the three geography variables—is $5.9 million, as shown in the first grey bar in Figure 4 (see Table A3ii for exact numbers). When we decompose this residual change, we always use residual covariates. For example, when we consider the impact of changes in wages, we use wages conditional on the three geographic covariates. The colored portions of the bars in Figure 4 display the amount of the overall change accounted for by these residual covariates, using initial period coefficients.

Row 2 examines the impact of wages using Current Population Survey (CPS) state-level wages for workers in the construction occupation (King et al. 2010). We find that changes in construction wages explain only 0.3 percent of the difference in residual per mile spending. Similarly, state-level changes in construction industry wages (also from the CPS) explain very little of the increase (row 3). Row 4 shows that changes in state-level annual construction payroll per employee (from the County Business Patterns: U.S. Census Bureau [1953–1993]; Duranton et al. 2014) also explain little of the total change. Even taken together (row 5), changes in these covariates jointly explain a statistically insignificant \$0.35 million of the \$5.9 million change. (See Appendix Table 3ii for exact numbers.)

Changes in materials prices and in nonwage benefits are also potential explanations for an increase in Interstate costs. Because we do not observe state-level variations in materials prices or compensation, we simply plot these national values over time. Figure 5 plots Interstate spending per mile (the national miles-weighted average of the six-year period data) and national measures of construction wages from the Bureau of Labor Statistics (Margo 2016), total compensation per construction employee (US Bureau of Economic Analysis 2021a–f), and materials prices from the Bureau of Labor Statistics (2017a–f).[26] To ease interpretation, we index all values to 100 in 1961.

The difference between the rise in Interstate costs and the relative flatness of wages, compensation, and material prices is striking. By the end of the 1960s, Figure 5 shows a small increase in spending per mile, commensurate with higher labor prices. After this, the series diverge. Spending per mile increases, while wages, compensation, and materials prices either increase modestly or fail to change in real terms by the end of the sample. Although construction compensation increases more than wages (see Swei 2018), its rise is quite small relative to spending per mile increase.

Thus, increasing labor and material prices are likely insufficient to explain much of the observed increase in spending per mile. Put differently, because the price of labor is roughly flat over the period of analysis, a Baumol cost disease-type explanation—in which high-priced labor accounts for an increasing share of expenditures—is inconsistent with the data (Baumol and Bowen 1965).

[26] We measure material prices as the equally weighted sum of prices for concrete ingredients and related products, construction machinery and equipment, construction sand, gravel and crushed stone, paving mixtures and blocks, and steel mill products. It is, of course, possible that we are missing important input prices that do increase over time. Swei and Gillen (2020) create a producer price index for concrete and show that current indices do not account for substantial quality improvements from 2005 to 2017.

Figure 5 further shows that the divergence between the price of the underlying components of highway construction—labor and materials—and overall highway costs begins in the early 1970s. This point is when Interstate spending per mile begins its especially dramatic upward trend. While many states have prevailing wage laws that could increase the per unit cost of labor (Philips et al. 1995), these laws generally predate our sample period. Furthermore, as they rarely change over time, they are unlikely to be drivers of increased costs.[27]

Finally, land price increases could explain highway cost increases. To assess the contribution of land prices, we digitized *Highway Statistics* data from 1961 to 1984 that divide expenditures into (i) construction and (ii) right of way combined with preliminary engineering.[28] These data show that Interstate builders spent less than 18 percent of expenditures over much of the period on right of way and preliminary engineering and never more than 28 percent in any given year (see Appendix Figure A15). Furthermore, this relatively small share falls over time.[29] Thus, these data show that the dominant cost of building the Interstates was construction itself, not planning or acquiring rights of way. So, although we show below that Interstate costs grew more in places with greater increases in housing prices—and higher housing prices could drive higher land acquisition costs—land's impact is necessarily limited since it accounts for less than one fifth of total costs.[30] While land prices might contribute to rising Interstate costs, it seems unlikely that they are the main driver.

Overall then, labor, materials, and land input prices appear insufficient to explain much of the Interstate cost increase. This stability of input prices suggests that, rather than price increases driving cost increases, the cost increase is more likely the result of quantity increases. This quantity increase would include, for example, discretionary features such as sound barriers,

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[27] Indeed, in the OB decomposition (Appendix Figure A14), the change in the presence of a prevailing wage law in a state explains almost none of the cost increase.

[28] Annual data are not available for the entire period. However, other statistics on total Interstate spending through 1991 (constituting the vast majority of the spending) show that right-of-way expenditures were only 12.7 percent of spending (Weingroff 2017a). Similarly, spending on planning, engineering, and research, along with "miscellaneous" expenses, amount to only 8 percent of spending through 1991. Notably, though, these figures are totals of nominal spending. Therefore, had land acquisition, planning and engineering, and research spending been done disproportionately in early years, their true share after adjusting the annual components of the total for inflation would likely be higher.

[29] At the same time, the decrease in the share of spending on right of way may be smaller in magnitude than one might expect given the general progression of Interstate projects from spending on right of way and preliminary engineering to construction.

[30] However, a constant share of expenditures on land acquisition over time is consistent with increasing per unit acquisition prices and declining land acquisition. As well, the small and declining share spent on right-of-way acquisition also suggests that changes in eminent domain law do not directly and substantially contribute to the increase in spending per mile through more spending on land acquisition. However, it is certainly possible that changes in eminent domain law could indirectly impact construction costs by yielding more expensive routes.

or more expensive, less disruptive building methods. Such quantity-driven cost increases are a subject of considerable debate in the healthcare literature (Skinner and Fisher 2010).

5.B. Changes in Income and Housing Prices Explain Roughly Half of the Cost Increase

Given the limited ability of supply-side input prices to explain the cost increase, we now turn to the demand side. There are at least two reasons that those with more resources could demand more expensive highways. First, demand for goods generally increases with income and wealth. Second, higher-income actors may have stronger voices in the political process and demand more expensive highways reflective of their particular concerns. Between 1956 and 1993, total personal income per capita doubled in real terms (US Bureau of Economic Analysis 2019), potentially increasing demand for highways. While wealth is harder to measure, we do know that homes are usually Americans' single most valuable asset (Fischel 2001) and that the value of the average owner-occupied home almost doubled in real terms from 1960 to 1990 (U.S. Census Bureau 2021). This subsection tests for the importance of these increases in explaining the Interstate cost increase.

How does demand for more expensive highways manifest? It can influence either the process or output of construction. As for process, some highways might be constructed more slowly, with greater deliberation, and in ways that are less disruptive to surrounding communities. As for output, citizen concerns could cause highways to be constructed with features such as noise walls, trenches, or overpasses. Alternatively, citizens could demand routes that reduce disruption to historical sites, the environment, or neighborhoods. All of these changes—process or output—increase costs.

We test to what extent changes in income and housing value explain the Interstate cost increase, given pre-1970 income and housing price coefficients, using the decomposition method. We report results in Figure 4. (Again, Appendix Table A3ii shows the numerical results. See the data appendix for a careful discussion of our measurement of income and home value.) The increase in real median family income from the pre-1970 era to post-1970 explains 31 percent of the increase in spending per mile (row 6).[31] The increase in real median home value explains roughly 51 percent of the increase.[32] The two together also explain 53 percent of the

[31] We measure median income and home value as the segment-weighted state period average of tract (or county, when tract is not available) of that variable.

[32] We do not believe that higher home values increase costs directly through higher land acquisition costs. In Section 5.A, we show that the combined category of preliminary engineering and right of way is never more than 28 percent of total costs, and that the share of expenditures in this category declined over time. Therefore, the mechanism through which increases in housing value drive highway costs must be primarily through the cost of construction, rather than the cost of land.

difference, suggesting that income and home value proxy for similar underlying drivers. This important role for income and wealth is consistent with a large literature in environmental economics that shows that demand for air quality and water quality increases with income (Kristöm and Riera 1996; Ebert 2003).

We also consider all key inputs in the decomposition together, since patterns of correlation among covariates may meaningfully modify the results. When we include the wage variables, income, and home value together, changes in income and home value explain roughly the same amount of the overall difference. Wages now "explain" a *decrease* in costs rather than an increase. Thus, we find that increases in income and wealth explain a roughly half of the increase in costs.

The potential welfare impact of a cost change driven by increased income or wealth is ambiguous. If higher costs are driven by positive income or wealth elasticities of demand, the cost increase is social welfare neutral, as the rise in costs is the efficient outcome of a demand for higher quality infrastructure. If, instead, higher costs are driven by unequal political power, higher costs may yield wasteful, welfare-decreasing spending, since spending may not go where it is most needed or valued, but rather to where voices are loudest or most influential. We cannot discriminate between the welfare-neutral and potentially welfare-decreasing hypotheses on the basis of the tests we present. It is worth noting the centrality of politics here, as all highways are built through political processes. This provides substantial leeway for the second, potentially inefficient mechanism, especially given states' limited financial liabilities with 90 percent of expenditures reimbursed by the federal government.

5.C. Increased Citizen Voice

The cost increase we document is notably absent until the late 1960s or early 1970s. A large literature suggests that in this period institutional changes significantly expanded the opportunity for citizens to directly influence government behavior to reflect their concerns. We call these changes the rise of "citizen voice." One outcome of this rise of citizen voice could be greater political pressure for more expensive highways—even beyond the relationship documented in the previous subsection (Altshuler and Luberoff 2003; Glaeser and Ponzetto 2017; Kagan 1991; Mohl 2004). In this subsection, we outline our "citizen voice" hypothesis and discuss evidence for its role. We acknowledge at the outset that this discussion is speculative and difficult to test empirically, given that some of the channels through which citizen voice affects costs are challenging to measure.

We characterize citizen voice by three types of institutional changes that helped lead to its rise: changes in legislation, judicial doctrine, and social organization. First, by our count, the late 1960s through the mid-1970s saw at least 11 significant pieces of federal legislation (listed in Appendix Table A6) that required the government to consider citizen concerns. Perhaps most prominent was the National Environmental Policy Act (NEPA), enacted in 1970, which requires environmental impact reviews for projects with significant federal funding. In addition, many states also passed their own environmental review statutes. Second, this bevy of legislation gained teeth with new judicial doctrine, most prominently the Supreme Court's landmark 1971 case, *Citizens to Protect Overton Park v. Volpe*. This case expanded citizens' ability to sue administrative agencies and subject their decisions to judicial scrutiny. Third, the new social movements and organizations that arose in this period gave citizens means of organizing. These include the rise of the environmental movement and the increasing political clout of homeowners (Altshuler and Luberoff 2003; Fischel 2001).

There are multiple reasons that these institutional changes could have increased the cost of building infrastructure. The first is the cost of litigation or conducting environmental reviews; statutes including NEPA require such reviews for projects involving significant federal funds. However, as we discuss above, the costs of Interstate highway projects are overwhelmingly in the form of construction itself, so we view these as unlikely mechanisms for major direct contributions to costs. Second, increased citizen voice may result in more expensive routes, methods of construction, or highway features to limit environmental impacts and otherwise satisfy citizen demands. The processes like environmental review required by new statutes, the ability of potentially affected parties to sue to stop or delay projects, and increased community organization all contribute to citizens' capacity to extract costly governmental concessions. We view this as the most likely mechanism of increased spending: growing citizen voice leads to more expensive routes and structures that respond to local concerns.

Two legs of I-696 in suburban Detroit—the first built in the 1960s and the second built in the 1980s at triple the cost—help illustrate the rise of citizen voice. The earlier leg faced little resistance and was built simply, while the latter faced significant community resistance. After decades of opposition from community activists who opposed splitting a predominantly Jewish community—and who filed lawsuits and took advantage of new statutes—the final compromise required the state to: 1) hire a rabbi to consult on the project, 2) depress the entire leg, 3) build three 700-foot-long plazas above the highway, 4) install noise walls along most of the route, and

5) install a network of pedestrian paths (Schmidt 1989). Apart from the rabbi, these features are shown in Appendix Figure A16. Further historical details are in Appendix E.

We evaluate evidence from four tests to assess whether these citizen voice concerns likely drive the cost increase. We begin with the role of litigation, asking whether the increase in land use litigation explains the increase in cost. We use Ganong and Shoag (2017)'s state-level measure of the per capita number of court cases in which the phrase "land use" appears. This measure captures all three pieces of citizen voice—legislation, judicial doctrine, and social movements—over time. After the late 1960s, there was an explosion of lawsuits as newly organized groups leveraged new legislative and judicial doctrine to advocate for their preferred land use outcomes, including Interstate modifications. In our decomposition, the change in the land use cases per capita explain 38 percent of the highway cost increase (Figure 4, row 9). When combined with income and housing, changes in these covariates explain 65 percent of the highway cost increase (row 10).

A critical part of the citizen voice hypothesis is that it argues that the new institutions magnify the impact of increases in income and housing wealth on Interstate costs from the late 1960s and early 1970s-onward. We test this claim by evaluating whether the strength of the relationship between income or housing value changes from 1970-onward. Since the decomposition method is limited in its ability to examine the time path of changes, or to compare among individual periods, we return to Equation (2) (spending as a function of period indicators, state fixed effects, and geographic covariates), and we add income or housing value in state s in period p as a covariate. Importantly, we allow this new covariate to have a separate relationship with spending in each period. In this way, we let the data tell us if and when the relationship between income or housing wealth and Interstate costs changes.

We report results in Appendix Table A7. We find that there is no statistically significant relationship between income and Interstate cost in the first two periods.[33] This result is consistent with a world in which income has a limited ability to impact policy outcomes. However, from 1970-onward, while the federal reimbursement rate for Interstate highways remained unchanged, the relationship between income and Interstate costs is positive and usually statistically significantly different from zero. Furthermore, the strength of the relationship between income and Interstate spending increases over time. By the late 1970s, the coefficient on median family income is 8.54, meaning that a one-standard-deviation increase in income (about $9,000) is

[33] Our related finding in the decomposition analysis is that the change in income, pre-1970 to 1970-onward, explains a large portion of the cost increase. This different method here shows that pre-period income is unrelated to pre-period costs. These different methods yield different results.

related to an increase in spending per mile of $7.3 million.[34]

This result could potentially be an artifact of the relationship between the income elasticity of demand and spending: If the income elasticity of demand for Interstates is greater than one, and income is increasing, we would always anticipate a larger impact from income in later periods. However, when we use the estimated coefficients in Appendix Table A7, together with the measured income levels, and back out the implied income elasticity of demand (second-to-last column), we find that this implied elasticity increases over time. This pattern repeats for home value (second column and last column). These findings suggest that the simplest story of rising income or wealth coupled with a positive income elasticity of demand may be insufficient to explain the rise in costs. Further, it may be evidence of a crucial change from 1970-onward in the ability of high-income citizens to modify government behavior.

Our third test is motivated by the contention that citizen voice should yield physical manifestations and that such manifestations should be much more prevalent from 1970-onward. And, indeed, in Section 4.E., we show that physical indicia of highway spending—noise walls, ramps, elevated highways, and wiggliness—all increased from 1970-onward. While this additional capital is consistent with income- or wealth-driven increases in demand, it is also consistent with citizen-voice-driven responses. Highway capital can play a direct role in addressing citizen voice concerns. For example, noise walls illustrate the welfare tradeoffs at play: they are expensive to construct yet very valuable to those living nearby. Noise walls postdate the 1972 Noise Control Act, which required federal agencies to consider the impact of excessive noise in their work and empowered the EPA to regulate noise levels.[35] Similarly, elevated highways mitigate the local negative externalities in highways, and more wiggly roads can avoid obstacles—physical or political—or create scenic views (Caro 1974; de Mesquita and Smith 2011). The National Environmental Policy Act, among other statutes, gave citizens an enhanced ability to challenge highway construction through the courts; government may respond by pro- or reactively building mitigative structures.

This capital is costly. Appendix Table A8 shows that the structural capital features we can measure are related to costs, and that the relationship between structural capital and costs strengthens after 1970. A one-standard-deviation increase in mile-long ramp or elevated highway correlates with an $6.37 million cost increase, and a one-standard-deviation increase in

[34] This comes from the late-1970s-period coefficient plus the baseline coefficient of -1.19.
[35] For highways specifically, interest in noise regulation began with the Federal-Aid Highway Act of 1970, which required (23 U.S.C. 109(i)) the development of a noise abatement policy (23 C.F.R. 772). Finegold et al. (2003).

wiggliness correlates with a $6.31 million cost increase.[36] When we allow structures to exert a different impact on spending per mile after 1970 via an interaction, we find that features in 1970-onward are about three times as strongly related to spending as the pre-1970 features (column 5). Estimates from other sources agree that such features are costly. The FHWA estimates that noise walls—which were virtually nonexistent before this period—cost roughly $2 million per mile (FHWA 2017a). Newspapers report costs as high as $920 million per mile for a tunnel or even $1.2 billion per mile for a depressed highway (Nelson 2017; Weaver 2019).

Finally, a prerequisite for the rise of citizen voice is a rise in the political salience of citizen concerns. In Brooks and Liscow (2021) we test whether this necessary condition is met, analyzing whether environmental concerns became more politically salient for members of Congress in the years after the passage of NEPA. Using a quantitative textual analysis of the *Congressional Record,* we find that before discussion of NEPA in 1970, the word "environment" is rarely used in association with the Interstate highways. In the leadup to the law's passage, we find these words more frequently in close proximity, and this association remains elevated through the end of our analysis period in 2017. Thus, the evidence from politician behavior is consistent with heightened attention related to issues of citizen voice.

As with the basic relationship between resources and costs, the welfare impacts of this increase in citizen voice are ambiguous. If increased citizen voice causes the government to internalize external social costs it previously ignored, then these changes could be welfare enhancing. For example, one could view the construction of Interstates through urban neighborhoods as examples of the government failing to internalize negative externalities. Tools that require the government to internalize social harms make construction more costly to the government and have the potential to increase welfare. Alternatively, an increase in citizen voice mechanisms could give powerful interests more levers to modify government choices to meet their needs in a way that does not improve overall welfare. For example, because of their superior access to legal processes, political donations, and influence, higher-income people are likely better positioned to take advantage of the tools of citizen voice (Caro 1974).

5.D. Cost Drivers with Limited or No Affirmative Evidence

There are many other potential cost increase explanations for which our data do not provide supportive evidence or for which we lack appropriate data. Additionally, even in cases where we have some data, the coarseness of our proxies can make the lack of predictiveness far from definitive. We summarize our analysis here and provide further details in Appendix F.

[36] For more detail, see Appendix E.

For four potential drivers, we use the decomposition to test for explanatory power and present results in Appendix Figure A14. These possible drivers are (i) fragmentation of governance as proxied by the number of governments per capita, (ii) state government quality as proxied by state bond rating, (iii) the presence of "right to work" laws as a proxy for a general pro- or anti-worker orientation,[37] and (iv) the extent of competition in the construction sector measured by firms or establishments per capita. For none of these four do we find that changes in the covariate explain a significant portion of the Interstate cost increase. The finding on the weak role of labor costs echoes the national data in Appendix Figure A17, which show that labor's share of costs, if anything, declines over time. We acknowledge that these measures, especially on market concentration, are imperfect.

We have little evidence for other potential explanations for increased costs where the mechanisms are quite difficult to measure. These possible drivers include (i) reduced economies of scale as the Interstate program wound up, (ii) the possibility that state builders could have been more inclined to spend money as the program's nearing conclusion weakened the cudgel of withheld funds, and (iii) the changing role of procurement practices.

6. Conclusion

Amid widespread concern about the condition of US infrastructure and the potential for new spending, it is helpful to establish basic facts about infrastructure costs, of which we have strikingly few. We contribute by studying the construction of the Interstate system, among the most extensive of US infrastructure assets. We show dramatic increases in per mile highway spending over time, and we demonstrate that these increases are not explained by observable pre-existing geographic cost determinants.

We find that common explanations for rising infrastructure costs, including per unit labor or material price increases, are inconsistent with the cost increase. Instead, our results suggest that higher per mile spending is driven by an increase in the quantity of labor and capital inputs. We show that construction costs rise with income and housing prices, which combined explain a little over half of the rise in construction costs. We also propose the citizen voice hypothesis, arguing that key social changes in the late 1960s and early 1970s empowered people to demand changes in government behavior that yielded increased costs. We find suggestive evidence consistent with this hypothesis.

[37] We tried collecting data on state-level unionization, but available data do not go back far enough to use in the decomposition.

The welfare impacts of the phenomena we document are ambiguous. One benign interpretation of these findings is that more expensive highways are an efficient response to the overall rise in US incomes. Another benign interpretation is that the rise of citizen voice causes government to internalize what were previously external costs of highway construction, raising the cost of highways but increasing social welfare. A malign interpretation is that the tools of citizen voice accentuate the voices of favored parties, yielding increased spending with little social value.

While we cannot discriminate between these interpretations with our data, we do hope that our establishment of a more solid factual foundation of a cost increase and its potential drivers helps move toward an improved ability to weigh whether the benefits of the increased spending justify the substantial costs.

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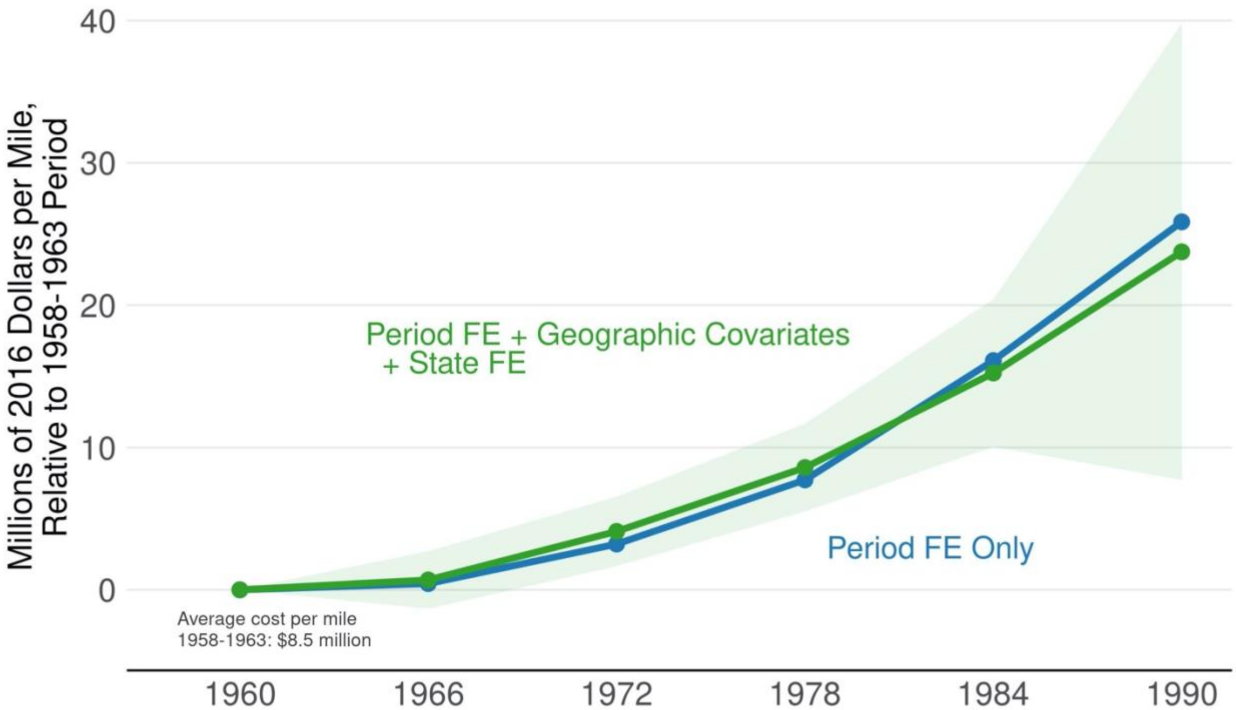
https://www.nap.edu/read/1101/chapter/9#78.

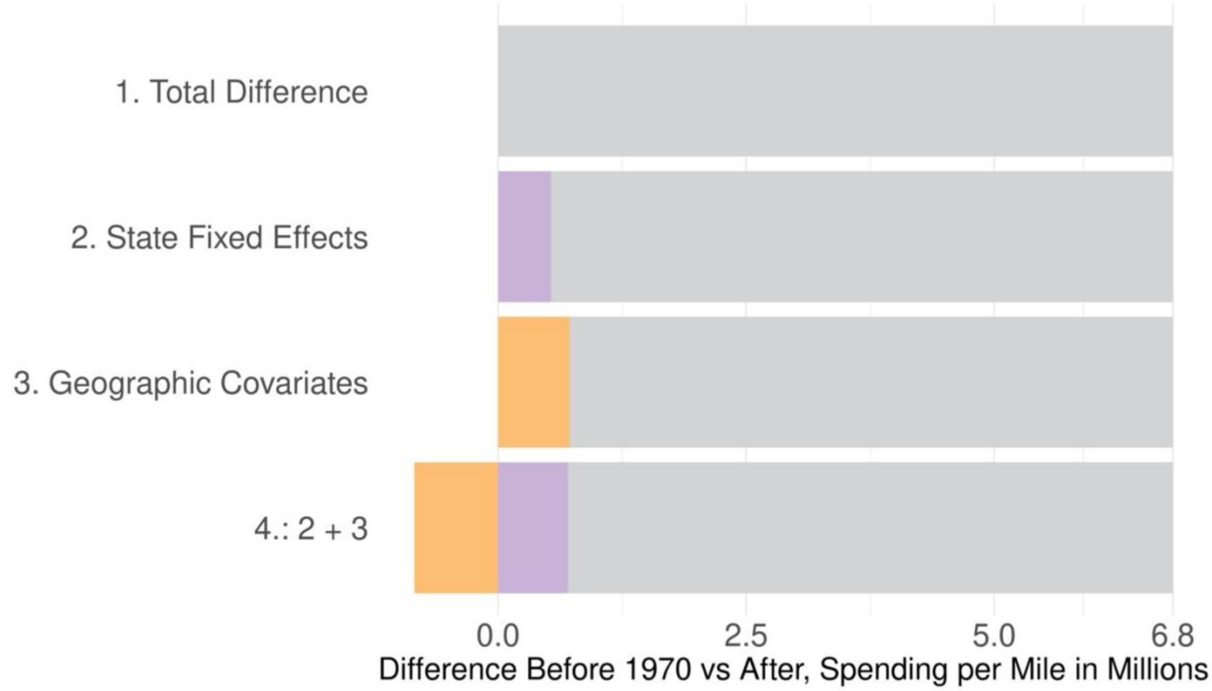
Figure 1. Interstate Costs Conditional on Physical and Human Geography Increase over Time



Notes: Points are the estimates for the period indicators in Table 1. "Period FE Only" reports coefficients from Table 1, column 1. "Period FE + Geographic Covariates + State FE" reports coefficients from the final column of Table 1. The light green area presents the confidence interval for the estimates in the final column of Table 1.

Sources: Geographic covariates are as follows: population density from Decennial Census, wetlands from U.S. Fish and Wildlife Service (2018), and slope from U.S. Geological Survey (2015). See Appendix A.2a–c for more details. See Appendix B for calculation of spending per mile.

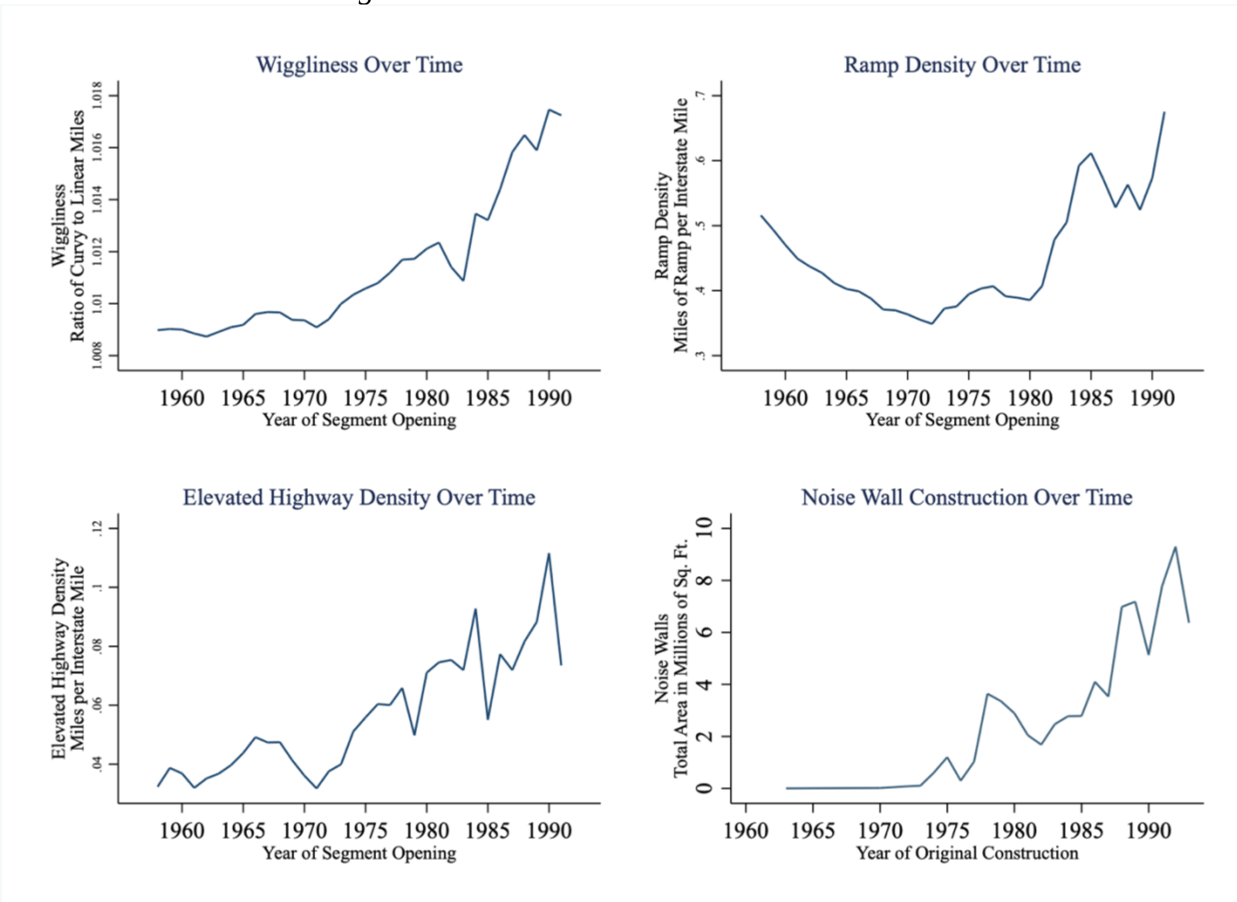
Figure 2. Geographic Covariates Play Limited Role in Explaining Temporal Increase in Spending per Mile



Notes: The grey bar in this figure reports the absolute average difference across states in spending per mile before 1970 versus 1970-onward. The purple bar shows the amount of the spending change accounted for by the change in state fixed effects over the period, given these fixed effects' impact in the 1958-1969 period (specifically, see Equation (2)). The orange bar shows the parallel estimation for standardized geographic covariates, which are the average population density, slope, and presence of water or wetlands for all construction completed in a given state-period level. The final bar includes the standardized geographic covariates and state fixed effects together in the same specification. In all rows, we weight the decomposition by miles completed. Appendix Table A3i shows the specific values for this figure and Appendix Table A4i shows the coefficients on the covariates for each analysis period (1958-1969, 1970-1993).

Sources: See source note for Figure 1.

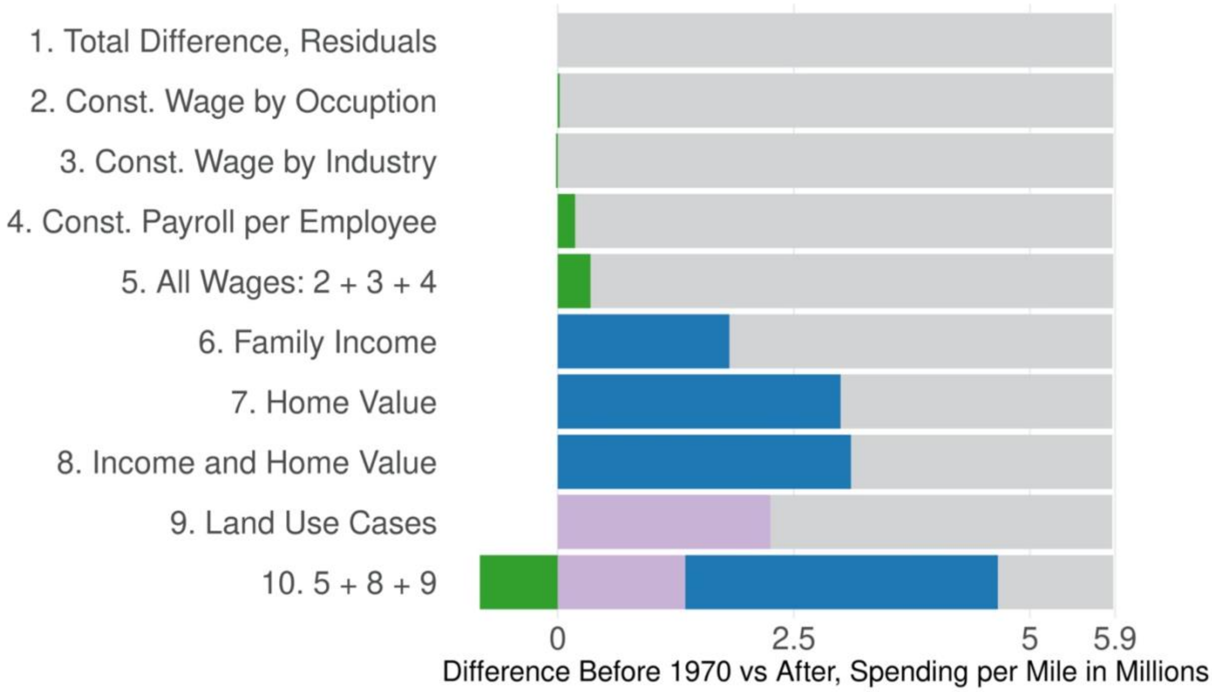
Figure 3. Time Trends in Interstate Attributes



Notes: Figures report centered five-year moving averages, so each series drops the first two and last two years. (We report data 1960-1991.) We weight all averages by miles. Wiggliness is the ratio of the true length of a segment to the “as the crow flies” distance connecting the segment’s endpoints. We measure ramp density and elevated highway density as the share of each highway mile accounted for by a ramp or elevated highway. For all segment-specific measures, we report on 83 percent of all segments. We were unable to match the balance of the segments that have opening dates in the Baum-Snow data uniquely with ground-truth Interstates from the associated shapefile. See Appendix A.2.b for more details.

Sources: Baum-Snow (2007), FHWA (2016a), and FHWA (2017a). See Appendix A.3 for more details.

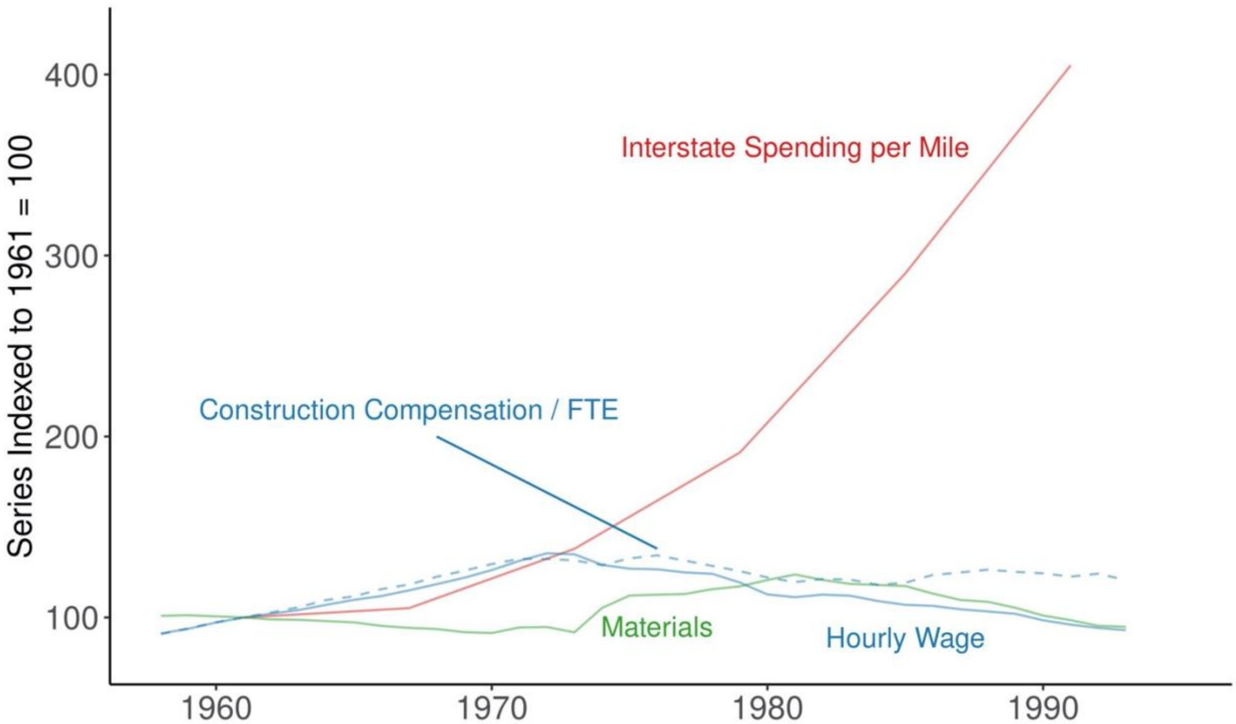
Figure 4. While Wages Explain Little of Cost Increase, Income, Home Values and Land Use Cases Explain a Substantial Amount



Notes: This grey bar in this figure reports the average difference across states in spending per mile conditional on geographic covariates (as listed in the notes for Figure 2) before 1970 versus 1970-onward. The colored portion on each successive bar shows the amount of the difference explained by a change in the list covariate(s) multiplied by the initial period relationship between the covariate(s) and spending per mile (as measured by the estimated coefficient in the pre-1970 period). Each covariate in the figure above is the residual from a regression of the standardized covariate on standardized geographic variables and state fixed effects. Wage variables are in green (King et al. 2010; U.S. Census Bureau [1953-1993]; Duranton et al. 2014); income and housing value variables are in blue (for income: Decennial Census; for housing value: U.S. Census Bureau 2008a; 2009; 2012). We use light purple for land use cases per capita (Ganong and Shoag, 2017). The final row reports results for all covariates included together. In all rows, we weight the decomposition by miles completed. Appendix Table A3ii shows the specific values for this figure, and Appendix Table A4ii shows the coefficients on the covariates for each analysis period (1958-1969, 1970-1993).

Sources: See Appendix A.4 for details on covariates cited above. See Appendix A.1 for Decennial Census details and citations. See Appendix A.2.a–c for sources and methods of variable creation of geographic covariates, and Appendix B for calculation of spending per mile.

Figure 5. Growth in Spending per Mile, Construction Wages, and Materials Prices



Notes: This figure shows Interstate spending per mile from our 6-year periods in red, along with the construction hourly wage (in blue; BLS (Margo 2006)), construction compensation per full time employee (dashed blue; US Bureau of Economic Analysis 2021a, b), and materials prices (green; US Bureau of Labor Statistics 2017a-e). We index all values to 100 in 1962.

Sources: See Appendix A.4.a–c for complete details on materials price components and wage variable; see Appendix B for calculation of spending per mile.

Table 1. Inclusion of Geographic Controls Has Little Impact on Spending-per-Mile Increase

	(1)	(2)	(3)	(4)
Period indicators, years				
1964-1969	0.43	0.04	1.03	0.72
	(0.72)	(1.13)	(0.82)	(0.94)
1970-1975	3.21***	3.33**	4.11***	4.15***
	(0.97)	(1.51)	(1.08)	(1.35)
1976-1981	7.72***	8.40***	7.45***	8.78***
	(1.64)	(1.97)	(1.55)	(1.81)
1982-1987	16.11***	15.79***	14.02***	15.30***
	(2.87)	(3.11)	(2.82)	(3.06)
1988-1993	25.85***	25.42***	21.26***	23.90***
	(7.56)	(7.82)	(7.73)	(8.47)
Geographic covariates, state average of segments constructed				
Population density, 1000s people/sq. mi			7.98***	4.76*
			(1.72)	(2.47)
Share intersecting wetlands, rivers			17.84*	-10.18
or other water			(10.45)	(33.68)
Slope			1.25***	0.61
			(0.31)	(0.62)
State fixed effects		X		X
Observations	270	270	270	270
R^2	0.14	0.36	0.32	0.39

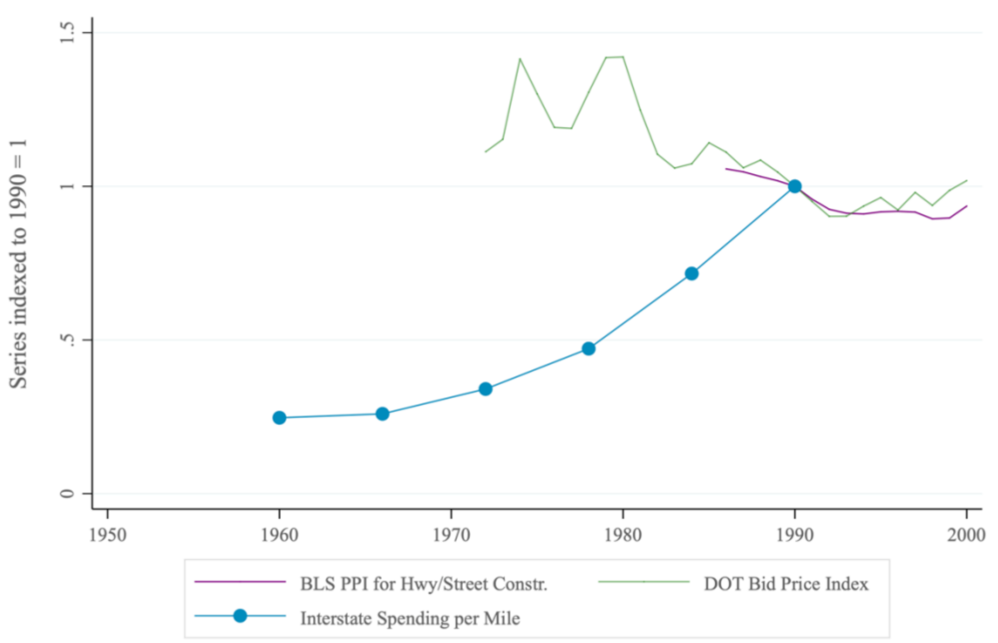
Notes: The dependent variable is spending per mile in 2016 dollars, and the unit of observation is a state in a six-year period. Apart from state fixed effects, we standardize all covariates to mean zero, standard deviation one for ease of comparison. We weight all regressions by miles completed in that six-year period and cluster standard errors by state. The excluded time period is 1958-1963. * p<0.10, ** p<0.05, *** p<0.01

Sources: See Appendix A.2.a–c for sources and creation of geographic covariates and Appendix B for calculation of spending per mile.

Online Appendix for “Infrastructure Costs,” by Leah Brooks and Zachary Liscow

Online Appendix Figures and Tables

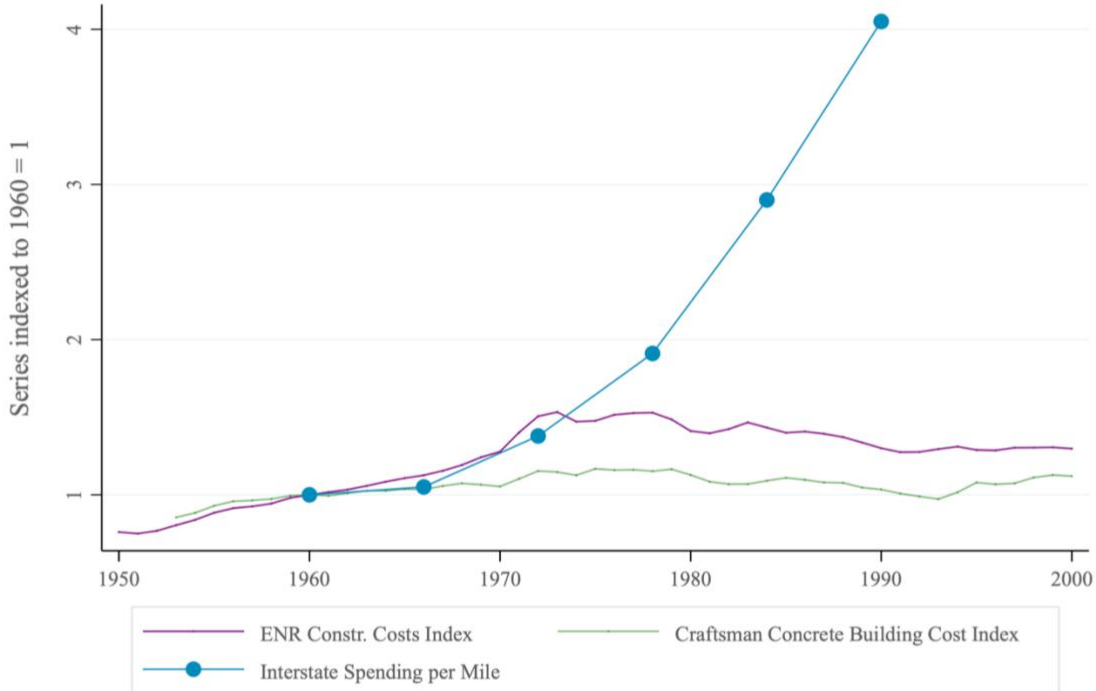
Figure A1. Government Transportation Construction Price Indices vs. Spending per Mile on Interstates



Notes: This figure presents average state spending per mile in each six-year period (see notes for Appendix Figure A6 for this measure), the US Department of Transportation Bid Price Index (FHWA 2019), and the Bureau of Labor Statistics Producer Price Index (US Bureau of Labor Statistics 2011) for Highway and Street Construction. We adjust all series to report in 2016 dollars and then index to 1990 to ease comparisons.

Sources: See Appendix B for calculation of spending per mile and Appendix A.6.c–d for cost indices sources.

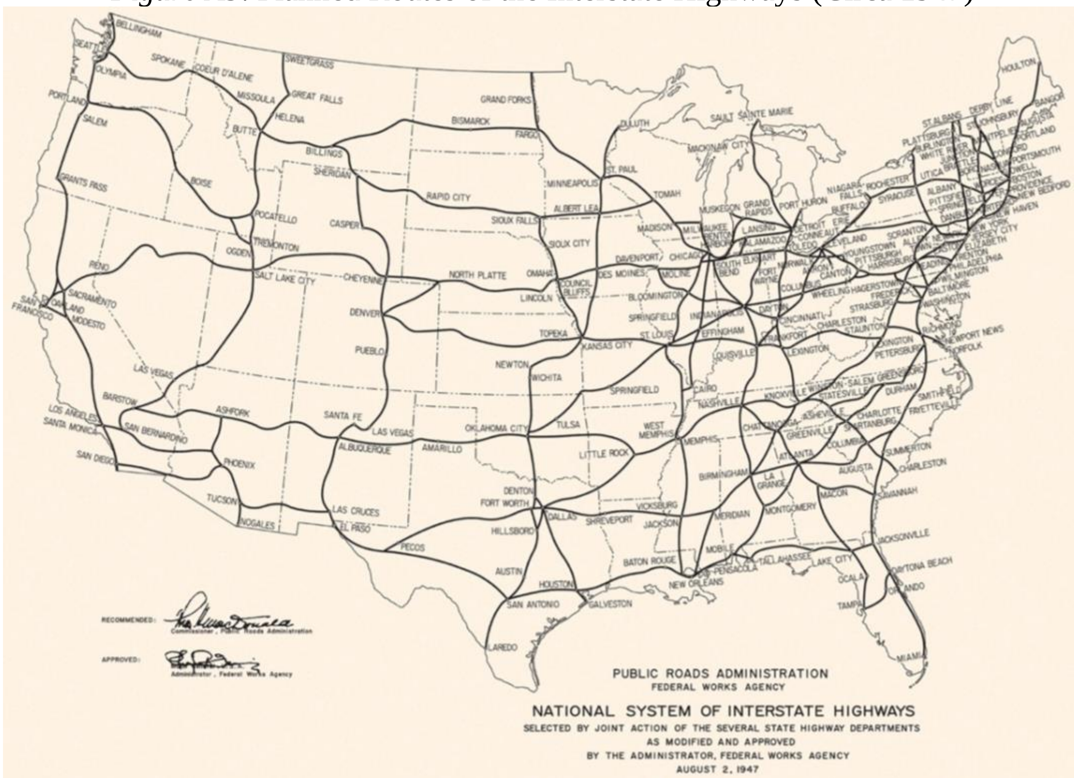
Figure A2. Overall Construction Price Indices vs. Spending per Mile on Interstates



Notes: This figure presents average state spending per mile in each six-year period (see notes for Appendix Figure A6 on this measure), the Engineering News-Record (ENR 2021) Construction Cost Index, and the Craftsman Concrete Building Cost Index (Moselle 2020). The ENR index is a price index for inputs into overall construction, and the Craftsman index is for the per-square-foot cost of a concrete building. We adjust all series to report in 2016 dollars and then index to 1960 to ease comparisons.

Sources: See Appendix B for calculation of spending per mile and Appendix A.6.a–b for cost indices sources.

Figure A3. Planned Routes of the Interstate Highways (Circa 1947)



Notes: This figure displays the federal plan Interstate routes as of the late 1940s.

Sources: Federal Highway Administration (2017c).

Figure A4. Total Number of Interstate Miles Constructed by Opening Year

Notes: This figure reports the total number of Interstate miles completed in each year. The series begins in 1956 and ends in 1993.

Sources: Baum-Snow (2007).

Figure A5. Timing of Interstate Opening

Figure A5i. Interstates Opening 1950-1959

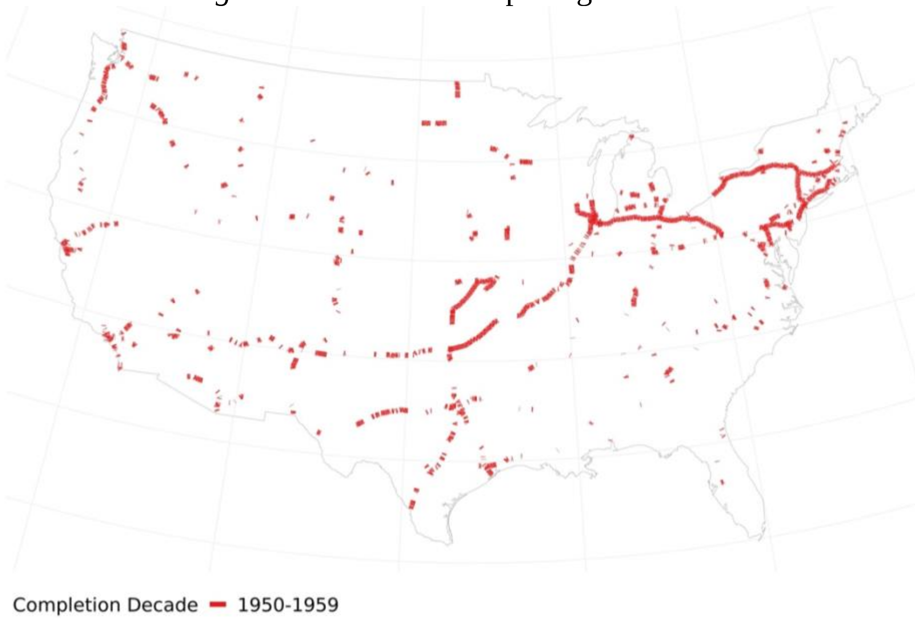


Figure A5ii. Interstates Opening 1960-1969

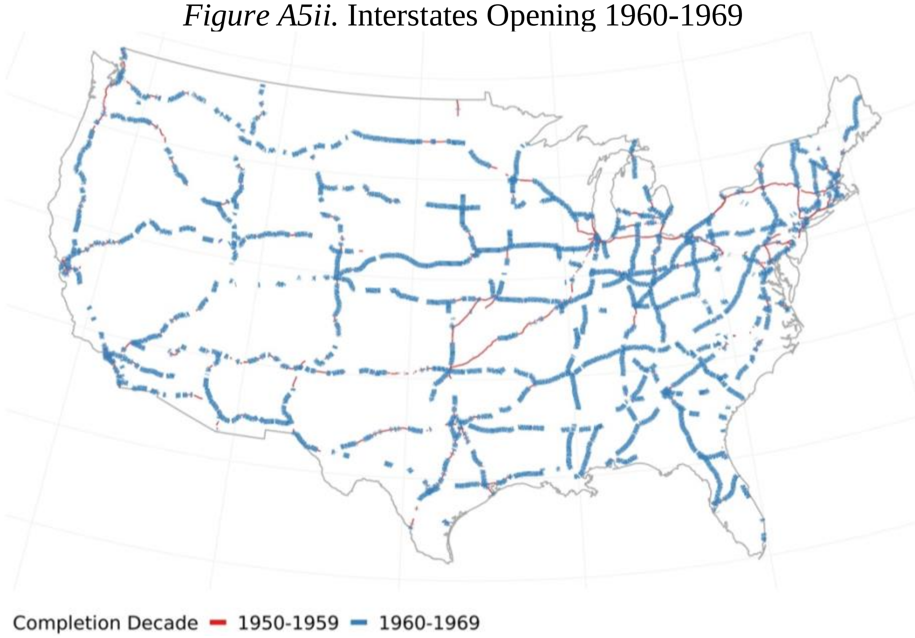


Figure A5iii. Interstates Opening 1970-1979

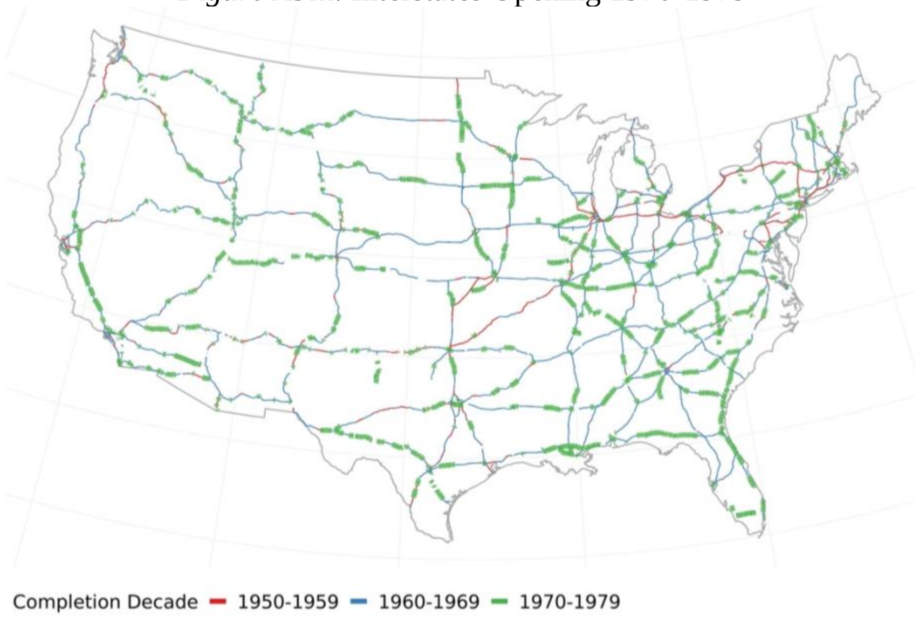


Figure A5iv. Interstates Opening 1980-1989

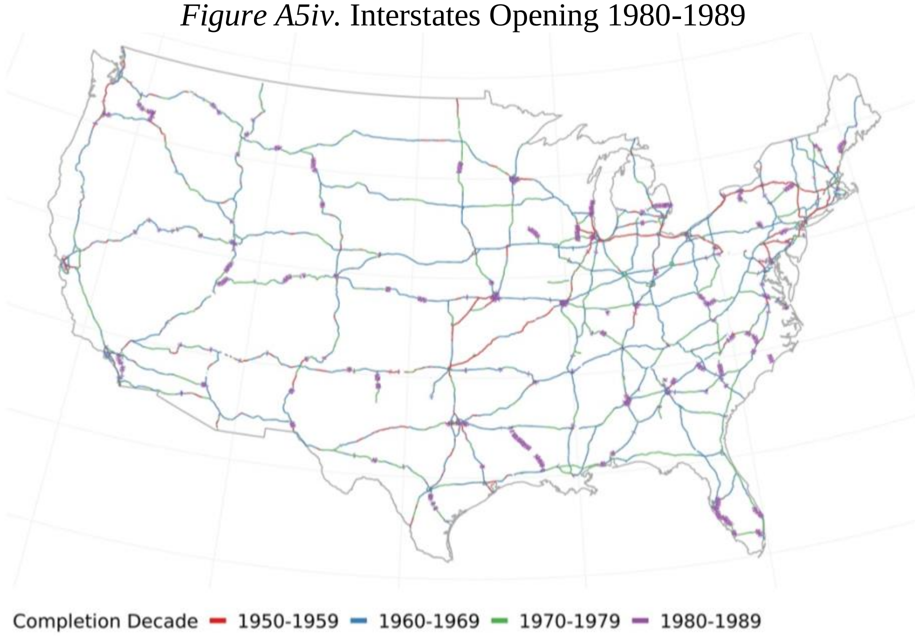


Figure A5v. Interstates Opening 1990-1993

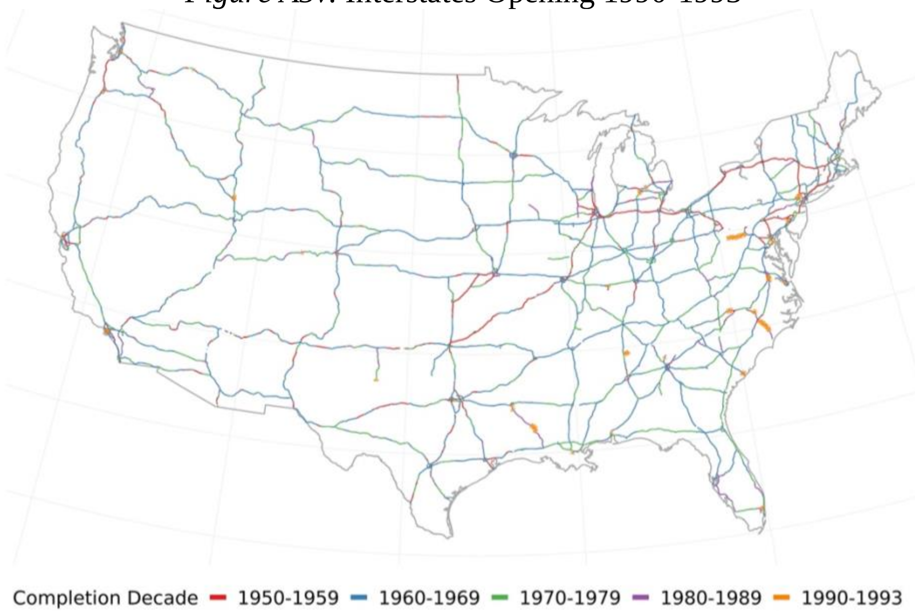
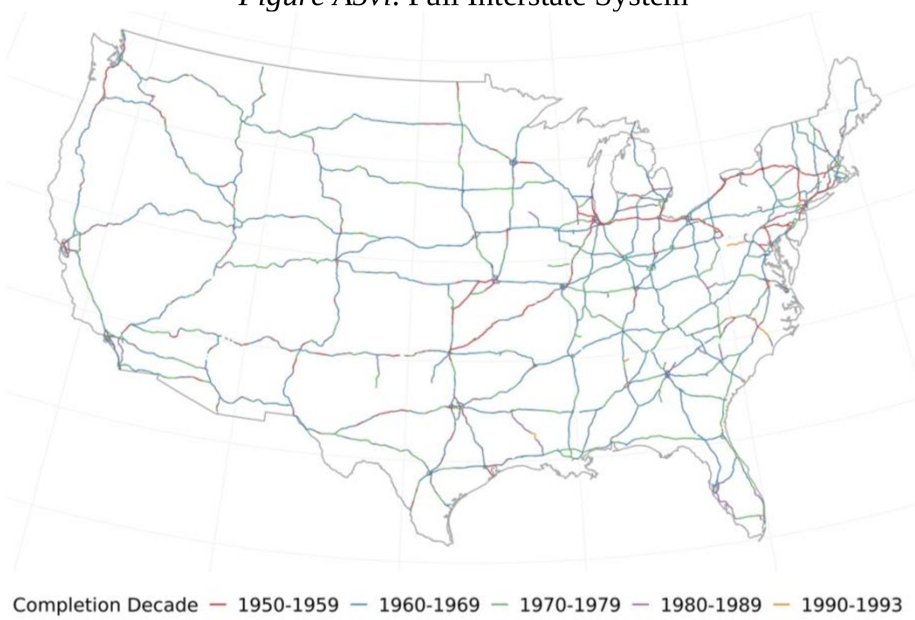


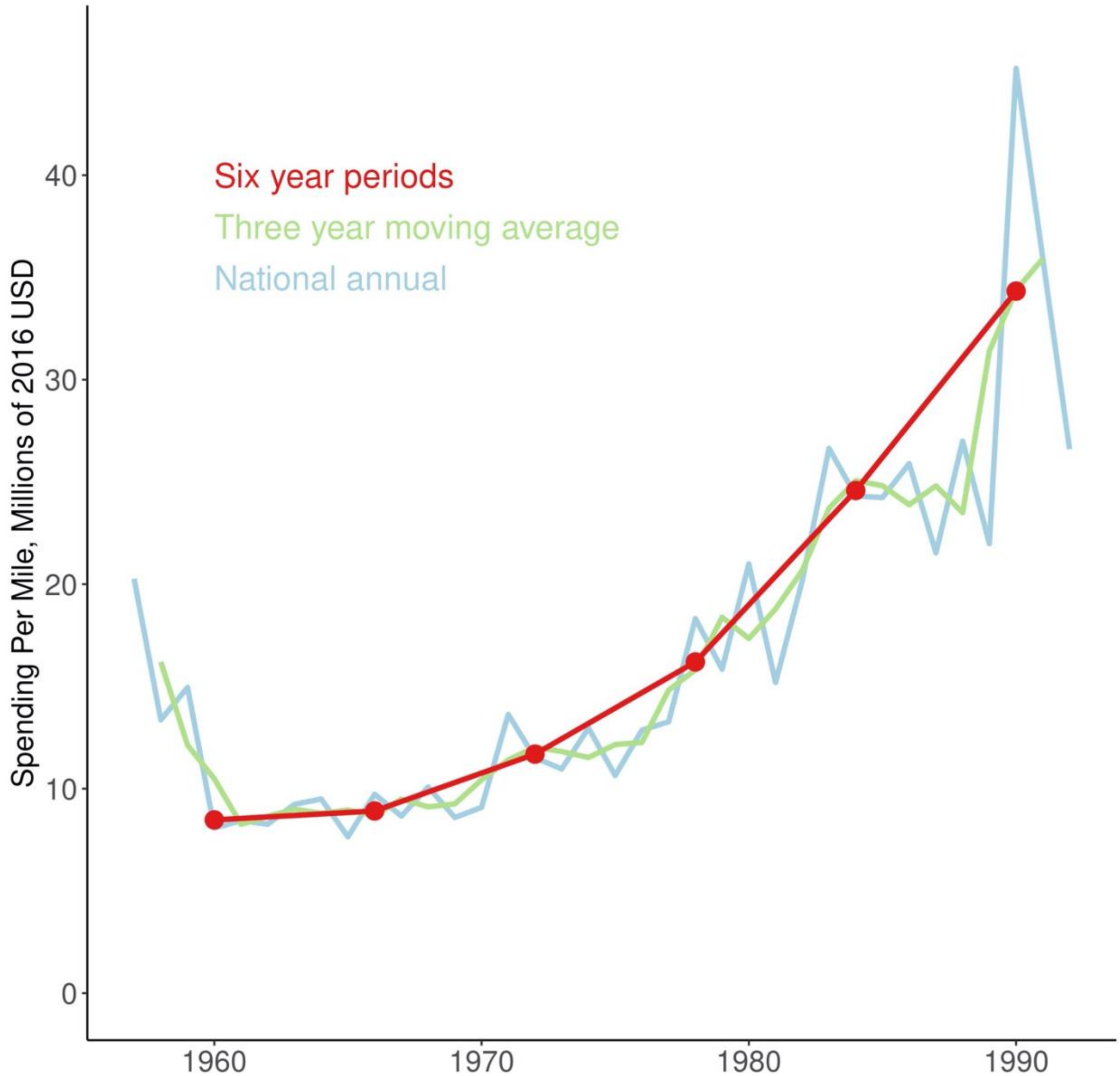
Figure A5vi. Full Interstate System



Notes: This figure reports which segments of Interstate opened in each decade.

Sources: Baum-Snow (2007).

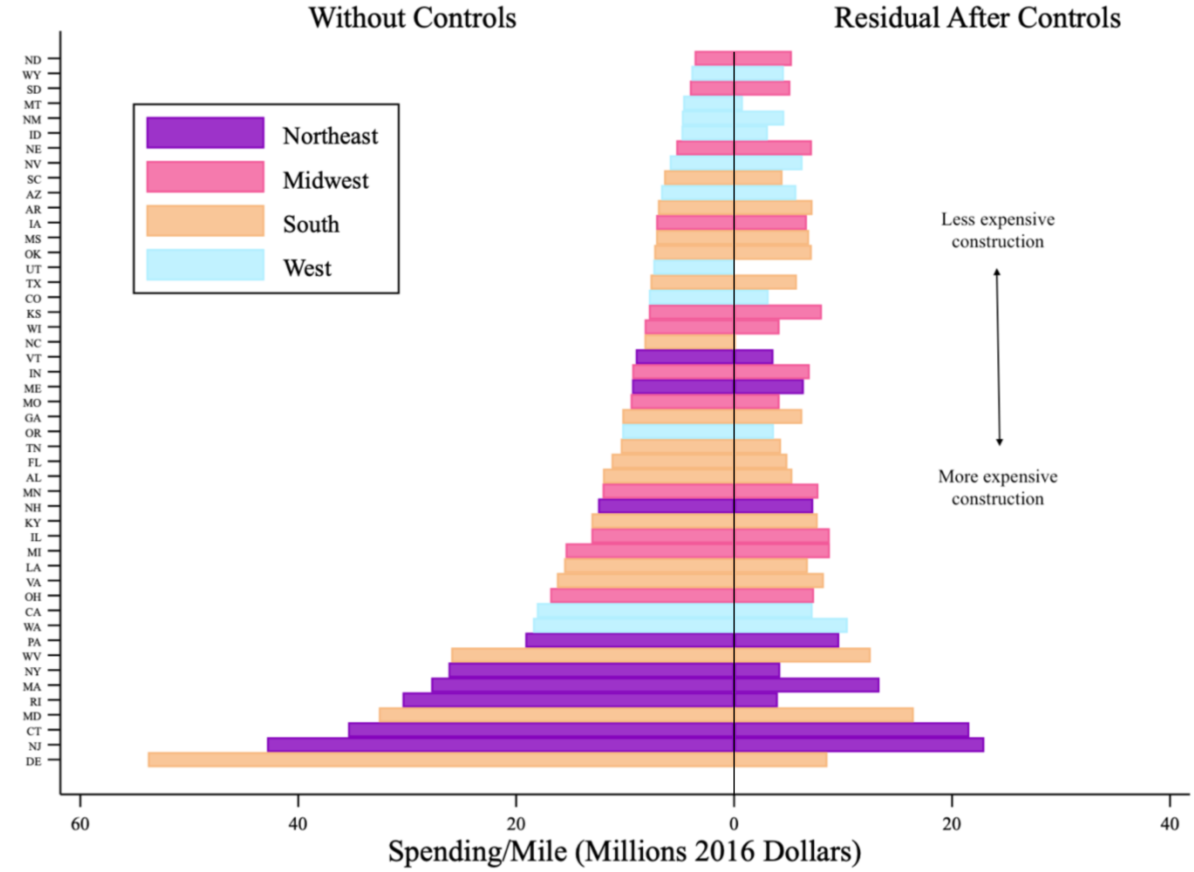
Figure A6. Interstate Construction Spending-per-Mile Increases over Time



Notes: This figure uses light blue to report national spending per mile, defined as the total spending in a given year divided by the miles completed in that year. The light green line presents the three-year moving average of this series. The red line with dots shows the miles-weighted average of state spending per mile by six-year periods as discussed in the text. For purposes of presentation, the national series omit 1993, which is a very high outlier and has very few newly completed miles.

Sources: See Appendix B for calculation of spending per mile and Appendix 2.a–c for sources and creation of geographic covariates.

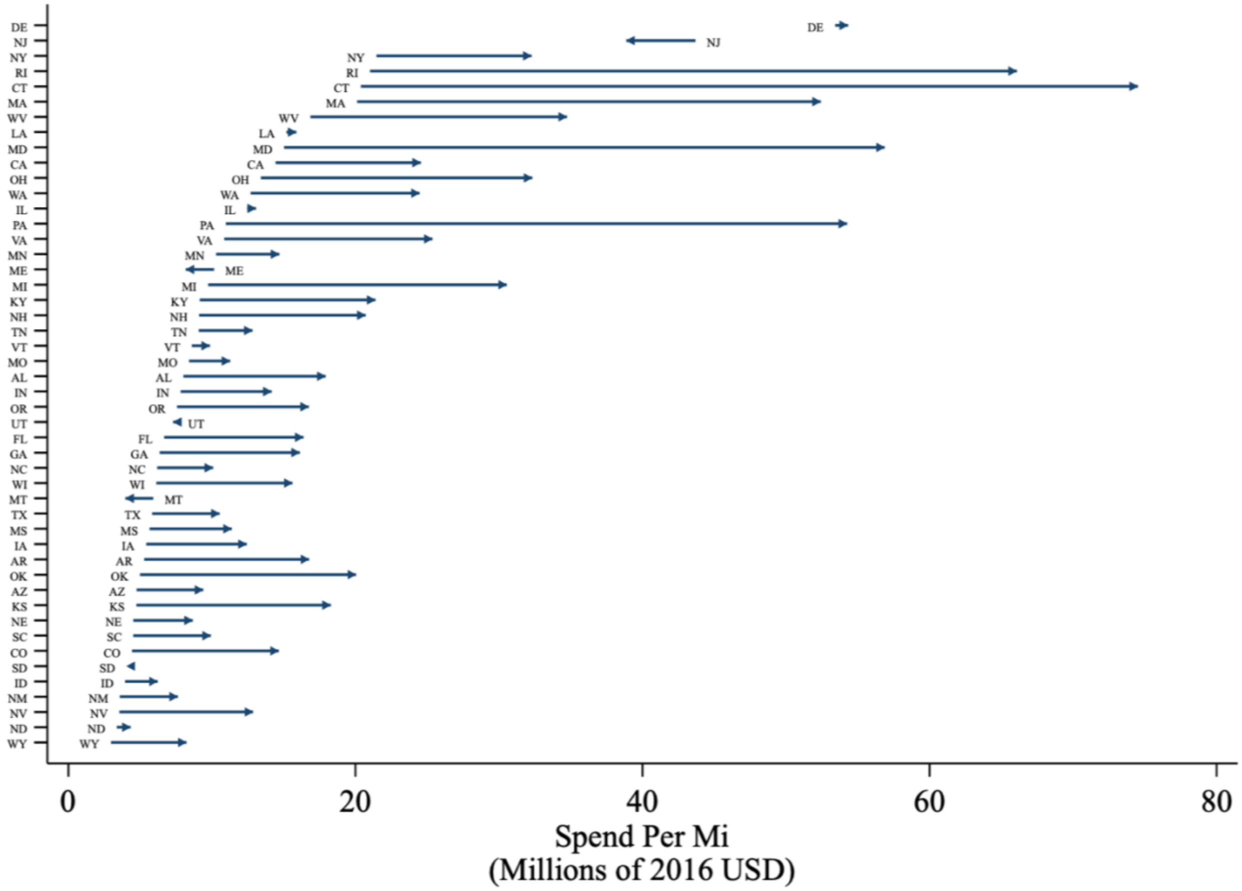
Figure A7. Interstate Spending per Mile by State



Notes: Values to the left of the vertical black line are total spending divided by total miles by state. Values in the right column are the miles-weighted averages of state-specific residual spending per mile (millions 2016 USD) after controlling for geography (from Table 1, column (3)).

Sources: See Appendix B for notes on the calculation of spending per mile and Appendix 2.a–c for sources and creation of geographic covariates.

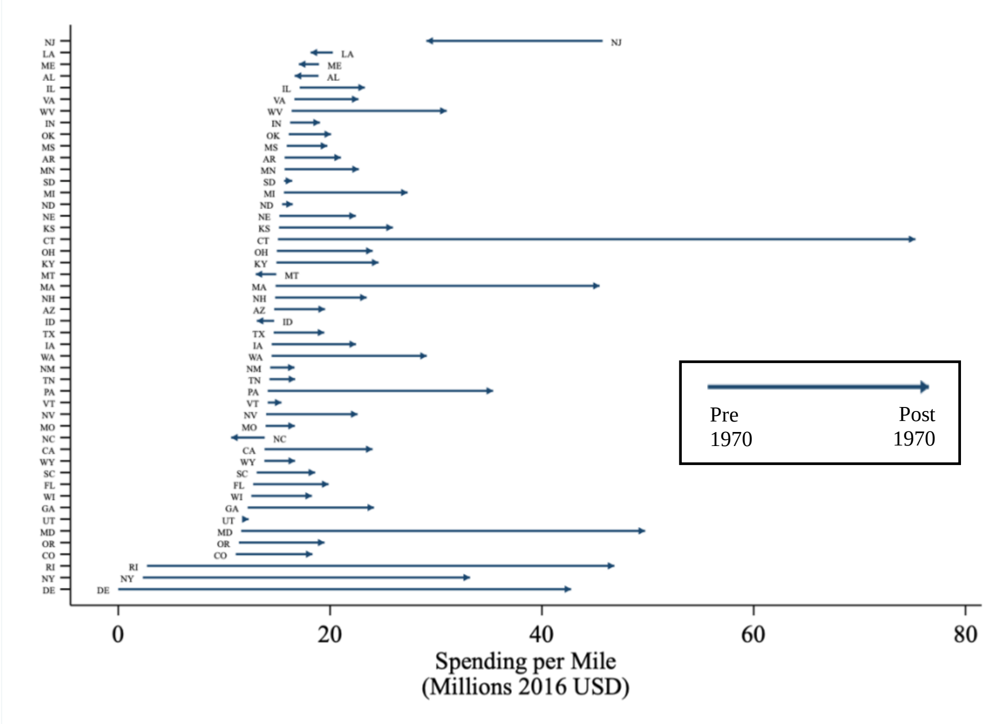
Figure A8. State Spending per Mile: Pre-1970 vs. Post-1970 Without Geographic Covariates



Notes: This figure reports average spending per mile in each state in the pre-1970 and 1970-onward periods, calculated as all spending divided by all miles in each state.

Sources: See Appendix B on the calculation of spending per mile.

Figure A9. State Spending per Mile: Before and After 1970, Controlling for Geography



Notes: This figure reports average spending per mile in each state in the pre-1970 and 1970-onward periods, conditional on geographic covariates. To calculate it, we weight the pre-1970 and post-1970 residuals of a regression of spending per mile on our main geographic covariates (as in Table 1, column (3)) by miles completed. To this value, we add the miles-weighted average of the period effects (pre-1970 and 1970-onward, also from column 3 of Table 1) to arrive at the numbers presented above. We scale the residuals so that the minimum pre-1970 residual value is 0.

Sources: See Appendix B on the calculation of spending per mile and Appendix 2.a–c for sources and creation of geographic covariates.

Figure A10i. Interstate Spending per Mile by State (Not Controlling for Geography)

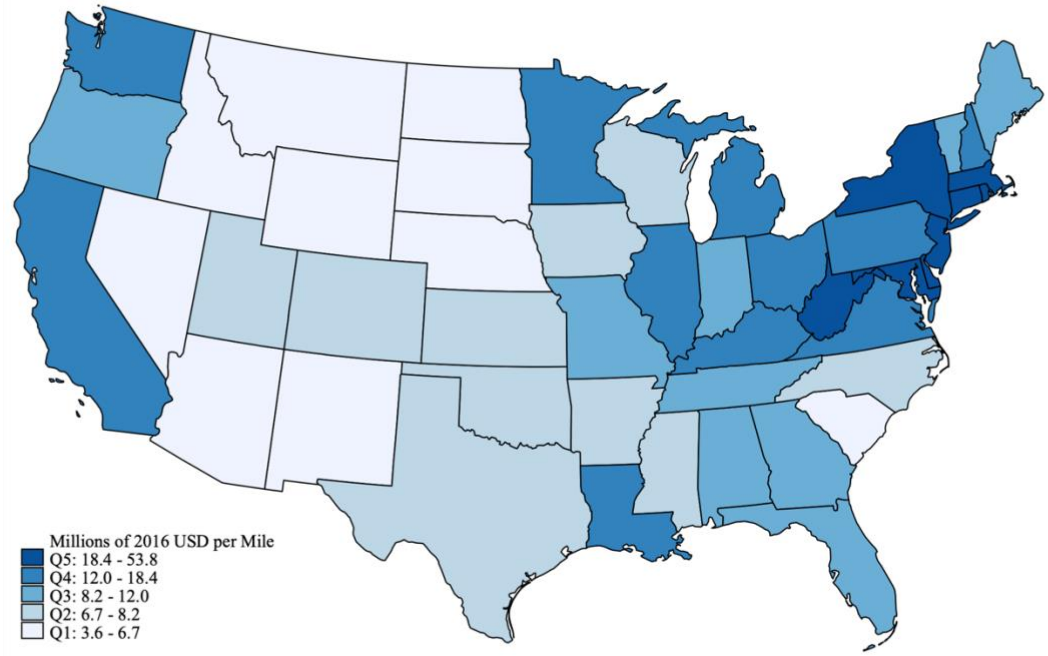
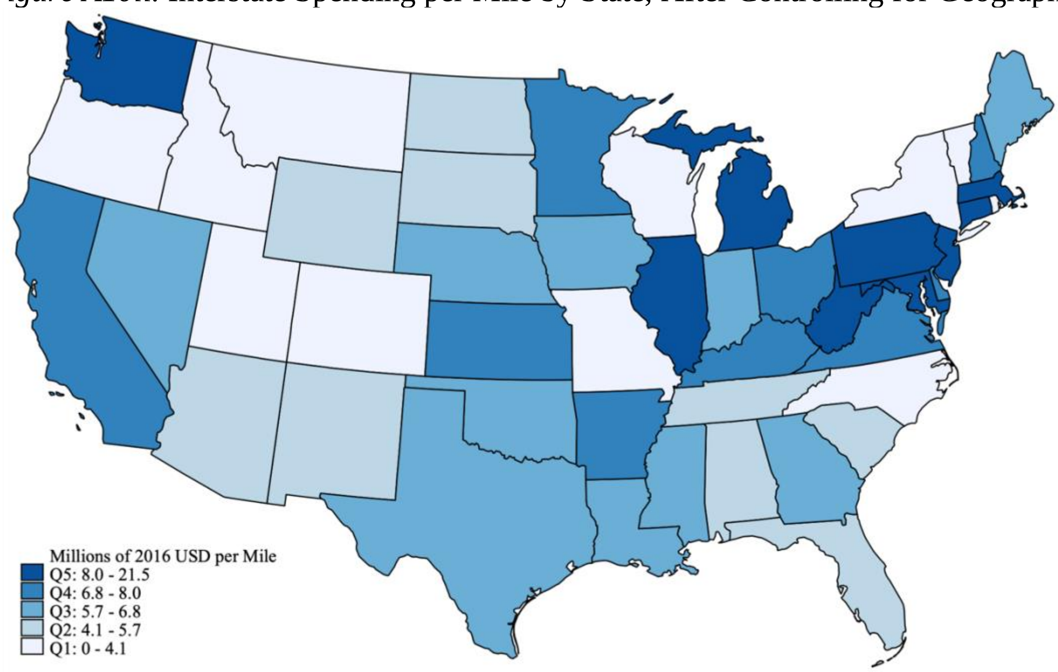


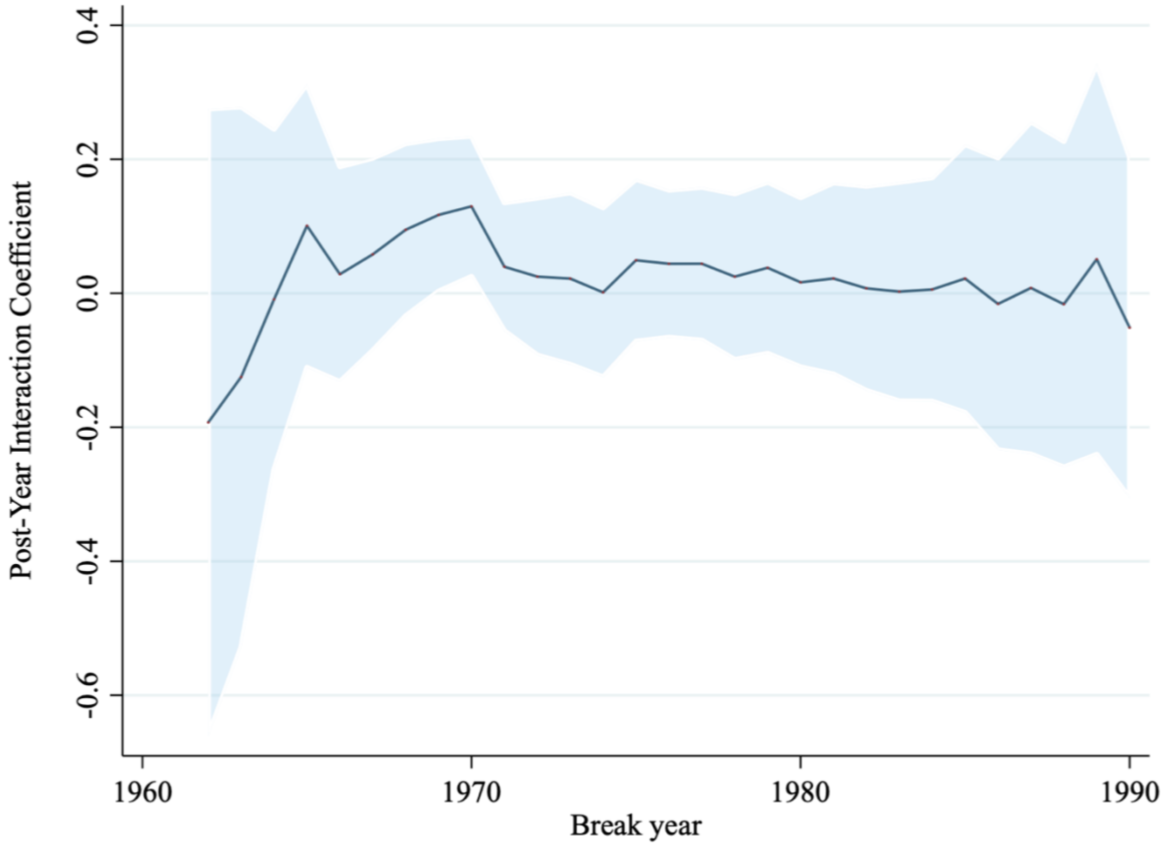
Figure A10ii. Interstate Spending per Mile by State, After Controlling for Geography



Notes: Panel (i) colors states by quintiles of spending per mile for all years in our sample, calculated as overall inflation-adjusted spending divided by overall miles by state. Panel (ii) colors states by the mileage-weighted residuals from column 3 of Table 1: a regression of spending per mile on the three geographic covariates as in Equation (2). We scale residuals so that the minimum is 0.

Sources: See Appendix B for calculation of spending per mile and Appendix 2.a–c for sources and creation of geographic covariates. State boundary map from U.S. Census Bureau (2017).

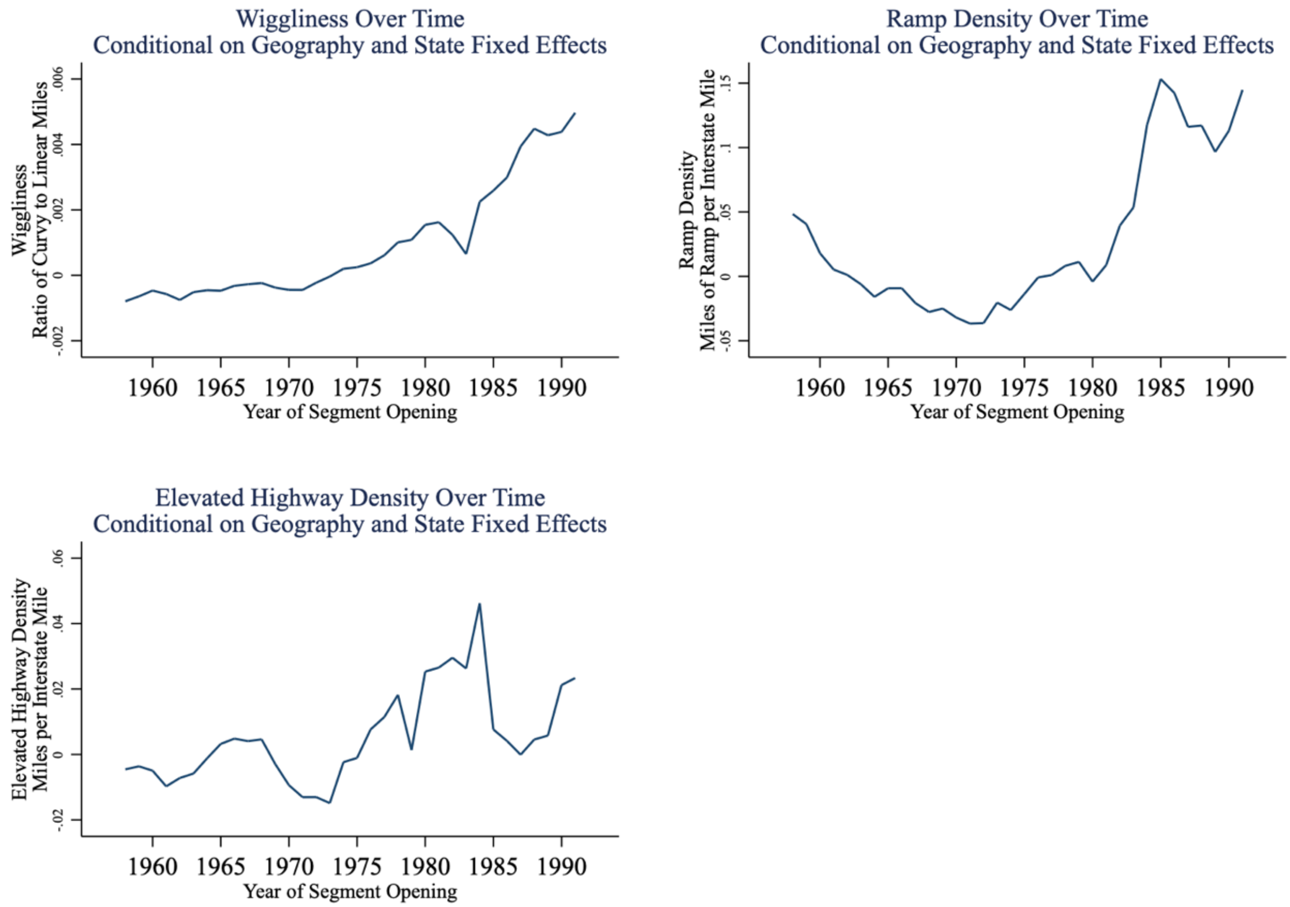
Figure A11. Regression Estimates of Time Trend After Trend Break, By Break Year



Notes: Each year *t* in this figure presents the coefficient (black line) and confidence interval (95 percent; light blue area) for the estimate of a trend break in year *t* following Equation (3). The unit of observation is state-year, rather than state-period as used in almost all other estimations. We omit the regression coefficients for the first three years for readability; those coefficients range from -3.14 to -0.35 and are all insignificantly different from zero at the 95-percent level.

Sources: See Appendix B for calculation of spending per mile.

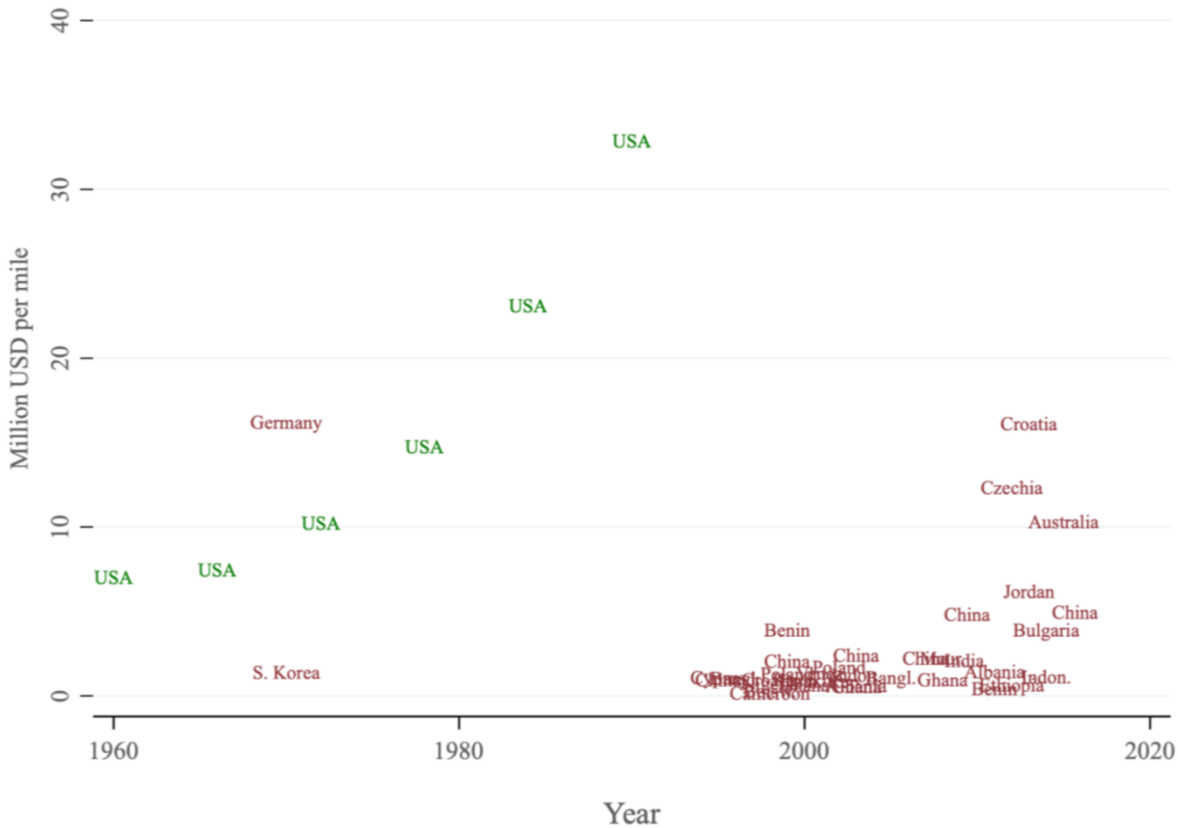
Figure A12. Time Trends in Interstate Attributes Controlling for Geography



Notes: This figure reports national annual averages for segment-level measures of highway attributes as in Figure 3. Here, however, we present residuals of these measures from a segment-level regression of each attribute on the three geographic variables that we use in Equation (2) (but here at the segment level) and state fixed effects. We weight the regression by segment length.

Sources: See Appendix A.2.a–b for structure and wiggliness variable sources.

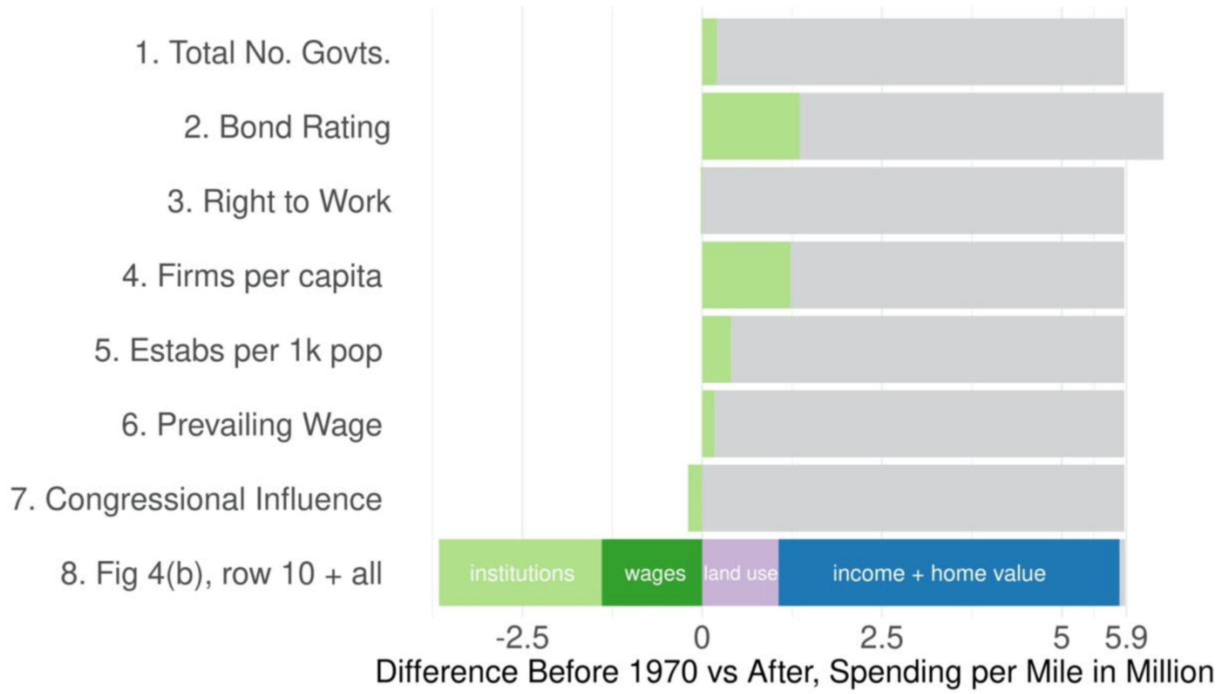
Figure A13. International Highway Spending Per Mile Over Time



Notes: This figure reports average state spending per mile by six-year period, as in Appendix Figure 1, with the points labeled "USA." We report spending per mile on other highway projects, also in 2016 dollars, with the name of the country to which the spending pertains.

Sources: See Appendix B for calculation of US spending-per-mile; see Appendix C for international data calculation and sources.

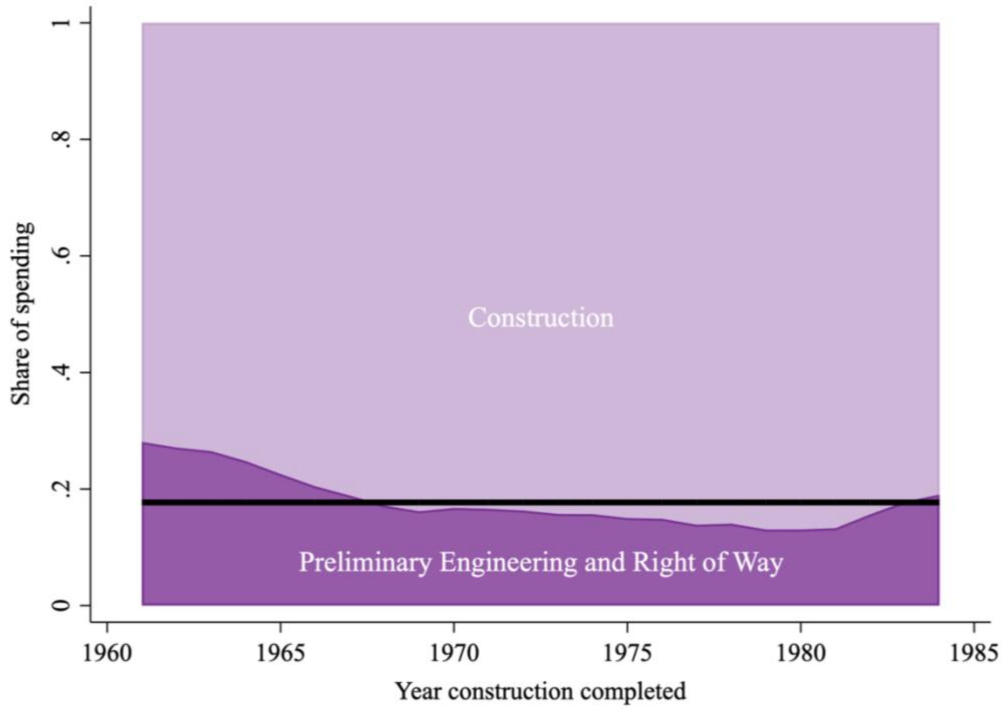
Figure A14: Other Institutional Measures and Spending per Mile Conditional on Geography



Notes: This analysis begins with the average difference across states in spending per mile conditional on geographic covariates (as listed in the notes for Figure 4) before 1970 versus 1970-onward. The colored portion on each successive bar shows the amount of the difference explained by a change in the covariate(s) listed to the left multiplied by the initial period relationship between the covariate(s) and spending per mile (as measured by the estimated coefficient in the pre-period). Each covariate in the figure is the residual from a regression of the standardized covariate on geographic variables and state fixed effects. All institutional variables are in light green; income and housing value variables are in blue, wage variables are in green, and the land use covariate is in light purple. The gray bar for bond rating is longer because of a slightly smaller sample. The final row reports results for all covariates included together (except for bond rating, to maintain the full sample). In all rows, we weight the decomposition by miles completed. Appendix Table A3ii shows the specific values for this figure, and Appendix Table A4iii shows the coefficients on the covariates for each analysis period (1958-1969, 1970-1993).

Sources: See sources note for Figure 4 for details of row 8. See Appendix A.3.k, l, n, j, o, m (in order of rows displayed) for information on sources.

Figure A15. Share of Spending on Preliminary Engineering and Right of Way



Notes: This figure reports data that divide national Interstate spending into either construction or "preliminary engineering and right of way" purchase. We show annual shares for all reported years. The dark black line at 17.8 percent is the average share of the latter spending category across all years.

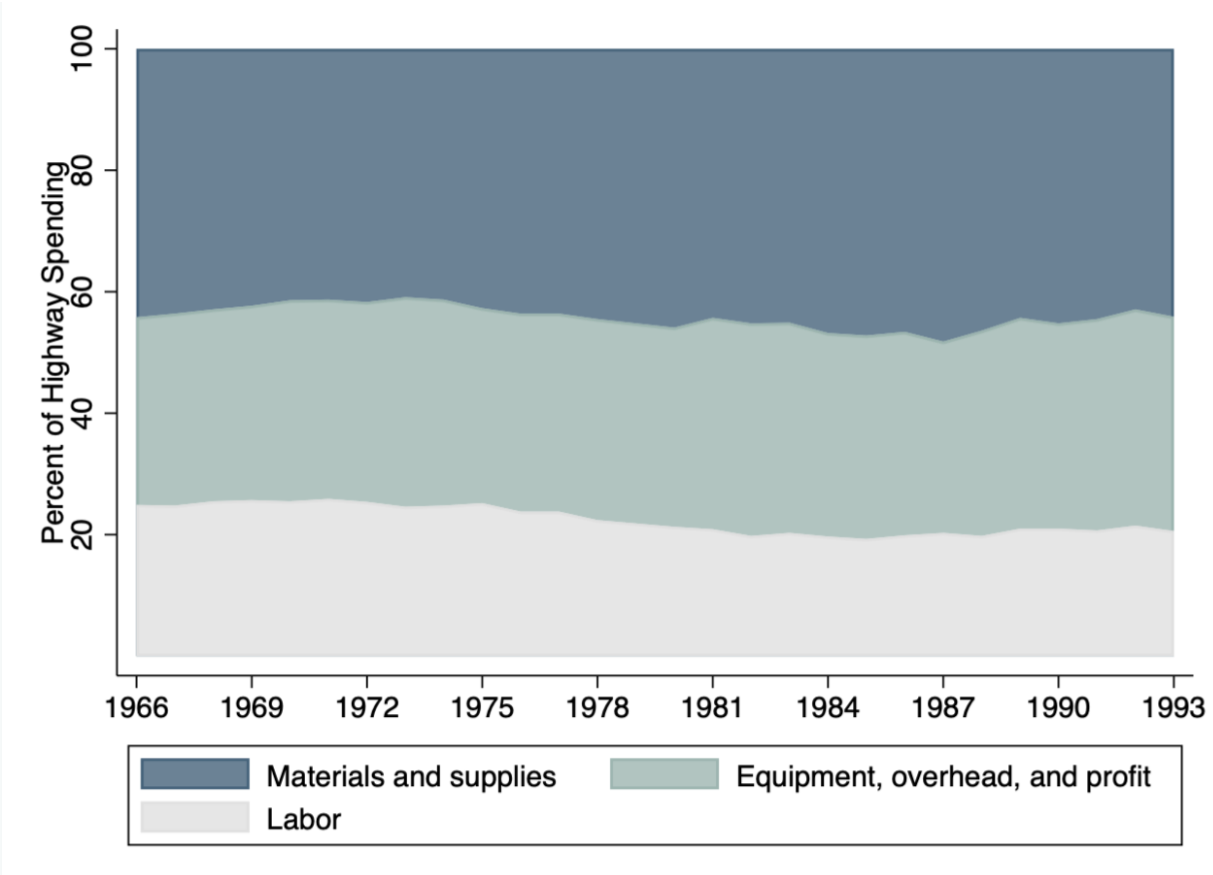
Sources: Data are from FHWA *Quarterly Reports* (FHWA [1963-1996]).

Figure A16. Pedestrian Plazas Across I-696 in Oak Park

Notes: This figure shows the final leg of I-696 outside of Detroit. This final leg of construction was much more expensive per mile than the previous two legs. The figure outlines a pedestrian plaza included to address community concerns.

Sources: Michigan Department of Transportation (2003).

Figure A17. Distribution of Highway Spending Over Time



Notes: This figure presents the percent of costs incurred by construction firms by spending type for all completed primary federal aid highway construction contracts. "Costs incurred by construction firms" does not include all costs due to planning, right-of-way access, or other state Department of Transportation costs.

Source: Data from *Highway Statistics* series (FHWA [1956-1995]). See Appendix A.5.b for further details.

Table A1. Mileage Openings Most Strongly Related to Spending in Two Years Prior

	(1)
Year *t* Expenditure	40.294**
	(15.17)
Year *t* -1 Expenditure	33.297***
	(10.91)
Year *t* -2 Expenditure	15.157**
	(5.72)
Year *t* -3 Expenditure	2.859
	(9.26)
Year *t* -4 Expenditure	4.159
	(9.31)
Year *t* -5 Expenditure	-8.169
	(6.31)
Year *t* -6 Expenditure	18.730*
	(10.66)
Year *t* -7 Expenditure	-14.785
	(10.69)
Year *t* -8 Expenditure	-8.972
	(11.22)
Year *t* -9 Expenditure	7.527
	(5.31)
Year *t* -10 Expenditure	-10.25
	(6.93)
Year *t* +1 Expenditure	-6.25
	(13.68)
Year *t* +2 Expenditure	-12.242
	(12.12)
Year *t* +3 Expenditure	8.267
	(12.84)
Year *t* +4 Expenditure	2.159
	(12.51)
Year *t* +5 Expenditure	19.094
	(11.70)
Constant	-2.807
	(3.98)
Observations	1100
R^2	0.582
Adjusted R^2	0.557

Notes: This table reports coefficients from a regression of the number of Interstate miles opened in year *t* in state *s* on state fixed effects and spending in year $t + n$, where n is in {-10, 5}. We use robust standard errors and cluster at the state level. * p<0.10; ** p<0.05; *** p<0.01.

Sources: See Appendix B for calculation of spending per mile. Segment opening dates from Baum-Snow (2007).

Table A2. Summary Statistics

	1958-1963	1964-1969	1970-1975	1976-1981	1982-1987	1988-1993	All years
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Spending per mile,	8.47	8.91	11.69	16.20	24.58	34.33	11.51
millions of 2016 dollars	(6.51)	(5.41)	(10.18)	(15.16)	(34.44)	(45.12)	(13.81)
New miles built	186.3	291.9	187.8	86.8	36.0	18.1	134.5
	(139.8)	(200.9)	(147.6)	(77.0)	(40.0)	(27.5)	(155.2)
State average for segments constructed in this period							
Pop. density, (1000s people/sq. mi)	0.69	0.55	0.52	0.57	0.82	0.96	0.60
	(0.99)	(0.54)	(0.52)	(0.74)	(0.59)	(0.68)	(0.69)
Share of segments in wetlands, rivers,	0.03	0.03	0.04	0.05	0.05	0.07	0.03
or other waters	(0.02)	(0.02)	(0.03)	(0.06)	(0.04)	(0.07)	(0.03)
Slope in degrees	2.68	3.04	2.94	3.31	3.23	4.03	2.99
	(1.30)	(1.53)	(1.77)	(1.80)	(1.82)	(3.50)	(1.66)
Local median family income	40,990	47,120	50,611	52,467	57,819	61,400	47,890
	(7,002)	(7,525)	(7,895)	(7,158)	(9,296)	(12,505)	(9,050)
Local median home value	79,383	81,437	81,896	119,660	133,943	131,146	88,637
	(16,047)	(17,363)	(19,074)	(33,408)	(42,191)	(57,921)	(28,351)
Observations	48	48	48	47	43	36	270

Notes: This figure presents summary statistics for the main dependent variables and covariates. We express all dollar figures in 2016 dollars. Later years have fewer observations because some states have completed their Interstate construction by those years.

Sources: See Appendix B for calculation of spending per mile. See Appendix A.2 and A.3.f–g for definitions and sources of the covariates.

Table A3i. Decomposing Spending per Mile with Geographic Covariates

			State Fixed Effects		Geographic Features	
	Overall Difference	Std. Error	Explained Amount	Std. Error	Explained Amount	Std. Error
State Fixed Effects	6.8	1.81	0.53	0.72		
Pre-determined Geog. Features	6.8	1.63			0.72	0.61
Both	6.8	1.80	0.70	0.68	-0.84	1.02

Notes: This table reports the exact numbers that underlie Figure 2. Each row is a decomposition. The figure reports the overall difference in spending per mile, expressed as the difference between the miles-weighted average across state-period data in the pre-1970 and 1970-onward eras, and the standard error of this difference. The following two columns report the contribution of state fixed effects to "explaining" the overall difference, as in Equation (4) in the main text (and the standard error of this explanation). The final pair of columns reports how much the geographic covariates (as listed in Equation (2)) "explain" of this difference. The final row reports results when we include all covariates in one estimation.

Sources: See sources note under Figure 2.

Table A3ii. Decomposing Spending per Mile with Wages, Income, Home Value and Land Use

	Wages		Income/Home Value		Land-Use Cases		Institutions			
	Explained Amount	Std. Error	Explained Amount	Std. Error	Explained Amount	Std. Error	Explained Amount	Std. Error	Overall Difference	Std. Error
Panel A: Wages, Income/Home Value and Land Use										
Wages										
2. Const. Wages by Occupation	0.02	0.10							5.88	1.36
3. Const. Wages by Industry	-0.02	0.66							5.88	1.36
4. Const. Payroll/Employee	0.18	0.42							5.87	1.36
5. 2 + 3 + 4	0.35	0.76							5.88	1.37
Income/Home Value										
6. Family Income			1.82	0.80					5.87	1.36
7. Home Value			2.99	0.79					5.87	1.36
8. 6 + 7			3.11	0.92					5.87	1.37
Land Use										
9. Land-Use Cases					2.25	0.76			5.87	1.36
Together										
10. 5 + 8 + 9	-0.83	1.35	3.31	1.35	1.35	0.79			5.88	1.38
Panel B: Institutions										
1. Number of Govts.							0.21	0.19	5.87	1.36
2. Bond Rating							1.36	0.59	6.41	1.53
3. Right to Work							-0.02	0.07	5.87	1.36
4. Firms per Capita							1.23	1.45	5.87	1.36
5. Estabs. per 1k Pop.							0.40	0.33	5.87	1.36
6. Prevailing Wage							0.17	0.17	5.87	1.36
7. Congressional Influence							-0.20	0.31	5.87	1.39
8. Fig 4(b), row 10 + all (w/o bonds)	-1.40	1.45	4.74	1.62	1.06	0.82	-2.26	1.64	5.88	1.42

Notes: This table reports the exact numbers that underlie Figure 4 and Appendix Figure 14. Each row is a decomposition. See notes for Figure 4.

Sources: See sources note for Figure 4 for Panel A, and sources note for Figure A14 for Panel B.

Table A4i. Coefficients and Means that Underlie Decomposition in Figure 2

		Before 1970			1970-Onward		
		Coefficient	Std. Error	Mean	Coefficient	Std. Error	Mean
Figure 2, Row in Figure							
3	Population Density	4.82	0.6	0.6	15.82	2.11	0.59
3	Wetlands	38.42	20.52	0.03	34.94	28.58	0.05
3	Slope	0.95	0.29	2.9	1.94	0.68	3.13
4	Population Density	2.77	0.99	0.6	15.96	3.9	0.59
4	Wetlands	-63.88	61.68	0.03	51.08	62.39	0.05
4	Slope	0.81	0.92	2.9	1.87	1.67	3.13

Notes: We estimate a decomposition as defined in Equation (4), where the dependent variable is spending per mile in a state-period. We standardize all covariates to mean zero, standard deviation one for ease of comparison (with the exception of state fixed effects). This table reports the coefficients β_{after} and β_{before} and their standard errors. We also report the mean of the covariate before and after 1970, as in Equation (4).

Sources: See sources note for Figure 2.

Table A4ii: Coefficients and Means that Underlie Decomposition in Figure 4

		Before 1970			1970-Onward		
		Coefficient	Std. Error	Mean	Coefficient	Std. Error	Mean
Figure 4, Row in Figure							
2	Const. Wages by Occupation	-1.65	1.2	0	-6.84	2	-0.01
3	Const. Wages by Industry	-0.03	1.13	-0.24	-5.65	2.78	0.35
4	Const. Payroll per Employee	0.49	1.11	-0.15	-2.46	2.78	0.22
5	Const. Wages by Occupation	-1.86	1.35	0	-6.3	2.41	-0.01
5	Const. Wages by Industry	-0.11	1.93	-0.24	-3.27	4.75	0.35
5	Const. Payroll per Employee	1.02	1.78	-0.15	2.98	4.22	0.22
6	Median Family Income	2.35	1.02	-0.31	8.54	2.11	0.46
7	Home Value	5.72	1.26	-0.21	6.44	1.31	0.31
8	Home Value	5.55	1.46	-0.21	4.99	1.59	0.31
8	Median Family Income	0.26	1.1	-0.31	3.98	2.52	0.46
9	Land-Use Cases	5.62	1.79	-0.16	10.8	2.38	0.24
10	Const. Wages by Occupation	-0.25	1.36	0	-2.65	2.49	-0.01
10	Const. Wages by Industry	-1.3	2.28	-0.24	2.52	5.1	0.35
10	Home Value	3.69	2.02	-0.21	2.86	2.22	0.31
10	Land-Use Cases	3.38	1.93	-0.16	7.33	2.76	0.24
10	Const. Payroll per Employee	-0.19	1.84	-0.15	0.29	4.05	0.22
10	Median Family Income	1.78	2.41	-0.31	3.71	2.95	0.46

Notes: We estimate a decomposition as defined in Equation (4), where the dependent variable is spending per mile in a state-period conditional on geographic covariates and state fixed effects. This table reports the coefficients β_{after} and β_{before} and their standard errors. We standardize all covariates to mean zero, standard deviation one for ease of comparison. We also report the mean of the covariate before and after 1970, as in Equation (4). All covariates are the residual of a regression of the covariate in the same geographic covariate and state fixed effects. Each covariate is the residual from a regression of the covariate on geographic variables and state fixed effects.

Sources: See sources note for Figure 4.

Table A4iii. Coefficients and Means that Underlie Decomposition in Appendix Figure A14

		Before 1970			1970-Onward		
		Coefficient	SE	Mean	Coefficient	SE	Mean
Appendix Figure A14, Row in Figure							
1	Total Governments	-2.95	2.52	0.03	1.87	7.39	-0.04
2	Bond Rating	4.46	1.46	-0.13	2.54	1.47	0.18
3	1{Right to Work State}	-0.66	2.41	-0.01	-1.67	5.7	0.02
4	Const. Firm per Cap	-1.97	2.32	0.25	-6.69	3.36	-0.37
5	Const. Estabs. per cap	2.02	1.46	-0.08	2.95	1.45	0.12
6	Prevailing Wage	1.86	1.52	-0.04	0.52	2.63	0.05
7	Senate: Share Reps. on Transp. Cmte.	0.17	7.48	0	2.25	15.52	0.01
7	Senate: Av. Representative Tenure	0.3	0.87	0.06	-0.6	1.69	-0.09
7	House: Av. Representative Tenure	0.49	1.16	0.01	-1.47	2.31	-0.01
7	House: Share Reps. in Majority	1.22	1.31	0.04	1.66	2.56	-0.06
7	Senate: Share Reps. in Majority	-0.5	0.98	0.08	-0.52	1.77	-0.12
7	House: Share Reps. on Transp. Cmte.	-1.26	0.84	-0.04	0.38	1.63	0.05
8	Const. Wages by Occupation	-0.2	1.42	0	-3.27	2.73	-0.01
8	Const. Payroll per Employee	-1.82	2.1	-0.15	-0.66	4.38	0.22
8	Median Family Income	1.92	2.59	-0.31	4.32	3.17	0.46
8	Home Value	6.23	2.25	-0.21	2.73	2.62	0.31
8	1{Right to Work State}	-3.37	2.54	-0.01	-2.81	5.84	0.02
8	Total Governments	-3.28	2.84	0.03	1.35	8.18	-0.04
8	Const. Firm per Cap	3.52	2.47	0.25	0.37	3.81	-0.37
8	Const. Estabs. per cap	-0.36	1.59	-0.08	-1.2	2.11	0.12
8	Prevailing Wage	2.87	1.82	-0.04	1.62	2.84	0.05
8	House: Av. Representative Tenure	1.01	1.15	0.01	-1.56	2.27	-0.01
8	House: Share Reps. in Majority	1.85	1.27	0.04	1.49	2.51	-0.06
8	Senate: Share Reps. on Transp. Cmte.	-3.7	7.3	0	-2.56	15.6	0.01
8	Senate: Av. Representative Tenure	0.95	0.85	0.06	-0.58	1.66	-0.09
8	Senate: Share Reps. in Majority	-0.21	0.97	0.08	-0.27	1.77	-0.12
8	House: Share Reps. on Transp. Cmte.	-0.35	0.83	-0.04	1.3	1.62	0.05
8	Const. Wages by Industry	-1.21	2.51	-0.24	2.15	5.62	0.35
8	Land-Use Cases	2.65	2.02	-0.16	7.49	3.04	0.24

Note: We estimate a decomposition as defined in Equation (4), where the dependent variable is spending per mile in a state-period conditional on geographic covariates and state fixed effects. This table reports the coefficients β_{after} and β_{before} and their standard errors. We standardize all covariates to mean zero, standard deviation one for ease of comparison. We also report the mean of the covariate before and after 1970, as in Equation (4). All covariates are the residual of a regression of the covariate in the same geographic covariate and state fixed effects. Each covariate is the residual from a regression of the covariate on geographic variables and state fixed effects.

Sources: See sources note to Figure A14.

Table A5. Temporal Cost Change Robust to Specification and Sample Changes

		Difference		Explained			Difference		
		Amount	S.E.	Amount	S.E.	Share of Diff	Amount	S.E.	Obs.
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Table 1 Specifications									
(1)	Col 4: geography + state FE	6.80	1.80	-0.09	1.03	-0.01	5.82	1.36	270
Remaining specifications described relative to Panel A									
Panel B. Alternative Geographic Specifications									
(1)	+ geographic cov. squared	6.80	1.81	-1.71	2.56	-0.25	5.71	1.34	270
(2)	+ geographic cov. squared and cubed	6.80	1.82	-26.37	16.68	-3.88	5.50	1.33	270
(3)	+ share in urban areas	6.80	1.80	0.33	1.09	0.05	4.14	1.30	270
(4)	+ ecoregions	6.80	1.84	-0.17	1.18	-0.02	5.33	1.33	270
(5)	+ average number of lanes	6.80	1.81	-0.28	1.02	-0.04	5.92	1.32	267
(6)	without weighting by miles constructed	31.55	7.46	-2.95	2.29	-0.09	30.79	6.21	270
Panel C. Robustness to Sample									
(1)	balanced panel	7.72	2.03	0.41	1.08	0.05	5.84	1.55	236
(2)	drop last period	5.71	1.76	-0.16	1.02	-0.03	5.16	1.25	234
(3)	balanced panel, no last period	6.50	2.01	0.34	1.10	0.05	5.13	1.44	201
(4)	dependent variable is spending without lag	6.80	1.80	-0.09	1.03	-0.01	5.82	1.36	270
(5)	omit Northeast region	5.21	1.75	-0.92	1.01	-0.18	4.62	1.31	239
(6)	omit Midwest region	7.14	2.18	-0.10	1.19	-0.01	5.22	1.66	230
(7)	omit South region	7.08	2.10	0.77	0.99	0.11	5.51	1.52	209
(8)	omit West region	8.27	2.21	0.28	1.32	0.03	5.81	1.68	228
(9)	3-year periods	6.43	1.39	0.61	0.73	0.09	5.82	1.14	504
(10)	5-year periods	8.18	2.17	0.77	0.85	0.09	6.41	1.68	313
(11)	7-year periods	7.69	1.77	-0.04	1.28	0.00	5.83	1.21	226

Notes: This table reports the difference in spending per mile (that is, the miles-weighted average of state-period figures) from pre-1970 to 1970-onward and that difference's estimated standard error in the first two columns. The third and fourth columns report the amount of this difference that is "explained" (in a decomposition sense, as in Equation (4) by our three main geographic covariates and state fixed effects (see Equation (2) for geography covariates). The sixth and seventh columns present the difference in residual spending for the same before and after periods. Residual spending is spending conditional on the three geographic covariates and state fixed effects, and it is the basis for the decomposition analysis in Figure 4. The final column notes the number of observations in each estimation. Panel A reports our baseline estimate. Panel B reports results using different specifications of the geographic covariates and different weighting. Panel C reports results for different sample choices. The five- and seven-year periods use 1973 and 1972, respectively, as breakpoints. Both exclude 1993. Panel B, row 5, is missing observations due to a small amount of missing lanes data. Sources: See Appendix A for complete details.

Table A6. Federal Legislation that Required Additional Consideration of Citizen Concerns

Legislation Title	**Year of Passage**	**Citation**	**Relevance Regarding Citizen Concerns**
National Historic Preservation Act of 1966	1966	16 U.S.C. 470 § 106	Requires the head of any federal agency with jurisdiction over the expenditure of federal funds to consider its impact on sites that are in the National Register.
Department of Transportation Act of 1966 §4(f)	1966	23 USC § 138, 49 USC § 303	For transportation projects that require land from parks, recreation areas, wildlife and waterfowl refuges, or historic sites, the project sponsor "must demonstrate that the need for these lands is unavoidable or that the project has only a minimal impact on the affected property."
Federal Highway Act of 1968	1968		Requires that highway construction projects hold two public hearings on site planning and design.
National Environmental Policy Act	1970	42 U.S.C. 55	Requires the submission of environmental impact statements and formal processes to collect public comments.
Clean Air Act of 1970	1970	42 U.S.C. §7401 et seq.	Allows for citizen suits, which enable citizens to (1) file suit to force a party to comply with national standards; (2) compel the administrator to perform a nondiscretionary duty; and (3) appeal final agency action to a Court of Appeals.
Federal-Aid Highway Act of 1970	1970	23 U.S.C. 109(i)	Requires the development of a noise-abatement policy
Uniform Relocation Assistance and Real Property Acquisition Act of 1971	1971	42 U.S.C ch. 61	Requires the create of standard relocation procedures for those displaced by federal eminent domain, expands the compensation available to those displaced, and requires the preparation of relocation plans.
Noise Control Act of 1972	1972	42 U.S.C. § 4901 et seq	Requires federal agencies to consider the impact of excessive noise in their work and empowers the EPA to regulate noise levels.
Clean Water Act	1972	33 U.S.C. ch. 23 § 1151	Allows for citizen suits to enforce the provisions of the Clean Water Act
Federal Highway Act of 1973	1973	23 U.S.C. 109(i)	Mandates that the Secretary of Transportation develop and promulgate standards for highway noise levels; permits the Secretary to approve plans for highways after 1972 only if they have adequate measures in place to control noise.
Endangered Species Act	1973	16 U.S.C. §1531 et seq.	Requires the FHWA, among other federal agencies, to use its authority to conserve listed species and ensure that transportation projects are not likely to jeopardize the continued existence of any listed species or result in the destruction or modification of critical habitat.

Notes: This table reports major federal legislation that requires citizen input, which create opportunities for citizen voice.

Table A7. Spending per Mile's Relationship to Income, Home Value and Implied Elasticities of Income and Home Value

	(1)	(2)		(3)	(4)
	Estimated Coefficients			Implied Elasticity	
	Covariate = Median Family Income	Covariate = Median Housing Value		Family Income	Housing Value
Demand Covariates			Period		
Covariate	-1.19	-1.87	1958-1963	-0.58	-1.75
	(2.26)	(2.94)			
Covariate * 1964-1969 period indicator	1.85	1.86	1964-1969	0.12	1.7
	(1.29)	(1.73)			
Covariate * 1970-1975 period indicator	4.17	4.71	1970-1975	1.18	3.3
	(2.50)	(3.96)			
Covariate * 1976-1981 period indicator	7.14**	4.87*	1976-1981	1.73	3.9
	(2.75)	(2.64)			
Covariate * 1982-1987 period indicator	4.24	3.90*	1982-1987	0.70	2.13
	(2.54)	(2.26)			
Covariate * 1988-1993 period indicator	15.02***	15.28***	1988-1993	2.40	5.84
	(4.15)	(2.47)			
Observations	270	270			
R^2	0.45	0.49			

Notes: The first two columns present results from regressions where the dependent variable is a state's real spending per mile in 2016 dollars in 6-year periods. We cluster standard errors by state. We standardize all covariates to mean zero, standard deviation one for ease of comparison. We weight both regressions by Interstate miles completed in that period. In addition to the reported coefficients, the regressions include our three main geographic controls, state fixed effects, and period fixed effects (as in Equation (2)). * $p<0.10$, ** $p<0.05$, *** $p<0.01$. The last two columns of results present the elasticities implied by these estimates, which we calculate as $\rho = \beta$ * mean(income or housing value) / mean(spending per mile).

Sources: See Appendix A.3.f–g for details on housing value and income covariates.

Table A8. Effect of Combinations of Highway Characteristics on Spending per Mile

	Alternative Specifications					
	(1)	(2)	(3)	(4)	(5)	(6)
Period Indicators, Years						
1964-1969	0.62	0.49	0.43	1.16	0.30	0.91
	(1.05)	(0.95)	(1.06)	(1.07)	(0.94)	(0.97)
1970-1975	4.70***	3.53**	4.07**	4.77***	4.64***	4.25**
	(1.45)	(1.52)	(1.66)	(1.60)	(1.29)	(1.69)
1976-1981	8.16***	7.60***	7.20***	7.92***	7.93***	7.86***
	(1.62)	(1.78)	(1.67)	(1.80)	(1.55)	(1.61)
1982-1987	12.37***	12.90***	10.65***	10.16***	11.26***	12.80***
	(3.01)	(3.00)	(3.04)	(3.05)	(2.94)	(2.68)
1988-1993	21.72***	19.08**	17.73**	17.75**	20.33**	17.30**
	(7.97)	(8.45)	(8.12)	(8.44)	(8.15)	(8.39)
Highway Characteristics						
Ramp & Elevated-Highway Density	6.37***		5.45***	4.32**	2.85**	
	(1.61)		(1.67)	(1.85)	(1.13)	
Wiggliness		6.31*	5.64	5.57		1.91
		(3.39)	(3.52)	(3.60)		(3.41)
Number of Lanes				2.85		
				(1.86)		
Ramp & Elevated Density * 1{year > 1970}					4.20**	
					(1.60)	
Wiggliness * 1{year > 1970}						5.10***
						(1.69)
Observations	270	270	270	267	270	270
R^2	0.43	0.44	0.47	0.48	0.45	0.46

Notes: This table reports regressions of spending per mile in state *s* in period *p* on listed covariates, as well as state fixed effects and geographic controls. We standardize all covariates to mean zero, standard deviation one for ease of comparison. We cluster standard errors by state. We weight regressions by mileage. Excluded time period category is for 1958-1963 and periods are six years long. Columns (2), (3), (4), and (6) have fewer observations due to missing wiggliness and lanes data. * p<0.10, ** p<0.05, *** p<0.01.
Sources: See Appendix A.3 for details on highway characteristics covariates.

Appendix A – Data Appendix: Data Summary and Variable Construction

We study the relationship of highway spending with covariates from many sources. This appendix reviews the sources and construction for each variable. For even more specificity in citations and how the data are obtained, see the online data directory.

Generally, we use data at the finest possible geographic and temporal granularity, and we match to our Interstate segment data.

1. *Initial notes*

Initially, we make four brief notes on the construction of our variables. First, we use many datasets from the Census, which we are able to spatially map to our segment datasets on ArcGIS using county- and tract-level shapefiles. Census data and shapefiles are provided by the Inter-university Consortium for Political and Social Research (ICPSR) or National Historical Geographic Information System (NHGIS) and can be found through the ID numbers.

These Census datasets and shapefiles are documented below:

- **State and county level**
    - Census data
        - 1950: ICPSR 2896, datasets 35 & 36 (Haines et al. 2010)
        - 1960: ICPSR 2896, datasets 38, 39, 74 (Haines et al. 2010)
        - 1970:
            - Housing: ICPSR 8107, all datasets (U.S. Census Bureau 2006a)
            - Population: ICPSR 8129, all datasets (U.S. Census Bureau 2006b)
        - 1980: ICPSR 8071, all datasets (U.S. Census Bureau 2008b)
        - 1990: ICPSR 9782, all datasets (U.S. Census Bureau 2006e)
        - And, all years except 1960: ICPSR 7736 (U.S. Census Bureau 2012)
    - Shapefiles (maps of county borders)
        - County borders from NHGIS (Manson et al. 2017)
- **Tract level**
    - Census data
        - 1940: NHGIS, dataset 76 (Manson et al. 2017)
        - 1950: NHGIS, dataset 82 (Manson et al. 2017)
        - 1960: NHGIS, dataset 92 (Manson et al. 2017)
        - 1970:
            - Housing: ICPSR 9014, all datasets (U.S. Census Bureau 2006c)
            - Population: ICPSR 8126, all datasets (U.S. Census Bureau 2006d)
        - 1980: ICPSR 8071, all datasets (U.S. Census Bureau 2008b)
        - 1990: ICPSR 9782 (U.S. Census Bureau 2006e)
    - Shapefiles (maps of tract borders)
        - 1940, 1950, 1960, 1970, 1980: NHGIS (Manson et al. 2017)
        - 1990: US Census Bureau website (U.S. Census Bureau 2017)

Second, the Interstate data from Baum-Snow (2007) partitions the Interstates into sections of varying lengths, for which we observe opening dates. Based on these sections, we divide the Interstates into roughly one-mile segments. These segments underlie many of our measures (e.g., the fraction of miles in a given state-year that pass through counties with characteristic X). We generally measure the segments by their true length (according to a high-fidelity map from Baum-Snow (2007)), but we also compute the end-to-end "as the crow flies" length of the segment to explore how segment "wiggliness" correlates with per mile construction spending.

Third, the variable descriptions below make reference to "periods," for example as in "state-period level data." In these contexts, a "period" is a unit of temporal aggregation. The variable descriptions are written to apply accurately to analysis of both annual data and aggregated periods.

Fourth, unless otherwise specified, we use the value of the nearest future year to backfill the values of our state-year aggregated time series measures for missing select state-years and those that are not available until after 1956 (when our data on spending and mileage begin). If a given variable is still missing after this backfilling, we then use the nearest past value to fill forward for any state-years from 1956 to 1993.

2. *Segment Geography*

a. Population Density

We construct a state-year level measure of the urban intensity of miles built using population density data from the Census. For most segments, we simply take the population of the segment's tract from the nearest Decennial Census and divide by the tract area (in square miles). For segments in areas not yet tracted at the segment's time of opening, we instead use the county population and area from the nearest Decennial Census. Our state-period level measure is then the segment-length-weighted average[38] of this measure across all segments opened in the given state and period. When we add as an additional control an indicator for being in a highly dense area (at the segment level) or the share of miles in a highly dense area (at the state level), we follow the Census definition of "dense" as being greater than 1,000 people per square mile.[39]

b. Wetlands, Water, and Rivers

To assess whether wetlands may have impacted per mile construction spending, we overlap a wetlands map from the US Fish and Wildlife Service with our segment data derived from Baum-Snow (2007) (US Fish and Wildlife Service 2018). This wetlands map is ecologically broad, covering documented waters that fall under the Cowardin classification system, which includes marine (roughly, oceanic), estuarine, riverine (roughly, flowing fresh water), lacustrine (roughly, lake waters), and palustrine (roughly, nonriver and nonlake fresh water) categories. Our segment-level measure is then the share of a segment's length passing through any part of this wetland map. At the state-period level, our measure is the segment-length-weighted average share of opened mileage constructed through wetland.

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[38] Here and in the descriptions that follow, the length we use for weighting is the length of the segment "as the crow flies." This length is very narrowly distributed around 1, so the weighted average approximates a standard arithmetic average.

[39] See https://www2.census.gov/geo/pdfs/reference/GARM/Ch12GARM.pdf.

c. Topography, as Measured by Slope

As a control for the impact of topography on per mile construction spending, we create a measure of the slope of the terrain in the area each Interstate highway segment is built. The granularity of our topographical data is one arcsecond (roughly a 30-meter-by-30-meter grid), and the data was collected by satellite in 2004. Data come from US Geological Survey Digital Elevation Model (US Geological Survey 2015).[40] To build our measure, first we average the slope values of each cell of data within 50 meters of each segment. The slope for a given cell is defined as the average difference between the cell's elevation and that of each of its eight neighbors. The state-period level measure is then the segment length-weighted average of these segment-level average slopes.

d. Construction Cost

Using the geography of each segment, we calculate a "construction cost" according to the formulation in Alder (2016) for one robustness test. We calculate

$$ConstructionCost = 1 + SlopePct + 25 \cdot 1[Builtup] + 25 \cdot 1[Wetland]$$

where $SlopePct$ is the segment's average slope in percent terms, $Builtup$ is a dummy variable for having a population density greater than 1000 people per square mile, and $Wetland$ is a dummy variable for segments that intersect with wetlands for more than 0.1 miles. The final variable is the miles-weighted average segment construction cost for each state over the period.

3. Interstate Attributes

a. Interstate Structures

To examine the presence of Interstate highway structures, we use a measure based on lengths of nearby Interstate bridges and ramps.[41] Data on these highway structures, themselves represented as segments, come from the 2016 Highway Performance Monitoring System (FHWA 2016a), which we matched to our dataset of Interstate segments derived from Nate Baum-Snow (FHWA 2016a; Baum-Snow 2007). Unfortunately, these data are measured as of 2016 (the earliest date to which we have access), and not at the time of construction; we have found no data on segment-level Interstate attributes at the time of construction. Because of this later date of measurement, these attributes are measured with error with respect to the initial opening date on which our analysis rests.

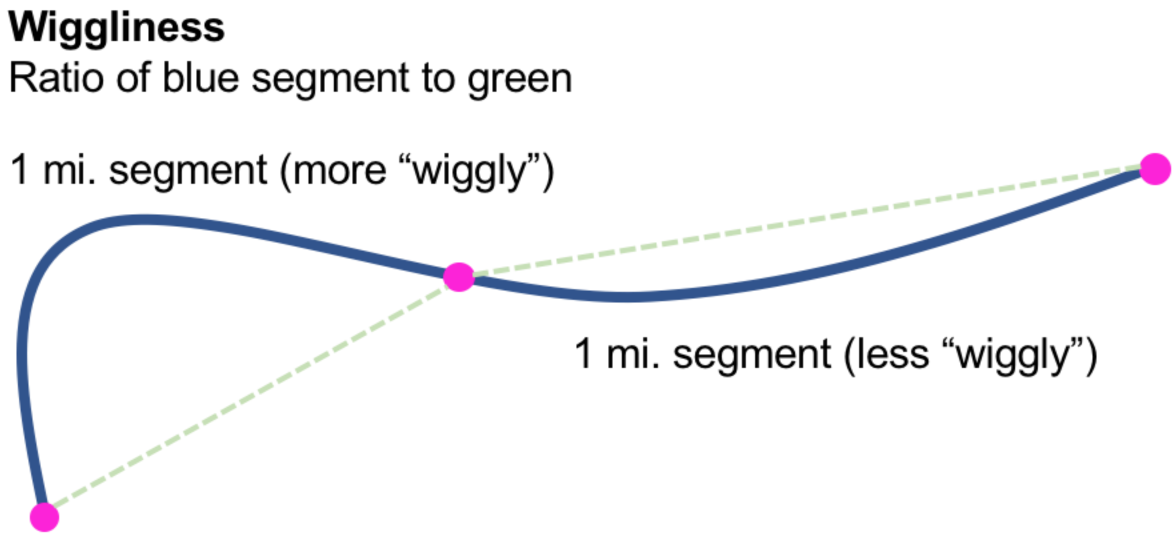
Assuming that these structures are constructed in the same year that nearby highway segments open, we can measure the length of structures associated with nearby Interstate mileage. To account for mild spatial mismatch, we assign each structure segment to its nearest highway segment, within 250 meters, and we exclude structure segments not within 250 meters of any highway segment. Our segment-level measure is then the sum of structure segment length divided by the highway segment length, and our state-period-level measure correspondingly represents the ratio of all structure mileage to all highway mileage opened in the state and period.

[40] Data is the 1 Arc-Second Seamless Standard DEM raster from the USGS 3D Elevation Program (3DEP).

[41] For definitions, see U.S.C. 23 CFR §650.305 and the HPMS 2016 Field Manual (FHWA 2016a).

b. Wiggliness

We measure the "wiggliness" (more formally, tortuosity) of a segment as the ratio of its true length to its length "as the crow flies" using our Baum-Snow segment data along with an auxiliary geographic shapefile of true lengths, also provided by Baum-Snow (2007). These segments partition a high-fidelity map of the Interstates into approximately one-mile pieces. We generate the ratio of "wiggly" to straight length of highways by dividing this one-mile length by the (smaller) geodesic length between the segment's endpoints. Our state-period level measure is then the total "wiggly" length of mileage open in the given state-period divided by the total linear mileage opened in that same state-period.



c. Number of Interstate Lanes

We also measure the total number of lanes (across both directions) of Interstate mileage using data from the Highway Performance Monitoring System (HPMS) (FHWA 2016a). HPMS data is provided in a geographic shapefile of Interstate segments, as is our mile segment data derived from Nate Baum-Snow (FHWA 2016a; Baum-Snow 2007). Importantly, the HPMS data only gives lane counts for Interstate mileage as of 2016. To account for mild spatial mismatch between the two, we take, for a given Baum-Snow segment, the length-weighted average number of lanes across all HPMS segments nearer to the given Baum-Snow segment than to any other. We exclude from this average any HPMS segments with fewer than two recorded lanes. Our state-period-level measure is then the average (weighted by Baum-Snow segment lengths) of these segment-level averages for all Baum-Snow segments built in the given state and period.

d. Noise Wall Area.

Data on the total area of noise walls on federal highways by year of construction come from the FHWA's Noise Barrier Inventory (FHWA 2017a).[42] For calculating the cost per mile, we multiply the average cost per square foot reported by the Noise Barrier Inventory from 1972-1993 by the number of feet in a mile by the average wall height reported by DOT.

4. Explanatory Variables

[42] Full dataset obtained via email with Aileen Varela-Margolles of the FHWA Highway Noise Program.

a. Construction Hourly Wage Index
We use an index of the hourly wage for construction workers using data that come from the Bureau of Labor Statistics (BLS) via Historical Statistics of the United States (Margo 2006).

b. Construction Compensation
We use the Bureau of Economic Analysis's (BEA) National Income and Product Accounts data on employee compensation (US BEA 2021e, 2021f), wages and salaries (US BEA 2021c, 2021d), and full time equivalent (US BEA 2021a, 2021b) in the construction industry.

c. Materials Index
We use indices from the BLS Producer Price Index of concrete (US BLS 2017e), construction machinery (US BLS 2017d), construction sand (US BLS 2017c), paving mixtures (US BLS 2017a), and steel mill products (US BLS 2017b) to create an index for construction materials prices.

d. Construction Wages
From the Current Population Survey (CPS) (1962 to 1993) hosted by IPUMS CPS (King et al. 2010), we use two measures of hourly construction wages, one using an occupation-based definition of construction, one using an industry-based definition. Early years of the CPS aggregated smaller states together, and we use this aggregation throughout for consistency. We adjust to 2016 dollars. Our final measure is the state-period average hourly construction wage.

e. Payroll per Employee
We use first quarter construction payroll data from County Business Patterns (CBP) available for 1953, 1959, 1962, 1964, 1965, 1967, 1969, and digitally for 1971-1993 (U.S. Census Bureau [1953-1993]). We use the detailed category of "highway and bridge construction" as well as the broader "heavy construction" and "construction" industries. We adjust first quarter payroll to 2016 dollars and interpolate for missing values. We multiply by four and divide by number of employees to approximate annual payroll per employee. The final metric is the state-period average annual payroll per employee.

f. Median Family Income
We use the Decennial Census's median family income, adjusted to tens of thousands of 2016 dollars, for a given segment's tract or, in the case of places and years not yet tracted, county (see Appendix A.1 for census citations). Our state-period measure, then, is the state-period average of segment median family income weighted by segment length.

g. Median Home Values
We use the Decennial Census's median value of an owner occupied home, adjusted to thousands of 2016 dollars, for a given segment's tract or, in the case of places and years not yet tracted, county (see Appendix A.1 for census citations). Our state-period measure, then, is the state-period average of segment home value weighted by segment length.

h. Congressional Record

We use the tm_map package for R to divide up the text of the *Congressional Record* (Gentzkow et al. 2018) (see https://data.stanford.edu/congress_text for details)—into strings of the 100 words before and after every appearance of the word "interstate" (excluding "interstate commerce"). We then measure the frequency with which words beginning with "environ" appear in those 201-word strings divided by total number of occurrences of "interstate" per Congress, from the 79th (1944-1945) to the 103rd (1993-1994).

i. Land Use Litigation

We base our study of local land use regulatory regimes on a historical tabulation of land use cases from Ganong and Shoag (2017). Available for each contiguous US state, and each year from roughly 1940 to 2010, this tabulation represents the number of cases in which the phrase "land use" appears in a state supreme or appellate court case. Our state-level measure for a given year is then simply this measure rescaled to the number of cases per ten thousand people, using state-level Decennial Census population data.

j. Construction Industry Concentration

We use two measures of market concentration.

First, we measure firms per capita from the Census of Construction Industries (U.S. Census Bureau [1971-1995]), from which we digitize state-level establishment counts from the "highway and street construction" category. The census series runs every 5 years from 1967, and we digitize it through 1992, linearly interpolating between census years. We divide this measure by the state population to yield a measure of concentration.

Second, we measure establishments per person using state-level counts of construction establishments from County Business Patterns (U.S. Census Bureau [1953-1993]) as an alternate measure of concentration. As we do for the Construction Census metric, we also divide this measure by state population.

k. Government Fragmentation

We construct a state-level measure consisting of counts of governments by state from the Census of Governments for 1957, 1962, and 1967 (U.S. Census Bureau 1963) and from the Willamette University Government Finance database (Pierson et al. 2015) for the remaining census years.[44] We linearly interpolate this measure between measured years to arrive at an annual measure of the number of governments by state.

l. Bond Ratings

To measure a state's level of fiscal responsibility, we use data on the state's general obligation debt ratings (or issuer credit rating where the general obligation debt rating is not available) from S&P Global Market (S&P Global Market Intelligence 2016). This dataset provides ratings for each state over time, since the year that S&P first issued each state's rating. (The date of initial rating varied from 1956 for Kansas and Colorado to 2014 for Idaho). We thank Kate Yang for sharing these data.

To quantify states' S&P bond rating, we assign a AAA-rated bond a value of one, and then we scale each of the remaining ratings based on the state's average percentage point increase in the interest rate on a ten-year bond relative to that of the average AAA bond. For example, we add sixteen for a year in which a state received a AA rating because its interest rate

[44] We use the two sources due to evidence of missing data in the Willamette database before 1967.

is sixteen basis points higher than that for a AAA ten-year bond (Violette 2018). Our state-year-level measure of a state's fiscal responsibility in a given year is thus the converted bond rating in that year; in analyses with periods of time longer than one year, the measure is a simple average of the yearly bond score across years within the period.

m. Congressional Variables
Using data from ICPSR (Swift et al. 2009), we calculate (for each state's representatives in the House and Senate) the average representative tenure at the beginning of each Congress, the percentage of state representatives in the majority party, and the percentage of state representatives on the transportation authorization committee, annually until 1992. Data for 1993 committee assignments come from Charles Stewart of MIT (Stewart 2017). For all six variables we use all members who ever served during the Congress, meaning that in the event of a resignation and replacement, for instance, both members who served in the seat over the course of the same Congress are part of the sample. Similarly, for percent majority and percent on transportation committee calculations, we count those who were ever part of the majority or on the transportation committee during the Congress, such that the few who switched parties mid-Congress or served fewer than two years on a transportation committee count as full members of the majority or committee. Representative tenure includes all congressional service, so if a member moved from the House to the Senate their tenure includes years spent in the House.

n. State Right to Work Laws
To measure the effect of state right to work laws on per mile Interstate spending, we use a value of one in a given state-year if the state had a right to work law (whether by statute or constitutional provision) in effect during any part of that year (National Right to Work Committee 2018). In any analysis with periods greater than one year, we use the share of years with a right to work law in place.

o. State Prevailing Wage Laws
To measure the effect of state prevailing wage laws on per mile Interstate spending, we use an indicator equal to one in a given state-year if the state had a prevailing wage law in effect during any part of that year (Philips et al. 1995, p. 4). In any analysis with periods greater than one year, we use the share of years with a prevailing wage law in place.

5. *Ancillary Construction Spending Data*

a. Preliminary Engineering and Right of Way Spending
We digitized annual state-level data from the FHWA's *Quarterly Report* series from 1961 to 1984 (FHWA [1963-1996]), on federal expenditures on Interstate preliminary engineering and right of way versus construction for completed projects.

b. Distribution of Highway Construction Spending
We digitized national data from the *Highway Statistics* series on the distribution of costs of construction of federal aid primary roads for completed contracts (FHWA [1956-1995]). Interstate specific numbers come from Table PT-2A, while overall numbers come from an unlabeled pie chart.

c. Interstate Cost Estimates
The *Interstate Cost Estimates* were produced periodically by the Department of Transportation between 1958 and 1991 and transmitted to Congress in official reports (DOT [1958-1991]; Weingroff 2017a). They estimated the amount of spending required to finish the Interstate system in each state.

6. Cost Indices

a. Engineering News Record (ENR) Construction Cost Index (CCI)
The ENR CCI (ENR 2021) measures the cost of construction. Components are common labor, structural steel price, Portland cement, and lumber. Data are available at the national-yearly level, and we adjust to 2016 dollars.

b. Craftsman Concrete Building Cost Index
The Craftsman Cost Index (Moselle 2020) measures the cost of construction. The index components are labor, material, equipment, plans, building permits, supervision, overhead, and profit. Data are available at the national-yearly level, and we adjust to 2016 dollars.

c. DOT Composite Bid Price Index (BPI)
The BPI (FHWA 2019) is composed of six indicator items: common excavation, to indicate the price trend for all roadway excavation; Portland cement concrete pavement and bituminous concrete pavement, to indicate the price trend for all surfacing types; and reinforcing steel, structural steel, and structural concrete, to indicate the price trend for structures. Data are available beginning 1972 at the national-yearly level, and we adjust to 2016 dollars.

d. BLS Producer Price Index (PPI)
The BLS PPI (US BLS 2011) is an index that measures road construction costs. It contains material input costs incurred by contractors, but it excludes capital investment and labor costs. Annual data are available nationally beginning 1986. We adjust to 2016 dollars.

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Appendix B - Cleaning Interstate Expenditures Measure

The basis of our measure of spending on Interstates is the "Interstate" column in Table FA-3 of FHWA's *Highway Statistics* series (FHWA [1956–1995]). To this basic data we make two small revisions because of two changes in the Interstate funding laws that led a small portion of expenditures from Table FA-3 to be used on non-Interstate projects. These two changes were first the introduction of the Interstate Withdrawal-Substitution Program and second the requirement, starting in 1982, that all states receive at least half a percent of each year's apportionment (the "Minimum Apportionment"). In what follows, we outline these two programs and explain the changes we made to our Interstate expenditures measure to account for these two changes. We end by discussing a small third feature for which we do not account, which could lead to a small underestimate of spending in the final years.

I. Legislative History

a. Interstate Withdrawal-Substitution Program

The Interstate Withdrawal-Substitution Program came out of states' desires to deviate from planned Interstate routes. The first such program was the Howard-Cramer Provision of 1968, which allowed states to withdraw planned Interstate routes and replace them with alternate Interstate routes of equal cost.[45] The Federal-Aid Highway Act of 1973 allowed the first substitution from Interstate highway projects to non-Interstate projects. States could withdraw planned highway segments within an urbanized area of the state and instead use the money for mass transit projects in the area.[46] The Federal-Aid Highway Act of 1976 expanded the program scope so that states could also withdraw Interstate segments connecting urbanized areas. The Act also allowed states to use the money from the withdrawn portion for non-Interstate highway projects.[47]

Save for a slight modification in the Federal-Aid Highway Act of 1978 that prohibited the withdrawal of Interstate segments after September 30, 1983,[48] the next major change in the Withdrawal-Substitution Program occurred with the Surface Transportation Assistance Act of 1982. Before the passage of that law, the money from withdrawn segments was available to be obligated at any time.[49] After the passage of the 1982 law, the government made available set amounts of money each year for substitution projects: 25 percent of each year's funds were to be allocated at the discretion of the Department of Transportation. The other 75 percent of the funds were allocated by formula: states were apportioned the fraction of the money that corresponded

[45] Pub. L. 90-238.
[46] Federal-Aid Highway Act of 1973, Pub. L. 93-87, § 137(b).
[47] Federal-Aid Highway Act of 1976, Pub. L. 94-280, § 110(a).
[48] Federal-Aid Highway Act of 1978, Pub. L. 95-599, § 107(b).
[49] 1976 U.S.C. 23 § 103(e)(4).

to the cost-to-complete estimates of their substitute projects as a fraction of the cost-to-complete estimates for all substitute projects in the country. States were apportioned this money using this formula for fiscal years 1984 through 1991. The money apportioned was available to be obligated for two years, after which that money would be withdrawn. Finally, the law allowed states to withdraw and substitute planned rural Interstate segments.[50]

The last change to the Withdrawal-Substitution Program came with the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Section 1011 of the law apportioned money through fiscal year 1995 and also changed the apportionment rules so that all of the money would be allocated according to the formula based on the substitute project cost estimates of the states. The law made the money apportioned in 1995 available until obligated, meaning the previous two-year timer was not put in place for 1995. Fiscal year 1995 was the last year in which the US apportioned money to states for highway substitute programs.

The concern, then, is that Interstate expenditure tabulations over this period include funds used for substitute projects. Indeed, in the raw data, we see large expenditures when states are not building Interstates but withdrawals under the Withdrawal-Substitution Program are large. For example, by 1982, Rhode Island had withdrawn from building any more Interstate mileage in the face of popular opposition (FHWA 1998a), but it still had large "Interstate" outlays in Table FA-3. At the same time, data that we digitized on these withdrawals shows that Rhode Island, in fact, had withdrawals of $592 million.

The one exception in the data is that it appears that mass transit projects that were funded with withdrawn funds were, in fact, excluded from the FA-3 Interstate spending category. For example, according to Table FA-3, Massachusetts spent around $100 million a year from 1974 to 1987 while opening over 30 miles of Interstate—approximately $1.4 billion dollars in total. But our data show that Massachusetts withdrew Interstate projects in 1974 and obligated around $1.5 billion dollars from this withdrawal to transit projects (FHWA 1998a). As a result, if this funding were included in the Interstate funding, it would mean that Massachusetts spent virtually nothing on its Interstates, which is implausible. This distinction between transit and non-transit projects may be due to language in the Withdrawal-Substitution Program providing that "sums obligated for mass transit projects shall become part of, and administered through, the Urban Mass Transportation Fund,"[51] meaning that the money was no longer considered highway money.

b. Minimum Apportionment

The Minimum Apportionment rule in Interstate funding required that states receive at least 0.5% of the total money apportioned to all states every year. In general, if states had finished building their Interstates, they were allowed to spend the money on any other Federal-Aid highway. The rule was first put in place with the Federal-Aid Highway Act of 1970 for fiscal years 1972 and 1973, though the law did not specify what states could do with money that exceeded the cost to complete their Interstate systems.[52] Starting with the Federal-Aid Highway Act of 1973, highway legislation extended the Minimum Apportionment rule through fiscal year

[50] 1988 U.S.C. 23 § 103(e)(4).
[51] *Id.*
[52] *Id.* § 105(b).

1990 and specified that money apportioned under this rule that exceeded the cost to complete the Interstate highway system could be spent on other Federal-Aid highways.[53]

The law left the procedure for tracking the money apportioned under this rule ambiguous. The early laws establishing the Minimum Apportionment rule suggest that money that exceeded the cost to complete the Interstate system would be reapportioned to the other Federal-Aid highway categories. For example, Section 104(b) of the Federal-Aid Highway Act of 1973 states,

> Whenever such amounts made available for the Interstate System in any State exceed the cost of completing that State's portion of the Interstate System, the excess amount shall be transferred to and added to the amounts apportioned to such State under paragraphs (1), (2), (3), and (6) of subsection (b) of section 104 of title 23, United States Code, in the ratio which these respective amounts bear to each other in that State.

The law thus leaves open the possibility that money given to a state under the Minimum Apportionment rule that exceeded cost-to-complete would not be considered "Interstate" money, but rather that it would be tracked according to its reapportioned Federal-Aid category. However, the Federal-Aid Highway Act of 1978 removed the language about reapportionment to simply say "the excess amount shall be eligible for expenditure for those purposes for which funds apportioned [for other Federal-Aid highway categories] may be expended,"[54] which leaves open the possibility that Interstate apportioned funds spent on other Federal-Aid Highways were considered Interstate expenditures for Table FA-3 purposes.

Ideally, if states spent Interstate apportionment money for purposes other than Interstate construction, the expenditure would have been recorded in the appropriate category rather than the Interstate expenditure FA-3 category. This does not appear to be the case. For example, North Dakota did not open new Interstate mileage after 1977 and had a cost to complete their highway system of zero after at least 1982 (DOT 1983). Despite that, the state regularly recorded yearly Table FA-3 Interstate expenditures above $10 million throughout the 1980s. Something similar occurred in Delaware, which regularly recorded yearly Interstate expenditures above $10 million in the 1980s despite also having a cost to complete of zero since at least 1982 (DOT 1983).

II. Accounting for the Data Issues as a Result of the Two Programs

a. Interstate Withdrawal-Substitution Program

In order to strip the Table FA-3 Interstate highway expenditure data of money likely spent on non-Interstate substitute projects, we employ three data sources. First, we digitized data from the FHWA's Office of Engineering on how much money each state obligated to substitute highway projects and when they withdrew their Interstate sections.[55] Second, Table FA-3's

[53] The Federal-Aid Highway Act of 1973 Section 104(b) extended for fiscal years 1974-1976; the Federal-Aid Highway Act of 1976 Section 105(b)(1) extended for fiscal years 1978 and 1979; the Federal-Aid Highway Act of 1978 Section 104(b)(1) extended for fiscal years 1980-1983; the Surface Transportation Assistance Act of 1982 Section 103(a) extended for fiscal years 1984-1987; the ISTEA extended for fiscal years 1988-1990.
[54] 1988 U.S.C. 23 § 104(b)(1).
[55] Apportionment is the act of dispensing funds to agencies; obligation is the designation of funds to particular goods and services; and expenditure occurs when agencies finally spend the money. See Appendix C for more details.

Interstate Highway Substitute expenditure variable tracks how much substitute money was spent after 1991 (FHWA 1998b). And, third, Table FA-4's Interstate Highway Substitute apportionment data[56] is available from the years 1983 to 1994, meaning that it is the apportionments for fiscal years 1985-1996.

Between the three data sources, we can determine the total amount of substitute expenditures that must be recorded in the Table FA-3 Interstate highway expenditure variable prior to 1992 (when substitute expenditures began to be tallied separately) and roughly when those expenditures occurred. In the following algorithm Steps (1) – (5), we use the difference between apportionment and later expenditure to back out the amount spent on substitute projects from 1985-1991 that must be erroneously included in the Table FA-3 Interstate expenditure variable. In Steps (6) – (8), we find the amount that states obligated to substitute projects in excess of the amount apportioned (having already corrected for the apportioned amount) in the years from when they withdrew their segments through 1991. Both sums we subtract from the Table FA-3 Interstate expenditure variable so that our resulting variable reflects only Interstate spending and not money spent on substitute projects.

Withdrawal-Substitution Algorithm

1. Calculate total amount apportioned for the Interstate Highway Substitute.
2. Calculate total amount of Interstate Highway Substitute expenditure. This is a variable that runs from 1992 to 2014.
3. Calculate the amount that must have been spent in the years 1985 to 1991. This is Step (1) – Step (2). The idea is that, if states were apportioned the money and did not spend it in the years after 1991, the money must have been spent between 1985 and 1991. It is possible that the money could have been apportioned but never used, but we assume the amount of such money is negligible.
4. We impute the minimum amount spent on substitute projects each year from 1985 to 1991 using the following method:[57]
    a. Calculate the sum of apportionments for 1985 through 1991.
    b. Calculate the apportionment of each year from 1985 through 1991 as a percentage of Step (4a).
    c. Because apportionments in a few states drop off very quickly (much more quickly than expenditures), if the percentage in either 1990 or 1991 is less than five percent, then replace the amount calculated for that year in (4b) with five percent. The amount added to these years is removed from the other years in proportion to the amount in Step (4b).
    d. Calculate the minimum amount spent on substitute projects each year by multiplying Step (3) by Step (4c).
5. Remove the minimum substitution amount results from Step (4) from Table FA-3's expenditure variable in each corresponding year.

[56] FHWA's *Highway Statistics* series contains a federal Interstate Highway Substitute expenditure variable in Table FA-3 and a federal Interstate Highway Substitute apportionment variable in Table FA-4. The apportionment variable starts in the first year of apportionment (fiscal year 1984) and continues through 1995. However, the federal expenditure variable for highway substitute projects begins in 1992. We think it is very unlikely that states only started spending money 8 years after they were apportioned it. It is more likely that FHWA only started tracking these expenditures in 1992.

[57] An alternate method we explored was to set this to be the average yearly amount of Step (3). However, sometimes this would lead to more money being spent than had been apportioned.

6. Subtract total highway substitute apportionment (Step (1)) from the total amount obligated to substitute highway projects (from FHWA 1998a). Because most states withdrew their segments before 1985, this amount—the substitute obligations in excess of known apportionments—represents money spent on substitute projects that we have not already accounted for but that could have been spent on substitute projects (and then recorded in the Table FA-3 Interstate expenditure variable) any year from the date of withdrawal to 1991.
7. Using this difference between highway substitute obligation and apportionment (Step (6)), we determine the maximum amount of Interstate expenditures from Table FA-3 (as modified in Step (5)) that was likely spent on Interstates specifically each year. In other words, we adjust the Interstate expenditure variable for the remaining amount of money that may have actually gone toward substitute projects. We do this in the following steps:
    a. Find the total amount of reported Interstate expenditure over this period by summing the Table FA-3 Interstate expenditure variable from the year of segment withdrawal to 1991.
    b. For each state, find the maximum amount recorded in the Table FA-3 Interstate expenditure variable over the time period when we know the amount found in Step (6) could have been spent, namely from the date of withdrawal to 1991.
    c. Find the average amount that a state could have spent on substitute projects but that is still contained in the Table FA-3 Interstate expenditure variable: Divide the amount found in Step (6) by the number of years in which it could have been spent, again from withdrawal to 1991.
    d. Find what we consider the maximum amount a state could have spent on Interstates alone each year by subtracting the amount found in Step (7c) from Step (7b).
    e. Use the value found in Step (7d) as a provisional ceiling for the portion of the Table FA-3 Interstate expenditure variable that we consider Interstate spending only.
    f. Record the difference between the initial overall Interstate expenditure variable (Step (7a)) and the new amount using the ceiling in (7e). For the first iteration, only the year of the maximum Interstate expenditure (as found in Step (7b)) will be affected and the total difference will equal the amount found in Step (7c).
    g. Subtract this amount purged from the overall expenditure tally, Step (7f), from the total amount spent on substitution programs but still contained in the FA-3 Interstate expenditure variable (Step (6)).
    h. Repeat Steps (7c) – (7g) until the amount of Interstate-only expenditure (from the Table FA-3 expenditure variable, see Step (7e)) has decreased overall by an amount roughly equal to the amount found in Step (6).
    i. Record the final ceiling value (Step (7d)).
8. Set the amount from Step (7i) as the ceiling for expenditures from the year of first withdrawal to 1991.[58]

b. Minimum Apportionment

[58] There are two reasons why we consider expenditures from date of withdrawal to 1991 and not just until 1983. First, money can be spent many years after it is obligated. Second, states could have received money from the 25-percent discretionary fund of the FHWA, not just the apportionments by formula (see Section I(a) of this Appendix).

To account for non-Interstate spending as a result of the Minimum Apportionment rule, we used the Interstate Cost Estimates (ICEs) produced by the FHWA, which we digitized (FHWA [1958–1991]). These were fifteen reports produced between 1958 and 1991 that were used to determine the distribution of each year's Interstate apportionment among the states. Crucially, states could spend money apportioned for Interstate construction on other kinds of highways only if the amount they were apportioned in a given year as a result of the Minimum Apportionment rule exceeded the cost to complete their Interstate system as reported in the most recent ICE. We use the cost-to-complete estimates from the ICEs to determine when states could have begun spending Interstate Minimum Apportionment money on non-Interstate projects and remove all spending that can plausibly be attributed as non-Interstate spending.

Minimum Apportionment Algorithm

1. Take the expenditures measure that has been cleaned of Withdrawal-Substitution spending as detailed above.
2. For the years in which the Minimum Apportionment Rule was in effect (1982 and on), impute the cost to complete (C2C) as reported in the ICE. The ICEs were only produced at the request of Congress, usually every two or three years. To determine the C2C of a state's system in a year in which an ICE was not produced, multiply the previous year's C2C by the miles not yet completed at the end of the current year divided by the number of miles not yet completed at the end of the previous year.
3. Identify the years in which the interpolated C2C was less than the amount apportioned for that year.
4. If a year *x* satisfies (3), then replace that year's Interstate expenditure with [year *x* C2C - year *x-1* C2C] (that is, the amount by which the estimated C2C decreased year over year), so long as the resulting value is less than the given state's spending in year *x*.
5. For the small number of cases in which miles are built after the C2C is zero, we assume negligible spending on those miles after the C2C went to zero, so we reassign the miles to the last year in which miles were opened before C2C went to zero.
6. Since Interstate Cost Estimates only go until 1990, we assume that the ICE for 1991, 1992, and 1993 is also zero if 1990 is zero. Otherwise, we make no guesses about the ICE. Therefore, we make no changes in expenditures for states for which the 1990 C2C is more than zero.

III. Results

Figure B1 below shows the evolution of the Interstate expenditure measure after we account for the Withdrawal-Substitution program and the Minimum Apportionment rule. The blue line represents the original Interstate expenditure measure from the *Highway Statistics* series. The red line shows the Interstate expenditure measure after adjusting for highway substitution, and the green line shows expenditures after adjusting for both highway substitution and the minimum. The lines begin to diverge in the mid-1970s, but the period of largest divergence occurs in the second half of the 1980s.

Figure B2 shows the share of the original total US Interstate real expenditures removed by accounting for the Withdrawal-Substitution Program and the Minimum Apportionment Rule. The share removed due to the Substitution program was less than ten percent each year from

1977 to 1984. After 1984 there was a surge in the removal, with the share removed as a result of the Substitution program never dipping below ten percent through 1991. Since the Interstate Highway Substitute variable in the *Highway Statistics* series starts in 1992, there was no more removal as a result of the Substitution program after 1991. The amount of real expenditures removed due to the Minimum Apportionment program was smaller than the amount removed by the Substitution program, but it grew over time. In total, the share of real expenditures removed by the Substitution program from 1977 to 1993 is 7.7 percent, while the share removed because of Minimum Apportionment rule is three percent.

We make a couple of notes about the final expenditure measure that we derived based on the methodology described above. First, it is much more reliable when considered over a period of years than when considered on a year-by-year basis. While we know how much a state that substituted spent on highway substitution, we do not know exactly how much was spent each year on substitution projects. Our method for dealing with this issue depends on the year of the money spent, but it requires either assuming that a year's substitute expenditure was correlated with that year's apportionment (see step 4 in the Substitution algorithm) or assuming that the years of highest expenditure between the year of withdrawal and 1991 were the years that contained the substitution expenses. Neither of these approaches guarantees that we will pin down the correct substitution expenditure in a given year.

Second, we may be overestimating the amount to be removed as a result of the Minimum Apportionment program. Our method for dealing with the minimum issue is to use the Interstate Cost Estimates from the FHWA. When a state begins to receive more in apportionment than they need to complete their interstate system, we replace its expenditure with the (imputed, based on completed mileage) change in that state's estimated cost to complete as reported in the ICE. If there were cost overruns in a state for an Interstate project, then we would be underestimating the amount of actual Interstate expenditure in that state. The effect of this measurement error is likely to be very small, as the amount subtracted from expenditures due to this factor is small, as shown in Figure B1, so the effect of overestimating it somewhat is yet smaller in magnitude. Finally, one countervailing factor, as we explain in the next section, is that a separate rule may cause a small amount of underestimation of Interstate spending.

IV. Minimum Federal-Aid Percentage Allocation

Similar to the Minimum Apportionment rule, the Minimum Federal-Aid Percentage Allocation ("minimum percentage rule") required that the sum of all federal-aid funds provided to states in a given year comprise a minimum percentage of the amount of taxes the drivers in that state paid towards the Highway Trust Fund in the fiscal year with the latest available data. States in which the funding formulas for the different kinds of federal-aid funding produced apportionments that were lower than the minimum percentage of taxes paid to the Highway Trust Fund received an additional apportionment that would cover the difference. Money apportioned as a result of this rule could be spent on any road that was eligible for federal-aid funding. The rule was first put in place in fiscal year 1982, when the minimum percentage was set at 85 percent. That minimum percentage stayed until 1992, when it was increased to 90 percent.[59]

The *Highway Statistics* series tracks the amount of money apportioned due to the minimum percentage rule as a separate variable. It also tracks the expenditure of this money separately from

[59] The exact wording and yearly requirements are in the Highway Improvement Act of 1982 Section 150(a) for fiscal years 1982-1986. For fiscal years 1987-onward, they are contained in the 1994 U.S. Code Section 157(a).

the spending of the specific categories. We therefore cannot know what category of Federal-Aid highways the money was spent on. It could have been spent on Interstates, but it could have also been spent on Federal-Aid Primary, Secondary, or Urban roads, among others. As a result, we likely underestimate the amount of money spent on Interstates. In addition to not knowing how much of the money was spent on Interstates, it is difficult to remove the effects of this money since the time between obligation and expenditure is uncertain, and the states could have not obligated the money at all. Between 1982 and 1994, no more than 19 states received an apportionment under the minimum percentage rule in any given year, with at least seven states receiving the money every year. From 1982 to 1993, expenditures of money apportioned as part of the minimum percentage rule were 20.6% percent of the cleaned measure of Interstate highway expenditures. We think that this rule does not lead to a large amount of mismeasurement though because, by this point, states were overwhelmingly spending their Federal-Aid funds on projects other than Interstates.

Figure B1

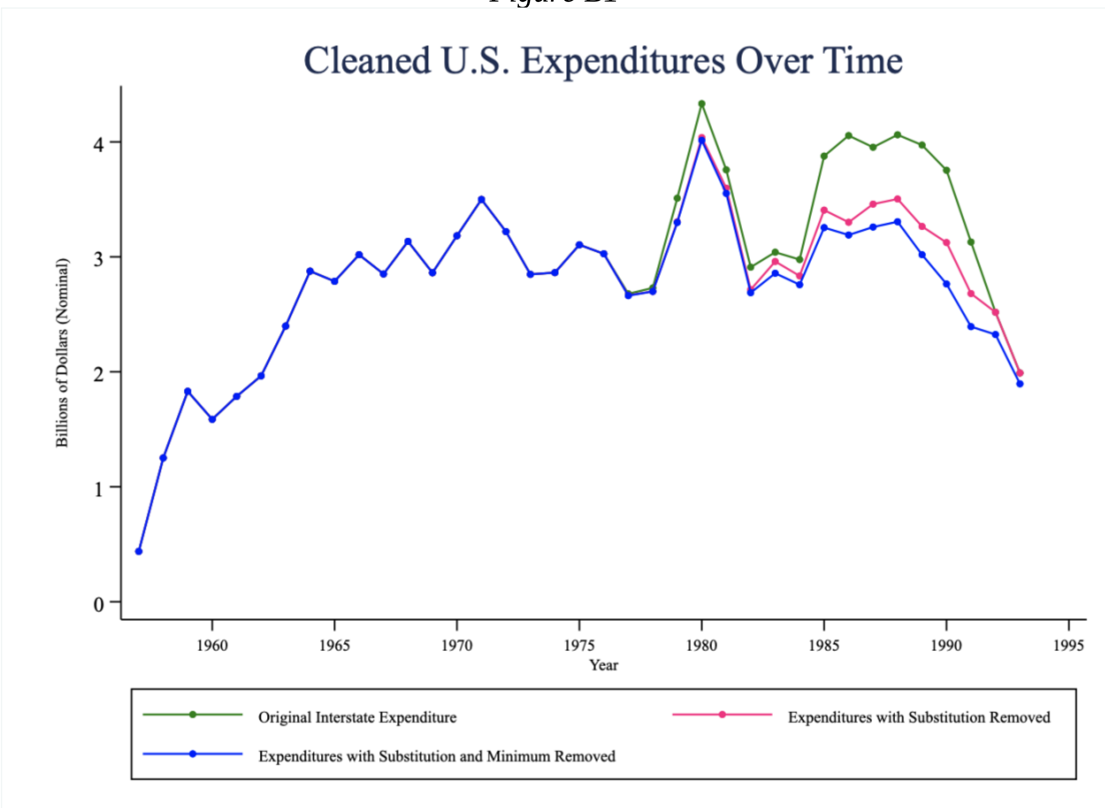
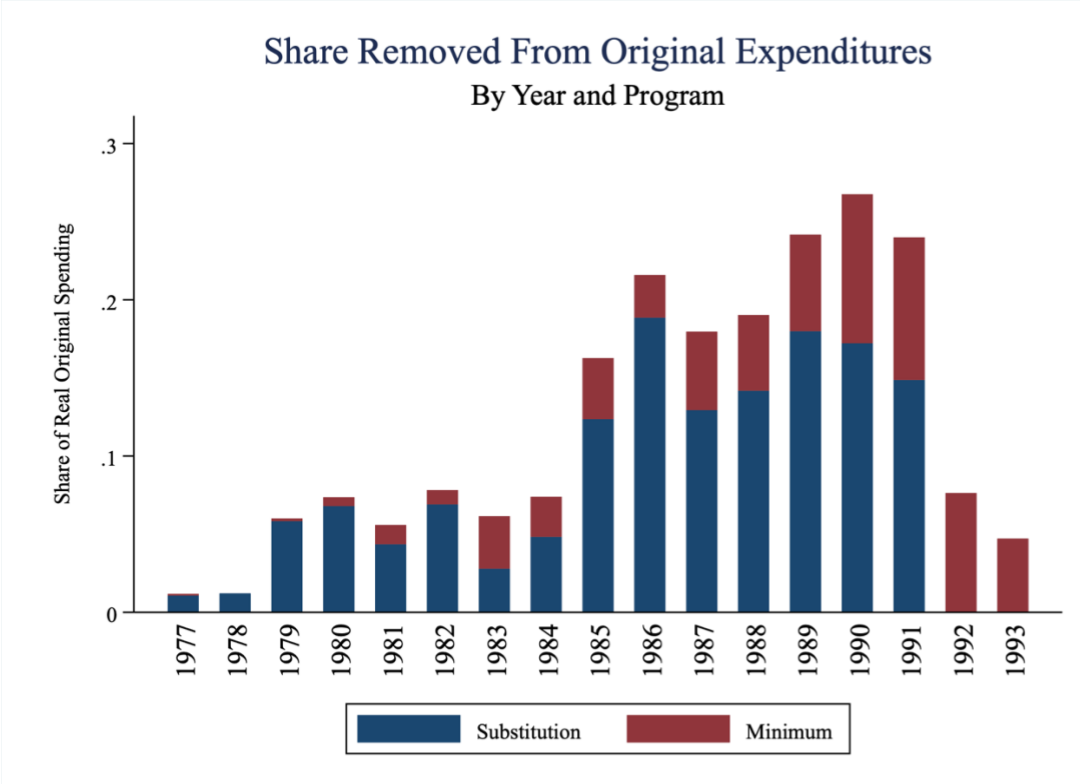


Figure B2



Appendix C – International Data

Our goal in this data collection was to gather available data on the per mile construction spending on completed, new, non-gravel highways outside of the United States. Importantly, we limited our search to projects that report completed, rather than projected or contracted, costs.

In all cases, we convert the original currency to US dollars using the Fxtop historical currency converter[60] and transform dollar figures to real 2016 dollars using the CPI-U as we do for the main dependent variable (Interstate spending per mile). We express all distances in miles, and we report spending per mile. (When raw data are in lane-miles, we adjust for the number of lanes.)

To make the data comparable with our US data, we report spending per mile in the same six-year periods as for our US data. In each six-year period, we report the weighted average cost for all projects in that country, where the weights are each project's mileage. The corresponding year value in the plot is the miles-weighted average of project completion years for that country.

We found data from many sources. Most of the data come from the Road Costs Knowledge System (ROCKS) database published by the World Bank, and the rest come from other sources. We review each in turn.

The ROCKS database systematically categorizes road works and provides unit cost data on road work costs per kilometer in low- and middle-income countries. "Version 2" contains

[60] Available at https://fxtop.com/en/historical-currency-converter.php.

projects from 1996 to 2006.[61] The database was updated in 2018, adding projects from to 1999-2016.[62] In ROCKS version 2, there are 74 relevant projects, yielding 17 datapoints after averaging to six-year periods.[63] In the ROCKS 2018 update, there are 33 relevant projects, yielding 12 datapoints in the six-year periods.

In addition to ROCKS, we collect eight cost datapoints that we report in the table below. We find most of these points in project completion reports, cost estimates audits commissioned by government transportation bureaus, and news articles.

[61] Available at https://www.doingbusiness.org/en/reports/thematic-reports/road-costs-knowledge-system.

[62] Available at https://collaboration.worldbank.org/content/sites/collaboration-for-development/en/groups/world-bank-road-software-tools.html.

[63] We keep only those whose worktype contains "new." We then drop those whose worktype contains "road," leaving only "new . . . expressway" and "new . . . highway." We then drop those with "gravel."

Table: Other International Cost Data

Country	Year	Raw spending figure	Clean: USD (2016) per mile	Source	Notes
Germany: Autobahn	1970	2,600,000 USD (1970) /mi	$16,049,344	Stueck, Hans J. 1970. "West Germany Modernizing 1,310 Miles of Old Autobahns." *New York Times*, Jan. 4, 1970. https://www.nytimes.com/1970/01/04/archives/west-germany-modernizing-1310-miles-of-old-autobahns.html.	These costs are high for many reasons. The article says: "Most run from west to east for rapid troop movements and have steep grades, up to 8 per cent. The Interstate Highway System in the United States has maximum grades of 3 per cent. . . . In mountainous central and southern Germany, some of the projects require up to 40 per cent of costs for bridges over rivers, railroads and low-lying built-up areas. . . . In the beautiful conutryside [sic] of mountainous southern Germany strict observance of ['embedding the highways into the scenery'] has cost millions of additional Deutsche marks."
South Korea: Gyeongbu Highway	1970	42.973 billion KRW (1970) / entire 430-km project	$1,234,556	Korea International Cooperation Agency. 2004. "Construction of the Gyeongbu National Expressway." *K-Developedia.* https://www.kdevelopedia.org/Development-Overview/official-aid/construction-gyeongbu-national-expressway--201412070000343.do?fldRoot=TP_ODA&subCate%E2%80%A6. Notes from Jeon, Chihyung. 2010. "A Road to Modernization and Unification: The Construction of the Gyeongbu Highway in South Korea." *Technology and Culture* 51(1), p. 66.	This was planned to be very cheap. "First, at least in principle, the route was designed to follow the shortest path between Seoul and Busan, keeping tunnels and bridges to a minimum for the sake of time and money. Second, due to budgetary constraints, engineers designed the Gyeongbu Highway with insufficient depth and width. The basic concept of the project was so-called stage construction, which aimed to build the highway with minimum initial investment and, when increased traffic flow began to cause problems, to perform repairs accordingly."
Cameroon: Connecting roads between Bafoussam and Foumbot	1998	220.890 million CFAF (1997) for 3.9-km stretch of new road.	$153,533	African Development Bank. 1998. "Republic of Cameroon Bafoussam-Foumban Road Project, Project Completion Report." https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/ADB-BD-IF-99-253-EN-CAMEROON-PCR-BAFOUSSAM-FOUMBAN-ROAD-PROJECT.PDF, p. 6, Table 4.6.1.	This estimate is specifically for the new road construction portion of the Bafoussam-Foumban Road Project.

Botswana: Trans-Kgalagadi Road Project	1998	94,605 USD (2006)/ lane km	$139,959	African Development Bank. 2014. "Study on Road Infrastructure Costs: Analysis of Unit Costs and Cost Overruns of Road Infrastructure Projects in Africa." *AfDB Market Study Series*, May 2014. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Study_on_Road_Infrastructure_Costs-_Analysis_of_Unit_Costs_and_Cost_Overruns_of_Road_Infrastructure_Projects_in_Africa.pdf **(hereinafter "AfDB Study")**, p. 40.	The Kang to Ghanzi Junction (221 km) of the 589km road between Sekoma and Mamuno.
Mauritius: South-Eastern Highway Project	2008	1,419,591 USD (2006)/ lane km	$2,100,324	AfDB Study, p. 37. Descriptions given by https://projectsportal.afdb.org/dataportal/VProject/show/P-MU-DB0-007.	Part of the National Physical Development Plan (NPDP). Consists of the upgrading of the Ferney Community Centre-Ferney Sugar Estate (2.34 km) and Kewal Nagar-Bel Air (8.69 km) and the new construction of Mahebourg Ferney Community Centre (6.19 km) and Ferney Sugar Estate-Kewal Nagar (7.83 km) segments.
Ghana: Apedwa-Bunso Road	2008	553,799 USD (2006)/ lane km	$819,362	AfDB Study, p. 37.	Construction of the 21.8km Apedwa–Bunso Section of the Achimota–Anyinam Road.
Czech Republic: multiple-lane highways average	2012	14,570,000 EUR (2012) /km	$12,185,640	Heralova, Renata S., Eduard Hromada, and Hal Johnston. 2014. "Cost Structure of the Highway Projects in the Czech Republic." *Procedia Engineering* 85, p. 225, Table 1.	The year 2012 is estimated because it says "[r]ecently built" in 2014. Includes preliminary engineering, right of way and utilities, and construction costs.
Australia: average based on completed motorways	2015	5,400,000 AUD (2017) /lane km.	$10,154,233	Australian Government Bureau of Infrastructure, Transport and Regional Economics (BITRE). 2018. "Road Construction Cost and Infrastructure Procurement Benchmarking: 2017 Update." BITRE, Canberra ACT. https://www.bitre.gov.au/sites/default/files/rr148.pdf, p. v.	We estimate that the average motorway in Australia is a dual carriageway, i.e., 4 lanes.

Appendix D - Additional Background Detail on the Interstates

Funding Structure

Once apportioned, Interstate funding was available to the states for obligation on a per-Interstate-project basis. An obligation is a guarantee from the federal government to reimburse a state for the eligible portion of a project's cost. To obtain an obligation, states[64] submitted specific projects for FHWA approval (FHWA 1983). States generally had a two-year time limit to apply for funding and receive an obligation. If a state failed to obligate apportioned funds within that time period, then the apportioned funds would be revoked and apportioned to other states on the basis of the funding formula. Once a project was approved by the FHWA, the state was free to begin work on the Interstate project. Whether a state was reimbursed over the course of the project or upon the project's completion varied over time and by state, but states were generally reimbursed for expenditures upon the submission and certification of vouchers documenting their expenditures for the FHWA (FHWA 1983; Manes 1964).

This entire apportionment-obligation-expenditure process had a varying and uncertain time window. While states could wait no more than two years between apportionment and obligation before they would lose funding, the time period between obligation and expenditure was less certain. There was generally no limit between the date of obligation and date of expenditure, though states sometimes had to meet timelines for the start (but not completion) of construction.[65] If an approved project was delayed, for example, there could be a long gap between the date of expenditure and the date of actual reimbursement.

To better understand states' spending incentives, we provide more detail on this funding process. We begin with discussing the process of annual apportionment to and across states, and then we analyze the determinants of the timing of state spending. Crudely, the federal government financed Interstate construction via the revenue generated by the portion of the federal gas tax dedicated to highway funding. This revenue was credited to the Federal Highway Trust Fund and was apportioned among the states by formula (Weingroff 1996). The Byrd Amendment to the Federal-Aid Highway Act of 1956 prevented the program from running a deficit by requiring the Secretary of Commerce "to reduce the apportionments to each of the States on a pro rata basis" when a deficit existed (Congressional Quarterly Almanac 1956). This amendment, together with increased costs, required occasional increases in the gas tax, as well as the imposition of new taxes (FHWA 2017b). The last Interstate construction funds were apportioned in the 1996 fiscal year (FHWA 2017a).

In form, the Interstate construction program was reimbursable, meaning that the federal government paid states back for money spent on building the Interstates (FHWA 1983). The

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[64] Later, after the passage of the Federal-Aid Highway Act of 1973, incorporated cities could also submit Interstate projects for Federal matching if 1) the relevant highway segments were designated as part of the Interstate system as of June 1, 1973, 2) the segments were entirely within the boundaries of the city, and 3) the city could pay the nonfederal share. 23 U.S.C. § 103(h) (1976) (as amended in 1973 by Federal-Aid Highway Act of 1973 § 110, Pub. L. No. 93-87, 87 Stat. 250, 256 (1973)).

[65] For example, projects that made use of the federal government's so-called "right-of-way revolving fund," which provided advance funding for land acquisition, were required for a time to commence construction on the purchased land not less than two years and not more than seven years from the end of the fiscal year in which the funds were approved. Federal-Aid Highways Act of 1968 § 7(b), Pub. L. 90-495, 82 Stat. 815, 818-19 (1968) (codified at 23 U.S.C. § 108(c)(3), amended 1973, repealed 1998).

process generally worked in the following manner. First, Congress annually authorized an amount of money for Interstate construction based on the estimated System completion cost and the funds available in the Highway Trust Fund. Next, this money was apportioned to the states.[66]

For all years after the first three,[67] states were apportioned funds in proportion to the estimated cost to complete their remaining planned Interstate mileage. Congress relied on state submissions of "Interstate Cost Estimates," which were prepared with federal oversight and which contained detailed estimates of costs by input (e.g., right of way purchase, planning, and construction) for planned Interstate segments (e.g., a two-mile segment of I-10) (Weingroff 1996). Congress required these submissions roughly every two to three years from 1958 to 1991.

Changes in Interstate Standards over Time

The only substantive change to federal highway standards of which we are aware is increased capacity requirements over time. This standard was put in place by the Federal-Aid Highway Act of 1966 and codified in 23 USC § 109(b). Prior to the enactment of this legislation, certain Interstate segments (rural, lightly traveled ones) were allowed to be constructed to a two-lane standard (one lane in each direction) and still receive full federal funding. The 1966 Act required that these lanes be brought up to the four-lane standard. This may contaminate our spending data, though likely only to a small extent. On the basis of congressional hearings over the 1966 Act, spending to upgrade two-lane segments under construction at the time of the legislation's passage was likely included in subsequent years of our expenditure data (Hearings 1965, Hearings 1966). But the hearings, as well as the 1968 Interstate Cost Estimate, suggest that this would have amounted to $335 million (DOT 1968, p. 12). Since this money was provided in the 1968 apportionment, inflating from 1969 to 2016 dollars provides a lower bound of approximately $2.19 billion (2016 USD) of possible additional spending. Because this is so small relative to the $504 billion (2016 USD) spent over the course of Interstate construction, we think it is unlikely to bias our estimates of cost change over time. As well, our analysis on the number of lanes in Appendix Table A5 shows that the number of lanes explains almost none of the cost increase.

Other changes to Interstate highway design standards included (1) increased specificity about the paving and design of highway shoulders between 1967 and 1991; (2) the reduction in median width in rural areas from 16 feet wide to 10 feet wide; and (3) a minimum 20-year future lifespan for bridges to remain in service.[68]

Appendix E – Further Evidence on Citizen Voice

[66] A certain amount of this authorized money was deducted to pay for FHWA operations and research (FHWA 1983).

[67] In the first three years of the Interstate program, the annual distribution of apportionments among states was determined by the population, area, and mileage formula used for determining appropriations in a much less ambitious earlier system.

[68] Compare "Geometric Design Standards for the National System of Interstate and Defense Highways," AASHO, 1967 (codified via 39 Fed. Reg. 35145 (1974) at 23 U.S.C. § 625.3(a)(2) (1975)) [hereinafter, DS-2] to DS-4. Additionally, (4) AASHO introduced pavement design standards in 1961, following the AASHO road test. See "Interim Guide for the Design of Flexible Pavement Structures," AASHO, 1961. Notably, much of the interstate system's design standards have remained constant over time. Compare DS-2 to DS-4.

1. Illustrative Example: Interstate Construction in Suburban Detroit

To illustrate how citizen demands, moderated by more responsive institutions, could increase costs, we give the example of a 28-mile stretch of I-696 in Detroit's affluent northern suburbs. It was built in three legs of similar lengths, all of which share a similar geography (Bureau of Public Roads 1955, p. 41; Hundley 1989).[69] The earlier two legs faced little resistance and cost far less than the final leg, which faced significant community resistance. The first leg was completed in 1964 at a cost of $13 million per mile (2016 USD) (Brown 1990; Hundley 1989). The second leg was completed in 1979 at a cost of $48 million per mile (2016 USD) (Brown 1990).[70] The last leg began planning in 1964—the same time as the second leg—and was completed a quarter century later, in 1989. It cost $86 million per mile (2016 USD), roughly seven times the first leg and twice the second leg.

This final leg disrupted a Jewish community around Oak Park, leading to years of community opposition (Center for Urban Transportation Research 1998). Given the prohibition in Judaic law on driving on the weekly Sabbath, an 8-lane highway through the neighborhood would significantly disrupt community members' lives. The community organized and lobbied, and in response, local governments opposed the project on their behalf.

Homeowners exerted especial power through a peculiarity of Michigan state law, which stipulated that the Interstate routes running through cities were subject to city approval.[71] Between the eight cities whose approval was required for the middle leg, the situation grew so tense that Governor George Romney stepped in: "[he] locked squabbling officials in a local community center overnight, and told them he would not let them out until they came to agreement" (Schmidt 1989). Local residents also used the recently enacted National Environmental Policy Act as a tool for highway opposition. According to the *New York Times*, in the 1970s, "foes began using new Federal environmental rules to oppose the road, arguing that it would wreak untold damage" (Schmidt 1989).[72] In addition, in the late 1980s, the state was required to replace 6.5 acres of wetland with eleven new acres (Woodford 1972, p. 54; Associated Press 1987).

The main text describes the outcome. Multiple strands of the rise of citizen voice are present in this story. The rise of community organizations shows the important of the rise of social movements in producing citizen voice. Legislation (NEPA) then gave opponents a judicial toehold for opposition.

2. Highway Attributes

The regression evidence in Appendix Table A8 shows that highway attributes are related

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[69] Furthermore, all three legs were built through fairly dense areas, passing through tracts with population densities above 1,500 people per square mile. That said, the 1960 population density of the western leg (1,657 people per square mile) was less than that of the middle (5,294 people per square mile) and eastern (4,107 people per square mile) legs.

[70] Data are from Baum-Snow (2007). Construction began in 1969-1971.

[71] United States Senate Committee on Public Works Subcommittee on Roads. 1970. *Report on the Status of the Federal-Aid Highway Program Hearing, Ninety-First Congress, Second Session, April 15, 1970*. United States Government Printing Office. Washington, D.C. p. 93.

[72] Furthermore, along I-696 as a whole, a reported 40 percent of homeowners challenged the state-paid relocation packages in court (Hundley 1989).

to higher costs—and are especially so after 1970. We combine elevated highways and ramps into "structure density," but we emphasize that these are only a portion of possible structures. For example, we do not capture tunnels, noise walls (which we do not have geocoded), or highway trenches. Column (1) implies that a one-standard-deviation increase in ramp density is associated with a $6.37 million increase in cost. Column (2) implies that an increase in wiggliness of one standard deviation is associated with a cost increase of $6.31 million.

Additionally, structures and wiggliness are more closely related to higher costs after 1970. For both structure density and wiggliness, we allow the measure to have an additional relationship with spending per mile after 1970. For structure density (column (5)), the post-1970 impact (7.05 = 2.85 + 4.20) is about three times as large as the pre-1970 impact (2.85). For wiggliness (column (6)), the impact again approximately triples, but the standard errors are too large to draw any conclusions. These results are consistent with the hypothesis that citizens are able to demand more expensive types of structures and route modifications after 1970.

Appendix F – Further Description of Cost Drivers with Limited or No Affirmative Evidence

Government Fragmentation: Some researchers suggest that infrastructure in the United States is more expensive relative to Europe because of the more fragmented governance system in the US. Interstate construction requires the coordination of many different levels of government that may have difficulty efficiently cooperating (Gillette 2001). While we cannot make a US-Europe comparison, we can assess whether greater fragmentation within the US is associated with higher costs. If this hypothesis is true, the number of governments per capita should explain some of the increase in the OB decomposition. We find that the temporal change in costs is little explained by inclusion of the number of governments per capita (Appendix Figure A14; all exact numbers for Appendix Figure A14 are in Appendix Table A3ii. Coefficients are in Appendix Table A4iii). However, the Census of Governments data do not contain all jurisdictions (e.g., many types of special districts), so this result may not reflect the complete picture.

State government quality. Government quality—for example, the effectiveness of government bureaucrats in contracting for construction services—may be linked to Interstate spending per mile. To test this hypothesis, we examine how well the state bond rating explains the cost increase. It does not significantly explain the increase. We take from this analysis that this measure of government quality is not an important driver of infrastructure cost increases.[74] We leave open the possibility that other measures we have not used may be more able to explain the change.

Increased use of labor. Figure 5 above shows that the price of construction labor has been fairly flat over the period. Thus, labor prices do not explain increased costs. However, using more labor per Interstate mile could increase costs. Some claim that "featherbedding," or hiring more workers than necessary for a project, often because of union work rules, is an important

[74] Knight (2002) finds that states' political power over federal transportation funding in Congress predicts transportation spending. We replicate his variables (average representative tenure, percent of representatives in the majority party, and percent of representatives on the transportation-authorization committee). See Appendix Figure A14, which shows that these variables explain very little of the change over time. This is consistent with the largely formulaic allocation of funds.

cost driver (Belman et al. 2007). Unions can demand such work rules in part because of "project labor agreements" signed by states that require union labor.

Appendix Figure A17 presents the share of federal-aid highway construction spending by type from 1966-1993.[75] This spending is amounts incurred by construction contractors, so they exclude land acquisition and planning. The relative amounts spent on the three input factors—materials and supplies; wages; and equipment, overhead, and profits—vary little over time. If anything, the wage bill actually *decreases* as a percent of total highway costs: wages constitute a high of 26 percent in 1971 and fall to around 21 percent of construction expenditures in the 1990s. We thus view it as unlikely that increases in the quantity of construction labor drive the overall cost increase.

To test this theory further, we include in the OB decomposition a variable that measures the likelihood that states mandate or encourage higher quantities of labor usage. We use the presence of "right to work" laws that make unionization more difficult, to account for the strength of the labor movement. As Appendix Figure A14 shows, this variable does not appreciably explain the cost increase.

Construction Industry Market Concentration. Basic economics suggests that increased market concentration may cause an increase in Interstate spending per mile. Recent work has noted long-run increases in market concentration (e.g., De Loecker, Eeckhout, and Unger 2018). A literature specific to state construction procurement offers evidence that builders may be able to manipulate their contracts in ways that increase spending (Bajari and Ye 2003; Gil and Marion 2013; Mochtar and Arditi 2001; Miller 2014).[76] However, whether these procurement practices are associated with increasing Interstate costs over time remains an open question.

Using two data sources (Census of Construction and County Business Patterns), we measure the number of construction establishments by state as an indication of industry concentration over the period.[77] Including the number of construction establishments as explanatory variables in the OB decomposition does not substantially explain the cost increase (Appendix Figure A14).

Notably, however, there are important concerns about these measures of concentration. Though our measures are in per capita terms, the measures do not adjust for the geographic size of the states or the total amount of funds available. Greater spending could attract more entry, especially if the extra spending is on items such as sound walls that are likely to be fulfilled by smaller, more specialized firms.

Economies of scale. Over time, the US produced fewer Interstates, which may have reduced economies of scale and thereby yielded higher spending per mile. That said, the United States continued both building other highways and roads and refurbishing existing ones, likely blunting this effect. One obvious way to test this explanation—associating the number of Interstate miles a state builds in a given period with spending per mile—is, in our opinion, so

[75] Figure A17 applies to all federal-aid primary highways. However, data specific to Interstates, available only until 1978, paint a similar picture in the overlapping years.

[76] Typically, state Departments of Transportation (DOTs) put out a specification with the needed quantities of materials, such as asphalt or guardrails. Construction firms bid a price per item, and the DOT is usually constrained to choose the lowest bidder. This creates an incentive for bidders to underbid on items for which the DOT is overestimating usage and overbid on items for which DOT underestimates usage. Bolotnyy and Vasserman (2019) show that in fact firms do exactly this.

[77] While the number of firms may measure concentration more directly than establishments, the two figures closely track one another: in 2016, for instance, the number of state construction establishments exceeded the number of firms by one percent on average, the maximum difference being three percent (US Census Bureau 2016).

problematic as to be worthless because of the way highway miles were funded. Since the federal government gave states a fixed budget in any year, years with more expensive miles must have fewer miles built. Thus, our data do not allow a test of this plausible hypothesis.

Moral hazard/end of repeated game. It is possible that the design of the Interstate program incentivizes states to build more expensively than they would if covering the entire cost. However, since federal reimbursement was set at 90 percent over the entire course of the Interstate program, it is not clear why the extent of this moral hazard problem would change over the course of building the Interstates.

The economics literature also discusses repeated games as a means of establishing social norms. Using this framework, it is possible to hypothesize that in the infancy of the program, state transportation officials perceived a repeated game in which there were future incentives for current economizing behavior. However, as the end of the repeated game—specifically, the end of the Interstate program—neared, the future benefits from state cost containment may have waned. States may have believed that the federal government would complete the Interstate system regardless of state behavior. At the same time, though, the federal government was funding large shares of many non-Interstate projects—both new mileage and maintenance—that it could use as leverage. If proof of fiscal responsibility was important in this continued relationship, then it is difficult to understand how the end of Interstate construction should therefore yield spending increases over time.[78] In any case, we have not developed empirical tests to better understand this dynamic.

Procurement practices. A sizable economics literature finds that procurement practices matter for spending (e.g., Bajari et al. 2014; Bolotnyy and Vasserman 2019). Unfortunately, we were unable to find cross-state data on procurement practices. We think that this is fruitful area for future research.

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[78] Alternatively, norms of thriftiness could have broken down over time.

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