Infrastructure Costs

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The state of our roads and other infrastructure generates considerable concern, with a perception that construction costs are very high. Yet we know surprising little about basic questions on infrastructure costs. We help to fill this gap by documenting state-level spending on Interstate highways—one of the nation's most extensive infrastructure assets—over the history of their construction using data that we digitized.

We make three main, primarily descriptive, contributions. First, we find that spending per mile on Interstate construction increased more than three-fold from the 1960s to the 1980s. We date the inflection point of increase to the mid-1970s. We further show that the increase is explained by neither the changing geography of spending nor increases in material or labor prices. Second, we document that there is substantial variation across states in infrastructure costs, with a nearly 15-fold difference between high- and low-cost states. Third, we provide suggestive evidence on the drivers of these cost increases, largely ruling out several prominent explanations and arguing that an increase in "citizen voice" in government decision-making is an explanation largely consistent with the data.

1. Introduction

The United States spends an enormous amount on infrastructure—over $400 billion a year.[2] Yet there is a widespread belief that we now get less for that spending - both less than we used to, and less relative to other countries.[3] For example, evidence suggests that recent transit

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[2] Shirley, Chad, "Spending on Infrastructure and Investment," Congressional Budget Office (Mar. 1, 2017), https://www.cbo.gov/publication/52463.

[3] See, e.g., Long, Elliott, "Soaring Construction Costs Threaten Infrastructure Push," Progressive Policy Institute (2017); Smith, Noah, "The U.S. Has Forgotten How to Do Infrastructure," *Bloomberg* (2017), https://www.bloomberg.com/view/articles/2017-05-31/the-u-s-has-forgotten-how-to-do-infrastructure. See also Taylor, Brian, "Why California Stopped Building Freeways," Access, 3 (1993) https://www.accessmagazine.org/fall-1993/why-california-stopped-building-freeways/; Beyer, Scott, "7 Reasons

projects are more expensive in the U.S. than in the rest of the world (Rosenthal 2017, Gordon and Schleicher 2015, Levy 2013). Apart from this, there is very little credible evidence on whether the US is getting less per infrastructure dollar, either over time or across place.[4] Much of the cutting edge in this area consists of New York Times exposes[5] and blog posts.[6] The issue of infrastructure costs is particularly important as calls for increased infrastructure spending come from both the left and the right, combined with prescriptions for dealing with higher perceived costs.[7]

We aim to help fill this evidentiary gap by documenting and analyzing spending on the construction of the US Interstates over the course of the second half of the 20th century. Highway construction is of particular interest because it is one of the largest components of infrastructure spending. In addition, and usefully for our analysis, it is a relatively uniform product across space and time, particularly in comparison with other big-ticket items such as mass transit and airports. This relative uniformity makes for easier comparisons across place. Two notable features of the Interstate program generate additional interesting variation. Interstate construction is funded 90 percent by the federal government, but implementation is left entirely to states,

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U.S. Infrastructure Projects Cost Way More Than They Should," CityLab (2014) https://www.citylab.com/life/2014/04/7-reasons-us-infrastructure-projects-cost-way-more-they-should/8799/.

[4] The Department of Transportation has maintained an index since 2003. DoT had an index before that was discontinued out of concerns about reliability. FHWA, National Highway Construction Cost Index (NHCCI) 2.0 (2017), https://www.fhwa.dot.gov/policy/otps/nhcci/desc.cfm. Some states produce regional versions of the NHCCI, though these are limited in the same ways. See, e.g., Huntsman, Brett, et. al., "Highway Cost Index Estimator Tool," Texas A&M Transportation Institute (2018). The Reason Foundation publishes an annual highway report comparing state highway systems. Fields, M. Gregory and Spence Purnell, "23rd Annual Highway Report on the Performance of State Highway Systems," Reason Foundation (Feb. 2018). But there has not been an overall evaluation of infrastructure cost drivers in the United States. Yglesias, Matthew, "Someone Killed a Congressional Inquiry into America's Sky-High Transit Construction Costs," Vox (2017), https://www.vox.com/policy-and-politics/2017/5/24/15681560/gao-report-transit-construction-costs.

[5] https://www.google.com/search?q=new+york+times+tunnel+costgs&oq=new+york+times+tunnel+costgs&aqs=chrome..69i57j69i64.5169j1j4&sourceid=chrome&ie=UTF-8.

[6] https://pedestrianobservations.com/construction-costs/.

[7] See http://thehill.com/policy/energy-environment/373414-trump-aims-to-speed-environmental-reviews-in-infrastructure-plan.

yielding rich potential for geographic variation. As well, the program has a fundamentally soft budget constraint. While funds were limited in any one year, the program's total amount was uncapped.

To analyze Interstate spending, we use newly-digitized state-level annual data on spending from 1956 to the present. We are not the first to make use of this data (Smith, Haefen, and Zhu 1999), but to the best of our knowledge, are the first to use it over the life cycle of the Interstates.[8] We also appear to be the first to combine these data with the number of miles completed in each year (Baum-Snow 2007), and with numerous other sources to measure the geographic determinants of cost, as well as the political and institutional determinants of spending.

We make three contributions, which are primarily descriptive. First, we document the change in Interstate spending over time.[9] This documentation reveals a dramatic increase in spending per mile of constructed Interstate. States spent three times as much to construct a highway mile in the 1980s as they did in the early 1960s. This temporal increase persists when we control for geographic drivers of spending.

Our second contribution is documenting a substantial variation in spending per mile across states, not explained by observable differences in geography. After netting out geography, the majority of the state variation in spending per mile persists; for example, 67% of the interquartile range of state per mile spending persists after controlling for observable differences

[8] Using the same data for the period 1990-1994, Smith, Haefen, and Zhu (1999) estimate a positive, statistically significant effect of environmental regulations on highway expenditures by comparing federal roads subject to certain environmental regulations with state roads that are not.

[9] Historically the Department of Transportation produced a Bid Price Index, but it was canceled out of reliability concerns and in any case measured input prices, not final costs. DoT later produced the NHCCI starting in 2003, which again was rehauled out of reliability concerns and again only measured input prices. FHWA, National Highway Construction Cost Index (NHCCI) 2.0 (2017), https://www.fhwa.dot.gov/policy/otps/nhcci/desc.cfm. Further, these indices are national in scope and does not offer regional specificity.

in geography. This finding parallels work on health care spending, which indicates a two to four-fold difference between the highest and lowest levels of observed spending among U.S. hospital referral regions after accounting for geographical and other 'uninteresting' covariates (Skinner and Fisher 2010, Cooper et al. 2018).

Our third contribution is to provide suggestive evidence on the causes of the increase in costs over time. Several prominent potential explanations are likely *not* important causes. First, observable changes in geography do not substantially change the overall pattern of cost increase, providing some reassurance that highway planners did not leave the "hardest" sections until last. Second, we show that increasing construction material and labor prices explain virtually none of the increase in spending over time. Analogizing to an important question in the healthcare literature (Anderson et al. 2003, Skinner and Fisher 2010; Cooper et al. 2017), this result suggests that increases in quantities, rather than increases in prices, drove the increase in costs. Third, we show that the cost increase was overwhelmingly driven by the costs of construction themselves, not the costs to attain right of way or conduct preliminary engineering: these latter costs are never very large and their share of total spending does not increase over time. So it is unlikely that changes in eminent domain law substantially increased costs, at least directly. Fourth, anything constant across time cannot explain the increase. For example, because the US is and was a common law country, the spending increase we document cannot be laid at the feet of the common law. More generally, whereas many explanations for high US infrastructure costs focus on features of the US that are little changed since the 1960s, our results suggest the importance of focusing on features that have changed. And fifth, we show that there have not been large changes in mandated Interstate standards that could have driven the increase.

One explanation that does appear consistent with the data is the rise of social movements, legislation, and judicial doctrine leading to an increase in "citizen voice" in government decision-making.[10] For example, the combination of the 1970 National Environmental Policy Act and the 1971 Supreme Court decision *Overton Park v. Volpe* meant that citizens opposed to a project had much more power to challenge it via courts because agencies were required to conduct environmental reviews, and courts were less willing to defer to agencies on the proper scope of those reviews. The hypothesized mechanism is not that the literal planning or litigation costs went up (those are too small), but rather that construction was more expensive—in the form of more expensive structures and routes—to reflect citizen concerns. We provide a variety of pieces of evidence consistent with this explanation, including the timing of the cost increase, as well as increases over time in the share of miles built slowly; the number of structures like tunnels, bridges, and ramps; and the wiggliness of the routes. We also show regression evidence from panel data that areas where citizens were more likely to become activated—in particular, areas with dense populations and expensive homes—saw larger increases in costs over time. To be clear, though, we are not making any causal claims. Nor are we saying anything about the benefits of citizen voice, even if it is the explanation. We are only discussing costs.

As well, there are many potential explanations about which we are able to say little. For example, an industrial organization literature on infrastructure contracting suggests that builders may be able to manipulate their contracts in ways that increase spending, though whether this has changed over time remains an open question (Bajari and Ye 2003, Gil and Marion 2013,

[10] Several studies suggest that environmental review may increase costs. Smith, Haefen, and Zhu (1999) compare expenditures on Federal-Aid highways subject to environmental regulations with state roads not subject to those same regulations, finding that measures of environmental resources like counts of endangered species and proximate Superfunds are positively associated with increased construction costs of Federal-Aid highways but not of state roads. Other scholars find that specific features of environmental review, such as litigation costs, mitigation costs, or project delay increase spending (Olshansky 2007, Greer and Som 2010, deWitt and deWitt 2013).

Mochtar and Arditi 2001, Miller 2014). Other potential explanations could include changing procurement practices and more expensive highways as a luxury good as the national income increased.

More importantly, the puzzles contained in our results raise important questions for future work: What precisely explains the enormous increase in costs over time that we have documented? And what explains the large variation in costs across states? Reams of papers are devoted to healthcare costs, but relatively little attention has been paid to the cost drivers of the 4% of GDP spent on infrastructure. We hope that our primarily descriptive contribution provides phenomena to explain, data to study, and helpful initial forays into the critical task of explaining infrastructure costs.

2. The Interstate System

The Federal-Aid Highway Act of 1944 established the National System of Interstate and Defense Highways as a 40,000-mile planned network of highways spanning the US. Construction of the roadway system set forth in the 1944 Act began in earnest with the passage of the Federal-Aid Highway Act of 1956. According to leading proponent President Eisenhower, the Interstates were meant "to relieve existing congestion, to provide for the expected growth of motor vehicle traffic, to strengthen the Nation's defenses, to reduce the toll of human life exacted each year in highway accidents, and to promote economic development" (Eisenhower 1956).[11] The Interstates also served as a form of fiscal policy in Eisenhower's eyes, helping to level out cycles of unemployment over the course of their construction (Ambrose 1984).

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[11] The 1956 Act states similar purposes: The Interstate system "shall be so located as- (i) to connect by routes, as direct as practicable, the principal metropolitan areas, cities, and industrial centers; (ii) to serve the national defense; and (iii) to connect at suitable border points with routes of continental importance." 23 U.S.C. §103(c)(1)(C).

The 1956 Highway Act authorized Congressional appropriations covering 90 percent of the estimated cost of the Interstates (with the remaining 10 percent to be borne by the states) not already built to full standard since 1944, and extended the planned system to 41,000 miles.[12] Though constructed, owned, operated, and initially paid for by the states, these miles were federally reimbursed under the 1956 Act, so were eventually paid for almost entirely by the Federal Government (Weingroff 2017a, FHWA 2017a).[13] In 1956, the government estimated that the network would cost $25 billion in federal funds (approximately $192 billion in 2016 dollars) to be disbursed over the course of a thirteen-year completion schedule (DOT 1958, p. 7).

Today's network of over 49,000 miles was largely determined by the framework set out under the 1956 Highway Act, though there have been modifications to the network since the Act's passage. The Federal-Aid Highway Act of 1968 made two notable such modifications. The first was to distinguish miles of the Interstate that would be eligible and those that would be ineligible for federal funding by allowing an unlimited number of miles, ineligible for federal funding, to be designated as part of the Interstate System through section 139 of Title 23. We

[12] 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 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. David L. Lewis, *State Highway System: Issues and Options* (Washington, D.C.: Congressional Budget Office, 1982), 10 n.1, https://www.cbo.gov/sites/default/files/97th-congress-1981-1982/reports/doc19b-entire.pdf; Department of Transportation, Federal Highway Administration, *Notice: Sliding Scale Rates In Public Land States - Rates Effective March 17, 1992*, 1992, N 4540.12, Washington, D.C., https://www.fhwa.dot.gov/legsregs/directives/notices/n4540-12.cfm. To account for this difference between states, we scale our observed federal spending to account for the differing federal share.

[13] Until 1976, all Interstate highway maintenance was financed and executed by state governments. The 1976 Federal Aid Highway Act established $175 million for 1978 and 1979 to pay for "resurfacing, restoring, and rehabilitating" Interstate highways (Weingroff 2017b). This Act also changed the definition of "Construction" so that federal funds could be used for "resurfacing, restoring, and rehabilitating" roads. The 1978 Surface Transportation Assistance Act created a permanent category for "Interstate 3R Funding," and allocated $900 million for years 1980 through 1983 to pay for 75% of this type of "heavy maintenance" on Interstates (Weingroff 2017b). The Federal-Aid Highway Act of 1981 clarified that interstate Construction funds should prioritize "completion" of the system, which initially reduced the portion of funding allocated to maintenance. At the same time, the 1981 Act expanded the definition of "Construction" to include "Reconstruction" (4R), and the next year's "Surface Transportation Act" dramatically increased federal funding for Maintenance and returned the funding ratio to 90% (Weingroff 2017b).

refer to eligible mileage as "funded" or "chargeable" and the remaining mileage as "unfunded." The second modification made by the 1968 Act was to increase the cap of funded mileage from the 41,000 miles set out in the 1956 Highway Act to 42,500 miles. Through various other legislative modifications, the cap on funded mileage eventually settled at 42,902.62 miles with the passage of the Surface Transportation Assistance Act of 1978, though the actual designation of some of these miles was left to the discretion of the Secretary of Commerce[14]. By 1997[15], approximately 42,794.49 funded miles had in fact been designated as part of the Interstate System and approximately 42,786.89 funded miles had been constructed, largely as new alignment[16]. Whether built with funding from tolls instead, designated through section 139, or otherwise added to the Interstate System without federal funding, roughly 6,000 unfunded miles have been added to what is now a roughly 49,000[17] mile system of constructed roadway[18]. In the end, construction took far longer and was far more expensive than anticipated, extending past the

[14] The Howard-Cramer Amendment of 1968 gave states the opportunity to withdraw planned mileage and, at the discretion of the Secretary of Commerce, use the withdrawn mileage to build alternate Interstate routes. An additional 200 miles were authorized to help states build this alternate mileage, a number which was later expanded to 500 in 1973. The Surface Transportation Assistance Act of 1978 froze the number of miles eligible for Interstate construction funds, meaning that no future mileage added to the Interstate System could receive these funds and no additional Howard-Cramer mileage could be used.
[15] https://www.fhwa.dot.gov/highwayhistory/data/page06.cfm.
[16] Earl Swift, *The Big Roads* (Boston : Houghton Mifflin Harcourt, 2011), 219-20. Approximately three quarters was new alignment. The reason for so much new alignment is that is that older roads had lots of development built up around them and knocking down existing buildings is expensive. Furthermore, the old roads were how farmers, homeowners, and businesses accessed their properties; building a limited-access Interstate would cut off that access and sometimes requite eminent domain for an entire farm. Also, newer alignments could be straighter. Discussing the construction of I-81 in Virginia, Swift wrote, "Had Virginia tried to buy access rights and property along the [existing] highway's length, it would still be paying for them today."
[17] Estimated at 49,072 miles in 2017 (FHWA 2018a).
[18] Mileage could be added if the road was (1) built to Interstate standards and (2) a logical addition to the system (FHWA 2018a). Mileage built using toll funds was ineligible for federal funding. Approximately 2,232 toll-funded miles had been built as part of the Interstate System by 1997. https://www.fhwa.dot.gov/highwayhistory/data/page06.cfm. Approximately 3,546 unfunded miles had been added to the System as of 2002 through section 139 of Title 23. https://www.fhwa.dot.gov/programadmin/interstate.cfm. And approximately 337 unfunded miles had been added under the Intermodal Surface Transportation Efficiency Act of 1991 and National Highway System Designation Act of 1995 as of 2002. https://www.fhwa.dot.gov/programadmin/interstate.cfm.

millennium and totaling approximately $504 billion in federal funding rather than the anticipated $192 billion (both in 2016 dollars).[19]

Figure 1 shows the progression of Interstate construction over time with the miles constructed in the decade at issue depicted with a wide line. The largest share of Interstate miles, 54 and 31 percent respectively, are constructed in the 1960s and 1970s. By the 1980s, construction slowed down appreciably (9 percent of Interstate miles). In geographic reach, most states do some construction in each of the 1950s, 60s, 70s, and 80s; just under half do in the 1990s. In addition, most construction does not start at one end of a highway and continue along the route. Instead, as is most clear in Figure 1a from the 1950s, the Interstates are built in bits, with those bits eventually connecting to complete the throughway.

We discuss funding for this construction in two parts: first the process of annual apportionment to and across states, and then the determinants of the timing of state spending. Crudely, the federal government finances Interstate construction via the revenue garnered from the portion of the federal gas tax dedicated to highway funding. This revenue is credited to the Federal Highway Trust Fund and is 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). As a result, completing the Interstates required occasional increases in the gas tax, as well as the

[19] The federal agency responsible for coordinating funding of the Interstates puts total federal spending at $119 billion through 1996, disbursed over the 40-year period from 1956 to 1996. https://www.fhwa.dot.gov/interstate/faq.cfm. Using the Interstate cost estimates, we inflate (approximately, because the Interstate cost estimates were published every two to three years so precise adjustments aren't feasible) this figure to 2016 dollars.

imposition of new taxes, as projected costs outpaced projected revenues (FHWA 2017b). The last Interstate construction funds were apportioned in the 1996 fiscal year (FHWA 2017a).

In form, Interstate construction was a reimbursable program, meaning that the federal government paid states back for money spent on building the Interstates (FHWA 1983a). The process generally worked in the following manner. Congress, through legislation, authorized each year an amount of money for Interstate construction on the basis of the estimated cost to complete the System, and on the health of the Highway Trust Fund. A certain amount of this authorized money was deducted to pay for FHWA operations and research (FHWA 1983a). The remaining money was then apportioned to the states.

In the first three years of the Interstate program, the annual distribution of apportionments among states was determined by a population, area, and mileage formula used for determining appropriations in a much less ambitious earlier system.[20] For all years after the first three, states received funds in proportion to each state's estimated cost to complete its remaining Interstate mileage. This estimated cost to complete came from state submissions to Congress, which were prepared in conjunction with federal oversight and contained detailed estimates of costs by input

[20] Major and consistent federal funding for United States highways began in the first quarter of the 20th century. While the funding started with the Federal-Aid Highway Act of 1916, it was the Federal-Aid Highway Act of 1921 that designated the first national road system. The system of roads this act designated came to be known as the Federal-Aid Primary Highway System, and federal funding was limited to this system of roads (FHWA 1983a). The Federal Government committed itself to paying for 50% of the costs of approved projects on the Federal-Aid Primary System. The Act also authorized and appropriated money for a couple of years according to this formula: one-third according to the state's share of population, one-third according to the state's share of land area, and one-third according to the state's share of mileage.

The Federal-Aid Highway Act of 1944 was the first to authorize the designation of "a National System of Interstate Highways" separate from the Federal-Aid Primary, Secondary, and Urban Systems. See https://www.fhwa.dot.gov/infrastructure/naming.cfm. The Interstate System was to contain no more than 40,000 miles of road which would be chosen by cooperation among the states. The legislation however, did not authorize money for the construction of the Interstate System. A small amount was later authorized by the Federal-Aid Highway Act of 1952. Continuing disagreements over the funding for the highway system prevented Congress from committing large sums for the completion of the Interstates (Weingroff 1996). As a result, some states did build up the designated Interstate mileage before 1956, but they largely did so using toll revenues (Baum-Snow 2007).

(e.g., right of way purchase, planning and construction) for planned Interstate segments (e.g., a 2-mile segment of I-10). (We are currently reviewing these records with the goal of conducting a case study.) Congress required these submissions roughly every two to three years from 1958 to 1991. Once compiled across states and transmitted to Congress and the FHWA, the resulting "Interstate Cost Estimate" served as the basis of Congress' total appropriations to the Interstates for the subsequent two to three years (subject, of course, to the constraint imposed by the Byrd Amendment) (Weingroff 1996).

Once apportioned, the money 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 submitted specific projects for FHWA approval (FHWA 1983a). 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 (at the rate of 90 to 95 percent of total spending, per 23 USC §120(a)(1)) upon the submission and certification of vouchers documenting their expenditures for the FHWA (FHWA 1983a, 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 the 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 commencement (but not termination) of construction.[21] 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.

In accepting Interstate funds, states were required to construct to "Interstate standards." In general, Interstates had to have at least two lanes in both directions,[22] full control of access, minimum design speeds of 50-70 mph, minimum lane widths, and adequate design to support the traffic volume expected for 1975 (a requirement that was later changed to the volume expected 20 years from project completion).[23] Mileage that received federal funding could not have tolls.[27] Congress also applied the Davis-Bacon Act to Interstate construction, which required that Interstate construction laborers be paid the prevailing wages of the area in which the project was carried out (Weingroff 1996). States were allowed to spend Interstate funds on right-of-way acquisition.

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[21] For example, projects that made use of the Federal Government's so-called "right-of-way revolving fund," which provided advance fund 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 (23 USC 108(c)(3)).

[22] 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 only $335 million (DOT 1968, p. 12). Since this money was provided in the 1968 ICE apportionment, inflating from 1969 to 2016 dollars provides a lower bound of approximately $2.19 billion of possible contamination in 2016 dollars. Because this is so small a fraction of the roughly $504 billion spent of the course of the Interstates' construction, we think it unlikely to substantially affect our estimates.

[23] See "A Policy on Design Standards," American Association of State Highway Officers (AASHO), 1956; "A Policy on Design Standards-Interstate System," AASHTO, 1991 (codified via 58 Fed. Reg. 25939 (1993) at 23 U.S.C. § 625.4(a)(2) (1995)) [hereinafter, DS-4].

[27] As stated above, the Federal-Aid Highway Act of 1956 authorized the designation of 41,000 miles of road as part of the Interstate system. The mileage designated as such was eligible to receive IC funds. States were also allowed to incorporate into this mileage limitation certain roads they had built before 1956. Many of these roads were grandfathered into the system, meaning some of the Interstate design rules were relaxed for these segments. Additionally, 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 IC funds (FHWA 2018b).

In practice, there was no cap on the total amount a state could spend to construct an approved Interstate highway route, so long as it 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 demands from other states and the amount of federal funds authorized for that year. However, 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 increased revenue into the Highway Trust Fund. Two additional notes bear consideration. Federal funds did not cover Interstate maintenance—only new construction.[28] And, as we explain in Appendix C, states were in some cases able to use small amounts of Interstate funds on non-Interstate projects, for which we adjust in our data construction.[29]

3. Data

A primary contribution of this paper is marshalling data to describe the long-run trajectory of Interstate expenditure by state and year. We do this by combining data on Interstate mileage over time with data on Interstate spending over time.

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[28] Before 1976, Interstate maintenance was the fiscal responsibility of states. Beginning with the Federal-Aid Act of 1976, the federal government began apportioning money to states for the purpose of rehabilitation, restoration, and resurfacing. In 1981, it also allowed for the use of Interstate maintenance funds for reconstruction (Weingroff 2017b).

[29] Three programs affect our estimation of Interstate expenditures over time. First, the Withdrawal-Substitution program allowed states to withdraw planned Interstate routes and use the money instead for mass transit projects or non-Interstate road projects. See Federal-Aid Highway Act of 1973 § 137(b), 23 U.S.C. § 103(e)(2) (2012). Second, the Minimum Allocation rule required that states receive at least half a percent of a year's Interstate Cost Estimate apportionment, regardless of the estimated cost-to-complete of their Interstates (states could thus spend in excess of their cost-to-complete on other Federal-Aid eligible roads). See Federal-Aid Highway Act of 1970 § 105(b)(1), Pub. L. No. 91-605, tit. I, 84 Stat. 1713 (1970). Lastly, the Minimum Percentage Allocation rule required that the total amount of Federal-Aid money apportioned to a state (IC funds as well as Federal-Aid Primary, Secondary and Urban funds) be at least a certain percentage of yearly tax revenues that the state's drivers contribute to the Highway Trust Fund. See Highway Improvement Act of 1982 § 150, 23 USC § 157 (1988). In the appendix, we explain in more detail the history of these programs as well as how they affect our estimates.

For highway mileage over time, we use Baum-Snow (2007)'s digital map and his digitization of the *Form PR-511 Database* maintained by the Federal Highway Administration. This database tracks the date of opening for each separately opened segment of the Interstate Highway System. Using both the map and data, we can identify the number of Interstate miles completed by state, county, and year from 1956 to 1993. A total of 39,793 mile-segments were completed by 1993, or 99 percent of the total system of 40,562 miles completed with federal funds by that year. We observe 37,435 of these miles, or about 94 percent.[30]

We complement these mileage data with 1956 to 2014 spending data that we digitized from the Federal Highway Administration's *Highway Statistics* series. We have standardized this data to 2016 dollars. As we explain in Appendix C we make small adjustments to the data using data from the *Highway Statistics* and elsewhere to account for the small amounts of money that, in some cases, could be used for non-Interstate purposes, thereby creating a measure limited to Interstate construction expenditures.

We observe expenditures in the year the federal government reimburses states for obligated expenditures—typically in the year in which the state spent the money. We observe miles, however, in the year in which they are completed (opened to the public). Where we need to know the precise timing of spending, this generates a mismatch between the two data series, including 471 state-year observations with expenditures but no completed miles (roughly 25 percent), and 4 state-year observations with completed miles but no expenditures (roughly 0.2 percent). We use a variety of methods to ease the severity of this mismatch. (We do not observe expenditures by Interstate mile, which would be one natural way to ease this problem.) The

[30] 40,378 federally funded mile-segments of Interstate highways have been completed as of December 31, 2017. The data through 1993 thus misses 585 completed mile-segments, in addition to the 177 mile-segments that have not been fully completed yet. Note that there are 42,793 Interstate miles that were eligible for Interstate construction funds, but 2,233 miles were toll roads and thus could not be built with federal funding (FHWA 2018a).

simplest method—and therefore the method with which we begin—is to aggregate the data into multi-year bands, likely bringing together the relevant spending and construction.

We combine these expenditure and mileage data with a variety of other data sources described briefly below and detailed in Appendix A. To measure the underlying geography on which the Interstates were built, we construct measures on the extent of urban development, wetlands, and ruggedness in a given Interstate segment's proximity. We define a segment as 'urban' if it is built through an area assigned a 1950 Census tract. In 1950 the Census tracted (defined small neighborhoods for statistical purposes) only highly urban areas (United States). We define a segment as having been constructed in wetlands if the ratio of federally-designated wetland area to the area of the county in which the segment was built was in the top 20 percent among segments, nationally and across time. Ruggedness remains under construction; our goal is to create a measure of variance in elevation of newly constructed Interstate miles by state and year.

We also measure characteristics of the construction itself. We measure the number of miles constructed through "expensive" areas (tract if available, county otherwise) - those with decadal median home value in the top 20 percent nationally among segments, in the decade the miles were built. We measure the number of "wide" miles, which we define as the number of miles built with greater than four lanes. We also measure highway structures built proximate to a mile; we define a segment as including a "structure" if, within a four-kilometer radius of an Interstate, we observe an Interstate tunnel, bridge, or causeway.

We also include measures of politics. We use the state-wide percentage vote share for the Democrat in the 1968 Presidential election. We also use the number of land use cases per 1 million people, as constructed by Ganong and Shoag (2017). We measure how much jurisdictional fragmentation there is where highway miles are built; we define a segment of Interstate to have been built through a fragmented county if the number of local governments operating within the county is in the top 20 percent, nationally and across time, among segments.

Finally, we include measures of government effectiveness or efficiency. These include the Standard and Poor's bond rating by state, which we convert to a numerical score using typical interest rates by bond rating and weighting by the number of miles built in the state-year. To measure competence in construction management, we measure the proportion of miles built slowly; we use those taking more than four years to complete from the start of construction work (the top 20 percent, nationally and across time). Finally, we use a 1999 state-level measure of corruption from Boylan and Long (2003).

4. Documenting Interstate Highway Spending Over Time and Space

With these mileage and spending data in hand, we now turn to our first significant contribution: documenting Interstate expenditures over time and space. We demonstrate four stylized facts about Interstate spending per mile. First, there is a dramatic increase—approximately three-fold—over time. Second, there is substantial variation across states. Third, states' rank in the expenditure distribution over time is remarkably persistent. Finally, all these findings are robust to controls for observable geographic determinants of highway cost.

To assess how spending changes over time, Figure 2 presents spending per mile from 1956 to 1993. The green points in the figure show the average across states of total spending divided by total completed mileage in each ten-year period in the data (the last period is eight years). This coarse time breakdown is relatively less likely to suffer from the mismatch of spending and miles, and even here we see an increase in spending per mile.

This increase in spending remains visible when we look at more fine-grained timing. The darker purple line reports the average across states of total spending divided by total completed mileage in each five-year period (the last period is eight years). The lighter purple line is the annual average across states of spending per mile. Though the annual data are clearly noisier, all methods show an increase in spending per completed mile over time. If there is an inflection point in this time series, it is around 1975, when spending per mile increases substantially. Overall, the data suggest that the cost of building a mile of Interstate highway roughly tripled between the 1960s and the 1980s, a huge increase that is especially striking in light of the fact that there were no major changes in highway standards over this time period and that highway-building technology actually advanced, which would suggest—all else equal—a *decline* in costs.[31]

[31] Some productivity advances were, for example, the use of high-strength steel to reinforce bridges during construction, which saved $30 million per year beginning in the 1960s, National Research Council, Transportation Research Board, *America's Highways: Accelerating the Search for Innovation*, 1984, Special Report 202, Washington, D.C.: Transportation Research Board, 1984, 26; "relationships for pavement structural designs based on expected loadings over the life of a pavement" from the American Association of State Highway Officials (AASHO) Road Test of 1956-1960, Richard Weingroff, "AASHO Road Test," *Highway History*. Federal Highway Administration, June 27, 2017, https://www.fhwa.dot.gov/infrastructure/50aasho.cfm (Accessed October 16, 2018); and Superpave asphalt, which "dramatically improved performance with little or no increase in cost" in the 1990s, Robert E. Skinner, Jr., "Highway Design and Construction: The Innovation Challenge," *The Bridge* 38, 2 (2008), 7. The Bureau of Labor Statistics noted in a 1970 report that "many of the technological innovations in highway construction are laborsaving rather than material saving," Department of Labor, Bureau of Labor Statistics, *Projections 1970: Interindustry Relationships, Potential Demand, Employment*, 1970, Bulletin No. 1536, Washington, D.C.: Government Printing Office, 96. The federally-funded Academies of Engineering and Technological Sciences analyzed trends in the construction industry more broadly and found that, from about 1978 to 1988, "the impacts of technology on the construction sector…in general… have been largely evolutionary." The Academies pointed to construction-related design, which helped enable concurrent engineering and construction and increased design speeds fourfold, as well as construction equipment and methods improvements, including "laser-based survey equipment, laser-guided excavation equipment, … honeycomb structures and foams for greater strength[,] polyester fiber for improved durability in the refitting of sewage and water pipes[, and] fiberglass fabric for rapid repair work." Alden P. Yates, "Technological Advances in the Construction Sector" in *Globalization of Technology: International Perspectives*, Janet H. Muroyama and H. Guyford Stever, eds. (Washington, D.C.: National Academies Press, 1988), 68-79, https://www.nap.edu/read/1101/chapter/9#78. As of 1984, federal and state governments spent a combined $70-75 million annually investing in highway research (National Research Council, 1984, 40, Table 10).

This increase is all the more striking given that the mismatch between spending and mileage in our data should, all else equal, result in smaller measures of spending per mile in later years, if spending has long been done and miles are just getting completed. Instead, using the five-year measures, we see a more than three-fold increase in spending per mile of completed Interstate. This difference between the first and last five-year period is statistically significant at the 2.5% level in a two-sided t-test.

Importantly, changes in average spending per mile could mask potentially large changes in the distribution of spending per mile. In other words, an increase in the average could be driven by all states spending more per mile, or by a few spending substantially more. Figure 3 uses the five-year aggregate measures to explore where changes occur in the distribution across states. This figure visually suggests that spending per mile increases most at the top of the distribution. In fact, the growth rate of the 25th percentile is statistically indistinguishable from zero at the 5 percent level, and the point estimate for the growth rate of the 75th percentile is statistically significantly larger than the point estimate for the growth rate of the 25th percentile (just over six times larger across the whole time period, just under nine times larger for the 1975 period and on – see columns 1 and 2 in Appendix B, Table B1).

In addition to variation over time, there is also substantial variation in spending across states. Figure 4a shows total spending divided by total miles constructed for each state over the entire period. States are ordered by spending and colored by their Census region. Figure 4b presents this data on a map. The difference between the highest and lowest spending states in this figure – Delaware and North Dakota – is about $52.1 million per mile, or nearly fifteen times North Dakota's spending per mile. Even the $7.4 million spent per mile in the 25th percentile state of Oklahoma is less than half of the $17.2 million spent per mile in the 75th percentile state of Ohio. This variation is consistent with the large amount of variation in health care costs across states (Anderson et al. 2003, Skinner and Fisher 2010, Cooper et al. 2017).

This state spending rank is quite persistent over time. Figure 5 shows the correlation between total spending divided by total miles from 1960 to 1969 to the same measure from 1980 to 1989. We estimate this correlation at 0.5383. The green line is the notional 45-degree line, on which all observations would lie if spending per mile in the 1960s were the same as spending per mile in the 1980s. Each point in the figure is a state. Only two states lie above the 45-degree line, meaning that only two states – South Dakota and Montana – spent less per mile in the 1980s than they did in the 1960s. Most states spent more, and those closest to the horizontal axis spent substantially more. Among the high spenders in the later period, Georgia and Pennsylvania stand out for their large increases. The slope in this figure is a statistically significant 0.19. And the map in Figure 6 shows the percent change in cost between a state's 1980s and 1960s spending per mile. The largest and smallest increases are fairly evenly disbursed throughout the country.

Finally, variation in spending per mile – either over time or across states – remains interesting, but is less policy-relevant, if it is driven solely by underlying costs related to geography. To assess whether the increase over time we document is attributable to geographic variation, we estimate the regression below.

$$\frac{spending_{st}}{miles_{st}} = \beta_0 + \beta_1 \cdot year\ fixed\ effects_t + \beta_2 \cdot \mathbb{I}\{miles\ missing_{st}\} + \beta_3 \cdot \mathcal{G}_{st} + \varepsilon_{st} \quad (1)$$

Indices are s for state and t for five-year time period as described above. The variable $\mathcal{G}$ denotes geographical controls. This regression assesses whether there is a change in the relationship between miles completed and spending over time, as measured by the β_1 coefficients. To address the issue that some states construct no miles in a given five-year period (there are 21 such observations, out of 315 total observations), we include an indicator for miles equal to zero ($\mathbb{I}\{miles\ missing_{st}\}$).

Figure 7 shows the β_1 coefficients from Equation (1) excluding the geographic controls. The β_1 coefficients report any difference by five-year period in per-mile spending relative to spending in the five-year period ending in 1960. This is a regression analogue of the five-year measures in Figure 2, and it shows a very similar trend. Spending per mile is roughly unchanged until about 1975, at which point it increases, so that by the end of the chart, states are spending over $45 million (2016 USD) more per mile than in 1960. The purple region denotes the 95 percent confidence interval for the green coefficients, showing that after 1975, average spending differs significantly from the 1960s level.[32]

Of course, it is possible that this change could be due to changes in the geography of Interstate construction. Figure 8 reports coefficients β_1 from equation (1) including controls for geography. The darkest green line represents the baseline (no geographical controls), the light green line adds a control for urban geography, and the medium green line adds a control for wetland geography. Regardless of the set of controls, the time pattern of spending remains relatively unchanged. (In future drafts, we plan to add elevation as a control here. We also plan to experiment with a richer set of controls, including soil conditions, rain, temperature, and bioregion.) Here the purple region is the confidence interval for the most complete specification. Individual (non-joint) pairwise Wald tests of the plotted coefficients suggest that (among other significant inter-period differences) the periods corresponding to 1993, 1985, and 1980 are significantly different from the 1965 and 1970 periods.

[32] Confidence intervals are not quite a perfect stand-in for a test of significant difference among the coefficients, however, pairwise Wald tests confirm the observation at the 5% level.

To demonstrate that there remains substantial variation in spending per mile across states after controlling for geography, we estimate the regression below:

$$\frac{spending_s}{miles_s} = \beta_0 + \beta_1 * \mathcal{G}_s + \varepsilon_s \quad (2)$$

Here we eliminate the time component from equation (1) by aggregating variables across the years 1956 to 1993. Although this simplification precludes the possibility of different effects for different time periods, it also obviates the need for our missing miles indicator, sidestepping our miles-spending mismatch dilemma. As in equation (1), s indexes the state and $\mathcal{G}$ denotes our geographic controls for the fraction of miles in the state built in 1) circa 1950 urban areas and 2) wetland-dense counties. Figure 9 shows the resulting residual spending per mile by state. After including these controls, most of the variation persists: the interquartile range of the residuals after controlling for geography ($6.52 million) is 67 percent of the size of the interquartile range of the per mile spending without controls ($9.68 million). This suggests that the state variation is driven by factors not controlled for here.

Ex ante, it is not clear that the rank ordering of states by spending per mile should persist after controlling for spending per mile. Given the modest role of geography in accounting for state variation, however, it is not surprising that the rank ordering is indeed relatively robust. We estimate a correlation of 0.76 between a state's all-time spending per mile and its all-time spending per mile net of geographic controls. Regressing the former on the latter yields a statistically significant coefficient of 1.0.

Our goal in the remainder of this paper is to consider leading explanations for this persistent increase in spending, pose new explanations, and assess which could be consistent with the observations we've noted here.

5. Regression and Other Evidence

In this section, we consider correlates of cost in a regression framework, net of geographic constraints, including construction type and location, political tastes and institutions, and government efficacy. We thus take advantage of this variation over time and space that we have documented to shed light on potential drivers of infrastructure costs. We then turn to a novel measure of highways, "wiggliness," and show how that has evolved over time.

a. Regression evidence

In this section, we consider potential determinants of spending per mile increases. We use the five-year aggregate data and add covariates to equation (1), sequentially controlling for construction type and location, political tastes and institutions, and government efficacy. Because we have not identified any exogenous cost or demand drivers for highway spending, this section is best understood as a set of suggestive, and ideally informative, correlations. Notably, this evidence remains an improvement over the current absence of knowledge.

To implement, we simply add potential measures of spending drivers to equation (1). In particular, we add $\sum_{X \in \mathcal{P}} \beta_X \cdot X_{st}$, where $\mathcal{P}$ denotes the set of measures we use to represent each grouping - construction type/location, political tastes/institutions, and government efficiency. The coefficient β_X reports the correlation of covariate X with spending per mile, conditional on our geographic controls (the share of miles built through 1950 tracts and the share of miles built through wetland-dense counties) and the other measures in $\mathcal{P}$. Appendix Table A1 provides summary statistics for these added variables, as well as those in the baseline specification in equation (1).

Table 1 reports these estimates. The first column reports the coefficients we present in Figure 7, indicating an increase in expenditure per mile. This increase – shown by the coefficients on the year fixed effects – is pronounced, but estimated with very wide confidence intervals. The share of miles built in a circa 1950 tracted (urban) area is positively correlated with spending per mile, as we would expect if these right of ways were more expensive, or if construction in populated areas required greater accommodations (e.g., higher relocation costs or additional highway features). This coefficient suggests that a 10 percent increase in the share of urban highway miles – a change of 0.9 in the percentage of urban miles – yields an increase of roughly $537,000 in spending per mile of highway. In contrast, the coefficient on the share of highway miles constructed through wetland-dense counties is much smaller and is not statistically significant.

Column 2 of Table 1 reports coefficients from a specification with covariates for the type and location of construction: the share of miles built in "expensive" areas (those for which the median home value was in the top 20 percent, nationally, in the most recent prior census), the share built with four lanes or more (we measure number of lanes as of 2016), and the share built near an Interstate structure such as a bridge, tunnel of causeway. Ex ante, we expect all of these features to increase the cost of highway construction; the first through land acquisition and perhaps through lobbying for "higher quality" highway features, and the last two through direct increases in the cost of construction.

Of these three coefficients, only one is statistically significantly different from zero: the coefficient on the share of miles built in "expensive" counties. Here, an increase of 10 percent in the share of miles built in counties with expensive homes – a change of 2.2 in the percentage of these miles – is associated with a $500 thousand increase in the per mile spending on Interstates.

The next column replaces these construction type and location measures with features of the local political environment. These include the state's share of votes for the 1968 Democratic presidential candidate, the number of land use cases per million people (taken from Ganong and Shoag (2017)), and the share of miles built through fragmented counties (counties wherein the number of local governments was in the top 20 percent among all segments, nationally and across time). The literature suggests that at least the latter two features could be associated with higher spending per mile.[37] Land use cases are a sign of local litigiousness, which could increase spending on a project through delay; they may also indicate great community involvement that could spur more costly construction in response to local demands. Other researchers have suggested that one reason infrastructure in the US may be more expensive relative to Europe is the US system of fragmented governance.[38] While we cannot make a US-Europe comparison, we can assess whether greater fragmentation within the US is associated with higher costs.

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[37] On the impact of litigation, see, e.g., Petra Todorovich and Daniel Schned, *Getting Infrastructure Going: Expediting the Environmental Review Process* (New York: Regional Plan Association, 2012), 8 ("The threat of environmental lawsuits motivates lead federal agencies to take time-consuming steps or redesign projects to avoid them, contributing to project delivery delays."), http://library.rpa.org/pdf/RPA-Getting-Infrastructure-Going.pdf; Susan A. MacManus and Patricia A. Turner, "Litigation as a Budgetary Constraint: Problem Areas and Costs," *Public Administration Review*, 53, no. 5 (1993): 468 (finding local government officials expected litigation costs to negatively impact bond ratings), https://www.jstor.org/stable/976347; Susan A. MacManus, "Litigation Costs, Budget Impacts, and Cost Containment Strategies: Evidence from California Cities," in *Local Government Management: Current Issues and Best Practices*, eds. Douglas, J. Watson and Wendy L. Hassett (New York: Rutledge, 2015), 169 (noting that increased public infrastructure litigation costs for mid-sized communities suggested higher-income and more knowledgeable suburban dwellers are more willing to sue over public infrastructure). Senior Trump Administration advisers have blamed "obstructionist lawsuits" in part for America's "crumbling" infrastructure. Wilbur Ross and Peter Navarro, "Trump Versus Clinton on Infrastructure." *PeterNavarro.com*. October 27, 2015, http://peternavarro.com/sitebuildercontent/sitebuilderfiles/infrastructurereport.pdf (Accessed October 15, 2018).

On the issue of local fragmentation, see, e.g., Tracy Gordon and David Schleicher, "High Costs May Explain Crumbling Support for U.S. Infrastructure," RealClear Policy (Mar. 30, 2015), https://www.realclearpolicy.com/blog/2015/03/31/high_costs_may_explain_crumbling_support_for_us_infrastructure_1249.html; David Schleicher, "City Unplanning," *Yale Law Journal* 122 (2013): 1676-77 ("The content of land-use procedure can generate 'localist' policymaking: seriatim decisions about individual developments or rezonings in which the preferences of the most affected local residents are privileged above more weakly held citywide preferences about housing."), https://www.yalelawjournal.org/pdf/1162_zn8saw36.pdf.

[38] See, e.g., Richard Briffault, "Localism and Regionalism," *Buffalo Law Review* 48 (2000): 8 (discussing the cost of competition among localities in economic development), https://digitalcommons.law.buffalo.edu/cgi/viewcontent.cgi?article=1369&context=buffalolawreview; Francis Fukuyama, "Too Much Law and Too Little Infrastructure," *The American Interest*, November 8, 2016,

The coefficients on the 1968 Democratic vote share and the land use cases are both positive, indicating an increase in the spending per mile with more Democratic voters and a more litigious population. However, all three additional coefficients in this specification are estimated with too much noise to draw any statistically significant conclusions.

Column 4 of Table 1 reports results controlling only for geographic covariates and measures of government efficacy: state bond rating, share of miles built "slowly" (taking more than four years to move from start of construction to completion), and a corruption index (estimated as of 1999, from Boylan and Long (2003)). We parameterize the categorical bond rating based on the percent increase in the interest rate on a ten-year bond in the middle of the rating 'class' (AAA+, AAA, AAA-; AA+, AA, AA-; etc.) from the interest rate on a ten-year AAA-rated bond. As with the previous set of coefficients, we find no statistically significant relationship between these variables and spending per mile. However, the coefficients on the year fixed effects – our measure of the increase in spending per mile over time – do decrease notably with the inclusion of these controls. It seems that the inclusion of these controls accounts for between a third and a half of the temporal increase in spending per mile in the latter half of the period.

The fifth and final column of Table 1 adds all covariates simultaneously. Here, we see no statistically significant relationship between any of the covariates and spending per mile. Additionally, with all covariates included together, there remains an upward trend in spending per mile over time (though this is not statistically significant). In other words, the set of

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https://www.the-american-interest.com/2016/11/08/too-much-law-and-too-little-infrastructure/ (Accessed October 15, 2018); Gordon, Tracy and David Schleicher, "High Costs May Explain Crumbling Support for U.S. Infrastructure," RealClear Policy (Mar. 30, 2015), https://www.realclearpolicy.com/blog/2015/03/31/high_costs_may_explain_crumbling_support_for_us_infrastructure_1249.html.

covariates we employ, while explaining some of the increase in spending per mile over time, is not sufficient.

However, we know from both the figures and tables that spending per mile began a substantive increase in the mid-1970s. This suggests that an underlying state feature could have limited impact on spending per mile before the mid-1970s, but could plausibly be associated with spending per mile after that time. To assess this hypothesis, we interact all covariates in equation (1) with an indicator for being 1975 or after. This allows covariates to have an additional impact in the 1975-onward period.

The format of these results in Table 2 repeats the organization of Table 1, but with these additional interactions. We concentrate on results in the final column. First, the year fixed effects (which are not included in the regression table) are no longer positive in later years, suggesting that the interaction effects completely account for the pattern of increase in spending per mile over time. Several variables are statistically significant, including those involving underlying geographic features (the share of miles built in 1950 urban areas), the location of construction (the share built near expensive homes), and political institutions (land use cases per million and the share of miles built in fragmented counties). Discussing each variable in turn, we find that while the coefficient on the share of miles built in circa 1950s urban areas is small for the entire period, it is large and significant from 1975 onward. In this period, states averaged 10 percent of Interstate miles built in such locations, so that a 10 percent increase in the share of such miles is associated with a \$965,000 increase in spending per mile.

Contrary to our expectations, we see a marginally statistically significant (at the 10% level) decline in spending per mile where construction was more heavily in wetland-dense counties after 1975. This decrease masked, in the previous table, what turns out to be an association between miles construction in a wetland-dense country and spending per mile before 1975.

More consistent with our expectations, and with the large literature suggesting the rise of homeowner power after the mid-1970s, we find that the share of miles constructed in counties with expensive homes is statistically significantly associated with spending per mile from 1975 onward, but not before. A ten percent change in the share of miles constructed in expensive counties (representing an increase of 2.1 in the percent of miles built through expensive areas) increases spending per mile by $817 million.

Finally, and again leaning on the large literature that pinpoints the rise of homeowner power in the mid-1970s, we anticipated that the number of land use cases should be more associated with spending per mile after 1975; we find the opposite. As with the wetland-dense counties, we see a pre-1975 positive relationship between land use cases and spending per mile, and the virtual erasure of this relationship from 1975 onward.

b. Segment-level findings on "wiggliness"

Most of our data analysis is limited by our observation of highway spending only at the state level. To push on this limitation, we calculate a novel measure that should be correlated with Interstate spending. We define the "wiggliness" of a segment as the true length of a highway segment divided by the "as the crow flies" distance of that segment from one endpoint to another (this measure is known as tortuosity in engineering). We hypothesize that roads curve to avoid obstacles such as litigious homeowners so that it may be indicative of decisions that may also result in higher costs.

Based on our division of the entire Interstate system into one mile as-the-crow-flies segments, we find that wiggliness is increasing over time. However, even more so than the measure of direct costs, the increases are concentrated at the very top. Figure 10 shows the 25th, 75th and 95th percentiles of the wiggliness distribution. For almost the entire period the 25th percentile shows little change, with wiggliness ratios at or just above 1. The 75th percentile shows a small increase over time, but the 95th percentile starts with segments that are slightly under 20 percent longer than their straight-line distance and ends with segments that are usually more than 40 percent longer than their straight-line distance. And overall, as Figure 11 shows, there is a substantial increase in average wiggliness over time. These findings are suggestive evidence of a possible mechanism for spending increases at the top end of the distribution.

6. Discussion: What Might Drive Increasing Infrastructure Costs?

Having described two puzzles—the large increase in cost over time and the unexplained cross-state variation—we turn to explanations of drivers of infrastructure costs. We first describe five hypotheses that appear largely inconsistent with the data. We then turn to one explanation—increasing citizen voice in government decision-making—that does appear consistent. However, we emphasize that we are not saying anything causal here. We are merely describing how well various explanations fit with the available data.

a. Hypotheses that do not appear to explain increasing costs

Five explanations of rising costs appear largely inconsistent with our data. We review each in turn. First, one may think that highways built later are those that were built on more difficult terrain, perhaps because planners left the more difficult segments until later. While we cannot speak to unobservable differences in geography across time, it is reassuring that, as shown in Figure 8, adding in controls for the most obvious geographic drivers of cost does not substantially change the trend in costs over time.

Second, the most straightforward explanation for increased highway spending per mile is an increase in labor input price, as suggested by Baumol's cost disease (Baumol and Bowen 1965, Baumol and Bowen 1966, Baumol 1967). Figure 12 indexes spending per mile, as well as construction materials and labor prices, to 100 in 1958. 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, and paving mixtures and blocks. (This may be implausible; however, as the figure shows, the conclusion is robust to any type of weighting among these prices.) We use the Bureau of Labor Statistics' hourly construction wages to measure construction labor prices (Carter et al. 2006).[39]

The difference between our cost measure and these price indices is striking. The figure shows a small increase in spending per mile in the 1960s, commensurate with increases in labor and materials prices. After that, spending per mile increases, while labor and materials prices are unchanged in real terms at the end of the period. Thus, the explanation of increasing labor and material prices—at least as measured here—is inconsistent with our measured construction cost increase over time. Note as well that the divergence between the price of the underlying components of highway construction – labor and materials – and overall highway spending begins in the early 1970s, consistent with when Interstate spending per mile begins its especially dramatic upward trend. This divergence suggests that changes in labor law (e.g., prevailing wage laws like Davis Bacon) that increase unit prices are unlikely to be drivers of increasing costs.

[39] Specifically, we use Table Ba4367-4372 of the Historical Statistics of the United States.

This divergence between input prices and final spending per mile may also speak to a question analogous to the important debate in health economics about whether prices or quantities drive high health care spending per patient in the US as compared to the rest of the world. Many in health economics argue that high American healthcare spending is driven by high prices, noting that along most measures of aggregate utilization ('quantity')—per capita physician visits, per capita hospital days, per capita acute beds, etc.—the US is actually *below* the OECD median despite having the highest per capita OECD spending (Anderson et al. 2003). In the same way that these low quantities suggest that high prices drive higher US health care spending per patient, the absence of increases in input prices over time suggests that high quantities of inputs may drive higher US infrastructure spending per mile of highway.[40] Of course, it is far too early to say that quantities, rather than prices, drive high infrastructure spending. For example, there could be unobserved input prices—and we are not making any claims about unobserved differences in quality. Still, we view our results as the first contribution in what we hope will be a large literature attempting to understand the question of whether prices or quantities drive high US infrastructure spending.

A third explanation is also largely inconsistent with the data: the cost of right of way acquisition or planning costs. To address this question, we digitized additional data that break out expenditures by type: construction versus preliminary engineering and right of way. As

[40] While prices seem to drive higher US healthcare spending when compared with the rest of the world, quantity effects – similar to those we may be observing here – help drive domestic regional variation, especially in the Medicare program (Skinner 2010). For example, while the median number of back surgeries per 1,000 Medicare enrollees nationally is 4.5, it is 2.9 in Maine, New York, and Wisconsin, but more than 6.0 in South Carolina, Colorado, Utah, and Wyoming. Inpatient Back Surgeries Per 1,000 Medicare Enrollees by Gender, *The Dartmouth Atlas of Healthcare*, 2015, http://www.dartmouthatlas.org/data/topic/topic.aspx?cat=22 (Accessed October 21, 2018). Among privately-insured patients, factors affecting prices, such as monopoly power, have a more substantial contribution to regional variation. (Cooper, et al. 2018) ("For the privately insured, half of the spending variation is driven by price variation across regions and half is driven by quantity variation."); see also "Healthcare Affordability: Untangling Cost Drivers," *Network for Regional Healthcare Improvement*, February 13, 2018 (finding the same), http://www.nrhi.org/uploads/benchmark_report_final_web.pdf (Accessed October 21, 2018).

Figure 13 shows, the share of spending on right of way and planning costs is fairly small: only 17.7% of expenditures.[41] And furthermore, the share is declining, not increasing, over time. Rather, the dominant cost of building the Interstates was construction itself—not planning or right of way, which suggests that construction is the dominant driver of cost increases. These data suggest that changes in eminent domain law do not make a large, direct contribution to cost increases over time.

Fourth, anything constant over time, of course, cannot explain the large increase in costs. For example, some authors have suggested that the increasing cost of infrastructure in the US is due to the strictures in common law, which provide more protection for property owners.[42] In theory, these protections allow individuals and small groups to slow down development with costly lawsuits and other legal challenges. Our data are inconsistent with the idea that something about the US common law tradition alone drives high spending. While it may be true that it is more expensive to build in common law countries relative to civil law ones, this is not a sufficient explanation for our particular case of increasing cost over time: the United States is and was a common law country. And it is difficult for something that has not changed to cause a large change in costs.

Finally, there were no large changes in Federal Interstate standards that would have increased cost. After an extensive search, apart from increasing capacity over time,[43] we are

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[41] Annual data are not available for the entire period. However, other statistics show that right of way expenditures were only 12.6% of the spending on building the Interstates through 1991 (the vast majority of the spending). Similarly, preliminary engineering, planning, and research spending, along with "miscellaneous" spending, amount to only 8.0 percent of the costs of building through 1991. https://www.fhwa.dot.gov/highwayhistory/data/page03.cfm. These figures do not adjust for inflation though—and these expenditures were probably disproportionately done in early years.

[42] Gordon, Tracy and David Schleicher, "High Costs May Explain Crumbling Support for U.S. Infrastructure," RealClear Policy (Mar. 30, 2015), https://www.realclearpolicy.com/blog/2015/03/31/high_costs_may_explain_crumbling_support_for_us_infrastructure_1249.html. But civil law countries may also have strong property protections. Id.

[43] See *id*.

unaware of any substantial changes in design standards that could have led to substantially increasing costs over time,[44] though we cannot rule out the possibility that many small changes of which we are unaware aggregated to a substantial impact.[45]

b. An explanation of increasing cost consistent with the data: citizen voice

If materials and labor prices, land acquisition costs, unchanging characteristics of US infrastructure spending, and other leading explanations of rising infrastructure costs do not explain the increases we observe, what might? We discuss here one potential leading explanation (or, group of explanations) that is consistent with our data: greater "citizen voice" in the development process: that is, in the late 1960s and early 1970s, a combination of social movements, legislation, and judicial doctrine significantly expanded the opportunity for citizen involvement in the process of infrastructure development. This environmental legislation and

[44] 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. 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.

[45] Another explicit statutory change was the increase in the minimum width from two to four lanes with Section 5 of the Federal-Aid Highway Act of 1966. Pub. L. No. 89-574, 80 Stat. 766, 767 (codified at 23 U.S.C. § 109(b)). Congress intended this change to apply to both already-constructed miles and miles yet to be constructed. See U.S. Congress, Senate Committee on Public Works, *Federal-Aid Highway Act of 1966: Report*, 1966, 89th Cong., 2nd sess., Washington, D.C.: Government Printing Office, 21-22, Table 10; U.S. Congress, Subcommittee on Roads of the Senate Committee on Public Works, *Federal-Aid Highway Act of 1966: Hearings*, 1966, 89th Cong., 2nd sess., Washington, D.C.: Government Printing Office, 369-72 (includes a table breaking out interstates based on whether they were "open to traffic" or "in progress"). And the policy was an exception to the rule that only new mileage was funded, which could create a problem for costs over time, since the spending would not be adding new mileage. However, estimates of the costs suggest that the extra cost of expanding was only a tiny fraction of the costs of building the interstates. As of April 30, 1966, Federal spending on interstate projects authorized, underway, or completed was $14.3 billion, while the estimated cost of upgrading interstates from two lanes to four lanes going forward was $264.8 million spread across 16 states, or 1.9% of the total cost to date. Senate Committee on Public Works, 1966, 12, 22 (compare Table 4 to Table 10). The President of the American Association of State Highway Officials estimated costs of $300 million to upgrade from two to four lanes on applicable interstate highways in 1966. Subcommittee on Roads of the Senate Committee on Public Works, 86-87. While, of course, the costs could have increased, the very low expected costs provide reassurance that the 4-laning of 2-lane miles was not a significant cost driver.

concomitant regulation and litigation started in the late 1960s, gaining teeth with the Supreme Court's landmark 1971 case, *Citizens to Protect Overton Park v. Volpe*.[46] This case established extensive judicial review over executive agencies by lessening the scope of decisions "committed to agency discretion" and thereby ensured citizen ability to sue on the basis of a variety of pieces of legislation. Those pieces of legislation include the National Environmental Policy Act of 1970 (requiring environmental impact reviews for projects with significant federal funding), the National Historic Preservation Act of 1966 (preventing development on national historic sites), the 1973 Endangered Species Act, the 1972 Clean Water Act protecting wetlands,[47] and other legislation making it more difficult to develop on public lands. This legislation also coincides with the founding of public interest environmental law organizations.[48]

There are multiple reasons that these changes could increase the cost of building infrastructure. The first is the cost of the environmental review itself: environmental review statutes require that projects involving significant government funds conduct environmental reviews. Litigation is costly too. However, as Figure 13 shows, the costs of these projects are overwhelmingly in the form of construction itself, so we view it as unlikely that this mechanism is a major contributor to costs. Second, the environmental review statutes may require more expensive routes or methods of construction to limit environmental impacts and otherwise respond to citizen demands. As well, environmental review statutes allow many potentially affected parties sue to stop or delay projects. As a result, projects may not only be delayed but may also take more expensive routes or use other more expensive methods to satisfy recalcitrant

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[46] 401 U.S. 402.

[47] The Army Corps of Engineers must affirmatively grant a permit to projects with the potential to harm wetlands under Section 404 of the Clean Water Act. The Corps often requires projects to mitigate any wetland losses. The Corps' jurisdiction has gradually expanded to cover almost all bodies of water in the United States.

[48] Paul Sabin, *Environmental Law and the End of the New Deal Order*, Law and History Review 33(4) 2015.

opponents empowered by statutes. We view this as the most likely mechanism of increased spending: citizen voice leads to more expensive routes and structures to respond to local concerns.

This cluster of explanations is generally supported by our data. Most importantly, the increase in costs in the mid-1970s coincides roughly with when these laws began to come into full effect. Miles were also built far more slowly over time (see Figure 14),[49] and were more frequently associated with auxiliary structures over time: more tunnels (Figure 15), more bridges and elevated highways (Figure 16), and more ramps (Figure 17). These trends could be taken as responsive to local demands—to mitigate impacts (with tunnels, as well as bridges and elevated highways) or increase commerce (with more frequent off-ramps). We also showed earlier (Figures 10 and 11) that highways became wigglier over time. This is plausibly consistent with a planning process more sensitive to citizen opposition and environmental protection, and more strongly characterized by the costs that sensitivity potentially entails.

The regression evidence is supportive too. Table 2 (column 5) shows that miles built through urban areas were more likely to predict expensive miles after 1975. Since urban areas are more likely than rural areas to have the people and structures that would lead to litigation (in addition to the popular revolts against construction that were centered in urban areas), this result is consistent with the importance of environmental concerns in increasing costs. As well, Table 2 (column 5) shows that areas with higher home values are increasingly predictive of high costs after 1975. This is consistent with the American homeowner movement, a period of activity characterized by greater subjection of local government to homeowner demands (Fischel 2001).

[49] Note though, that slow construction does not predict greater costs, as shown in Table 1 (though the standard errors are large). Also note that this figure has a different x-axis from the rest of the figures: this figure has year that construction of the Interstate segment began, rather than the year that it ended, to address the concern that later miles built later are more likely to be censored.

It is reasonable to think that wealthier homeowners would account for more of these demands, which could drive the greater correlation between costs and home values over time.

Two pieces of evidence suggest some nuance: As Table 2 shows, land use cases actually become *less* correlated with Interstate costs over time, the opposite of what we would expect if land use cases were driving costs. However, it makes sense that land use cases would not be increasingly correlated with per mile spending over time, since local land use law should have little control over state-funded highways. Rather, what we suspect is happening here is that there are states that persistently have more restrictive land use controls. And, since there are far more cases over time, a given case becomes less predictive in later years, generating a negative coefficient. Also, the absence of an increased relationship after 1975 between construction in more wetland-dense counties and spending per mile (Table 2, column 5) suggests that new water-related legislation may not be an important component of increasing costs.

Overall, the evidence tells a story consistent with the idea that highways construction became increasingly responsive to citizen voice over time, specifically in ways that increased cost. However, we emphasize that, though several other explanations appear inconsistent with the data, this explanation is merely *consistent* with the data—and is not necessarily an important cause, nor a cause at all. Furthermore, we say nothing here about the benefits of citizen voice, even if they are causally related to rising costs. We speak only to the costs.

As well, there are many potential explanations that we do not fully explore here, including declining economies of scale, reduced competition in the construction industry, changing procurement practices, and demand for more expensive highways because of increases in income. For other explanations—such as corruption and government quality and jurisdictional fragmentation—though we have data, we do not have enough statistical power to say much about them.

7. Conclusion

As Congress considers a new infrastructure bill amid widespread criticism of the state of US infrastructure, and as the Administration considers mitigating infrastructure costs, it is helpful to establish basic facts about infrastructure costs, about which we know strikingly little. This paper does so by studying the historical construction of one of the most extensive US infrastructure assets, the Interstates. We show dramatic increases in per mile highway construction costs over time that are not explained by observable differences in geography. This increase appears inconsistent with some common explanations of infrastructure costs, like increases in labor and materials costs, since these do not exhibit the same time trend. These data speak to the question, like that in the health care literature, of whether prices or quantities have driven higher per mile spending. Our data favor the latter. As well, the results emphasize the importance on focusing on factors that have changed since the 1960s, rather than those, like the common law system, that have not.

We explore one potential explanation that does appear largely consistent with the data: a combination of social movements, legislation, and judicial doctrine leading to increased citizen voice. The concurrency of these changes with rising costs; the increases in the time to build, the prevalence of structures, and wiggliness; and the locations of the largest cost increases (urban areas and those with high housing prices) all point in the direction of citizen voice. However, the evidence is just suggestive, not causal.

At the same time, we also show that there is huge variation in costs across states that is not explained by observable differences in policy or in the geography of where the miles are built. This puzzling but striking unexplained residual resembles the large unexplained residual in health care spending across states and merits further investigation.

Our paper thus raises questions for future work on infrastructure costs: What explains the enormous increase in costs over time? And, what explains the variation in costs across states? A large literature explores these questions in healthcare, yet we are just beginning to understand what even needs to be explained for infrastructure.

So much more work should be done to help understand the drivers of such an important part of the economy. This work could take many forms. For example, there are GIS data on the location of historic structures and endangered species, along with the designation of those structures and species. Did construction costs especially increase in those areas? Some contractors suggest that increased bureaucratization of the procurement and contract management process could explain rising per mile costs.[50] Perhaps analysis of data on state departments of transportation could provide evidence bearing on such a mechanism. These unexplained cost increases and variation across states are enormous; understanding them may help us understand how to reduce costs or, depending upon the mechanism and the resulting benefits, whether those costs are worth bearing.

50 Conversation with Darryl Goodson, September 20, 2018.

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Figure 1: Timing of Interstate Opening

Figure 1a: Timing of Interstate Opening, 1950-1959

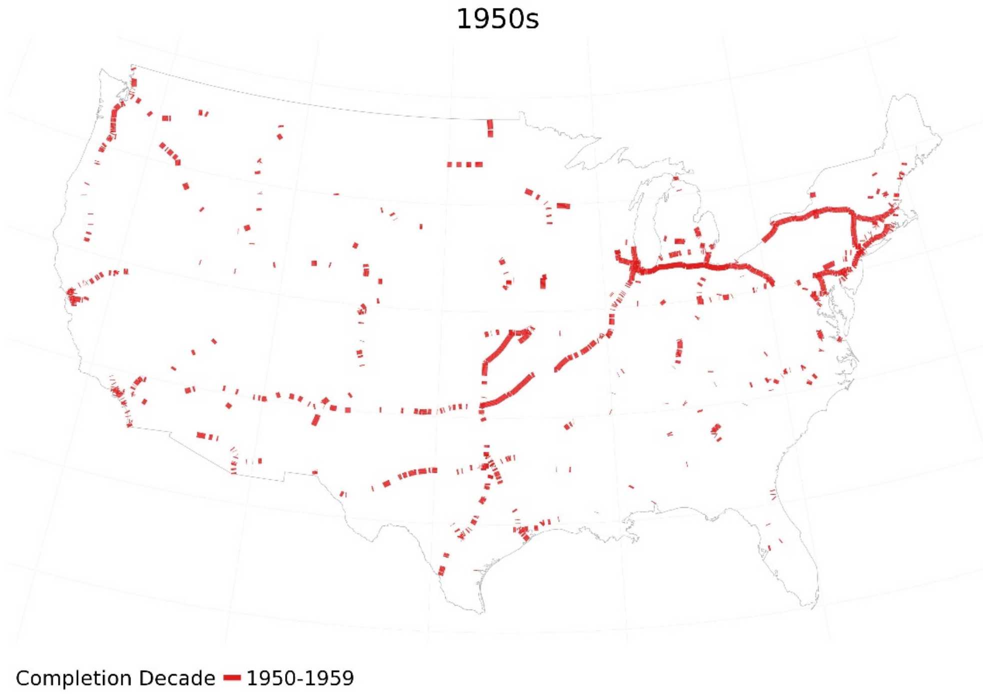


Figure 1b: Timing of Interstate Opening, 1960-1969

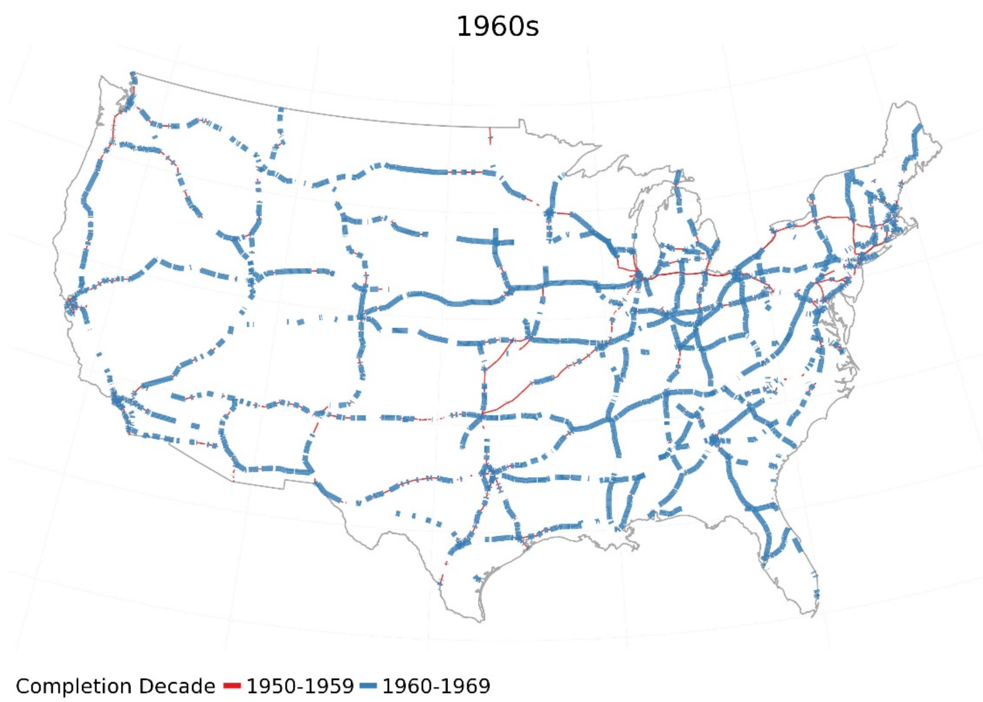


Figure 1c: Timing of Interstate Opening, 1970-1979

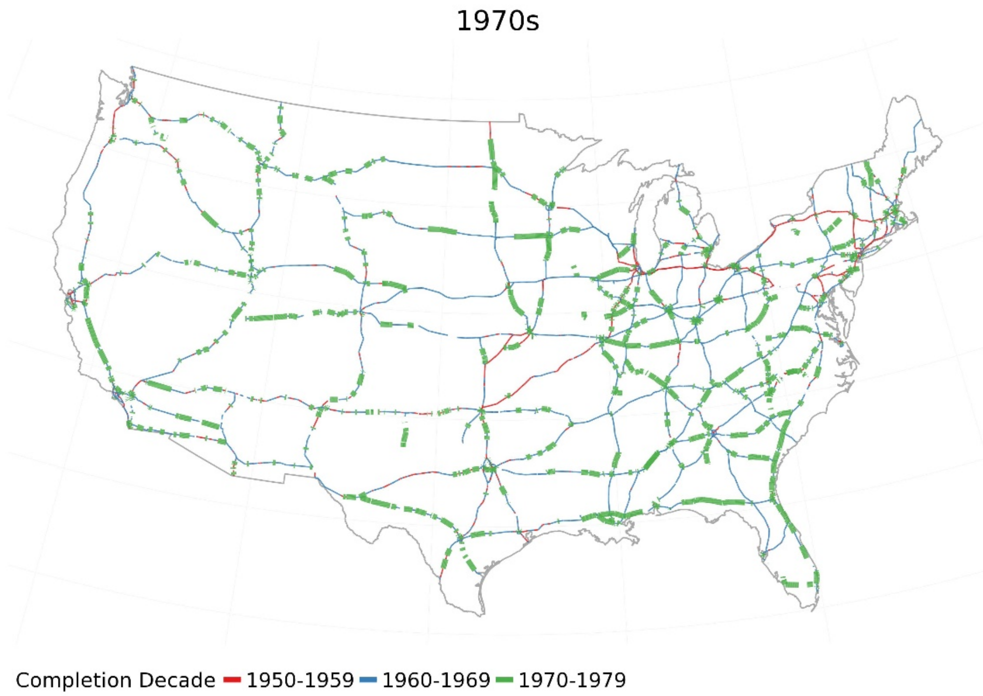


Figure 1d: Timing of Interstate Opening, 1980-1989

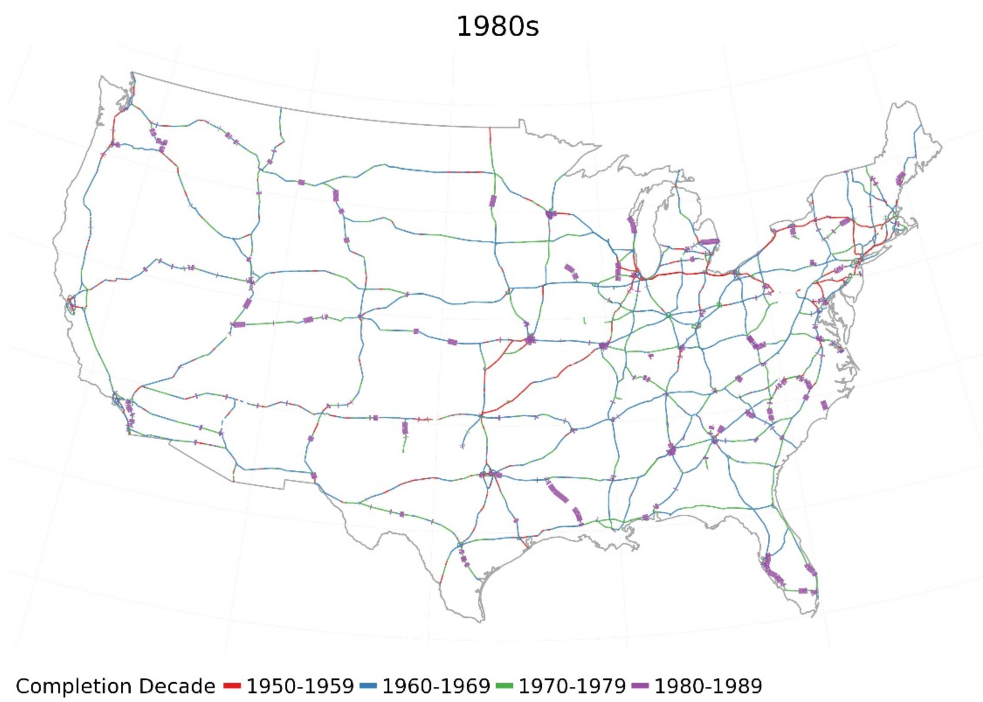


Figure 1e: Timing of Interstate Opening, 1990-1999

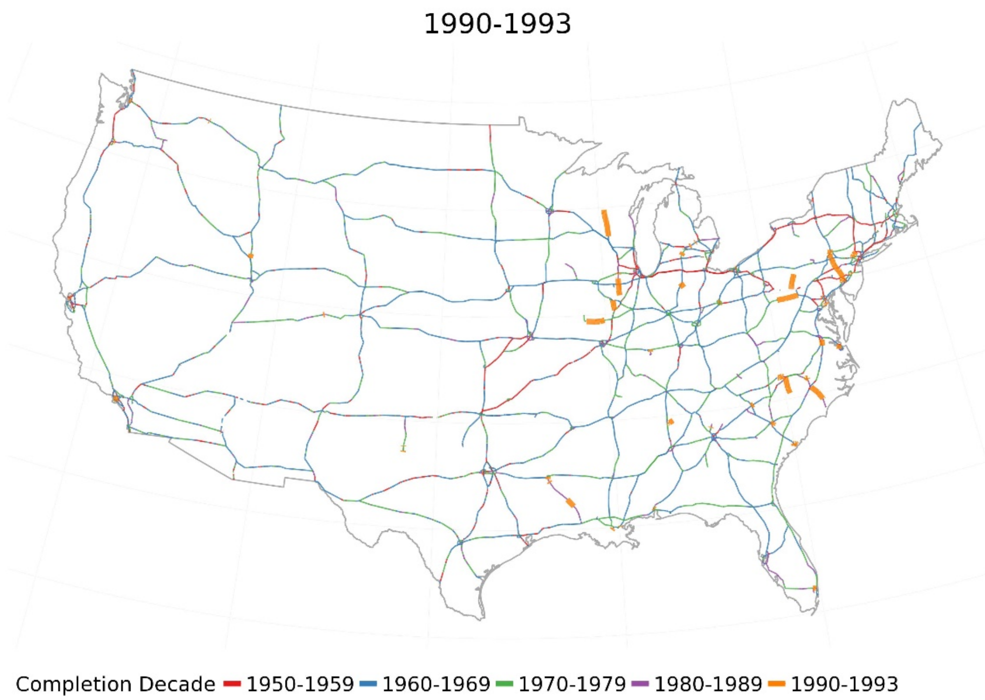


Figure 1f: All Interstate Segments, Over Time

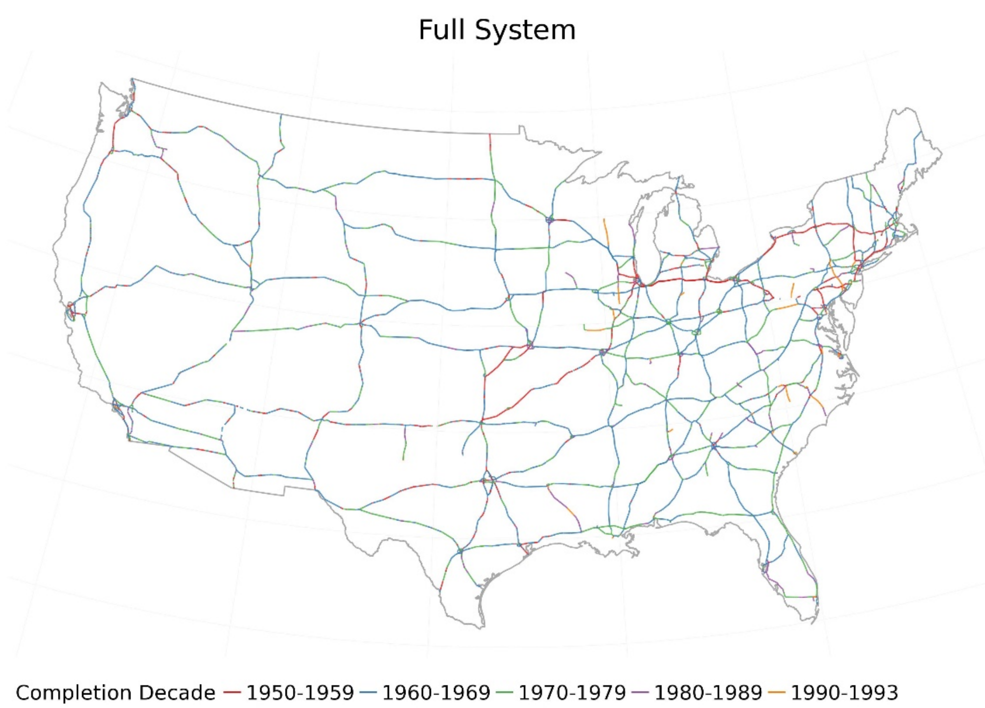


Figure 2: Substantial Increase in Average State Spending per Mile Over Time

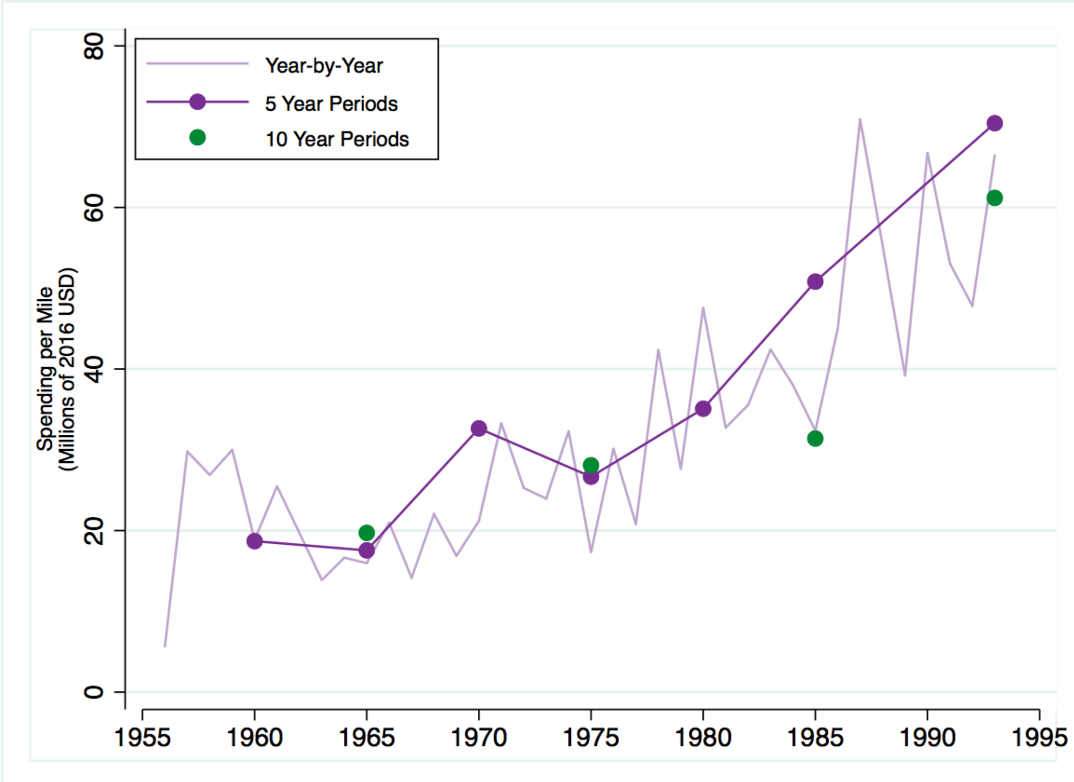


Figure 3: Quartiles of State Spending per Mile All Increase Over Time

Figure 4a: Substantial Variation in Total Spending per Mile by State

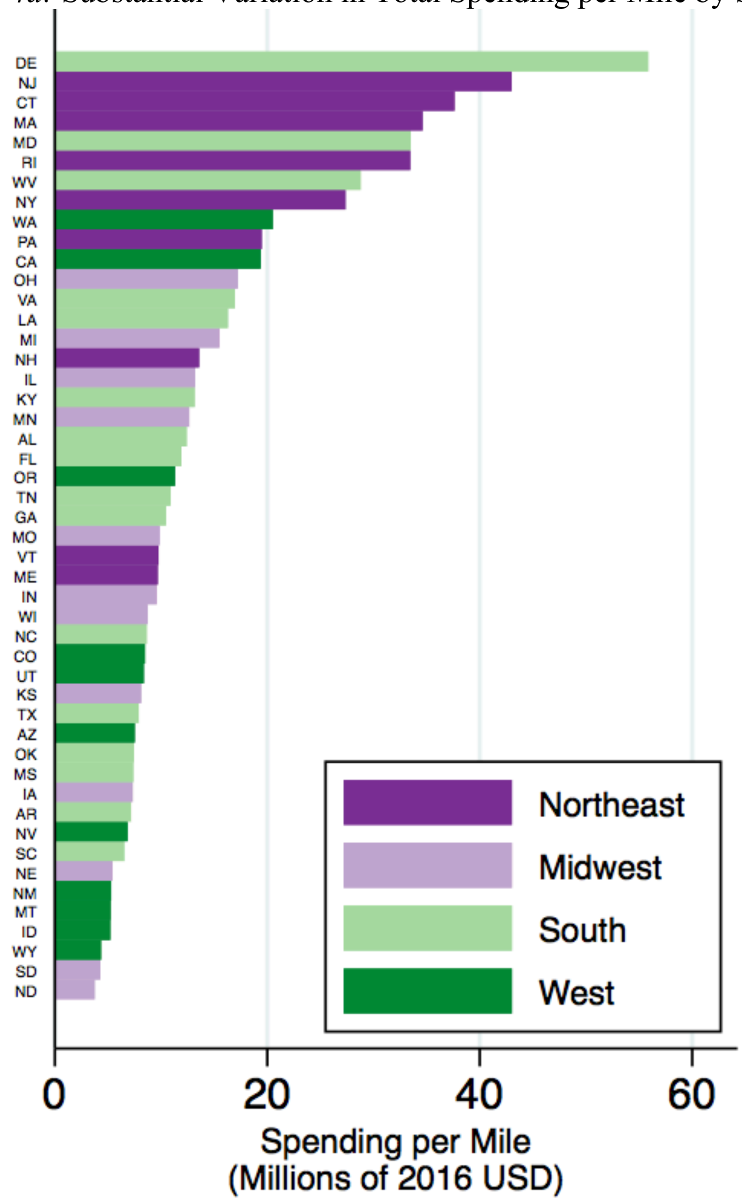


Figure 4b: All-Time Spending per Mile Map

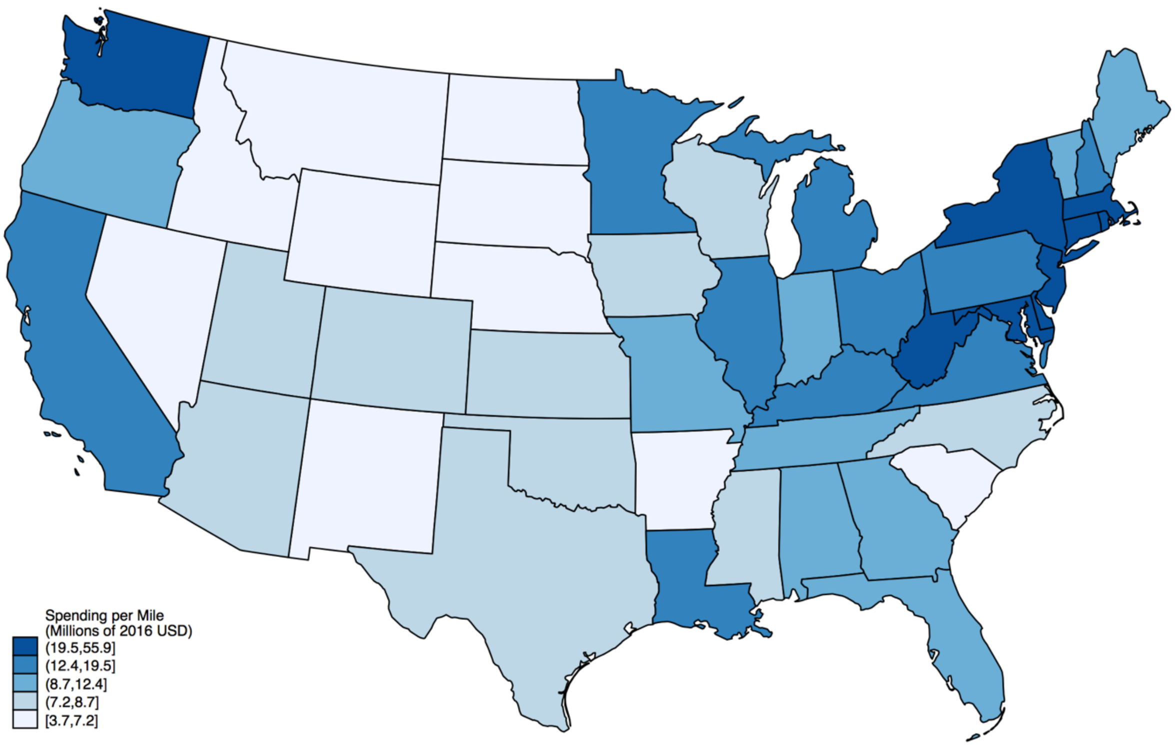


Figure 5: Nearly All States Spend More per Mile in 1960s versus 1980s

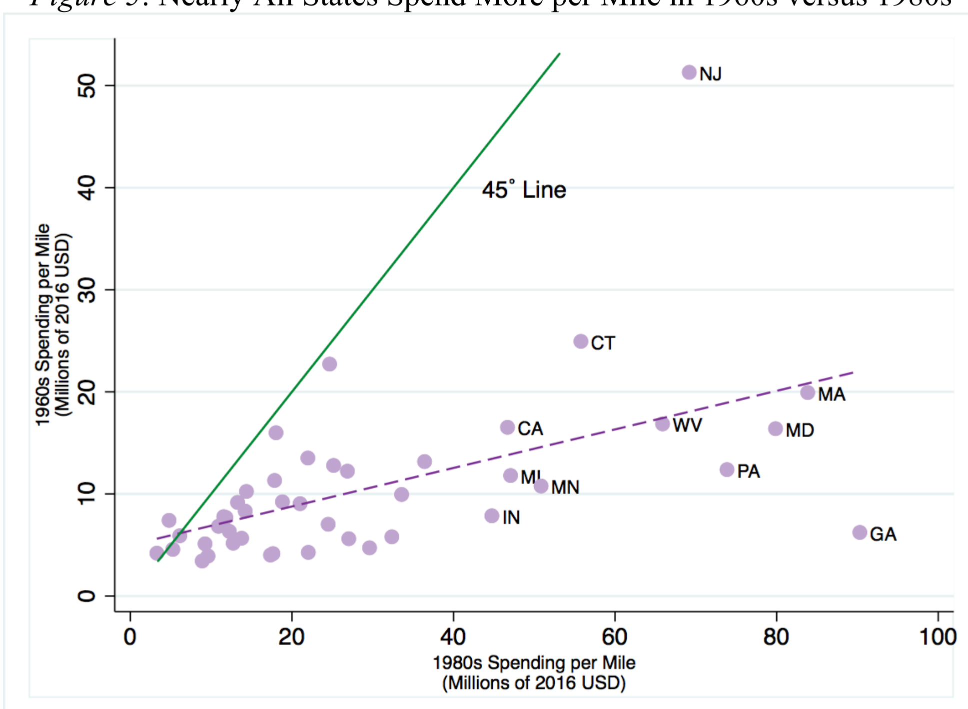


Figure 6: Percent Increase in Spending Per Mile, 1960s to 1980s

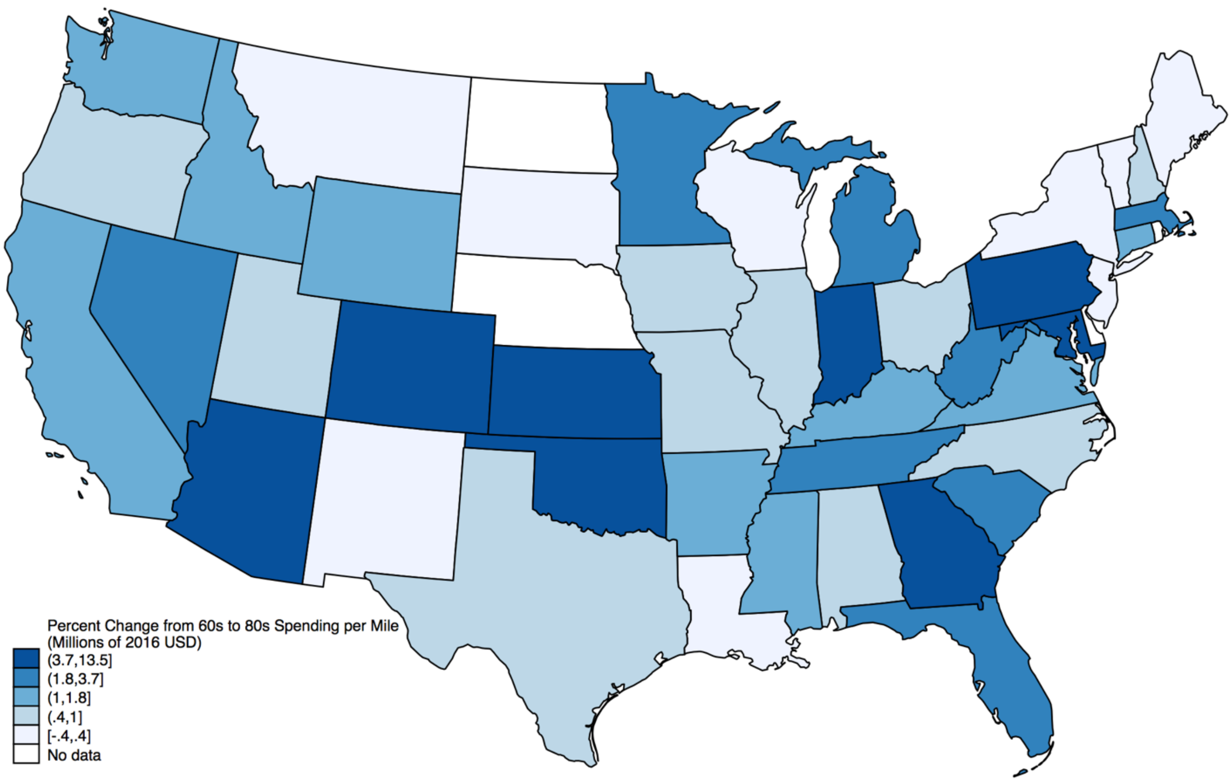


Figure 7: Regression Estimates Consistent with Increase in Average Spending per Mile

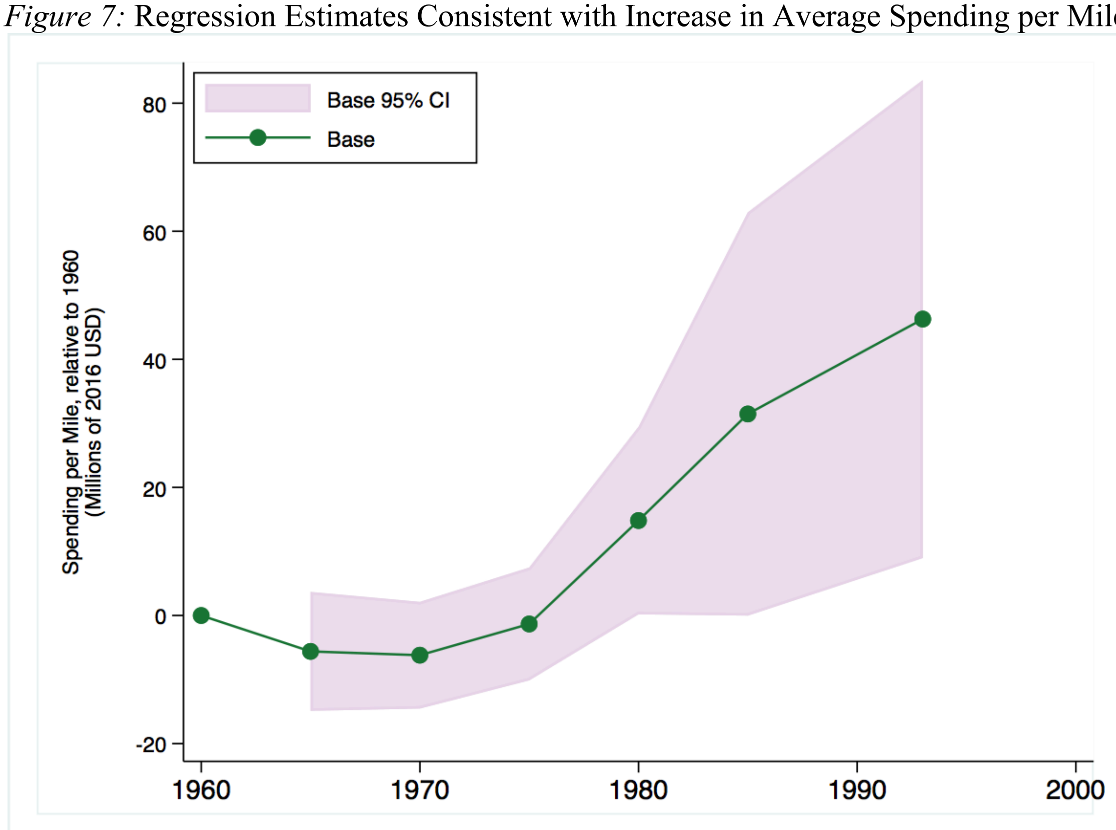


Figure 8: Regression Estimates of State Spending per Mile Little Influenced by Geographic Controls

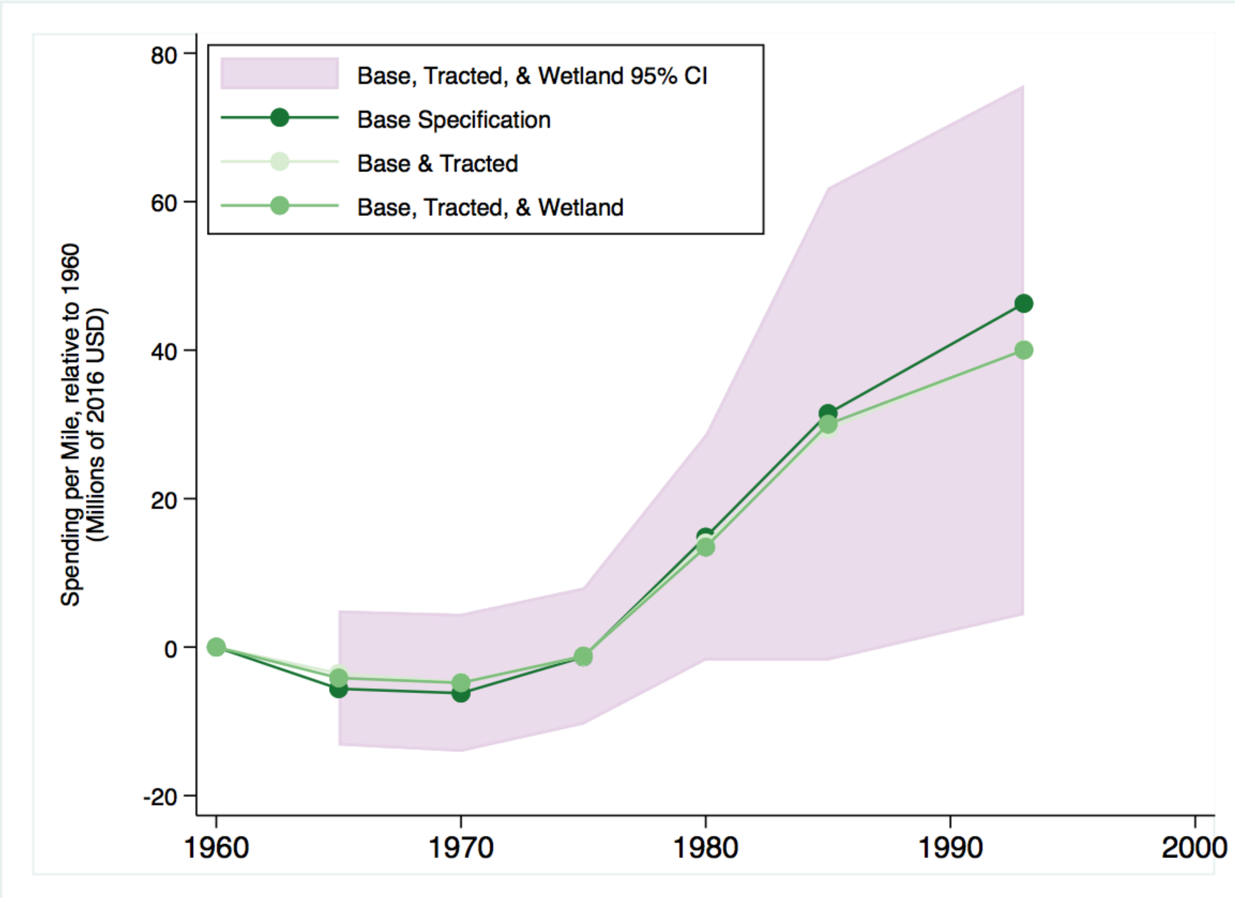


Figure 9: Substantial Variation in Spending per Mile Remains Across States After Controlling for Geography

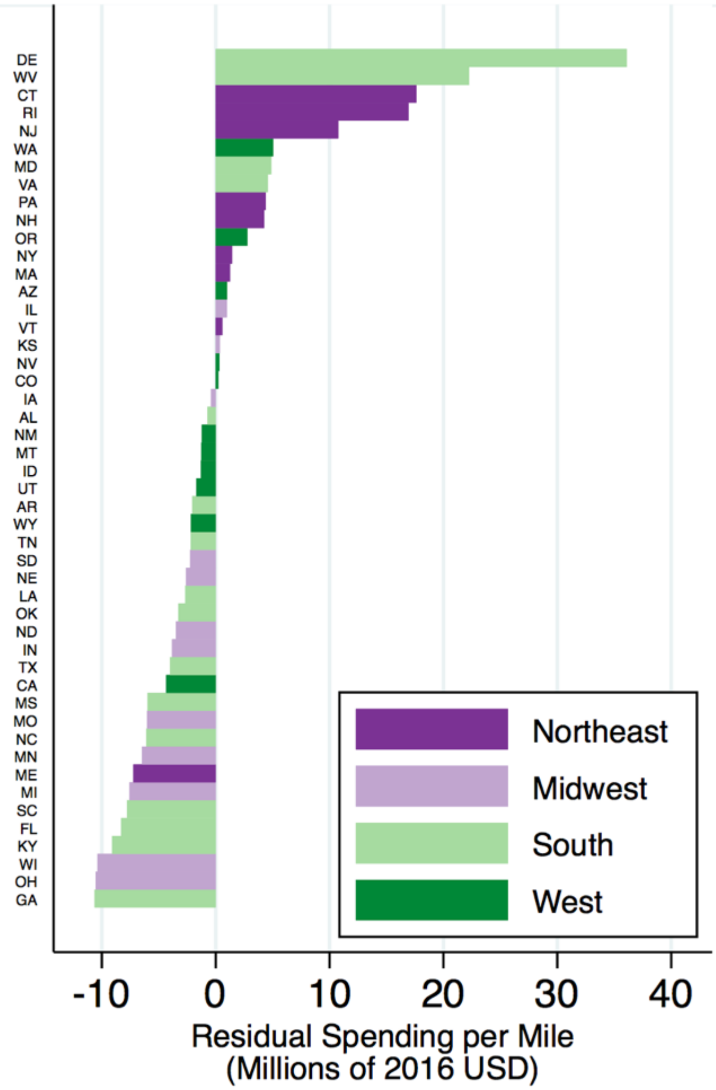


Figure 10: Increasing Wiggliness at Top of the Distribution Suggests Possible Relationship with Increasing Spending per Mile at the Top of the Distribution

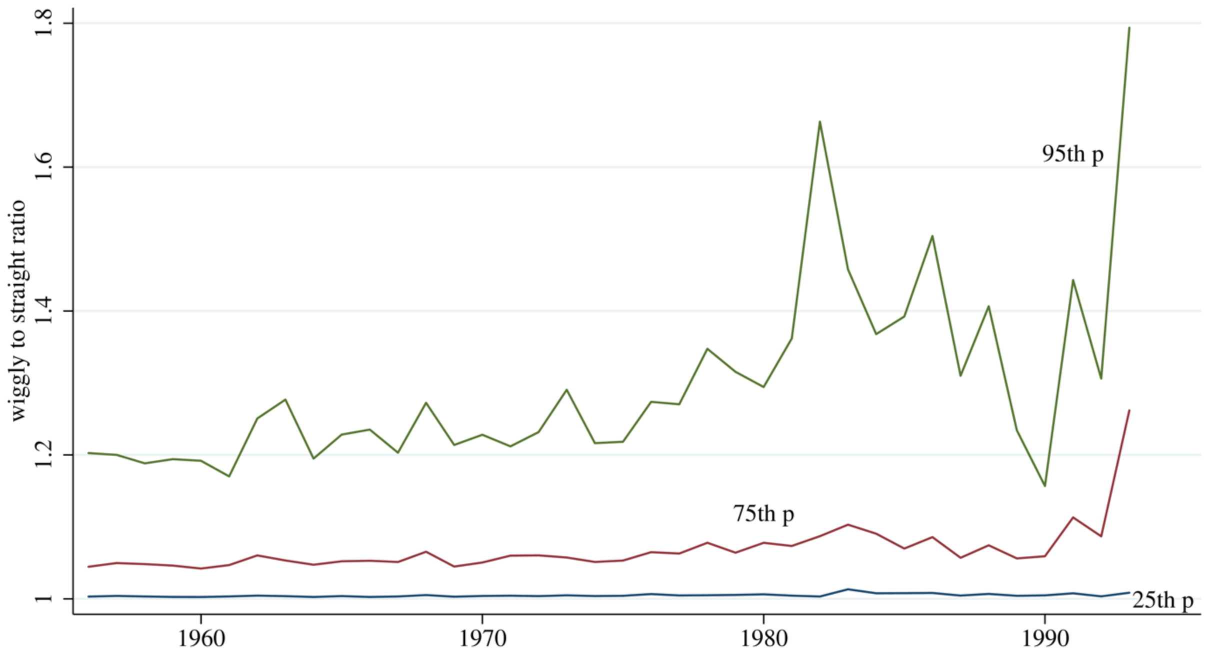


Figure 11: Average Wiggliness of Interstate Miles Over Time

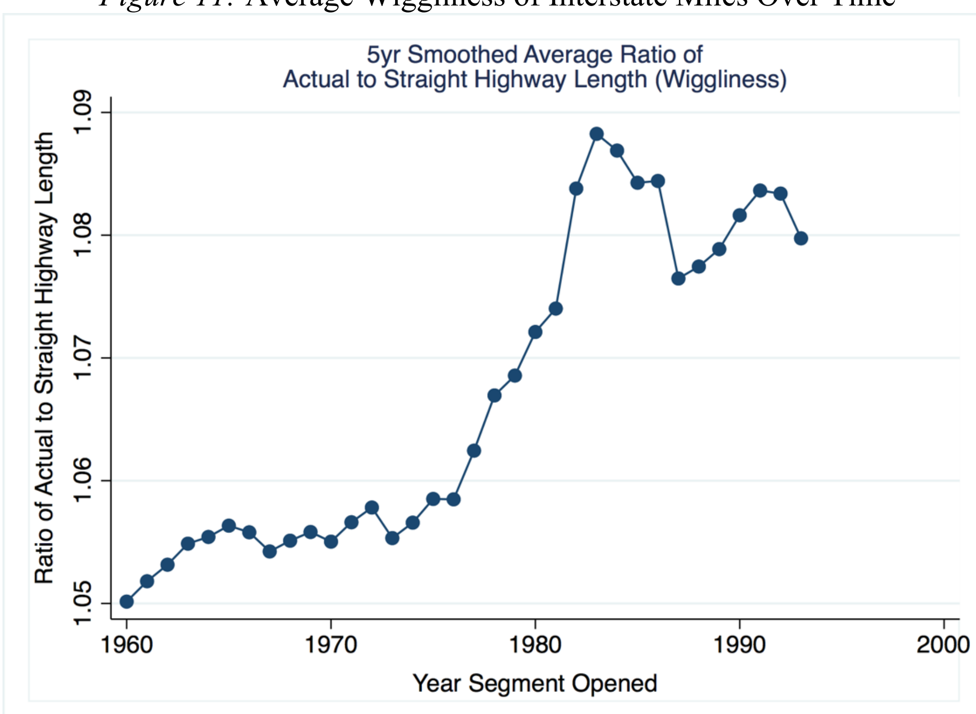


Figure 12: Labor and Material Costs Don't Explain Increasing Spending per Mile, and Diverge from It in the 1970s

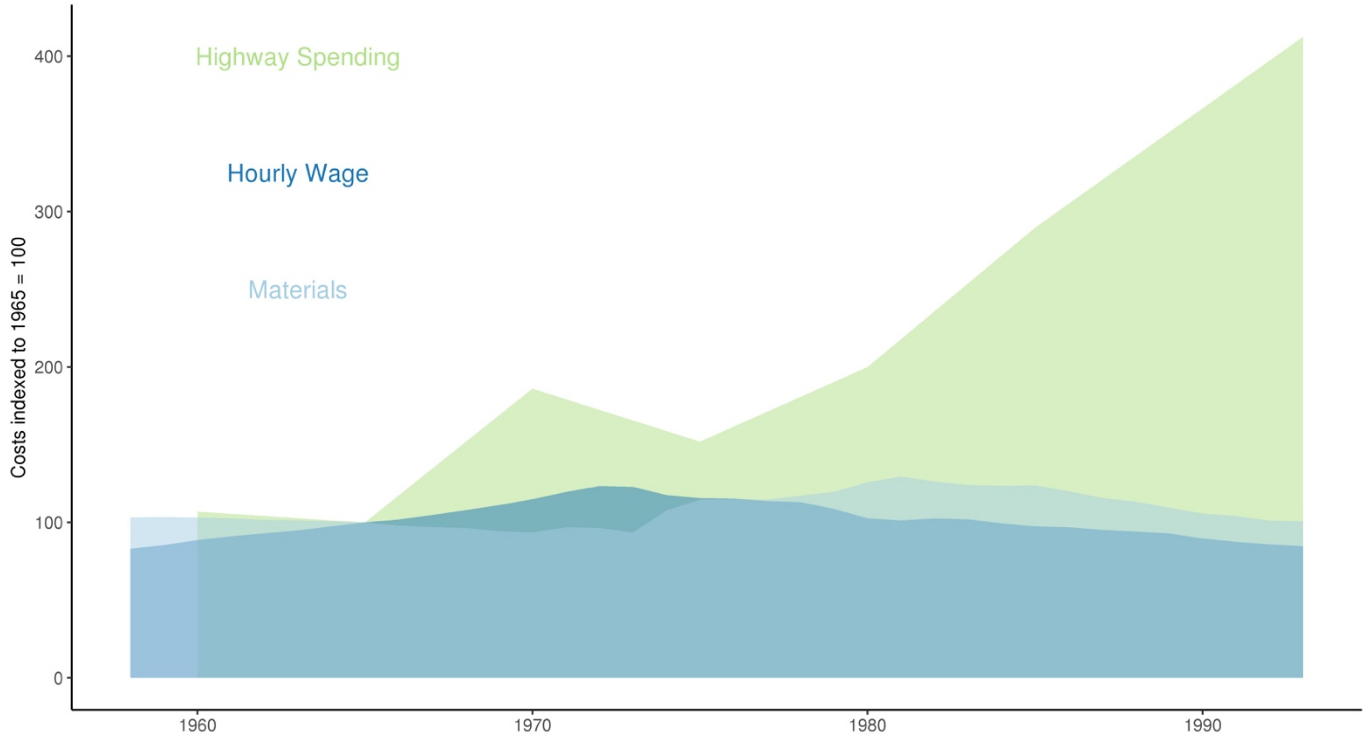


Figure 13: Share of Spending on Preliminary Engineering and Right of Way

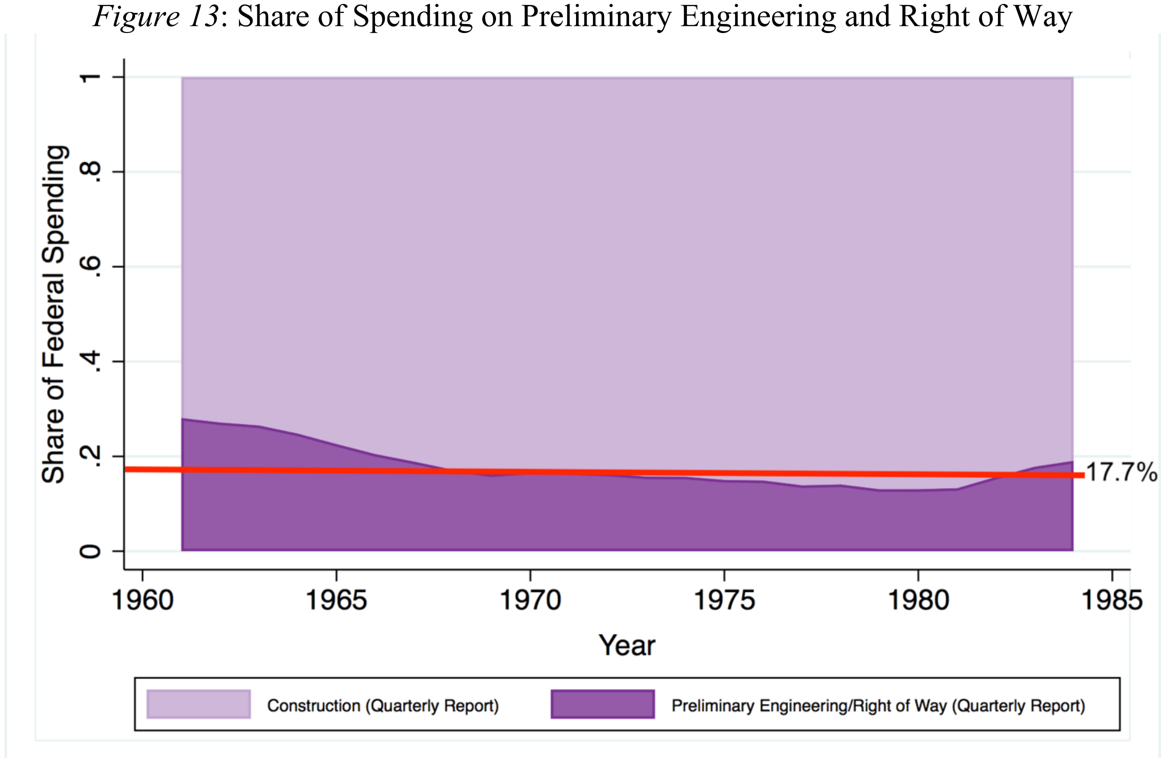


Figure 14: Share of Miles Built Slowly Over Time

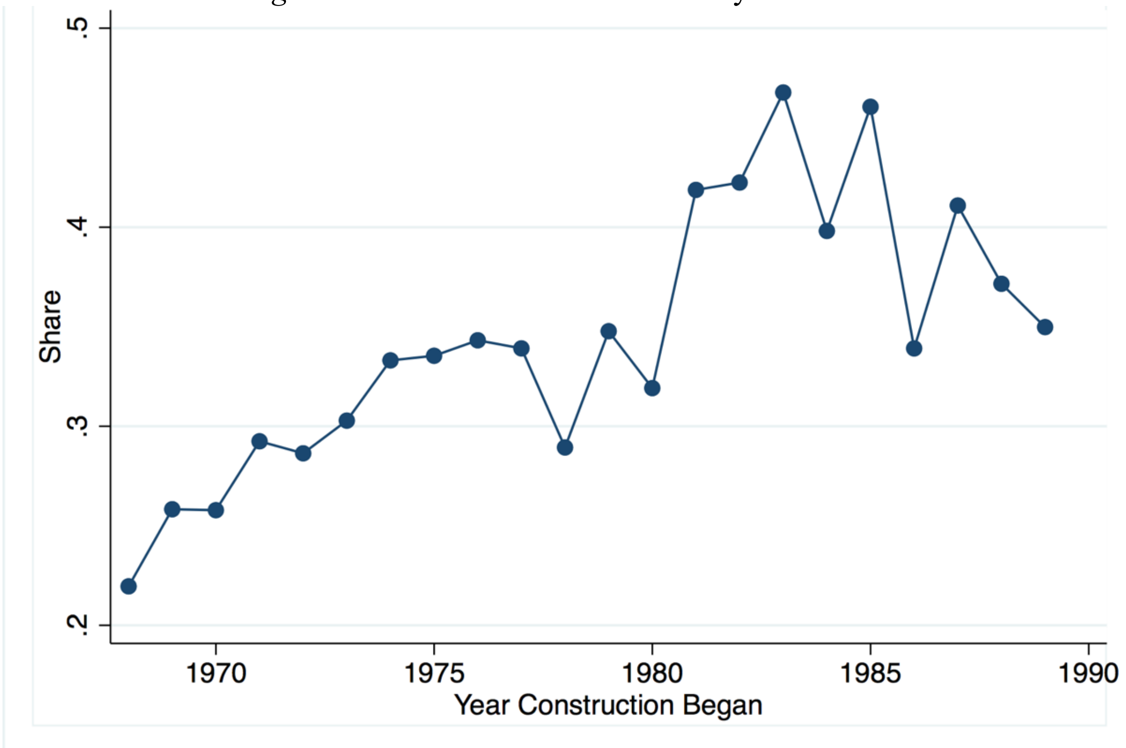


Figure 15: Share of Interstate Miles Built with Tunnels Over Time

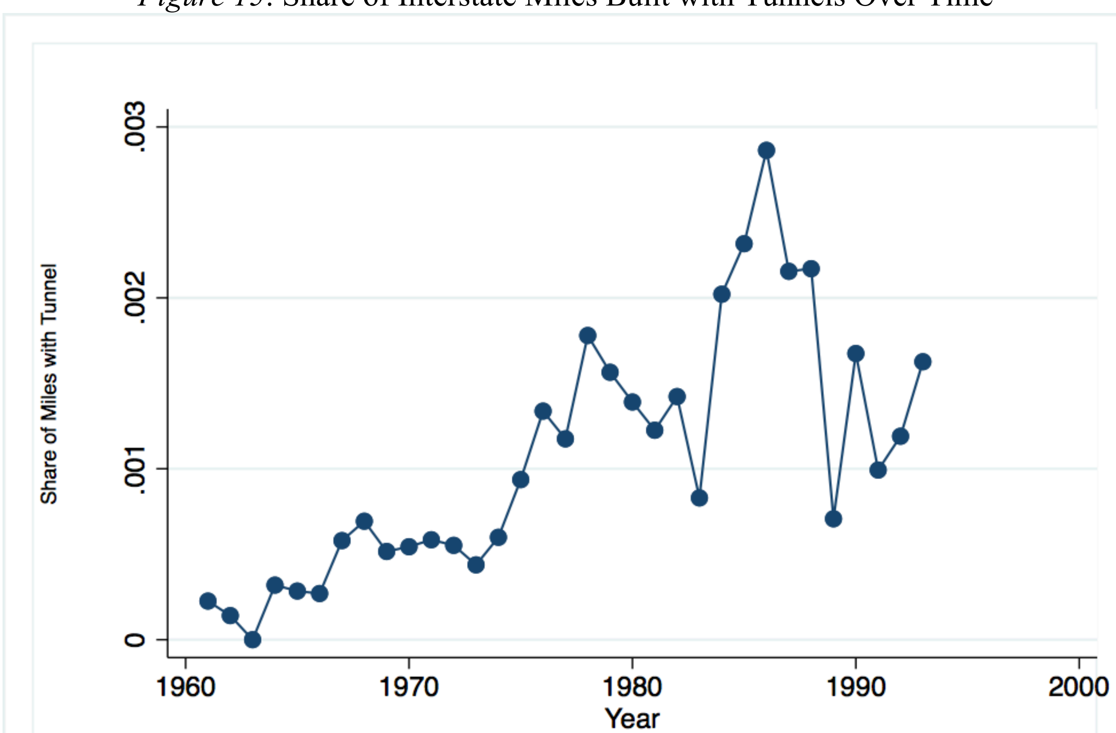


Figure 16: Interstate Bridges and Arial Highways Built Over Time

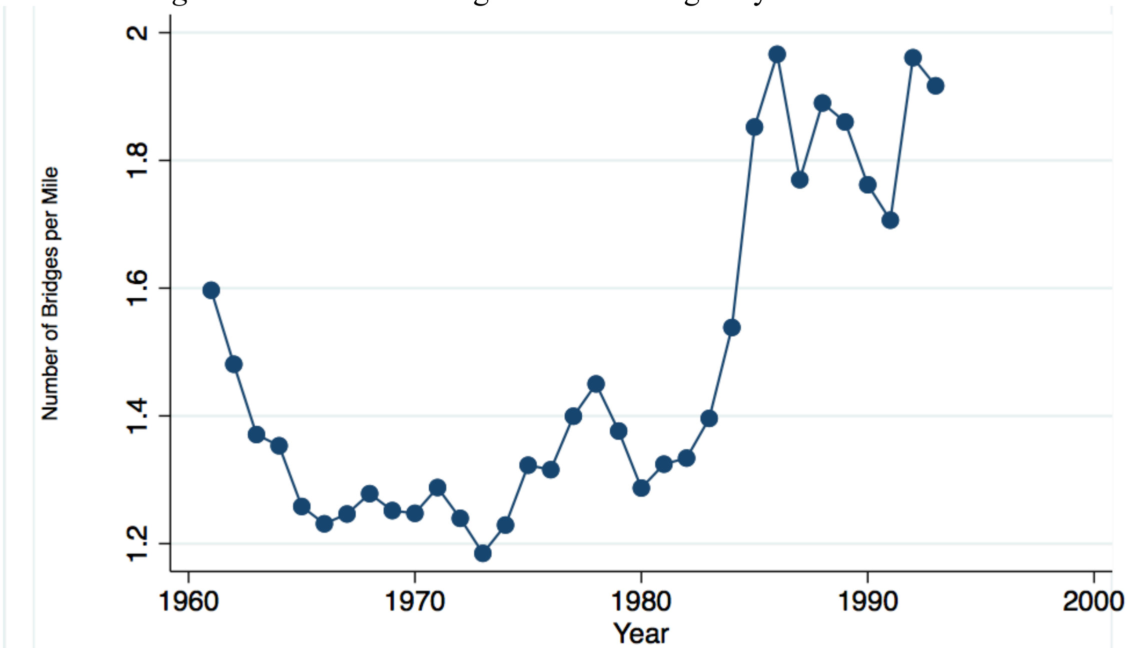


Figure 17: Interstate Ramps Built Over Time

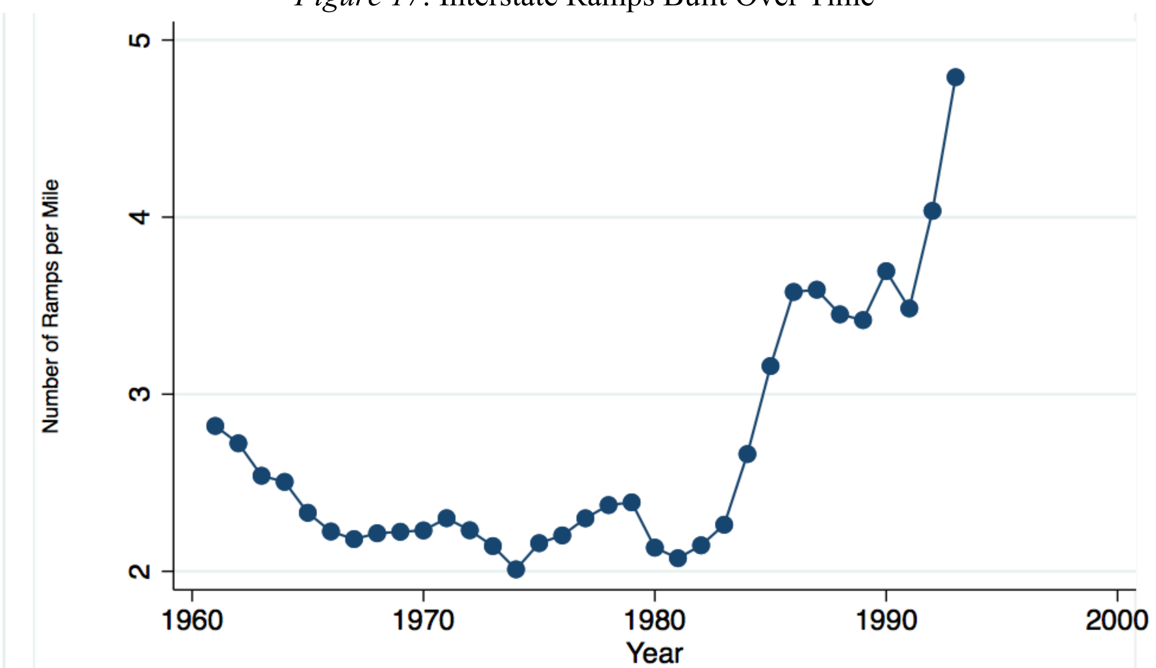


Table 1: Regressions of Spending per Mile on Possible Explanatory Variables

	(1) Spending per Mile	(2) Spending per Mile	(3) Spending per Mile	(4) Spending per Mile	(5) Spending per Mile
1[No miles completed]	-32.00***	-2.567	-42.23**	-24.29**	-3.637
	(8.063)	(9.040)	(12.96)	(8.449)	(11.91)
1965 FE	-5.402	-7.099	-6.016	-5.422	-6.585
	(5.129)	(4.871)	(4.873)	(5.387)	(4.538)
1970 FE	-6.032	-5.211	-5.503	-8.052	-5.123
	(4.682)	(5.391)	(5.092)	(5.655)	(5.786)
1975 FE	-1.711	-1.855	1.644	-6.584	-1.409
	(4.825)	(5.246)	(6.750)	(9.313)	(7.166)
1980 FE	12.37	9.253	16.66	4.961	8.954
	(8.092)	(8.132)	(11.52)	(12.78)	(10.13)
1985 FE	27.14	25.90	34.13	16.77	25.01
	(17.60)	(16.36)	(26.78)	(9.361)	(14.55)
1993 FE	20.18**	16.93*	26.89*	10.85	17.80
	(7.027)	(7.881)	(12.62)	(14.39)	(10.73)
Frac. through 1950 Tract	59.68*	43.26	61.68*	52.22	36.68
	(26.32)	(33.30)	(23.33)	(28.41)	(30.32)
Frac. through Wetland	6.235	5.194	10.01	1.139	4.255
County	(8.690)	(7.110)	(8.223)	(12.96)	(9.393)
Frac. Near 'Expensive'		22.73*			14.96
Homes		(8.445)			(8.921)
Frac. Built Wide		-25.48			-16.49
		(27.94)			(25.10)
Frac. Near >= 1 Tunnel,		83.33			85.14
Causeway, or Bridge		(48.84)			(46.23)
Dem. Vote Shr., '68 Pres.			0.859		1.095
Election			(0.665)		(0.793)
Land Use Cases per 1M			0.450		-0.740
People			(1.816)		(1.894)
Frac. through Frag'd			-19.74		-24.72
Counties			(21.10)		(19.89)
Mi. Wtd. Avg. S&P Bond				1.157	0.943
Score				(0.775)	(0.767)
Frac. Built Slowly				10.69	13.83
				(22.58)	(23.99)
Corruption Index				1.522	-0.677
				(2.786)	(3.443)
N	315	315	315	315	315
R^2	0.112	0.199	0.131	0.122	0.229
adj. R^2	0.086	0.167	0.097	0.087	0.182

Notes: Standard errors clustered at state level are displayed in parentheses. D.C. excluded. Data aggregated across seven 5 year periods for each state. LHS units in Millions of 2016 USD per mile. Column 1: Baseline. Column 2: Hwy Features. Column 3: Politics. Column 4: Gov't Efficacy. Column 5: Everything

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Regressions of Spending per Mile on Possible Explanatory Variables, Allowing Different Effects Pre- and Post-1975

	(1) Spend/Mi.	(2) Spend/Mi.	(3) Spend/Mi.	(4) Spend/Mi.	(5) Spend/Mi.
1[No miles completed]	-33.40***	4.166	-47.71**	-22.59*	0.866
	(8.478)	(10.82)	(14.83)	(9.068)	(14.99)
Frac. through 1950 Tract	21.25	-24.51	-14.39	13.19	-38.41
	(12.05)	(25.62)	(21.78)	(15.53)	(26.83)
Frac. through 1950 Tract * 1[Year > 1975]	44.26	80.73	89.97**	38.25	96.46*
	(32.63)	(45.03)	(31.70)	(36.82)	(41.16)
Frac. through Wetland County	24.72*	21.59*	22.84*	25.29	23.04*
	(12.14)	(8.388)	(8.694)	(13.16)	(9.338)
Frac. through Wetland County * 1[Year > 1975]	-31.82*	-30.99	-20.13*	-44.09	-30.33
	(14.64)	(16.28)	(9.322)	(22.76)	(15.63)
Frac. Near 'Expensive' Homes		15.50			-2.684
		(10.87)			(8.532)
Frac. Near 'Expensive' Homes * 1[Year > 1975]		21.41			38.91*
		(21.81)			(18.39)
Frac. Built Wide		13.49			15.69
		(17.28)			(19.33)
Frac. Built Wide * 1[Year > 1975]		-65.01			-60.61
		(47.46)			(45.35)
Frac. Near ≥ 1 Tunnel, Causeway, or Bridge		25.07			24.45
		(22.96)			(19.74)
Frac. Near ≥ 1 Tunnel, Causeway, or Bridge * 1[Year > 1975]		94.00			103.2
		(71.04)			(65.61)
Dem. Vote Shr., ‘68 Pres. Election			-0.00628		0.145
			(0.243)		(0.243)
Dem. Vote Shr., ’68 Pres. Election * 1[Year > 1975]			1.645		1.961
			(1.104)		(1.277)
Land Use Cases per 1M People			15.35		11.55*
			(7.930)		(5.721)
Land Use Cases per 1M People * 1[Year > 1975]			-16.04*		-13.75*
			(7.916)		(5.373)
Frac. through Frag’d Counties			51.30		38.64
			(32.22)		(27.65)
Frac. through Frag’d Counties * 1[Year > 1975]			-84.09*		-87.23*
			(38.36)		(40.82)
Mi. Wtd. Avg. S&P Bond Score				-0.480	-0.524
				(0.419)	(0.502)
Mi. Wtd. Avg. S&P Bond Score * 1[Year > 1975]				2.432*	1.812
				(0.955)	(1.126)
Frac. Built Slowly				-20.97	-15.56
				(16.18)	(20.77)
Frac. Built Slowly * 1[Year > 1975]				36.13	33.05
				(31.06)	(33.63)
Corruption Index				3.669	-0.238
				(3.089)	(2.115)
Corruption Index * 1[Year > 1975]				-2.908	-1.491
				(4.252)	(5.329)
N	315	315	315	315	315
R^2	0.123	0.244	0.164	0.142	0.309
adj. R^2	0.092	0.201	0.117	0.093	0.239

Notes: Standard errors clustered at state level are displayed in parentheses. D.C. excluded. Year fixed effects not shown. Data aggregated across seven 5 year periods for each state. LHS units in Millions of 2016 USD per mile. Col. 1: Baseline. Col. 2: Hwy Features. Col. 3: Politics. Col. 4: Gov't Efficacy. Col. 5: Everything. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix A - Data Summary and Variable Construction

Table A1: Summary Statistics for Variables Appearing in Equation (1) Regression.

	All Years	1956-1974	1975-1993
Federal Expenditures in 5yr Period; Millions of 2016 USD	24.65	14.78	32.06
	(52.93)	(22.61)	(66.36)
Frac. Mi. Completed in 5yr Period that were Built through	0.09	0.07	0.10
Area Tracted by 1950	(0.16)	(0.10)	(0.19)
Frac. Mi. Completed in 5yr Period that were Built through	0.19	0.21	0.18
Wetland-Dense County	(0.31)	(0.30)	(0.32)
Frac. Mi. Completed in 5yr Period that were Built Near	0.35	0.35	0.35
Interstate Structures	(0.22)	(0.18)	(0.25)
Frac. Mi. Completed in 5yr Period that were Built Wide	0.24	0.23	0.25
	(0.27)	(0.24)	(0.28)
Frac. Mi. Completed in 5yr Period that were Built Near	0.22	0.22	0.21
Expensive Homes	(0.30)	(0.27)	(0.32)
Pct. of Vote to Dem. in 1968 Pres. Election	39.37	39.37	39.37
	(8.89)	(8.91)	(8.90)
Land Use Cases per 1M People	1.29	0.53	1.86
	(2.04)	(0.59)	(2.50)
Frac. Mi. Completed in 5yr Period that were Built through	0.17	0.02	0.27
Fragmented Counties	(0.29)	(0.07)	(0.35)
Boylan and Long (2003) Corruption Index	0.01	0.01	0.01
	(0.73)	(0.73)	(0.73)
Mi. Wtd. Avg. S&P Bond Rating Score	2.21	0.87	3.21
	(3.80)	(2.54)	(4.25)
Frac. Mi. Completed in 5yr Period that were Built Slowly	0.26	0.05	0.42
	(0.33)	(0.12)	(0.35)
Observations	315	135	180

Notes: Mean displayed with standard deviation in parentheses. Variables represent data aggregated across 5-year periods (e.g., 1956-1960).

I. Variable Construction

We study the relationship of highway spending with a variety of variables, which we get from many sources. This appendix reviews the sources and construction for each variable. Where available, we use data at relatively fine geographical and temporal granularities (tract or county, and year), which allows us fullest use of our knowledge of where and when Interstate mileage opened. For policy topics where we observe only state-level values or values at a single point in time, we are not able to take advantage of this same knowledge.

Two brief notes on the construction of our variables. First, many make use of supporting datasets, from the Census in particular. These supporting datasets are documented below:

State and County level

- 1940: ICPSR 02896, Historical, Demographic, Economic and Social Data: The United States, 1790-2002, Dataset 38: 1950 Census I (County and State)
- 1950
    - ICPSR 02896, Historical, Demographic, Economic and Social Data: The United States, 1790-2002, Dataset 38: 1950 Census I (County and State)
    - Census of Population, 1950 Volume II, Part I, Table 32.
- 1960: ICPSR 02896, Historical, Demographic, Economic and Social Data: The United States, 1790-2002, Dataset 38: 1960 Census I (County and State)
- 1970: ICPSR 8107, Census of Population and Housing, 1970: Summary Statistic File 4C -- Population [Fourth Count]
- 1980: ICPSR 8071, Census of Population and Housing, 1980: Summary Tape File 3A
- 1990: ICPSR 9782, Census of Population and Housing, 1990: Summary Tape File 3A
- 2000: ICPSR 13342, Census of Population and Housing, 2000: Summary File 3
- 2010: U.S. Census Bureau, 2010 Decennial Census Summary File 1, Downloaded from http://www2.census.gov/census_2010/04-Summary_File_1/
- 2010 (2008-2012): U.S. Census Bureau, American Community Survey, 5-Year Summary File, downloaded from http://www2.census.gov/acs2012_5yr/summaryfile/2008-2012_ACSSF_All_In_2_Giant_Files\%28Experienced-Users-Only\%29/

Tract level

- Shapefiles
    - 1940, 1950, 1960, 1970, 1980 from NHGIS (Minnesota Population Center. National Historical Geographic Information System: Version 2.0. Minneapolis, MN: University of Minnesota 2011)
    - 1990 through 2010 from block group shapefiles provided by the US Census Bureau on their website.
- Historical Data
    - 1940, 1950, 1960 form NHGIS (datasets 76, 82, and 92)

- 1970, 1980, 1990 and 2000 from the Interuniversity Consortium Political and Social Research (1970: Summary Tape File 4a #6712, 1980: Summary Tape File 3a #8071, 1990: Summary Tape File 3a #9782)
- 2010 (officially the 5-year estimates for 2008 to 2012 from the American Community Survey) directly downloaded from the Census website.

Second, our Interstate data from Baum-Snow (2017) partitions the Interstates into roughly mile-long segments. These Baum-Snow segments underlie many of our measures (e.g., the fraction of miles in a given state-year that pass through counties with characteristic X). Because the provided data only contain the beginning and end points of a given segment, we generally approximate the segment length as the linear distance between these two points. We have begun to tighten this approximation, exploring the 'wiggliness' of segments over time (see final measure below), for future iterations of this study.

a. Urban Geography
We construct a state-level measure of the urban-intensivity of miles built in a given year using data on which areas of the country had been assigned a census tract by 1950. Whether an area was tracted circa 1950 is a good indicator for whether the area was and is urban (United States 1947). We therefore define a given segment to have been built through an urban area if any part of that segment passed through a 1950 census tract. Our state-level measure for a given year is then the share of miles opened in that year that were built through these tracts.

b. Wetland Geography
To assess whether the highway is near a wetland, we overlap a wetlands map from the US Fish and Wildlife Service with our map of counties and Baum-Snow (2017) Interstate segments (US Fish and Wildlife Service 2018). For each county a segment passes through, we compute the density of wetland within the county as the fraction of the county's area designated as wetland. We then define a segment to have been built through a wetland-intensive area if this county density was in the top 20 percent, nationally and across time, among segments. Our state-level measure for a given year is then the share of miles opened in that year that were built through these wetland-intensive counties.

c. Land Use Restrictiveness
Our study of local land use regulatory regimes is based a historical tabulation of land uses cases from Ganong and Shoag (2017). Available for each continental state, and each year from roughly 1940 to 2010, this tabulation represents the number of cases (per million people) in which the phrase "land use" appears in a state supreme or appellate court case (Ganong and Shoag 2017). Our state level measure for a given year is then simply this count of cases per million in the year, rescaled to the number of cases per thousand.

d. State Government Corruption
We also use a corruption index developed in Boylan and Long (2003). Their index is a normalized average of the responses of surveyed State House reporters in each state (excepting NH, NJ, and MA) to 6 questions about fraudulence, bribery, overall corruption, and group-specific (e.g., legislatorial) corruption within state government (Boylan and Long 2003). Higher values of the index indicate greater levels of perceived corruption among respondents. The

survey was carried out from March 1998 to March 1999, so the data is only available for one point in time, though we take the index to reflect states' levels of corruption across our study period (Boylan and Long 2003).

e. Government Fragmentation
We construct a measure of government fragmentation using Willamette University's Government Finance Database, a compilation of the historical Censuses and Annual Surveys of Government (Pierson et al., 2015). Though the Government Finance Database has data since 1962.[51] The database contains the Census of Governments, which surveys the universe of governments in the U.S. every five years, and the Annual Survey of Governments, which surveys a sample in the intermediate years (United States 2018). We then linearly interpolate between census years to yield a dataset of the number of local governments (including special governments and school districts) in each county and year. We subsequently define a county to be have a "fragmented" government if the number of local governments within the county is in the top twenty percent across all states and years. Our state-level measure of government fragmentation for a given year is then the share of miles opened in that year that were built through counties with fragmented governments.

f. Time to Complete
To examine the relationship between the time to complete a segment of Interstate mileage from the start of construction, we used data reported on the FHWA's PR-511 forms, digitized and made available to us by Nate Baum-Snow (Baum-Snow 2007). These forms report the date a segment opened to traffic for 99.9 percent of funded segments for which we have data, as well as the date that construction started. The date of construction starting is indicated by a movement from "Status Group 4" (indicating "[p]reparation of plans, specifications and estimates, and/or right-of-way acquisition") to "Status Group 3" ("under construction, not open to traffic") (Weingroff 2017c). We have both pieces of data for a sample of the segments, ranging from 40% in 1982 to just over 90% in 1972. We define completion time for a segment as the difference between the open date and the date construction started. We in turn define a segment to have been built "slowly" if its completion time was in the top twenty percent of length, which was four or more years. Our state-level measure for a given year is then the share of miles opened in that year that were built slowly.

g. Democratic Share
To measure a state's political leanings, we use the 1968 state Presidential vote share. We took the state's vote share for the Democratic candidate to represent its political leaning for the years in our study period, 1956 to 1993 (Federal Election Commission 2017, Leip, Willamette). We additionally took the change in a state's Democratic vote share between the 1968 and 1980 election to represent the change in the state's political leaning from the 60s to the 80s.

h. Structure Proximity
To examine the presence of, and proximity to, Interstate highway structures, we used a measure based on counts of nearby Interstate bridges, tunnels, and causeways.[52] Data on these highway

[51] The Census of Governments has been carried out since 1957, but we do not include years before 1962 because they were not included in the dataset and inclusion would require significant digitization.
[52] For definitions, see U.S.C. 23 CFR §650.305 and the HPMS 2016 Field Manual (United States 2016).

structures come from the Highway Performance Monitoring System (FHWA 2016a), which we matched to our dataset of Interstate segments provided by Nate Baum-Snow (FHWA 2016a, Baum-Snow 2007). On the assumption that these structures are constructed in the same as that of nearby segments' openings, we can count the number of proximate structures these structures were built with. To account for mild spatial mismatch, we count the number of structures within 4km of a given segment. We then define a segment as constructed "near an Interstate highway structure" if it was built within 4km of a least one Interstate tunnel, bridge, or causeway. Our state-level measure (measures counting the more stringent) in a given year is thus the share of miles opened in that year that were near an Interstate highway structure.

i. 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 time 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 drop state-years for which a state had not yet been rated or was otherwise "Not Rated." To convert each rating to a numerical score, we assign AAA to a score of 0 then to each of the three classes AA+ to AA-, A+ to A-, and BBB+ to BBB- a score equal to the percent change from the interest rate on a 10-year municipal bond graded in the middle of the class (e.g., AA for the AA+ to AA- class) to the interest rate on a 10-year municipal AAA bond (Violette 2018). Our state-level measure of a state's fiscal responsibility in a given year is thus the converted bond rating in that year.

j. Interstate Width

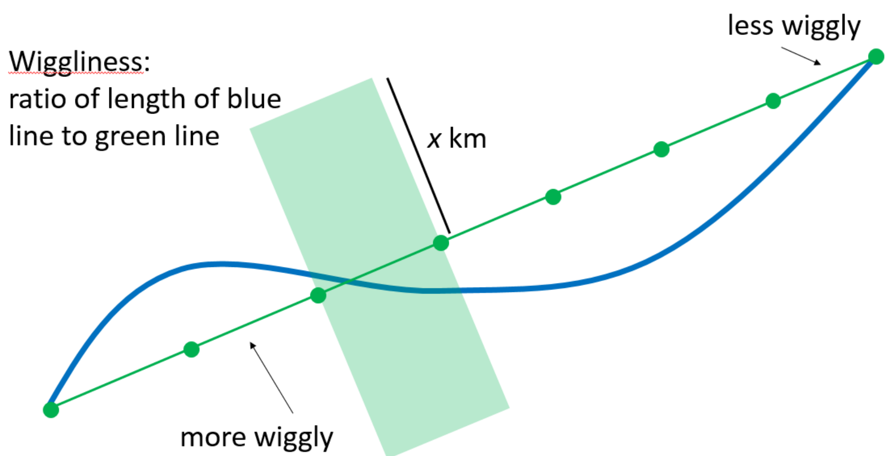
We also measure the approximate width of Interstate mileage using data from the Highway Performance Monitoring System (HPMS) on the number of lanes that make up an Interstate segment (FHWA 2016a). HPMS data is provided in a geographic shapefile, as is our mile segment data that Nate Baum-Snow provided (FHWA 2016a; Baum-Snow 2007). To account for mild spatial mismatch between the two, we take the number of lanes in a given segment from the Nate Baum-Snow data to be the average of the number of lanes among HPMS segments within 4km. We then define a segment of Interstate mileage as "wide" if our measure exceeds 4 lanes for the segment. Our state-level measure of width in a given year is thus the share of miles opened in that year that were wide as of 2016.

k. Housing

To measure land value/acquisition costs, we use data on median home values from the decennial U.S. Census, digitized in a number of sources (Haines et al 2010, Minnesota Population Center 2001, Sylla et al 1993, United States 2006a, United States 2006b, United States 2008a, United States 2008b, United States 1988, United States 2012). Collectively, these sources provide tract data on median home values for 1980 and 1990, and county data on median home values for all the decadal years from 1950 to 1990. With each segment, we associate the more granular measure of median home value available—tract or county (generally county pre-1980, generally tract in 1980 and 1990). We then define the segment to have been built in an "expensive area" if, among other segments built in the same decade, its corresponding median home value was in the top 20 percent. Our state-level measure in a given year is then the share of miles opened in that year that were opened in expensive areas.

l. 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). We generate the ratio of “wiggly” to straight length of highways by taking the former (linear) highway segments map and drawing a rectangle perpendicular to each Baum-Snow segment. See the picture below for intuition. The rectangle is 4 km long (2 km from each side of the straight line) and one mile wide.



We then count and measure the length of all “wiggly” segments from the auxiliary Baum-Snow map that fall into this rectangle. Of the linear segments, 83 percent match to one curvy segment. If there is a wiggly segment that matches the interstate number of the straight segment, we call this a match and calculate the “wiggly/straight” ratio from this match. This accounts for about 83 percent of all straight segments. We can reliably match approximately 95 percent of all straight segments. We anticipate using this segment-level measure to construct a state-level measure for a given year by thresholding the wiggly/straight ratio and computing the fraction of miles built in that year with wiggly/straight ratio above the chosen threshold.

Appendix B - Ancillary Results

Table B1: Spending per mile trends in 50th and 75th percentiles (relative to 25th percentile) among states over 1956-1993 (5 year periods)

	(1) 5 Period Spending	(2) 5 Period Spending
Year (Linear)	0.247	-0.444
	(0.248)	(0.349)
1{50th Percentile}	-790.9	
	(693.8)	
1{75th Percentile}	-2414.9***	
	(693.8)	
Year * 1{50th Percentile}	0.404	0.00179
	(0.351)	(0.00178)
Year * 1{75th Percentile}	1.234***	0.00583***
	(0.351)	(0.00178)
Year * 1{Year > 1975}		0.722
		(0.475)
1{Year > 1975}		-1419.0
		(937.6)
1{50th Percentile} * 1{Year > 1975}		-1557.9
		(902.9)
1{75th Percentile} * 1{Year > 1975}		-4371.5***
		(902.9)
Year * 1{50th Percentile} * 1{Year > 1975}		0.789
		(0.455)
Year * 1{75th Percentile} * 1{Year > 1975}		2.214***
		(0.455)
N	21	21
R^2	0.846	0.958
adj. R^2	0.795	0.924

Notes: Data aggregated across 5 year periods (e.g., 1956-1960, 1961-1965, etc.) for each state. LHS units in Millions of 2016 USD. Constant not shown.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix C - Cleaning Interstate Expenditures Measure

We measure spending on Interstates using the Interstate column in Table FA-3 of FHWA's *Highway Statistics* series. Changes in the Interstate funding laws and anomalies in the expenditure data, however, made us suspect that the Interstate expenditures from Table FA-3 were not all money spent on Interstates. The two changes were the introduction of the Interstate Withdrawal-Substitution Program and the requirement, starting in 1982, that all states receive at least half a percent of each year's apportionment—which we refer to as the Minimum Apportionment. In what follows, we outline the legislative history of these two programs, present evidence for why we suspect these two programs contaminate the Interstate column of in Table FA-3 and explain the changes we made to the Interstate expenditures measure to account for these two programs. Then we discuss the new interstate expenditure measure and additional spending on Interstates that we may be missing.

I. Legislative History

a. Interstate Withdrawal-Substitution Program

The Interstate Withdrawal-Substitution Program came out of states' desires to deviate from the planned Interstate routes. The first such program was the Howard-Cramer Provision of 1968, which allowed states to withdraw planned routes and replace them with alternate routes of equal cost.[53] 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 in an urbanized area of the state and use the money instead for mass transit projects in the area.[54] The Federal-Aid Highway Act of 1976 altered the program so that States could also withdraw Interstate segments connecting urbanized areas. It allowed them as well to use the money from the withdrawn portion for non-Interstate highway projects.[55]

Save for a slight modification in the Federal-Aid Highway Act of 1978 that prohibited the withdrawals of Interstate segments after September 30, 1983,[56] 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.[57] After the passage of the 1982 law, the government made available set amounts of money each year for substitution projects. 25% of the funds made available each year were to be allocated at the discretion of the Department of Transportation. The other 75% of the money was allocated by formula: states were apportioned the fraction of the money that corresponded 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 via this formula for fiscal years 1984 through 1991. The money apportioned was available to be obligated for two years, after which the money apportioned would be withdrawn. Finally, the law allowed states to withdraw and substitute planned rural Interstate segments.[58]

[53] Public Law 90-238
[54] Federal-Aid Highway Act of 1973 (Public Law 93-87) Section 137(b)
[55] Federal-Aid Highway Act of 1976 (Public Law 94-280) Section 110(a)
[56] Federal-Aid Highway Act of 1978 (Public Law 95-599) Section 107(b)
[57] 1976 U.S. Code Title 23 103(e)(4)
[58] 1988 U.S. Code Title 23 103(e)(4),

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. The fiscal year of 1995 was the last year in which the U.S. apportioned money to states for highway substitute programs.

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 no more Interstates to spend the money on, 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 of their interstate systems.[59] Starting with the Federal-Aid Highway Act of 1973, highway legislation extended the Minimum Apportionment rule through fiscal year 1990 and specified that money apportioned under this rule that exceeded the cost to complete of the Interstate highway system could be spent on other Federal-Aid highways.[60]

The law left some ambiguity as to how the money apportioned under this rule would be tracked. The early laws pertaining to the Minimum Apportionment rule suggest that money that exceeded the cost to complete of 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 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 would be tracked according to the Federal-Aid category to which it was reapportioned. 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,"[61] which leaves

[59] Section 105(b)
[60] 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.
[61] Section 104(b)(1)

open the possibility that Interstate apportioned funds spent on other Federal-Aid Highways were considered Interstate expenditures for Table FA-3 purposes.

II. Issues in the Data

a. Interstate Withdrawal-Substitution Program

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.

We have good reason to believe that before 1992, expenditures on substitute projects were included in the Interstate expenditures measure in Table FA-3 of FHWA's *Highway Statistics* series. Take, for example, Rhode Island. In our mileage data, the state last opened Interstates in 1976, when it opened 16 miles of highway. Rhode Island opened no new mileage after that. From 1977 to 1982, Rhode Island had two remaining Interstate projects. However, local opposition led the state to withdraw the planned mileage in 1982 (FHWAOE 1998). The projects it withdrew had a total withdrawal value of $592 million.

In the Interstate expenditure data, Rhode Island had very light expenditures (usually no more than $10 million a year) from 1977 to 1982. It is conceivable that these expenditures had to do with preparations for the two Interstate projects Rhode Island had left. After 1982, Rhode Island's expenditures skyrocket—never dipping below $20 million from 1983–1985 and never dipping below $60 million from 1986 to 1991. These expenditures then collapse in 1992, when they fall below $20 million and quickly fall below $10 million. Rhode Island, though, opened no new Interstate mileage from 1977–1993. These massive Interstate expenditures in Rhode Island despite not having any remaining Interstate projects are strong evidence that money spent on substitute projects are included as Interstate expenditures in Table FA-3.

We checked the trends in Rhode Island's expenditure data against information from the FHWA's Office of Engineering 1998 report, which detailed all segments of the Interstate system that were withdrawn under the Withdrawal-Substitution Program. According to the report, Rhode Island obligated a total of $642.3 million dollars to substitute projects after withdrawing its Interstate projects in 1982 (FHWAOE 1998). Looking back at the Interstate expenditure FA-3 data, Rhode Island spent about $470 million on Interstate expenditures from 1983 to 1991 despite not opening a new mileage. Interstate expenditure collapse starting in 1992, and, conversely, Rhode Island spent $260 million on Interstate Highway Substitute expenditures in the years after 1992 (remember, this variable only appears starting in 1992).

A visual look can clarify the dynamics. Appendix C Figure C1 below shows Rhode Island Interstate expenditures from 1970 to 1997 and Interstate Highway Substitute expenditures from 1992 to 1997. The solid line shows the last year in which Rhode Island opened new mileage, and the dotted line show the year in which Rhode Island withdrew its remaining planned Interstate mileage. After the dotted line, Rhode Island's Interstate expenditures surge until they collapse suddenly in 1992, when the Interstate Highway Substitute expenditures series begins. This evidence suggests that states' expenditures on substitute projects were classified as

Interstate expenditures until 1992, when the Interstate Highway Substitute variable began. Evidence from other states that withdrew Interstate mileage supports this conclusion.

There is one caveat about the kind of substitute spending shows up as an Interstate expenditure. Recall that the money made available from Interstate withdrawal could be spent on two types of projects: transit projects or non-Interstate highway projects. It appears that if the substitute money was spent on transit projects, the money did not show up as Interstate expenditures. As evidence, consider the case of Massachusetts. Massachusetts withdrew Interstate projects in 1974 and obligated around $1.5 billion dollars from this withdrawal to transit projects (FHWAOE 1998).

[*Figure C1*: Rhode Island Expenditures Over Time]

However, as Appendix C Figure C2 shows, Massachusetts barely spent around $100 million a year from 1974 to 1987 while opening over 30 miles of Interstate. This means that if the amount spent on transit projects was counted as an Interstate expenditure, Massachusetts' true Interstate expenditure would be close to zero from 1974 to 1987, which seems unlikely given how many miles of Interstate they opened in that time period. Our best guess for what is going on is that the substitution money was counted as Interstate expenditure if it was obligated to highway substitute projects but not if it was obligated to transit substitute projects. There is evidence that this might be the case based on the law governing the Withdrawal-Substitution Program. The 1976 U.S. Code states that "sums obligated for mass transit projects shall become part of, and administered through, the Urban Mass Transportation Fund,"[62] meaning that the money was no longer considered highway money. It is therefore plausible that FHWA would not have recorded expenditures of money on transit substitute projects as Interstate expenditures while it would have recorded expenditures on highway substitute projects.

[*Figure C2*: Massachusetts Expenditures Over Time]

b. Minimum Apportionment

We would have hoped that if states spent Interstate apportionment money on things other than Interstates, then the expenditure would have been recorded in the corresponding category on which the money was spent rather than the Interstate expenditure FA-3 category. This does not appear to be the case. For example, North Dakota did not open new mileage after 1977 and had a cost to complete of their highway system of 0 since 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 occurs in Delaware, which regularly recorded yearly Interstate expenditures above $10 million in the 1980s despite having a cost to complete of 0 since at least 1982 (DoT 1983). For these reasons, we believe that if states received money as a result of the Minimum Apportionment rule, expenditures of this money were recorded as Interstate expenditures regardless of what they were actually spent on.

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

a. Interstate Withdrawal-Substitution Program

[62] Title 23 Section 103(e)(4)

From FHWA's Office of Engineering, we know exactly how much money each state obligated to substitute highway projects and when they withdrew their Interstates. Table FA-3's Interstate Highway Substitute expenditure variable tracks how much substitute money was spent after 1991 (FHWAOE 1998). We therefore know how much money must have been spent before 1991. Using Table FA-4's Interstate Highway Substitute apportionment data, we use an algorithm to determine how much expenditure by year should be removed from the Interstate expenditure variable to account for money spent on substitute projects.

Withdrawal-Substitution Algorithm

1. Calculate total amount apportioned for the Interstate Highway Substitute. This is a variable available from the years 1983 to 1994, meaning that it is the apportionments for the FY1985-1996.
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 Calculation (1) – Calculation (2). The idea is that if they were apportioned the money and did not spend it in the years after 1991, this must have been spent between 1985 and 1991. This idea might be a bit of a stretch, as the money could have been apportioned but never used. We assume this is negligible.
4. We impute the minimum amount spent (the reason why it's only the minimum amount will become clear later) on substitution projects each year from 1985 to 1991 using the following method.[63]
    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 Calculation (4a)
    c. Because apportionments in a few states drop off very quickly (much more quickly than expenditures. In fact, some substitution states get no apportionment for the last two years), if the percentage in any one of the years 1990 and 1991 is less than 5% then replace the amount in (4b) with 5%. The amount added to these years is removed from the other years in proportion to the amount in Calculation (4b).
    d. Calculate the minimum amount spent on substitute projects each year by multiplying Calculation (3) by Calculation (4c).
5. Remove the minimum substitution amount results from Calculation (4) from the expenditure variable
6. Subtract Calculation (1) from the total amount obligated to highway projects (from FHWA OE 1998)
7. We determine the amount of expenditures that, when used as a ceiling for expenditures (adjusted by Step 5) from the date of withdrawal approval to 1991, removes enough expenditures from those years to account for the amount in Calculation (6).

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

8. Set the amount from Calculation (7) as the ceiling for expenditures from the year of first withdrawal to 1991.[64]

b. Minimum Apportionment

To account for non-Interstate spending as a result of the Minimum Apportionment rule, we used the Interstate Cost Estimates (ICE) produced by FHWA. These were 15 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 only 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 of their Interstate system as a reported in the Interstate Cost Estimates. 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
2. Interpolate the cost to complete (C2C) as reported in the ICE. The ICEs were not produced every year but rather only when requested by Congress, which was usually every two or three years. To determine the cost to complete of a state's system in a year in which an ICE was not produced, we linearly interpolated the cost to complete from the years that were reported.
3. Identify the years in which the interpolated C2C was less than the amount apportioned for that year.
4. If a year x satisfies (2), then replace that year's Interstate expenditure with [year x C2C - year $x-1$ C2C], so long as that value is less than the given state's spending in year x.
5. Since Interstate Cost Estimates only go until 1990, we assume that the Interstate Cost estimate for 1991, 1992, and 1993 is also 0 if 1990 is zero. Otherwise, we make no guesses about the Interstate Cost Estimate. Therefore, we make no changes in expenditures for states for which the 1990 C2C is more than zero.

IV. Results

Appendix C Figure C3 below shows the evolution of the Interstate expenditure measure as we account for 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 when the highway substitution spending is accounted for, and the green line show expenditures when both highway substitution and the minimum are accounted for. The lines begin to diverge in the mid-70s, but the period of largest divergence occurs in the second half of the 80s.

[64] 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% discretionary fund of FHWA, not just the apportionments by formula (see Section I(a) of this Appendix).

[*Figure C3*: Cleaned U.S. Expenditure Over Time]

Appendix C figure C4 shows the share of the original total U.S Interstate real expenditure removed by accounting for the Withdrawal-Substitution Program and the Minimum Apportionment Rule. The share removed due to the Substitution program is less than 10% each year from 1977 to 1984. After 1984 there is a surge in the removal, with the share removed as a result of the Substitution program never dipping below 10% through 1991. Since the Interstate Highway Substitute variable in the *Highway Statistics* series starts in 1992, there is no more removal as a result of the Substitution program after 1991. The amount of real expenditures purged due to the Minimum Apportionment program is smaller than the amount removed by the Substitution program, but its influence grows over time. In total, the share of real expenditures removed by the Substitution program from 1977 to 1993 is 7.7%, while the share removed because of Minimum Apportionment rule is 2.8%

[*Figure C4*: Share Removed From Original Expenditures]

We make a couple of notes about the final expenditure measure. 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 depended on the year of the money spent, but it required 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.

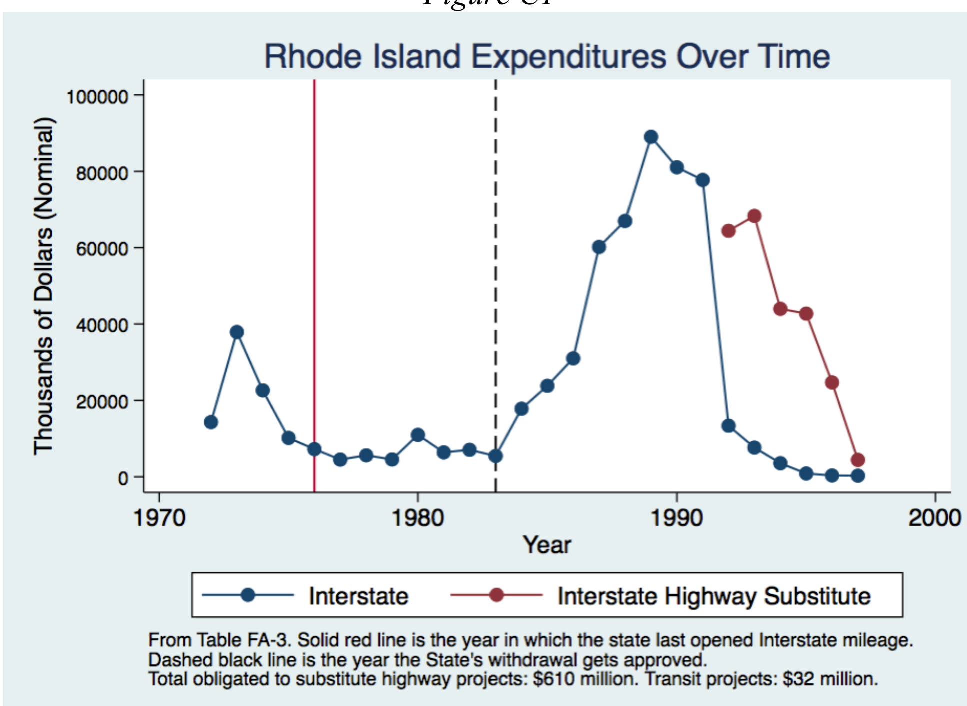
Second, we may be overestimating the amount to be removed as a result of the Minimum Apportionment program. Our method for dealing with the minimum issue is to use the Interstate Cost Estimates from FHWA. When a state begins to receive more in apportionment than they need to complete their interstate system, we replace its expenditure with the (interpolated) change in that state's estimated cost to complete as reported in the ICE. If there were cost overruns in a state, 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 states to which this measurement error applies were spending a relatively small amount to begin with. Finally, as we will explain in the next section, we may be underestimating the amount spent on Interstates because of the 85%-90% allocation rule.

V. Minimum Federal-Aid Percentage Allocation

Similar to the Minimum Apportionment rule, the Minimum Federal-Aid Percentage Allocation required that the sum of all federal aid funds given to states in a given year be at least a certain 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%. That minimum percentage stayed until 1992, when it was increased to 90%.[65]

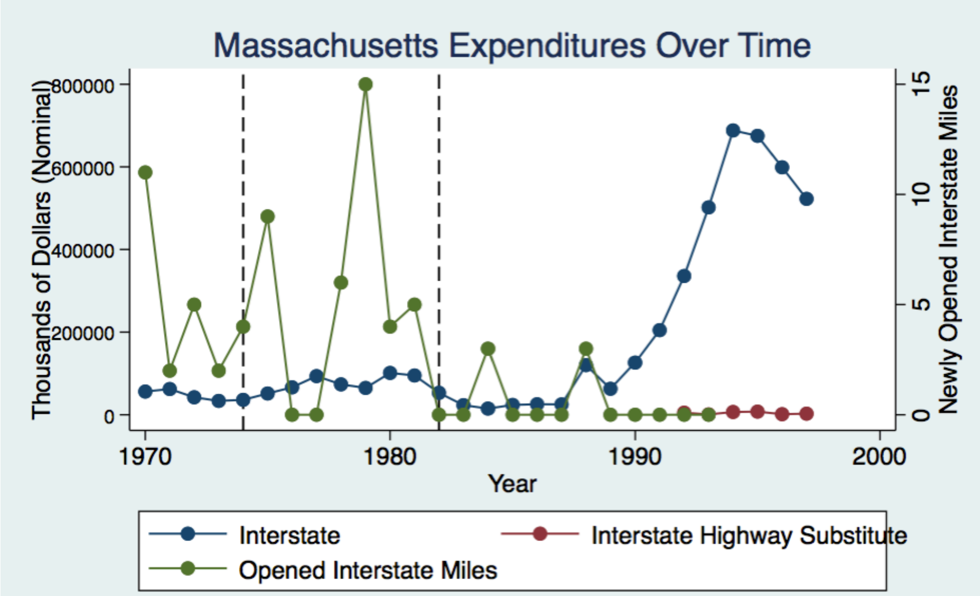
The *Highway Statistics* series tracks the amount of money apportioned due the minimum percentage rule as a separate variable. It also tracks the expenditure of this money separately from the spending of the specific categories. We therefore cannot know what category of Federal-Aid the money was spent 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 very 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 just 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 (not necessarily the same states) receiving the money every year. From 1982 to 1993, expenditures of money apportioned as part of the minimum apportionment rule were 20.6% percent of the cleaned measure of Interstate highway expenditures. From 1982 to 2014, the corresponding percentage was 29.2%.

Figure C1



[65] 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 onwards, they are contained in the 1994 U.S. Code Section 157(a).

Figure C2



Expenditure data from Table FA-3. Mileage data form Nate Baum-Snow. Dashed black lines are the years the State's withdrawals get approved. I suspect the big increase in Interstate expenditures in the 90s is from the Big Dig
Total obligated to substitute highway projects: $100 million. Transit projects: $1,452 million.

Figure C3

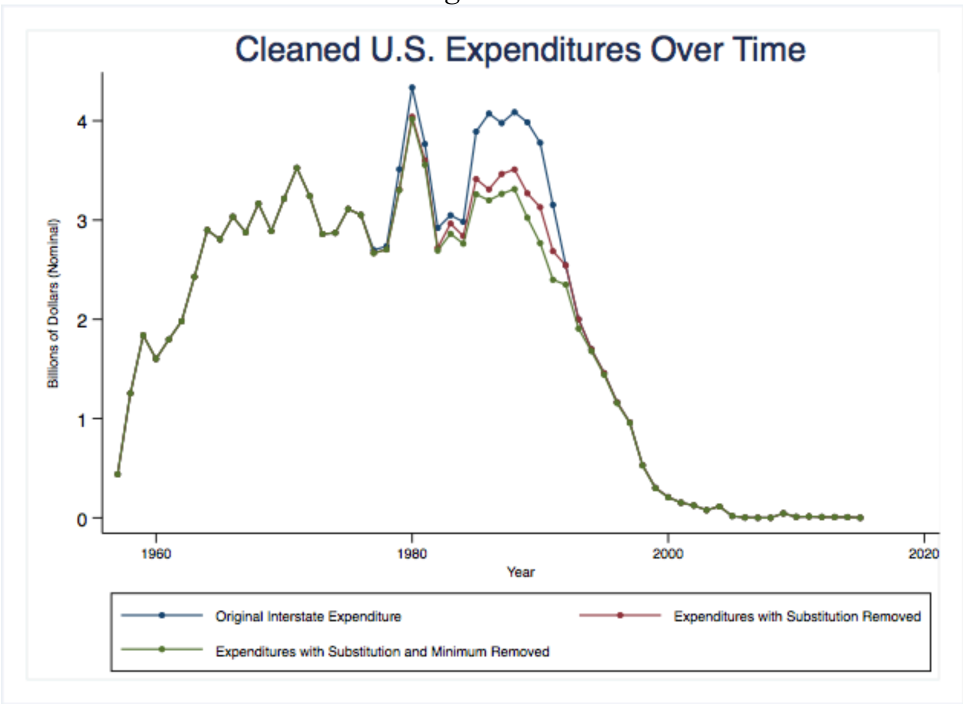
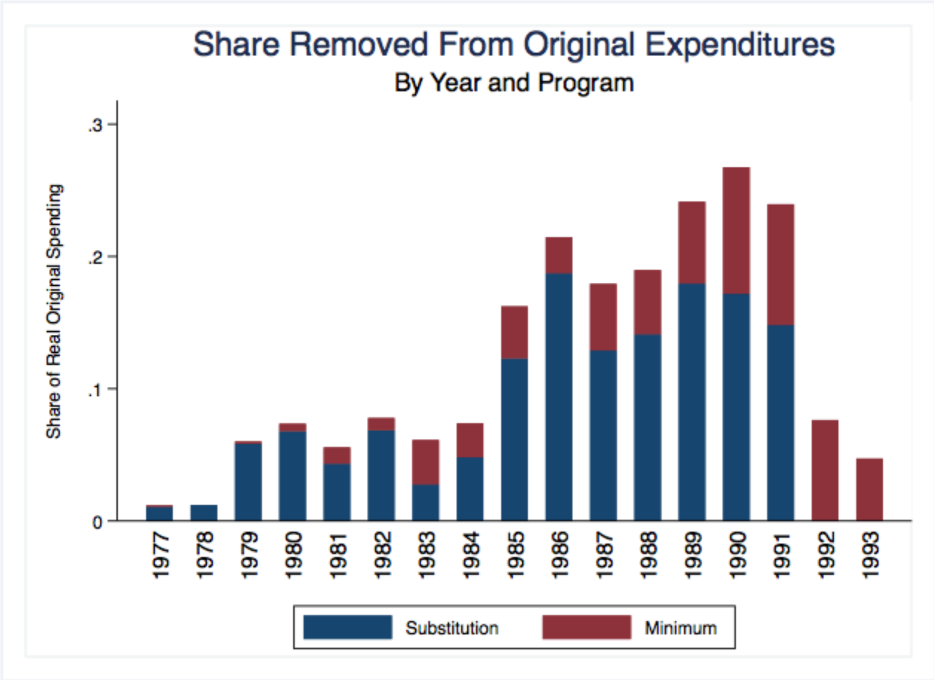


Figure C4


Share Removed From Original Expenditures
By Year and Program
Share of Real Original Spending
.3
.2
.1
0
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
Substitution
Minimum