Unintended Consequences of the Appalachian Development Highway System on Mortality

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This Version: November 5, 2020

Abstract

A growing literature aims to undercover the causal link between highways and economic activity. However, specific attention to federally funded rural roads and highways is sparse given implicit endogeneity concerns about road placement decisions for the sake of rural development and market exposure. This study examines the impact of the Appalachian Development Highway System (ADHS), one of the largest and most expensive federal infrastructure projects in the United States, on mortality outcomes in the region. Instrumental variable (IV) results suggest ADHS construction significantly reduced travel-time-sensitive mortality rates, such as heart disease and hypertension, in earlier decades of the sample. IV results also suggest the ADHS may be associated with increased mortality rates, notably accidents, in later decades of the sample. The additional cost caused by the ADHS in terms of mortality is estimated to be $24.2 billion dollars over the length of the sample. However, benefits such as improved travel times, employment, and income increases outweigh these costs.

Keywords: Appalachian Development Highway System, regional accessibility, mortality, place-based policies

JEL Classification: I15, N72, O18, R42

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Transportation infrastructure construction has been linked to the location of employment, innovation, population, and economic growth (Agrawal, Galasso, & Oettl, 2017; Baum-Snow, 2007; Chandra & Thompson, 2000; Duranton & Turner, 2011, 2012; Michaels, 2008).[1] Increased accessibility through lower transportation costs represents one of the main mechanisms through which infrastructure impacts locations (Brooks & Donovan, 2020; Holl, 2016). Little economic research focuses on the relationship between transportation driven accessibility changes and health outcomes.[2] Standard economic models of health outcomes do not include locational characteristics among factors affecting health outcomes (M. Grossman, 1972). However, changes in transportation infrastructure could generate both intended and unintended impacts on health outcomes. For example, a more extensive road network could increase access to physicians and doctors, improving individual health outcomes.

The economic history literature contains a few examples of papers that estimate a causal relationship between infrastructure construction and health outcomes. These papers focus on the advent of modern transportation modes in the 19th century. Zimran (2020) analyzed the impact of the expansion of canals on mortality in Antebellum United States and Tang (2017) analyzed the impact of railway expansion on mortality in Japan. Both papers found significant increases in mortality from communicable diseases caused by the expansion of modern transportation modes. Other papers that examine the direct relationship between health and transportation infrastructure fail to establish a causal relationship or only examine inputs to health, rather than health outcomes themselves (Bell & van Dillen, 2018; Blimpo, Harding, & Wantchekon, 2013).

Recent research found reduced travel times positively associated with decreased mortality among hospital patients. An analysis conducted in both rural and urban counties in Oregon and Washington found rural patients more likely to die within 24 hours, relative to urban patients, due to higher transfer rates between health care centers and longer travel times to hospitals (Newgard et al., 2017). In several regression models in Røislien, Lossius, and Kristiansen (2015), travel time was a significant predictor of mortality in Norwegian municipalities.

This literature identifies important differences in health outcomes for urban and rural patients. Urban patients are more likely to live near hospitals and health care facilities. Over 40 million

[1] See Redding and Turner (2015) for an overview of this literature.

[2] Currie and Walker (2011) and Knittel, Miller, and Sanders (2016) discuss the effect of transportation infrastructure on infant health outcomes; this paper focuses on end-of-life outcomes for the entire population.

Americans lack access to a level I trauma center within a 60 minute drive from their home; most of those 40 million live in rural areas (Branas et al., 2005). This distinction likely affects health outcomes in Appalachia, a largely rural, isolated region.

Due to the lack of comprehensive public transportation across Appalachia, access to healthcare and other amenities depends heavily on road networks. Appalachia is a region historically associated with concentrations of poverty and reduced accessibility in terms of transportation. To overcome these issues, particularly focused on accessibility concerns, Congress created the Appalachian Regional Commission (ARC) to provide federal funding to states and counties in the Appalachian region to address limited accessibility by building highways. This highway construction project represents one of the largest place-based policies ever implemented in the United States. At its inception in 1968, ARC allocated over 75% of the initial \$1.1 billion of federal funds received to construct the Appalachian Development Highway System (ADHS).[3] Construction of the ADHS began in the late 1960s and continued for over 50 years. This research focuses on the impact of the ADHS on morality in Appalachia. It investigates the presence of both intended and unintended effects on mortality.

Estimating the causal influence of the ADHS on mortality outcomes requires accounting for the non-random assignment of highway segment construction over space and time in Appalachia. I exploit an instrumental variables (IV) approach similar to past research using historic infrastructure maps to analyze the current effects of infrastructure (Agrawal et al., 2017; Baum-Snow, 2007; Baum-Snow, Brandt, Henderson, Turner, & Zhang, 2017; Duranton, Morrow, & Turner, 2014; Duranton & Turner, 2011; Garcia-López, Holl, & Viladecans-Marsal, 2015; Hsu & Zhang, 2014).[4] The new instrument proposed in this paper is the President's Appalachian Regional Commission (PARC) highway map created during the Kennedy administration. This map was drawn before the guarantee of federal funding for Appalachian highway construction and before official federal classification of the "Appalachian" region.

The instrument is relevant because the unused highway plan resembles, and directly informed, the actual construction plans used for the ADHS. The instrument is excludable, like Baum-Snow

[3]The remaining 25% of the \$1.1 billion was allocated to other development projects in the region (Comptroller General of the United States, 1976).

[4]In addition to historic infrastructure maps, economic analyses have included old maps to study a variety of topics including, but not limited to, Africa's slave trades (Nunn, 2008) and Indian city shape and sprawl (Harari, 2020).

(2007) and Duranton and Turner (2011), because it is plausible that the only reason an unused 1964 Appalachian highway plan affects mortality over time is through its strong relationship to actual ADHS road construction. This exclusion restriction becomes more plausible when conditioning on county level factors such as hospital density, simultaneous ARC health development projects, and historic road infrastructure density.

Instrumental variable results show that ADHS construction causes reductions in heart disease and hypertension mortality rates. A decrease in county centroid distance to an ADHS segment decreases mortality rates in certain decades in the sample. These results likely reflect a mechanism in which ADHS road construction improved individual access and travel time to healthcare facilities. Controlling for the number of local hospitals, the number of contemporaneous ARC health-related investment projects, and 1960 county-level road density confirm these results. The impact dissipates in later decades in the sample.

Findings also suggest that accident mortality rates in Appalachia increased as distance to ADHS segments decreased, especially in the last two decades in the sample period. The increase in accident mortality reflects increases in drug and medicinal overdoses and not other accident causes such as car accidents. Overdose mortality increases by 0.80 standard deviation. This result implies that, while the ADHS road construction improved some mortality outcomes early in the sample period, it caused an increase in other mortality outcomes as the highway network, and use of the network, increased later in the sample period. In sum, not all segments of the ADHS generated the same effects on mortality, and not all mortality outcomes changed in the same way over time.

As of 2020, the ADHS spans over 3,000 miles across 13 states. Over the course of construction, approximately \$11.2 billion dollars was spent to reach current completion levels.[5] An additional \$10.9 billion dollars in spending will be required to complete the remaining segments of the ADHS. Due to the large share of federal funding devoted to the ADHS compared to other non-infrastructure ARC funded projects, the current research critically informs the evaluation of the overall impact of the ADHS on the Appalachian region.

The net mortality changes caused by the ADHS over the sample period contributed approximately \$24.2 billion dollars morality-related costs to society. However, the statistical value of additional lives lost does not outweigh the total benefits from improved travel times, increased

[5]Reported in current year spending, not adjusted for inflation (Economic Development Research Group, 2017).

employment, and higher incomes in the Appalachian region (Economic Development Research Group, 2017). This implies the ADHS infrastructure project still generated a net benefit despite the large costs associated with mortality.

This paper contributes to three bodies of literature. This paper contributes to the analysis of the effectiveness of place-based transportation infrastructure policies by analyzing end-of-life health outcomes, not previously examined in the literature, generated by a large-scale place-based policy. The paper employs a novel historical map, the President's Appalachian Regional Commission highway map, as an instrument, contributing to the literature using historical maps as instruments. This work also contributes to the literature evaluating ARC policies by using a causal inference approach.

The remainder of the paper is organized as followed – Section I provides a brief history of the ADHS and reviews relevant literature, Section II describes the primary data sources utilized, Section III discusses the method and identification strategy, Section IV presents the results, Section V provides robustness and mechanism arguments, Section VI provides a benefit-cost analysis of the ADHS, and Section VII concludes.

I Historical Background and Literature Review

I.a Appalachian Development Highway System

The President's Appalachian Regional Commission (PARC) was created by President John F. Kennedy in the early 1960s to carefully analyze problems throughout Appalachia and suggest policy recommendations to help the region "catch-up" with the rest of the country. On the subject of isolation, the report noted that "the Interstate Highway System has largely bypassed by Appalachian Region, going through or around the Region's rugged terrain as cost-effectively as possible" (PARC, 1964). To potentially overcome this isolation, the report says the following:

> Developmental activity in Appalachia cannot proceed until the regional isolation has been overcome...by a transportation network which provides access to and from the rest of the nation and within the region itself...The remoteness and isolation of the region, lying directly adjacent to the greatest concentrations of people and wealth in the

country, is the very basis of the Appalachian lag. Its penetration by an adequate transportation network is the first requisite of its full participation in industrial America.

Figure 1a shows a copy of the planned "development highway" described in the PARC report.[6] After continuous lobbying by the Conference of Appalachian Governors, the Appalachian Regional Development Act (ARDA) was proposed in Congress in the spring of 1964. At first the ARDA failed to receive sufficient support, however, the bill was resubmitted to Congress in 1965 following a few changes, including the addition of Ohio and South Carolina as beneficiaries of federally funded projects. The modified ARDA was signed into law on March 9, 1965. The Act created the Appalachian Regional Commission (ARC) and initially designated counties in Alabama, Georgia, Kentucky, Maryland, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia to receive $1.1 billion in federal grants with $840 million earmarked for highway spending (Comptroller General of the United States, 1976)[7].

Since its inception in 1965, the ARC region has grown. In 1967, as shown in Appendix Figure A.1, Mississippi and New York saw several counties' entry into the ARC boundary. Including this 1967 expansion, 47 counties have been added inside the ARC boundary to be eligible for federal grants, bringing the total count of Appalachian counties from 373 in 1965 to 420 in 2020.[8]

This paper's focus is related to highway development in the Appalachian region due to the creation of the ARC. The purpose of highway construction in Appalachia has been cited to be two-fold: open areas with an economic developmental potential and improve local access to educational, health, recreational, commercial, and industrial facilities (Rephann & Isserman, 1994). As of 2020, approximately 90% of the highway system has been constructed and opened to traffic.

Jaworski and Kitchens (2019) aim to answer questions concerning the effect of the ADHS on total income in the United States, and how various counterfactual highway networks would have impacted total income differently. Motivated by a model of inter-regional trade, the authors estimate the elasticity of total income with respect to market access, which they then use to evaluate the overall impact of the ADHS. They find that removing the ADHS would have reduced total

[6]Figure 1b shows a digitized version of Figure 1a with just the planned highway segments extracted.

[7]The remaining $260 million was devoted to a wide-reaching collection of development projects from education to land stabilization (Comptroller General of the United States, 1976)

[8]In addition, eight independent cities in Virginia have also joined the ARC region over time, with most joining in 2008.

income by $54 billion in the United States and $38 billion, or 4.4 percent, in the Appalachian region.

The road data from Jaworski and Kitchens (2019) come from newly digitized network data of the Appalachian, interstate, national, and state highway systems in 1960, 1985, and 2010. Jaworski and Kitchens (2019) notably use an instrumental variables strategy to isolate variation in changes in market access based on physical distance and the change in average speed between county pairs due to improvements throughout the transportation network. In regards to the current work, the same area has been georeferenced, but a larger quantity of construction progress maps have been digitized to capture yearly variations in road segment openings across time.

I.b Mortality and Place-Based Policies

Location-based health outcomes runs contrary to popular health models. In traditional models of the demand for health (M. Grossman, 1972), one's utility from health is realized with investment in medical care. The Grossman model, however, assumes individual factors such as education, income and geographic location to be independent from one's health demand. Exploring these factors as they relate to mortality outcomes has important implications for the health economics literature and policy. The current work contributes to the growing "place-based health outcomes" literature.[9]

The association between location and mortality, although not traditionally modelled, has a few empirical footholds in the literature. Early works attempted to find correlations between economic development and life expectancy. For example, Preston (1975) examines the positive correlation between income and life-expectancy across the United States. Murphy and Topel (2006) find improvements in long-run health outcomes create substantial economic gain to society.

Later empirical studies have focused on quasi-experimental approaches to examine the effects of location on mortality. Doyle (2011) uses health emergencies of visitors to Florida to show that hospitals in high-spending areas produce better health outcomes than hospitals in low-spending areas. Hall and Neto (2018) test the impact of MedExpress entry on different health outcomes in the Appalachia region. They find MedExpress entry leads to a reduction in short-term hospital

[9] For more general overviews of the mortality literature, please see Cutler, Deaton, and Lleras-Muney (2006), Currie and Schwandt (2016), and Chetty et al. (2016).

admissions, inpatient days, outpatient visits, and trips to the emergency room (supply side outcomes). Finkelstein, Gentzkow, and Williams (2019) find that individuals moving from a 10th to a 90th percentile location would increase life expectancy at age 65 by 1.1 years, and equalizing location effects would reduce cross-sectional variation in life expectancy by 15 percent. Places with favorable life expectancy effects tend to have higher quality and quantity of health care, less extreme climates, lower crime rates, and higher socioeconomic status. The large role the authors estimate for health capital (individual behaviors) is consistent with conventional wisdom, but the results also show that there is a substantial causal impact of place-based factors that conventional health modeling approaches may underestimate. Using Hurricane Katrina as a natural experiment, Deryugina and Molitor (2020) track Medicare survivors who were displaced by Hurricane Katrina. Those who moved to higher-mortality regions experienced higher mortality rates than those who moved to lower-mortality regions.

A growing literature cites the importance of community-based health departments and centers. Hoehn-Velasco (2018) describes the role of community health departments on rural infant mortality in the early 20th century and finds decreased infant mortality because of community health departments. Hoehn-Velasco (2020) finds improved later-life outcomes due to early exposure to public health programs. Bailey and Goodman-Bacon (2015) examine the expansion of community health centers (CHCs) in the United States. They note that access to primary care has long-term health benefits, even for those with near full-coverage insurance. The authors find that the CHCs themselves are responsible for a two percent reduction in age-adjusted mortality rates for those fifty years and older.

In general, the approach surrounding place-based healthcare studies falls in line with studies of place-based policies in general.[10] One potential policy initiative to increase positive outcomes in rural areas is increasing access to more urbanized areas. These urban areas arguably offer more amenities and opportunities to potentially increase the quality of life of rural residents. Greenberg (2016) emphasizes the importance of place-based, sub-county initiatives for poverty alleviation in Appalachia. Partridge and Rickman (2008) suggest that one potential policy for alleviating poverty in rural counties in the United States could be by increasing access through road construction. The

[10] Bartik (2020), for example, recently discusses the potential benefits associated with place-based job policies and the need for greater targeting of distressed areas.

current work directly evaluates the impact of a large, transportation place-based policy in terms of mortality outcomes.

I.c Quantifying Impact of Roads

This work also fits broadly into the literature quantifying the various impacts of roads in the United States and throughout the world. Chandra and Thompson (2000) examine the relationship between highway spending and economic activity. Interestingly, this paper finds that highways have different impacts across industries and across counties. New highways are associated with growth in industries that can benefit from the reduced transportation costs, and shrinkage in some industries because of the reallocation of economic activity along the highway. From a spatial perspective, this paper finds that new highways raise the level of economic activity in the counties they pass through while drawing activity away from adjacent counties, essentially having a zero net effect on regional economic activity. This paper assumes that new highways are an exogenous shock to the non-metropolitan counties that they run through, and uses a simple linear fixed effects model to conduct its empirical analysis. Although this assumption may hold true for many places across the country, in Appalachia particularly, the use of federal funds to construct highways in rural counties is not exogenous. Rogers and Marshment (2000) also attempt to quantify the impact of highway bypasses on small town retail sales. The authors examine the impact of highways bypassing small towns using a difference-in-differences analysis, finding no significant impact of bypasses on local retail sales.

Newer empirical contributions to this literature attempt to overcome the endogeneity problems associated with highway placement: areas showing more population growth, income growth, or employment growth may have more highways or may attract new highway openings more than a comparable control group. Therefore, estimates of the "true" effect of highways on any of the before-mentioned outcome variables could be upwardly biased. Rephann and Isserman (1994) find that the counties that benefited the most from interstate highways are those counties that had a highway route pass directly through them and were in close proximity to an urban area; these areas saw significant growth in their populations. Counties that bordered "interstate" counties or rural counties exhibited few positive direct effects from highway construction.

Several papers use old highway plans that were never utilized as instruments for current highway placement; these old maps meet both the relevance and exclusion properties of a valid instrument variable. After using a 1947 highway map plan to instrument for current highways, Baum-Snow (2007) finds one new highway passing through a central city reduces its population by about 18 percent. Using old highway plans as an instrument, Michaels (2008) identifies the labor market effects of the reduced trade barriers associated with the construction of the interstate highway system; it shows that counties where the interstate highway system passed through experienced an increase in trade-related activities, such as trucking and retail sales.[11]

There are also many papers that examine the impact of roads in developing countries.[12] The results from these papers generally do not find as large of an impact of roads on various outcome variables as do the studies that focus on cities in the United States. For example, Asher and Novosad (2020) study the impact of rural roads in India. Due to the institutional nature of the Prime Minister's Village Road Program, this paper is able to tease out the causal effect of road construction on various development outcomes. Using a fuzzy regression discontinuity design, this paper finds no significant impact of roads causing development in remote Indian villages. The paper does point to evidence that the main effect of rural roads in India is allowing farmers access to non-farm employment opportunities.

I.d General Analysis of ARC Policies

A plethora of books and reports published over the past several decades highlight the successes (and non-successes) of ARC policies in the Appalachian region. Bradshaw (1992), for example, discusses the successes and failures of ARC in its first 25 years in existence, highlighting the political influences on the direct contributions and goals of the commission in its early years. Widner (1990) summarizes key statistics from ARC's first 25 years, citing improved incomes, health, and employment in the region. Several other technical reports cite the decline of poverty (Black & Sanders, 2004), rise in standards of living (Black & Sanders, 2007), and increases in educational attainment (Haaga, 2004) due to ARC involvement in the Appalachian region. On the

[11]More recent papers using old highway maps as instruments in a U.S. setting include Duranton and Turner (2011), Duranton and Turner (2012), and Duranton et al. (2014).

[12]For example, see Hsu and Zhang (2014) and Baum-Snow et al. (2017).

other hand, Glaeser and Gottlieb (2008) are hesitant to call ARC outright effective, noting that finding the true effect of the ARC separate from all other simultaneous policy interventions may never clearly present itself in the data.

More recent empirical papers have examined the impacts of ARC policies and funding without specific attention to highway funding. Isserman and Rephann (1995) provide one of the first major empirical analyses of the effects of the Appalachian Regional Commission (ARC) on the 391 counties that were in Appalachia at the time of the study. Using matching methods, this paper finds that Appalachia grew significantly faster than did the control group in income, earnings, population, and per capita income. This paper, in additional to the empirical contribution, also provides an extensive historical background on the ARC and criticisms the commission has received. Sayago-Gomez, Piras, Jackson, and Lacombe (2018) find that, after using matching methods, counties that received ARC funding grew faster than control counties in terms of per capita income and employment from 1970 to 2012. D. Grossman, Humphreys, and Ruseski (2019), using difference-in-differences, examine the effect of water, sewage, and sanitation-related ARC investment projects on individual outcomes like the presence of complete indoor plumbing and running water in dwellings.

Beyond general reports published by the ARC and other empirical contributions concerning non-highway ARC impacts, the analysis of rural roads in Appalachia has some limited empirical footholds. Apart from Jaworski and Kitchens (2019), a relatively comprehensive and rigorous analysis of the impact of the ADHS, one component of total ARC projects, has not been thoroughly studied in the literature. Quantifying the impact of this rural highway network on mortality outcomes in the Appalachian region contributes to several bodies of literature simultaneously, adding to our understanding of the possible unintended consequences of this federal road building project in the United States.

II Primary Data Sources

II.a Data Creation: Appalachian Development Highway System (1965-2018)

Although the history and progress of the ADHS has been tracked extensively by state and federal agencies, a usable data set capable of being manipulated by statistical or GIS software is not publicly available. Newly digitized maps were created to determine what states and counties received a new section of the ADHS and when that section's construction was completed. PDFs and scans of historical maps, similar to Figure 1a, were collected from the mid-1960s to the present. After digitizing these maps over time using QGIS, a manipulable data set tracking the construction of road segments can be utilized to explore various outcome variables.[13] The result of this process is a dynamic representation of the ADHS construction, similar to Figure 2.

Figure 2 displays the progress of ADHS construction from 1968 until 2017. The black lines in each figure show the existing road network at the beginning of the time period and the red lines show the construction progress over the length of the decade. Most of the construction occurred between 1968 and 1978.

II.b NVSS: NCHS Restricted-Use Mortality Files (1968-2017)

The main objective of this paper is to isolate the causal effect of the ADHS on mortality outcomes in the Appalachian region. The National Center for Health Statistics (NCHS), through the National Vital Statistics System (NVSS), has data on mortality outcomes in the United States. This sample starts from 1968 and continues to 2017. Restricted-use vital statistics are used to track the number of deaths in Appalachian counties over time.[14] This restricted-use data set is particularly informative because it not only has the location of residence and death, but also has the specific cause of death, as indicated by International Classification of Diseases (ICD) codes, for every individual in the data. This fact can be utilized to isolate the causes of death where quick access to healthcare could have played a role in preventing premature death.

[13] The exact opening dates of the road segments are unknown. It is possible that the road segments could have been open to traffic before construction was officially completed. However, the current empirical strategy hopes to overcome this by examining medium- to long-run mortality outcomes.

[14] The public-use data sets do not include fine geographic indicators for place of birth, residence or death beyond 1988. This is why restricted-use data is used.

Throughout the length of the mortality data (1968-2017), the ICD codes went through three revisions, essentially changing the way causes of death were coded in the data. Appendix Table A.1 shows the changes in the ICD code system over time and lists what ICD codes translate to each broad cause of death that will be analyzed in this study.

Figure 3 depicts Appalachian death trends over the length of the sample using the consistent death definitions described in Appendix Table A.1. The top left panel shows all-cause deaths in the Appalachian region have increased over time. Other causes of death vary in their trends throughout time. Changes in mortality at the county level are shown in Figure 4. Darker shades of blue represent decreases in mortality rates over the decade, white represents relatively no change, and orange shades represent increases in mortality rates. Figure 5 isolates the change in heart disease mortality over time and Figure 6 shows total accident mortality rate changes. Other causes of death mapped over time can be found in Appendix A.

All model specifications will use *case-specific mortality rates* as outcome variables. Specifically, the case-specific mortality rate takes the following form:

$$m_{iy} = \frac{N_{iy}}{C_{iy}} * (100,000) \tag{1}$$

where *m* is the case-specific mortality rate in county *i* in year *y*, *N* is the number of deaths from a specific cause in county *i* in year *y*, and *C* is the total population of county *i* in year *y*.[15] This rate is multiplied by 100,000 to express the rate as a whole number: deaths per 100,000 people. Expressing deaths as a rate per 100,000 controls for high population levels that may be driving mortality outcomes.

III Method and Identification Strategy

III.a Endogeneity Concerns of ADHS Segment Construction

Construction of segments of the ADHS was not randomly determined across space. The PARC set out specific guidelines that the ARC used to determine what areas of the country, more specifically

[15]Estimates of county-level intercensal populations from 1970-2014 are available from Roth (2016). 1970 population estimates were used to proxy for 1968 and 1969 population. 2014 population estimates were used to proxy for 2015-2017 populations.

what areas of Appalachia, were in need of more access to markets, employment opportunities, and health care options. The PARC map places road segments in these areas of Appalachia. However, the actual timing of the segments' opening varies across time. Places that were arguably more "remote" in the eyes of the federal government potentially saw construction and completion of road segments sooner than other areas of Appalachia. On the other hand, areas isolated due to the mountainous terrain could have potentially seen construction and completion of segments at later dates compared to areas with more level terrain. Either way, this non-random assignment of both potential and actual segment allocation and construction over time could lead to potentially biased estimates of the impact of the ADHS. Unfortunately, this concern has not been considered in empirical studies until very recently.

To overcome this potential bias, an instrumental variable approach will be used to instrument for the location of ADHS segments.

III.b Instrumental Variable Approach

Construction of the ADHS will be instrumented with the original PARC plan for Appalachian highway construction. This plan can be seen in Figure 1a.

Notably, this original plan is much smaller than what the ADHS has eventually become. One can argue that this instrument is both relevant and excludable. The PARC highway plan, developed in 1964, was never officially utilized once construction of the ADHS began. Between the initial development of the PARC highway plan and the creation of ARC, many counties that were not originally considered to be possible recipients of federal funding for highways were added to the definition of the "Appalachian" region. Therefore, the highway plans were redrawn after the creation of ARC. The original PARC plan has been digitized using QGIS's geo-referencing tools as shown in Figure 1b. A comparison of the 1964 PARC plan versus a plan created in 1966 after the formation of ARC is shown in Figure 7.[16] Although relatively similar in the general route-planning aspects, the 1966 plan was created after the guarantee of federal funds. This, plus the addition of several parts of the country into the Appalachian region, rendered Figure 1a obsolete.

It is important to point out another characteristic of Figure 7 that informs the predicted sign of the first stage relationship in Equation 2. Even though the two plans shown are generally similar in

[16]The original 1966 plan is shown in Appendix Figure A.2.

terms of the highway system as a whole, decade to decade *changes* in a county centroid distance to the 1964 PARC plan is constant over time, while actual construction of the ADHS segments is completed in smaller chunks. Therefore, if a county was planned to get a route relatively close to its centroid in the 1964 plan, the distance measure would be a small length. If, following the suggestions of the 1964 plan (and subsequent later plans), that same county received an ADHS segment *when there were no other segments that were generally close to that county constructed up until then*, then there will be a large *change* in the distance to an ADHS segment. In other words, small distances to the 1964 plan are likely to translate to large, negative distance changes to actual ADHS construction. If this line of logic holds, then one should expect a *negative* first stage relationship.

Formally, the first stage relationship takes the following form:

$$\Delta ADHS_{cd} = \alpha + \phi_1 PARC1964_c + \beta_1 \mathbf{X}_{cd} + \epsilon_{cd}, \tag{2}$$

where $\Delta ADHS_{cd}$ stands for the change in county centroid distance to nearest ADHS road segment across a given decade, $PARC1964_c$ stands for county centroid distance to nearest planned PARC highway segment. Subscript *c* represents county-level data. *d* stands for the decade across which the changes in ADHS and mortality rates are examined. There are five decade changes examined: 1968-1978, 1978-1988, 1988-1998, 1998-2008, and 2008-2017.[17] **X** is a vector of county-level controls added in fully specified equations. These controls are described in Section III.c. The second testable hypothesis is whether or not exogenous increases in ADHS construction locations have consequences on mortality rate outcomes. This is estimated in Equation 3:

$$\Delta MortalityRate_{cd} = \theta + \beta_1 \Delta \widehat{ADH}S_{cd} + \beta_2 \mathbf{X}_{cd} + u_{cd}, \tag{3}$$

where $\Delta \widehat{ADHS}_c$ stands for the fitted values from estimating Equation 2. β_1 is the coefficient of interest. Meeting additional assumptions of independence, SUTVA, and monotonicity, β_1 represents the local average treatment effect (LATE).

[17] The last "decade" is only nine years instead of ten due to mortality data availability.

SUTVA Concerns – The stable unit treatment value assumption (SUTVA) requires treated units to be only impacted by the treatment the unit was assigned, not the treatment assignment of surrounding units. This assumption could potentially not hold when geographic units are considered; geographic units may be impacted not only by the treatment they receive but the treatment of neighboring geographic units. In the context of this research design, there could be potential spatial spillovers of mortality outcomes into neighboring counties when there is an ADHS segment in one county, even if the neighboring counties did not receive an ADHS segment themselves.

A common solution to contain potential spillovers of treatment is to aggregate to a higher spatial unit (Duranton, Henderson, & Strange, 2015). Papers typically aggregate up from county level analyses to MSA level to contain potential spillovers if SUTVA concerns exist (Duranton & Turner, 2011). To address SUTVA concerns, Jaworski and Kitchens (2019) examine entire changes to road network travel times to address SUTVA concerns.[18]

III.c Potential Threats to Internal Validity

To pin down the mechanism of increased healthcare accessibility through the ADHS construction, additional controls are arguably necessary to confirm the internal validity of the estimation techniques used. In other words, to be confident that the estimations yield unconfounded estimates, one would have to control for factors that both reduce mortality and occur relatively at the same time as an ADHS segment's opening.

The following subsections discuss additional data used to aid in confirming the proposed mechanism.

Hospital Density – The county-level density of hospitals is a potentially confounding variable: a higher density of hospitals may be correlated with mortality outcomes in a county. This correlation exists regardless of ADHS construction in a county, so not including this control will overestimate the impact of the ADHS. As of 2020, there were 643 hospitals open in Appalachia.[19] Unfortunately, a data set with both the exact geographic (lat/long) location, as well as the opening dates/closing dates of hospitals does not exist. So, tracking these 643 hospitals over time is impos-

[18] Future extensions of this work will address potential SUTVA violations.

[19] These hospital locations are shown in Appendix Figure A.7. Source: https://hifld-geoplatform.opendata.arcgis.com/datasets/hospitals

sible; it is also unknown how many hospitals that were open earlier in the sample have closed, and therefore, not counted in the current data.

To remedy this problem, County Business Patterns (CBP) data from the U.S. Census will be utilized. The CBP data include a measure of the number of hospital establishments at the county level. This measure can be used to control for existing health care facilities in a particular county.[20] [21] These data are available for Appalachian counties for the entire length of the sample period: 1968-2017.[22]

Figure 8a shows that the number of hospitals in Appalachia did fluctuate over the length of the sample. Even though it appears that the number of hospitals began to decline after 1990, the number of counties with hospitals steadily increased, as shown in Figure 8b. At the start of the sample, less than half of counties in Appalachia had at least one hospital. By the end of the sample, almost all counties had at least one hospital.

Simultaneous Federal Development Projects – ADHS construction was not the only form of federal development investment occurring in Appalachia during this time period. Administrative data on ARC-funded projects from 1968-2016 is used to control for simultaneous development projects that may have impacted the health outcomes of Appalachian residents. These data include the type of development project, as well as the states and/or counties to which they were targeted.[23] As shown in Figure 9, there was a large spike in both total ARC investment, as well as just health-related investment projects between 1968 and 1978. After this time, investment projects of all types decreased and remained relatively constant after 1988. In fully specified models, a sum of the number of health-related investment projects at the county level over a decade is used to proxy for potentially simultaneous federally funded health improvements in the region.

Existing Road Density – Additionally, the existing road density could play a role in determining the relative impact of the ADHS. Existing roads could have also increased the accessibility to healthcare facilities in the Appalachian region regardless of ADHS construction. To control for

[20] Bailey and Goodman-Bacon (2015) has detailed Community Health Center (CHC) data, but not hospital data.
[21] Hospital SIC code: 8062; NAICS code: 622110
[22] Source: `https://catalog.archives.gov/search?f.ancestorNaIds=613576&q=*:*&sort=naIdSort%20asc`
[23] A list of the types of development projects can be found in Appendix Table A.2.

these other roads to isolate the effect of the ADHS on mortality rates, a control for the existing 1960 road density is added to fully specified models.[24]

IV IV Results: ADHS and Heterogeneous Impacts Across Time

The following subsections describe the IV results of estimating the two-step process described in Equations 2 and 3. To summarize, the ADHS's impact on mortality outcomes depend both on the time period examined and the cause of death of interest. In all specifications and decades examined, there is a significant, negative, first-stage relationship between a county centroid's distance to the 1964 PARC plan and that county's change in distance to an ADHS segment. Cumulative summary statistics by decade can be found in Table 1. Results for additional mortality outcomes can be found in Appendix B. All 2SLS models without controls can be found in Appendix C.

Total Mortality – 2SLS results with added controls for ARC health investment projects, count of hospital establishments, and historic road density are shown in Table 2. Panels A-E represent different decades of analysis. The F-statistic is above 10 in all decades, except 2008-2017 in Panel E. Robustness checks in the next section account for potentially biased standard error calculations due to the weak instrument. In all decades, there is not a significant relationship between total mortality and construction of the ADHS.

Heart Disease – 2SLS results with added controls are shown in Table 3. Again, there is a consistently significant first stage result. In Panels B and D, a large change in county centroid distance to an ADHS segment is associated with lower rates of heart disease mortality between 1978-1988 as well as 1998-2008. In other words, in those decades, a county centroid being closer to an ADHS segment caused a significant reduction in heart disease deaths. This result supports the proposed mechanism of the ADHS causing increased accessibility to healthcare facilities. The decreases in heart disease mortality, however, are relatively small compared to the sample average changes shown in column 1 of Table 3.

[24] Data on 1960 road density comes from Jaworski and Kitchens (2019). Appendix Figure A.8 shows the road network in 1960, before the construction of the ADHS. The length of the historic road network is calculated at the county level.

A possible explanation for the dissipation of results over time concerns the hospital density variable. Counties with at least one hospital became more prevalent over the course of the sample, as shown in Figure 8b. The fact that more counties were receiving hospitals in the 1988-1998 time period would explain why the distance to the ADHS did not matter as much to heart disease mortality. If a county that never had a hospital finally received one, people would no longer have to cross county borders to reach a hospital, which is what the ADHS helped facilitate.

Hypertension – 2SLS results with added controls are shown in Table 4. The only decade with significant results is 1988-1998, displayed in Panel C. Just like heart disease, there is a negative relationship between mortality and distance to the ADHS, suggesting that the ADHS caused a decrease in hypertension deaths between 1988 and 1998. This is an interesting result given the general mortality rate in the Appalachian region associated with hypertension was increasing during this time, as shown in Figure 3c and in column 1 of Table 4.

Total Accidents/Trauma – Table 5 displays the two-stage results for accident death rates in Appalachia. In earlier decades of the sample, there is no significant relationship between ADHS and accident mortality rates. However, in the last two decades of the sample, as shown in Panels D and E, there is a positive, significant second stage relationship: as a county centroid got closer to an ADHS segment, the larger accident mortality rates became in the 2000s. This is in contrast to the negative and significant relationship estimated in the reduced form models in the same decades. The increase in accident mortality between 2008-2017 is equivalent to a 0.93 standard deviation increase in the accident mortality change compared to the sample mean.

The total accident outcome includes a wide breadth of possible causes of death. Accident rates in all decades include car accidents, so this could be a potential mechanism for the positive and significant second stage results in later decades. As the ADHS was constructed over time, more and more drivers took advantage of the roads. This increased demand for road usage over time could have potentially led to an increase in car accident mortality rates. Additionally, greater access to larger urban areas could also lead to an increase in accidental drug and medicinal overdoses. Further disaggregation into these two more specific outcomes – car accidents and overdoses – is shown in the following section.

V Robustness and Mechanism

The following subsections discuss robustness exercises conducted.

Disaggregation of Total Accidents – In the previous section, the analysis of accident mortality rates includes *all* accidental deaths. These causes of death range from car accidents, to falls and poisonings. To add further weight to the proposed mechanism, two types of accidents are examined separately: car accidents and overdoses. Figure 10 displays the mortality rates for car accidents and accidental overdoses. Independently, these types of accidental deaths may have some associated with decreased distance to an ADHS road segment. If more people use the highway system, over time, one would expect to see an increase in car accident mortality rates. However, as shown in Table 6, this does not seem to be the case.

In terms of overdose deaths, one could expect to see counties that became closer to the ADHS over time had increased access to larger, urban areas.[25] With the potential for income and employment also comes increased access to more negatively associated aspects of city life. In fully specified IV models, shown in Table 7, there is a positive and statistically significant coefficient for overdose mortality in the last three decades of the sample: counties that got closer to ADHS segments experienced a significant increase in overdose mortality rates.[26] In the last decade of the sample, the increase in the change in overdose mortality estimated is equivalent to a 0.80 standard deviation increase.

Corrections for Weak Instruments – In all of the 2SLS specifications for 2008-2017 discussed in Section IV, the F-statistic testing for weak identification was below 10, a signal that the instrument is considered "weak." This could be driven by the fact that the ADHS was practically completed by this time, so few areas of Appalachia experienced large changes, if any changes at all, in the distance to an ADHS segment. Panel E in Tables 5 and 7 include Anderson-Rubin (AR) confidence intervals for the second stage point estimate.[27] Andrews, Stock, and Sun (2019) notes that AR confidence intervals are efficient for just-identified models.

[25] For example, Corridor H, when completed, will connect interior West Virginia to the Washington, D.C. metro area. Source: http://www.wvcorridorh.com/route/route.html

[26] In terms of comparability across time, the mortality data does not track what specific drugs or medicines were the cause of overdose deaths.

[27] Appendix Tables C.1, C.2, and C.8 also include the adjusted confidence intervals.

In Panel E of the above-mentioned tables for total mortality, heart disease, total accidents, and overdose mortality outcomes, the significant second-stage coefficient in the 2008-2017 decade does not appear to be driven by a statistically weak instrument. The coefficients fall between the two-step confidence interval proposed; this suggests that the significant relationships found in the 2008-2017 decade for total accidents and overdoses is not due to a relatively weak instrument.

Cumulative Effect of the ADHS on Mortality – The main results presented in Section IV are a set of repeated cross-sections. The cumulative effect of the ADHS on various mortality outcomes can be estimated by pooling the results across the entire length of the sample. Formally, the panel 2SLS approach takes the following form, with Equation 4 the first stage and Equation 5 the second stage:

$$ADHS_{cy} = \alpha + \phi_1 PARC1964_c * \gamma_y + \beta_1 \mathbf{X}_{cy} + \gamma_y + \delta_s + \epsilon_{cys}, \tag{4}$$

where $ADHS_{cd}$ stands for the county centroid distance to nearest ADHS road segment across a given decade, $PARC1964_c$ stands for county centroid distance to nearest planned PARC highway segment. In this panel setting, the PARC distance is interacted with a year fixed effect to allow the instrument to be time-varying. Subscript c represents county-level data. y stands for the year in which mortality rates and distances are examined. $\mathbf{X}$ is a vector of county-level controls added.[28] In the panel setting, year fixed effects (γ_y) and state fixed effects (δ_s) are employed.

$$MortalityRate_{cy} = \theta + \beta_1 \widehat{ADHS}_{cy} + \beta_2 \mathbf{X}_{cy} + \gamma_y + \delta_s + u_{cys}, \tag{5}$$

where $\widehat{ADHS}_c$ stands for the fitted values from estimating Equation 4. β_1 is the coefficient of interest.

Appendix Table D.1 reports the total effect of the ADHS across the entire length of the sample. Select causes of death are examined: total mortality, heart disease mortality, hypertension mortality, total accident mortality, and accidental overdose mortality. All second stage F-statistics are above 10. Although marginally significant results are found for certain causes of death, overall it

[28] These controls are the same used in Section IV: count of hospitals in a county, number of ARC investment projects in a county, and the existing 1960 road density.

appears the cumulative impact of the ADHS on mortality was minimal. Decade-to-decade examinations of the ADHS, however, yield a deeper story of the relationship between the ADHS and mortality.

County of Residence – In Appalachia over the sample, counties appear to have more mobile residents. This is explicitly shown in Figure 11. Every death in the data has an indicator for both county of death and county of residence. Therefore, one can get a sense if an Appalachian county is home to a large share of people who died outside of the county in a given year. If the total count of deaths occurring in a "county of residence" in county i is larger than the deaths categorized as a "county of death" in county i, more residents died outside of the county compared to those that died within the county.[29] Over time, Appalachian counties increasingly saw more residents dying outside of the county of residence. This is suggestive evidence that Appalachian residents became more mobile during the ADHS construction time period.

Unobservable Changes in Health Inputs – One limitation of the current analysis is the inability to account for unobserved historical changes in health inputs. The construction of the ADHS implies many simultaneous connections: connections to urban areas increase wealth and employment opportunities in addition to reducing travel times. The current estimation does not seek to directly estimate these benefits. However, there have been estimates of the benefits to the Appalachian region caused by the ADHS, as shown by Economic Development Research Group (2017); these benefits will be utilized more in the following section. Additionally, over the course of the sample, quality of care improvements go unobserved.

VI Benefit-Cost Analysis

Using the estimates discussed in Section IV, calculations of the relative benefits and costs of the ADHS are examined below. For each cause of death, the additional increase or decrease in mortality caused by the ADHS can be translated into fewer or greater deaths in the Appalachian region.

[29] For example, if county i had 1000 deaths in the county of residence measure and 800 deaths in the county of death measure, county i had more people's deaths occur outside of the county compared to deaths that occurred inside of the county.

Heart Disease Lives Saved – As shown in Table 3, there was a significant decrease in heart disease mortality between 1978-1988 as well as between 1998-2008. To calculate the lives saved by the ADHS, the decrease in the heart disease mortality rate can be converted to reflect the number of lives saved in Appalachia. The average population across Appalachian in the 1978-1988 time period was 21.371 million people.[30] With a decreased death rate of 2.974 per 100,000, this corresponds to 636 fewer deaths in the Appalachian region due to heart disease between 1978-1988.[31] Between 1998 and 2008, the average Appalachian population was 23.961 million residents.[32] With a decreased death rate of 4.132 per 100,000, this corresponds to 990 fewer deaths in the Appalachian region due to heart disease between 1998-2008 because of the ADHS.

In total, because of the ADHS, 1626 fewer Appalachian residents died due to heart disease over the length of the sample.

Hypertension Lives Saved – Table 4 shows there was a significant decrease in hypertension mortality between 1988 and 1998. The mean Appalachian population during this time period was 22.327 million people.[33] 106 fewer people in the Appalachian region did not die of hypertension between 1988 and 1998 due to the ADHS.

In sum, *1732 fewer people died in the Appalachian region of heart disease or hypertension because of the ADHS.*

Overdose Lives Lost – Although there were fewer lives lost to heart-related conditions, there were more lives lost to accidental overdoses because of the ADHS, as shown in Panels D and E of Table 7. Between 1998 and 2008, the average population of the Appalachian region was 23.961 million people.[34] With an increased death rate of 0.920 per 100,000, this corresponds to 220 more deaths in the Appalachian region due to accidental overdoses between 1998-2008. Between 2008

[30] Figure A.9 shows the intercensal population estimates of Appalachia from 1970-2014. Population in 1978: 21.1531 million, population in 1988: 21.6101 million.

[31] A mortality rate of 2.974 per 100,000 = 0.00002974 chance of one person dying. Out of a total of 21.371 million people: 0.00002974 x 21371000 = 636 fewer deaths.

[32] Population in 1998: 23.043 million, population in 2008: 24.878 million.

[33] Population in 1988: 21.610 million, population in 1998: 23.043 million.

[34] Population of 1998: 23.043 million, population of 2008: 24.878 million.

and 2017, the 15.622 per 100,000 increased death rate can be interpreted as 3933 more people who died of accidental overdoses because of the ADHS.[35]

In sum, *4153 more people died in the Appalachian region of accidental overdoses because of the ADHS.*

Benefit-Cost Analysis – Based on the findings above, there was a net increase in 2421 lives lost in the Appalachian region due to the ADHS. This means 2.3 times more people died of overdose deaths than those that were saved with heart disease or hypertension. To be able to compares the financial costs and benefits of the ADHS, the "value of a statistical life" (VSL) will be used. The VSL is a common measurement used in policy-informing research. The average value of a statistical U.S. life is $10 million (Kniesner & Viscusi, 2019).[36] This estimate can directly translate as the willingness to pay for a small reduction in the probability of death. So, if an individual is willing to pay $100 per year to reduce the probability of dying by 0.00001, then collectively a group of 100,000 would be willing-to-pay $10 million per year to prevent the loss of one "statistical life" (Colmer, 2020).

The previous subsections noted there was a net increase of 2421 deaths due to the ADHS in the Appalachian region. In terms of the value of a statistical life, this would amount to $24.2 billion, in addition to the direct construction costs of the ADHS. The construction costs of the current ADHS has been estimated to be $11.2 billion; the remaining, unbuilt segments of the ADHS are estimated to cost another $10.9 billion (Economic Development Research Group, 2017).[37] The $24.2 billion in unintended mortality consequences plus the $22.1 billion in past and future construction costs brings the total cost of the ADHS to $46.3 billion.

As mentioned in the previous section, direct benefits of the ADHS are not calculated in this paper. However, potential benefits of the ADHS include travel time savings, employment growth, income growth, and increased domestic and international trade. According to a 2017 ARC report, the total benefits of the ADHS, quantified in transportation cost savings and productivity gains to the Appalachian region, amount to $10.7 billion per year (Economic Development Research

[35] The average population of the Appalachian region between 2008 and 2017 was 25.178 million. Population in 2008: 24.878, population in 2015: 25.478.

[36] Estimate in 2017 dollars.

[37] About 90% of the ADHS has been constructed. The remaining 10% of the ADHS is being constructed in more rugged terrains, which is why the price is significantly more per mile.

Group, 2017). Over the 49 years of the sample period (1968-2017), this amounts to approximately \$524.3 billion cumulative benefits. Based on this estimation of total benefits, it appears that, despite the total costs of the ADHS more than doubling with the addition of unintended mortality consequences, the benefits of the ADHS outweigh the total costs.

VII Conclusion

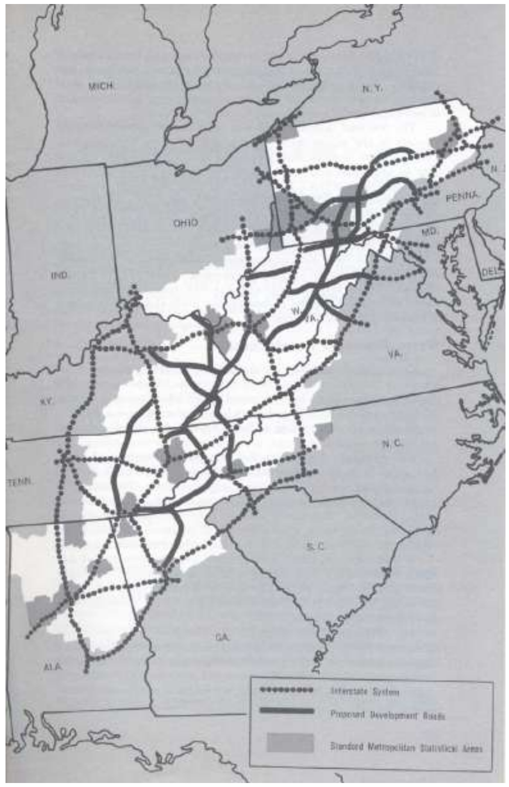
The construction of the Appalachian Development Highway System (ADHS) was one of the largest federally funded infrastructure projects in U.S. history. Using a newly digitized instrument, newly digitized construction maps, and restricted vital statistics, this work contributes to the growing economics literature connecting health outcomes to location-based attributes. This work has uncovered an undocumented positive consequence of the ADHS – improved mortality outcomes of time-sensitive conditions such as heart disease and hypertension. However, there is also evidence of increased mortality rates in certain decades for certain causes of death, notably accidents; these increases appear later in the sample and are driven by overdose mortality rates. Controlling for potential confounding factors such as hospital density, simultaneous ARC health-related investment projects, and existing 1960 road density does not diminish the IV results.

Although Appalachian mobility, in terms of county of death, appears to have increased over the sample, various relationships that could have also changed given the construction of the ADHS (quality of healthcare as well as individual wealth and employment) are not directly estimated in this paper. Using simple benefit-cost analysis, the unintended mortality costs caused by the ADHS are more than double the actual construction costs incurred. However, these increased costs do not overtake previously calculated benefits of improved travel times, employment, and income growth associated with the ADHS in the Appalachian region. Future extension of this work will incorporate aggregated changes to the road network to address potential spillovers of accessibility to neighboring counties.

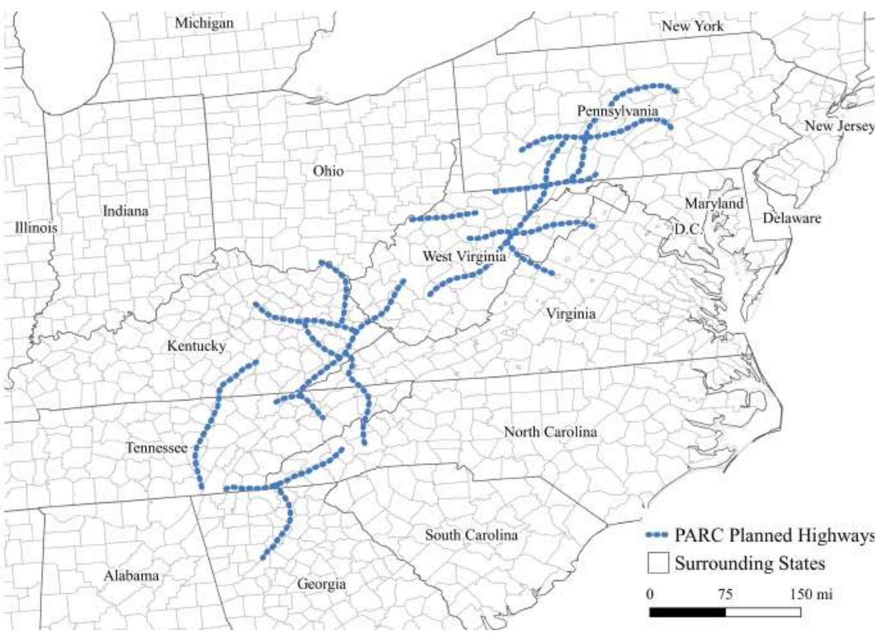
While approaching internal validity, the current estimation approaches and research questions considered do not touch much on external validity. The ADHS was a very unique federally funded infrastructure project in the United States. Because this infrastructure stock now exists, another project at this scale is unlikely to be seen in the United States. However, in developing counties, these results could be pertinent in cost-benefit analyses of large, infrastructure projects.

Figure 1: 1964 President's Appalachian Regional Commission (PARC) Highway Plan

Panel A: 1964 Original Map



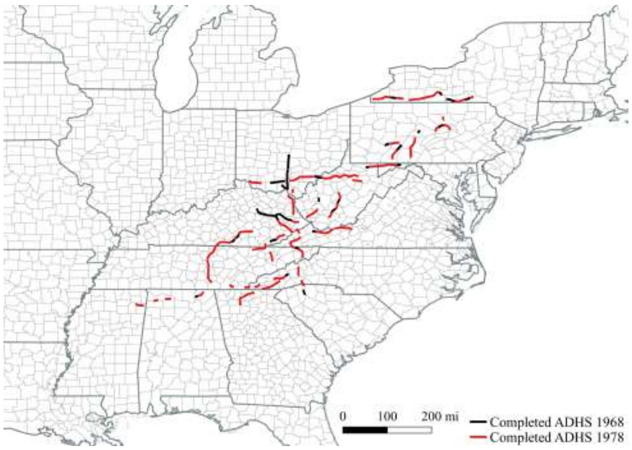
Panel B: 1964 PARC Highway Plan Digitized



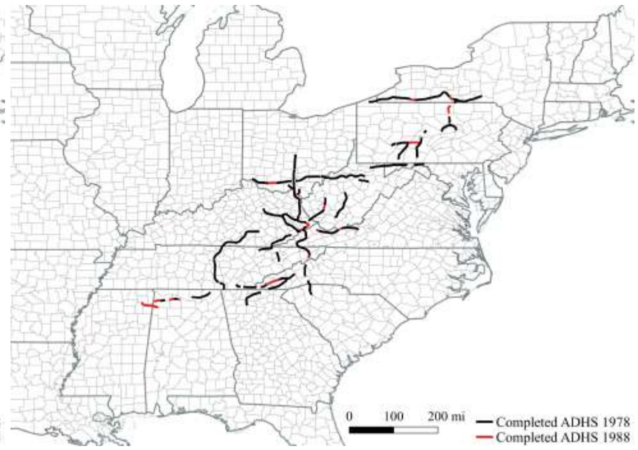
Note: Panel A shows the 1964 PARC highway plan map. Solid lines show the original plan for federally funded highways in the region. This plan was never utilized after the creation of the Appalachian Regional Commission (ARC) in 1965. New plans were drawn (See Figure A.2) after the guarantee of federal funding, as well as the expansion of the Appalachian region into New York, Alabama, and Mississippi by 1967. Panel B is a digitized version of Panel A, which shows the proposed highway segments in the PARC report as blue-dashed lines. Figure was digitized using QGIS. Source for Panel A: PARC (1964).

Figure 2: Appalachian Development Highway System Progress: 1968-2017

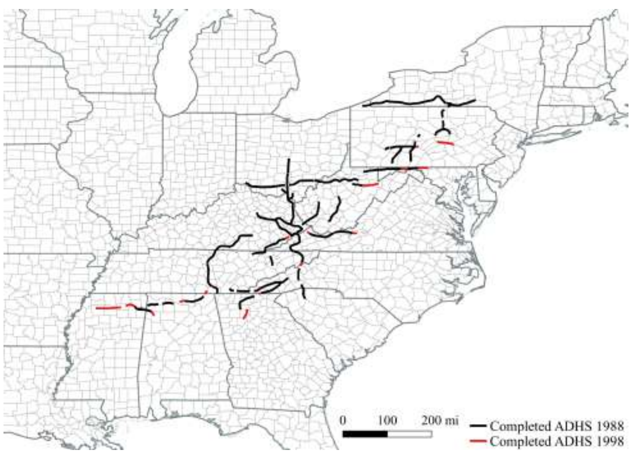
Panel A: ADHS Progress 1968-1978



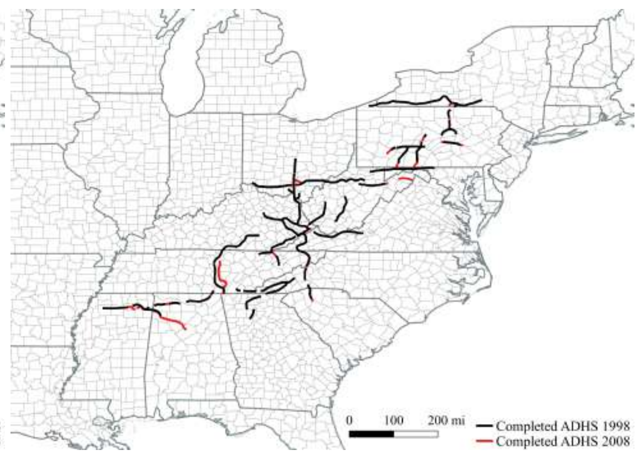
Panel B: ADHS Progress 1978-1988



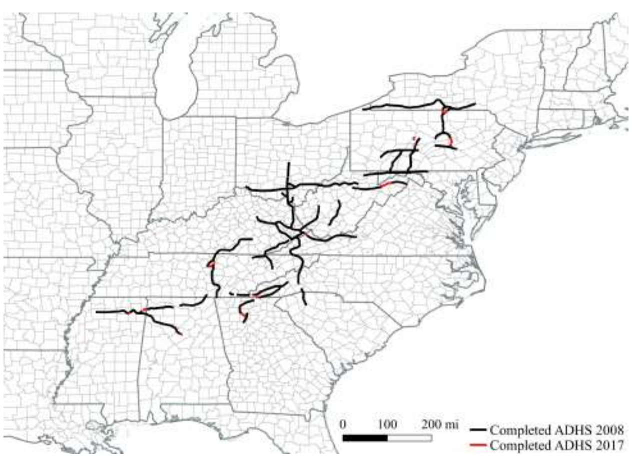
Panel C: ADHS Progress 1988-1998



Panel D: ADHS Progress 1998-2008



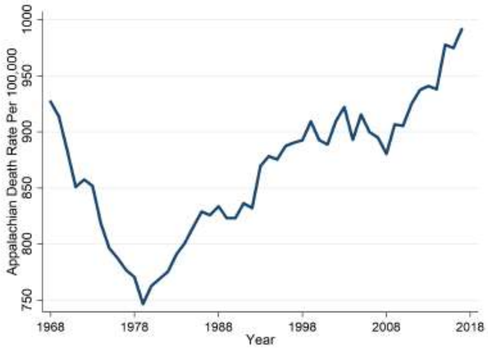
Panel E: ADHS Progress 2008-2017



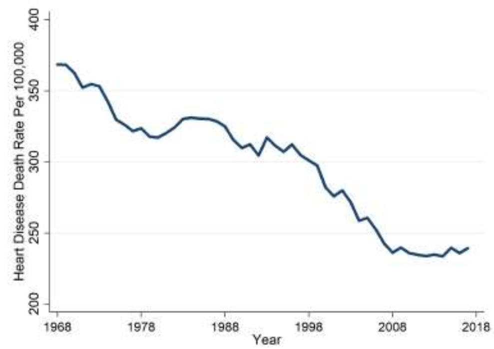
Note: Figures display construction progress of the Appalachian Development Highway System. In all Panels, black lines represent highway segments already constructed at the start of the period. Red lines represent highway segments completed in each time period. Figure created using QGIS.

Figure 3: Appalachian Mortality Rates 1968-2017: Per 100,000

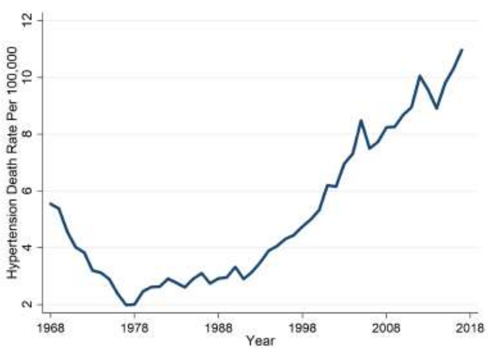
Panel A: Total Death Rate



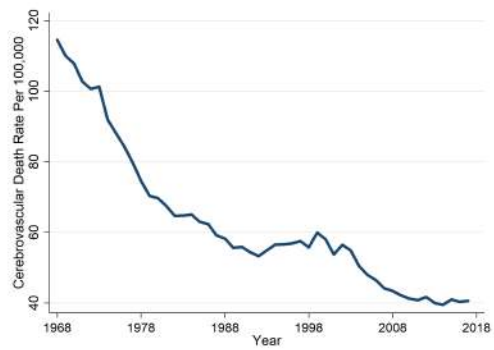
Panel B: Heart Disease Rate



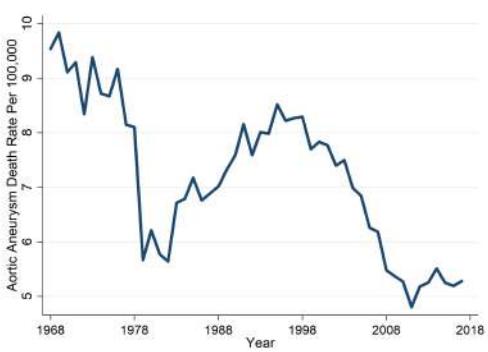
Panel C: Hypertension Rate



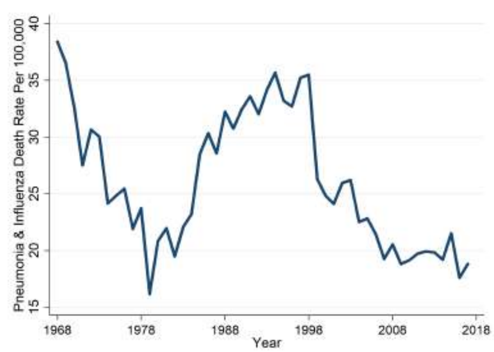
Panel D: Cerebrovascular Disease Rate



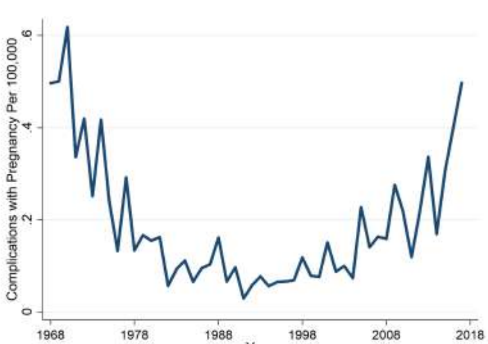
Panel E: Aortic Aneurysm Rate



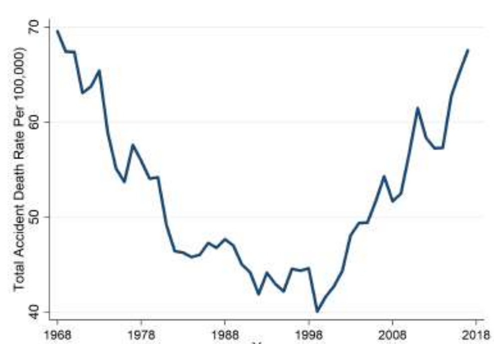
Panel F: Pneumonia & Influenza Rate



Panel G: Complications with Pregnancy Rate



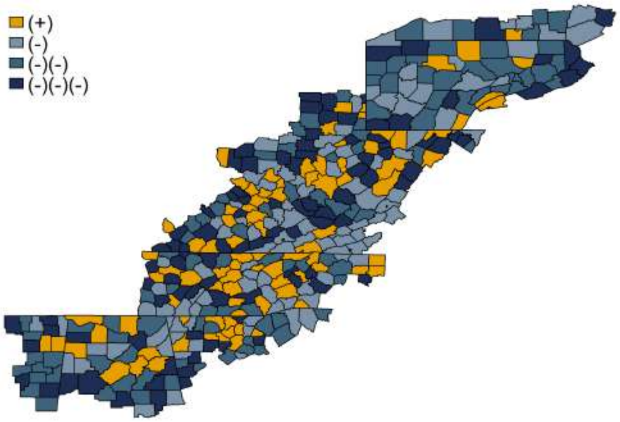
Panel H: Accident Rate



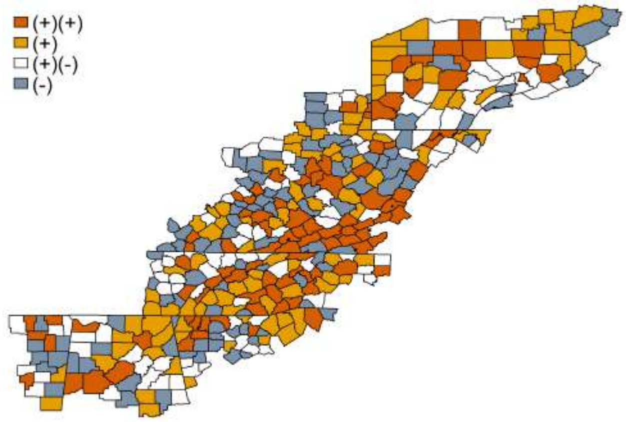
Note:: Appalachian death rates per 100,000 for various causes of death are shown above. Rates for county of death graphed.

Figure 4: Appalachian County Change in Mortality Rates: 1968-2017

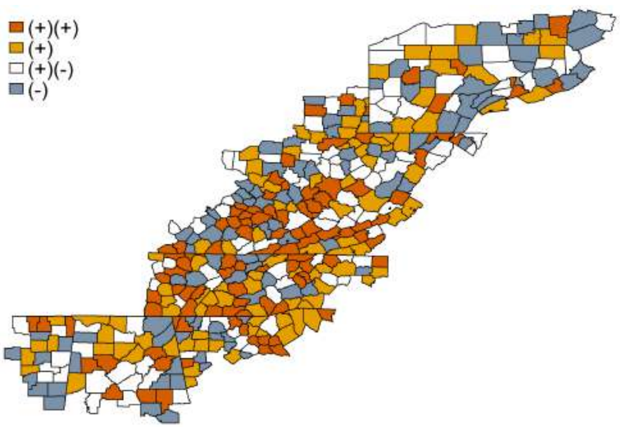
Panel A: Change in Total Mortality: 1968-1978



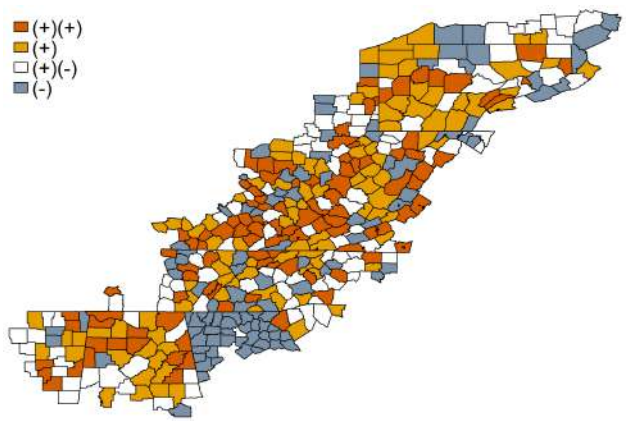
Panel B: Change in Total Mortality: 1978-1988



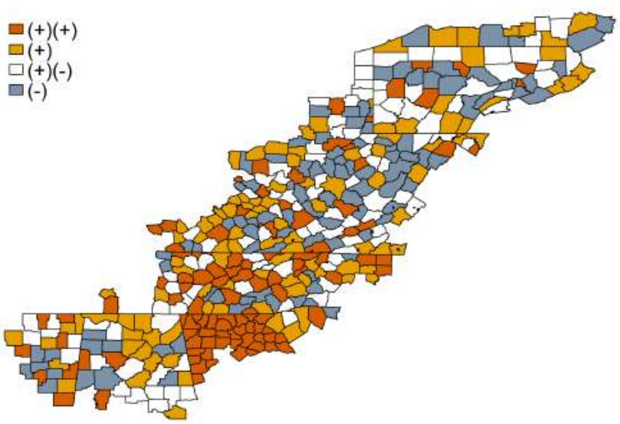
Panel C: Change in Total Mortality: 1988-1998



Panel D: Change in Total Mortality: 1998-2008

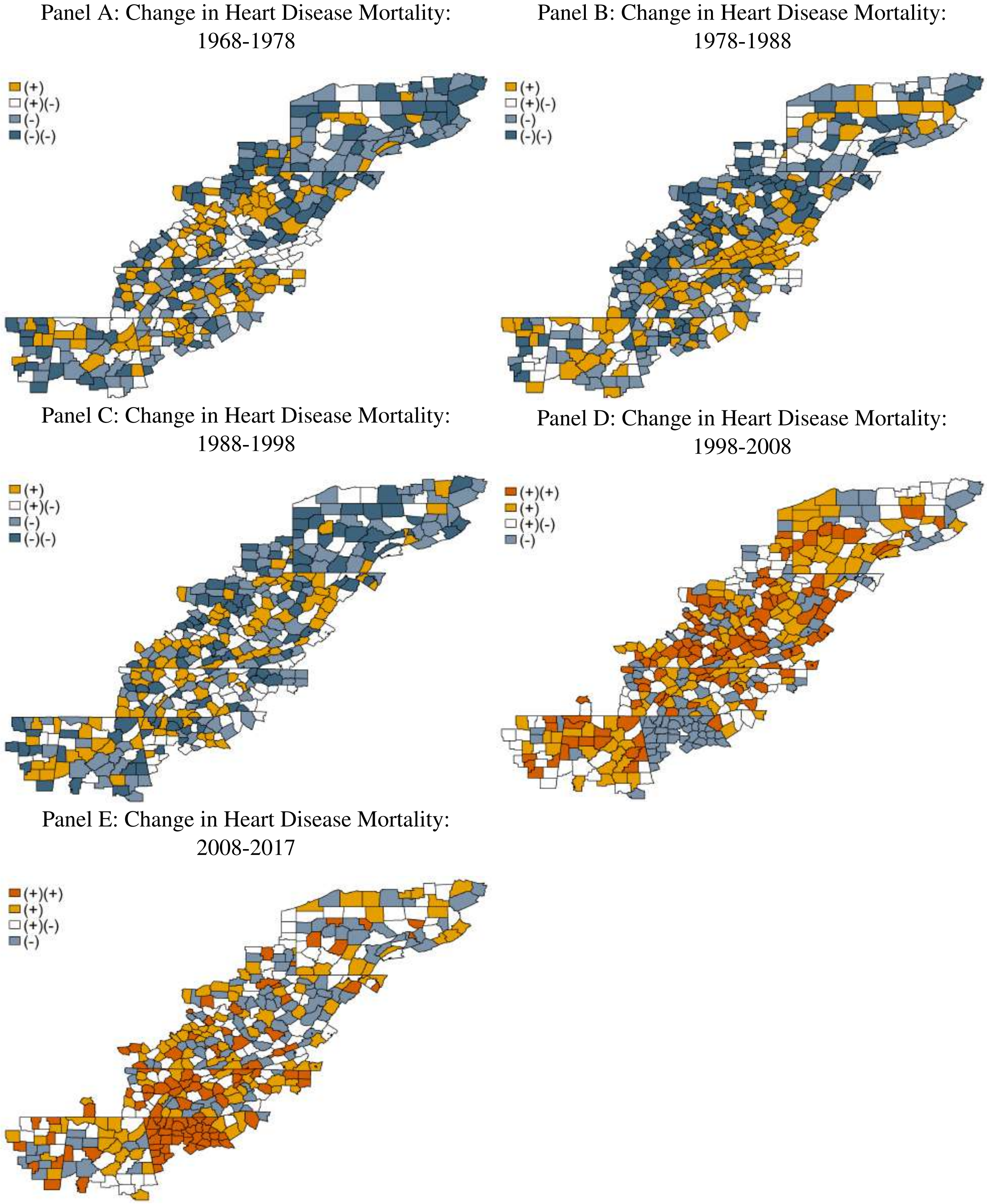


Panel E: Change in Total Mortality: 2008-2017



Note: Appalachian county changes in total mortality rates are shown above. Darker shades of blue represent negative changes (improved mortality over the decade), while darker shades of orange represent positive changes (worse mortality over the decade). White counties represent no significant change. Counties grouped into equal quantiles per decade. County of death mapped.

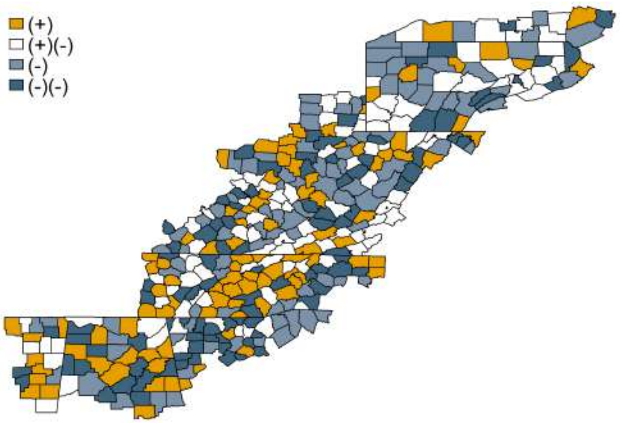
Figure 5: Appalachian County Change in Heart Disease Mortality Rates: 1968-2017



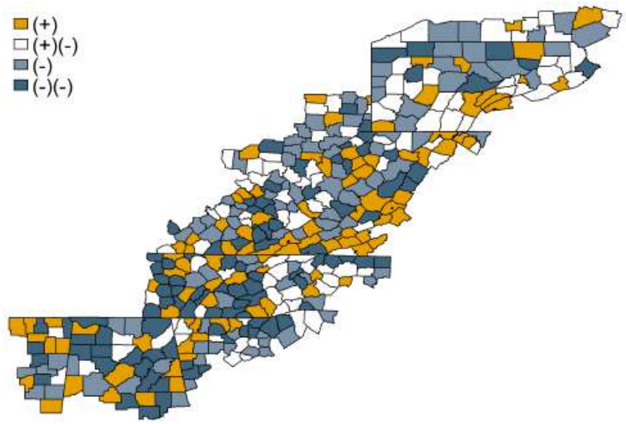
Note: Appalachian county changes in heart disease mortality rates are shown above. Darker shades of blue represent negative changes (improved mortality over the decade), while darker shades of orange represent positive changes (worse mortality over the decade). White counties represent no significant change. Counties grouped into equal quantiles per decade. County of death mapped.

Figure 6: Appalachian County Change in Total Accident Mortality Rates: 1968-2017

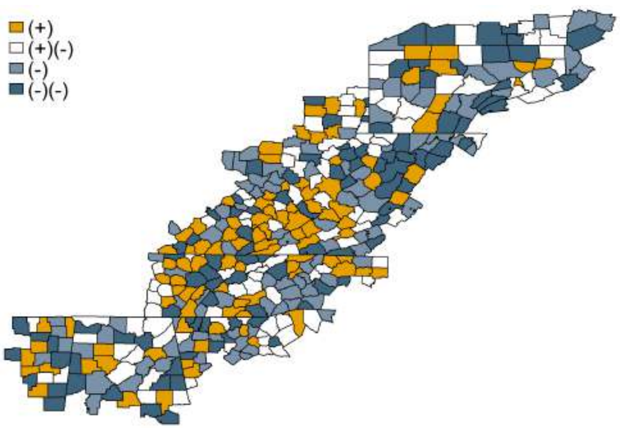
Panel A: Change in Total Accident Mortality: 1968-1978



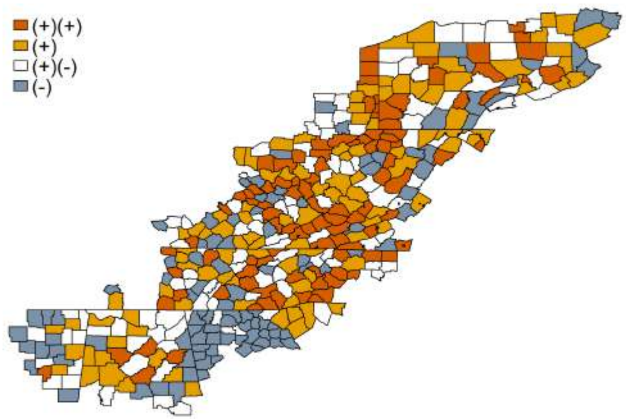
Panel B: Change in Total Accident Mortality: 1978-1988



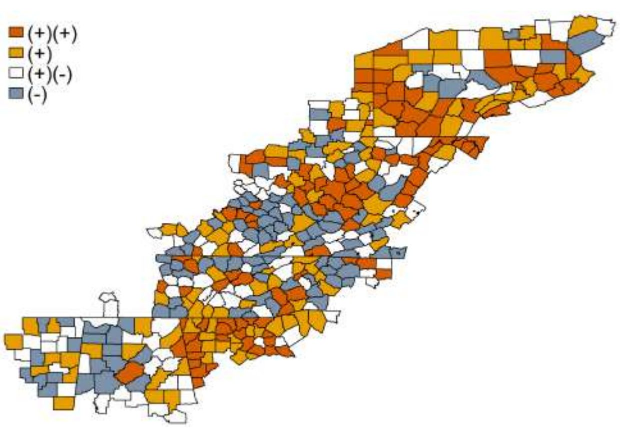
Panel C: Change in Total Accident Mortality: 1988-1998



Panel D: Change in Total Accident Mortality: 1998-2008

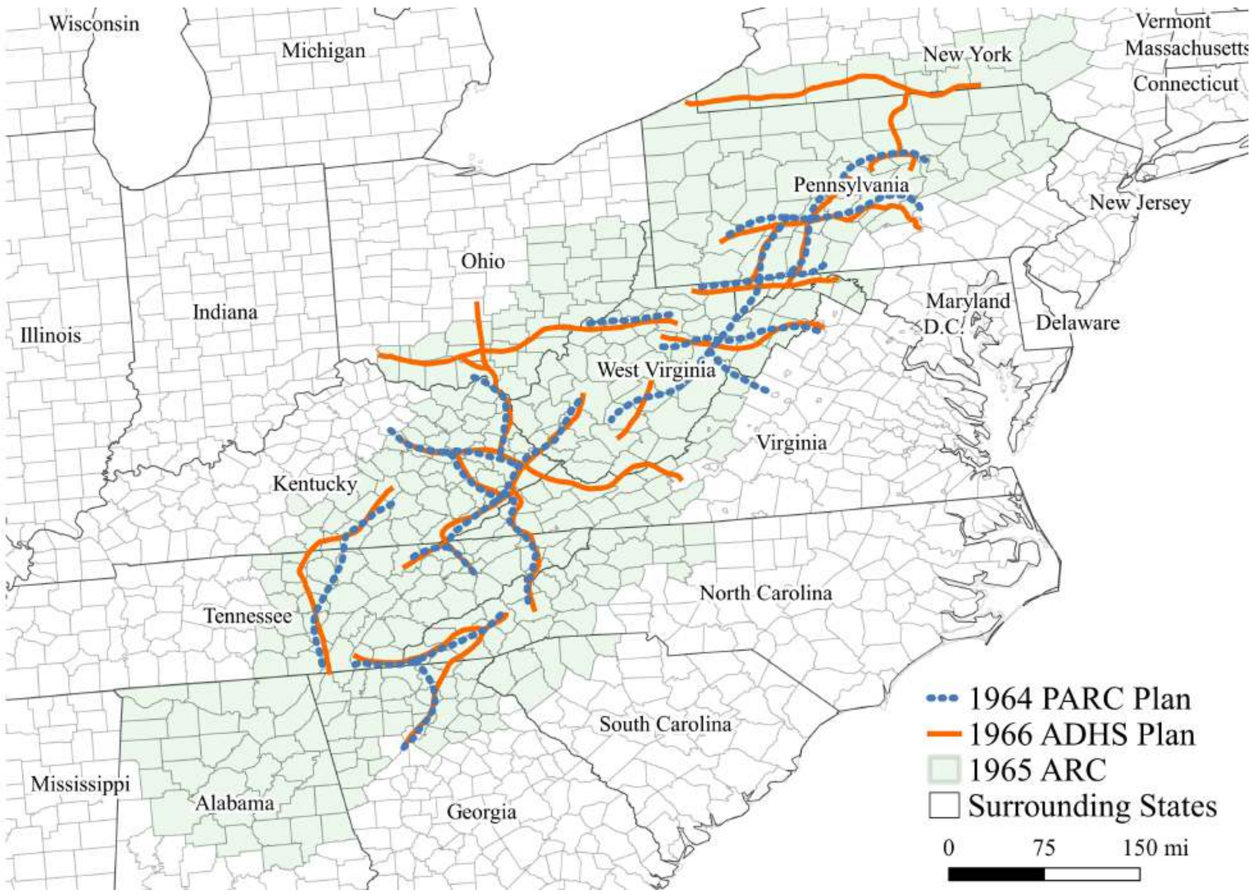


Panel E: Change in Total Accident Mortality: 2008-2017



Note: Appalachian county changes in total accident mortality rates are shown above. Darker shades of blue represent negative changes (improved mortality over the decade), while darker shades of orange represent positive changes (worse mortality over the decade). White counties represent no significant change. Counties grouped into equal quantiles per decade. County of death mapped.

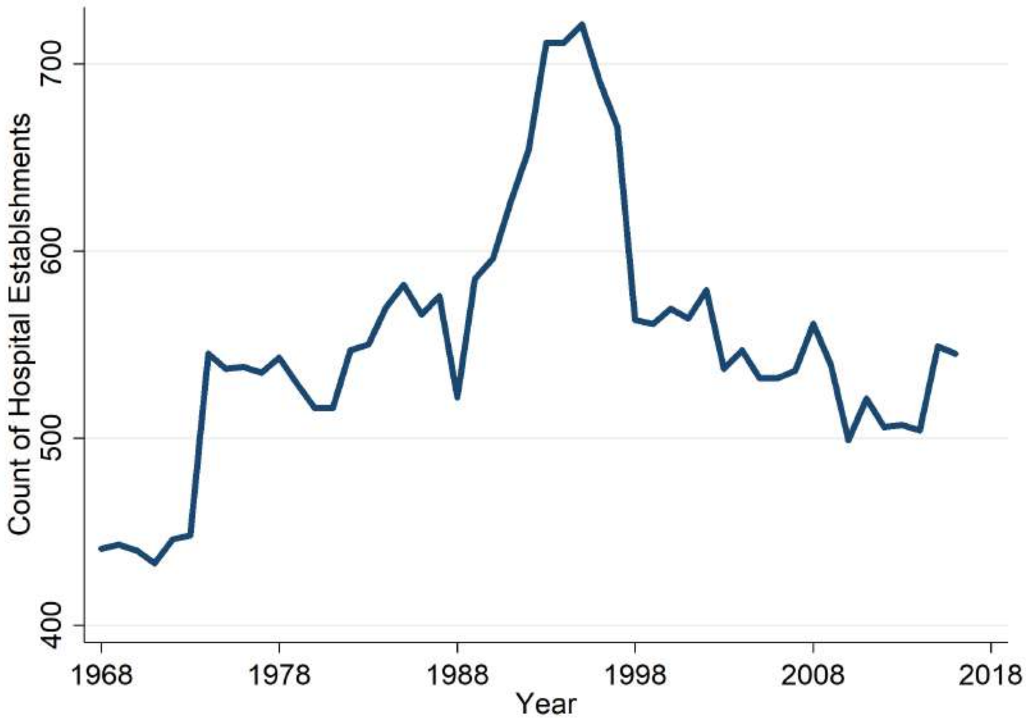
Figure 7: 1964 PARC Planned Highways vs. 1966 ADHS Planned Highways



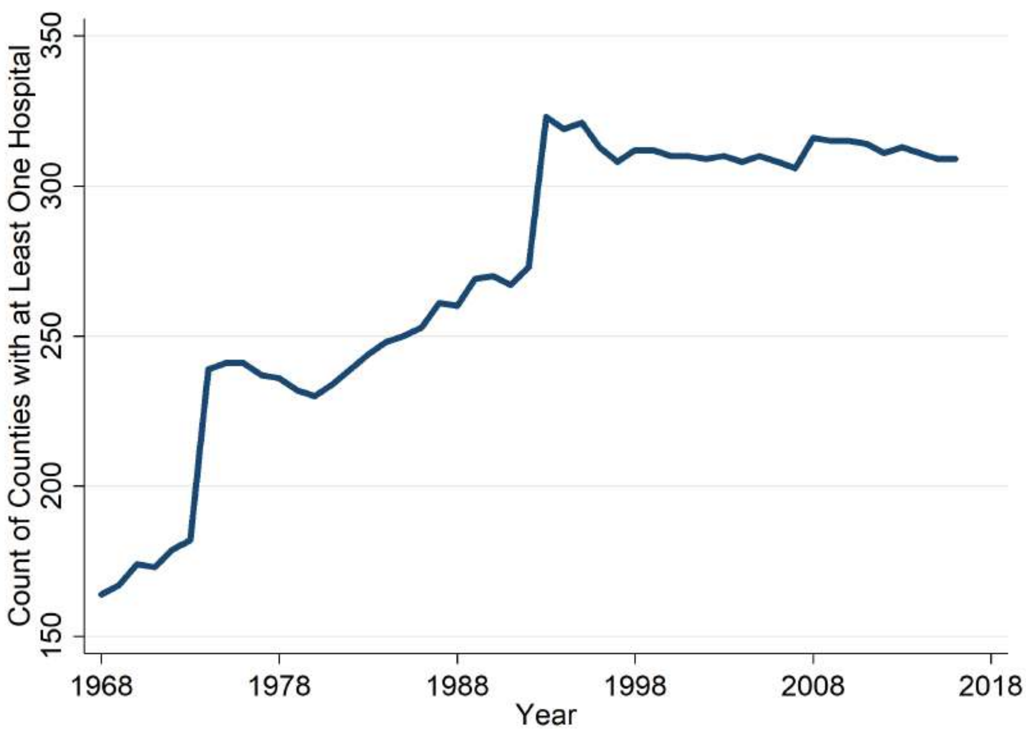
Note: This map visually compares the PARC planned highways location compared to a later plan after the creation of ARC. Figure was created using QGIS.

Figure 8: Hospitals in Appalachia over Time

Panel A: Count of Hospital Establishments

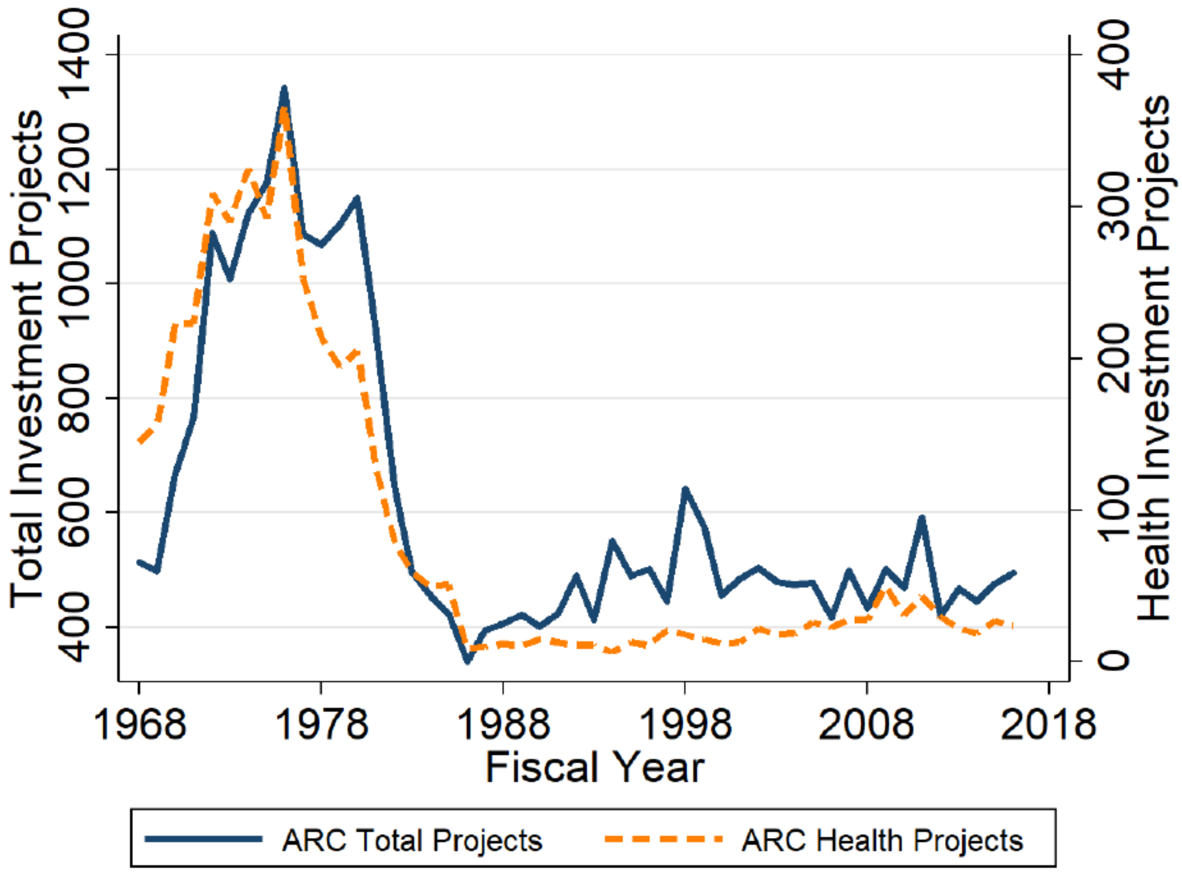


Panel B: Number of Counties with at Least One Hospital



Note: Panel A displays the count of hospitals in the Appalachian region over time. Panel B displays the number of counties in Appalachia with at least one hospital.

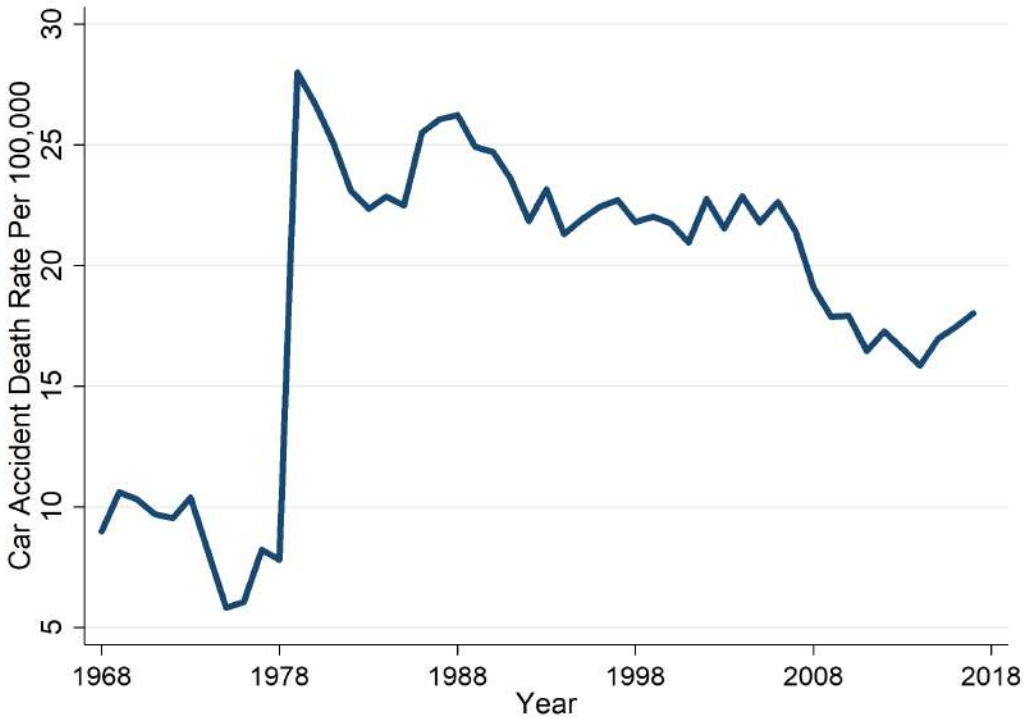
Figure 9: Count of ARC Investment Projects: 1968-2016



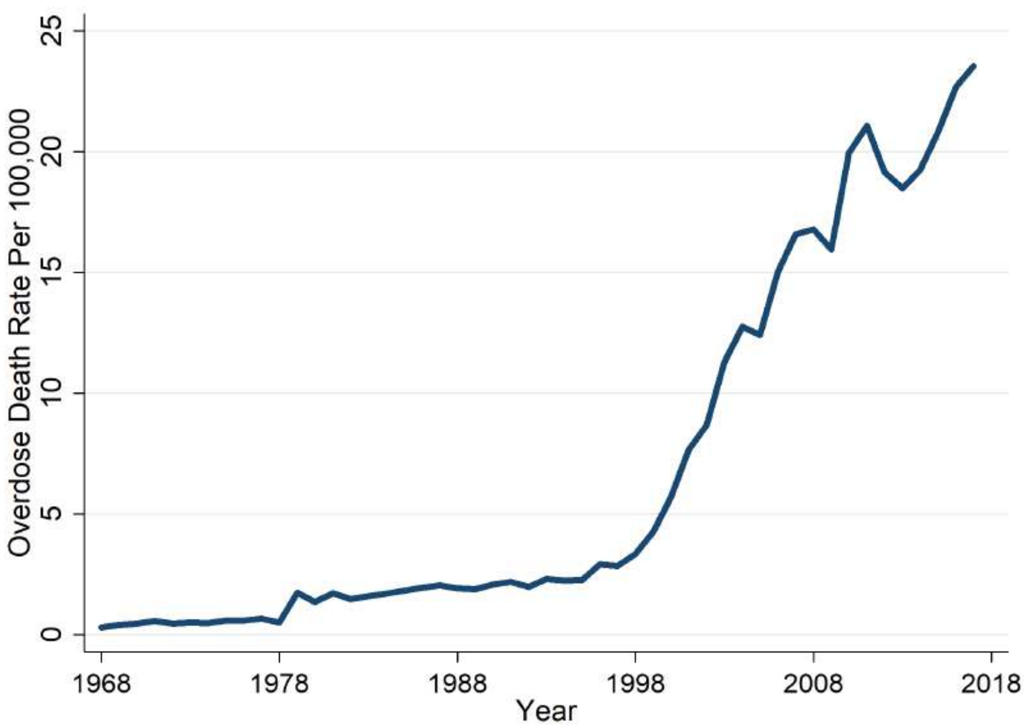
Note: Graph shows ARC investment projects from 1968-2016. The blue line shows the total count of ARC investment projects, while the orange dashed line shows the total count of projects that explicitly cite "health" in the project description.

Figure 10: Disaggregating Total Accidents: Car Accidents and Overdoses

Panel A: Car Accident Mortality Rate

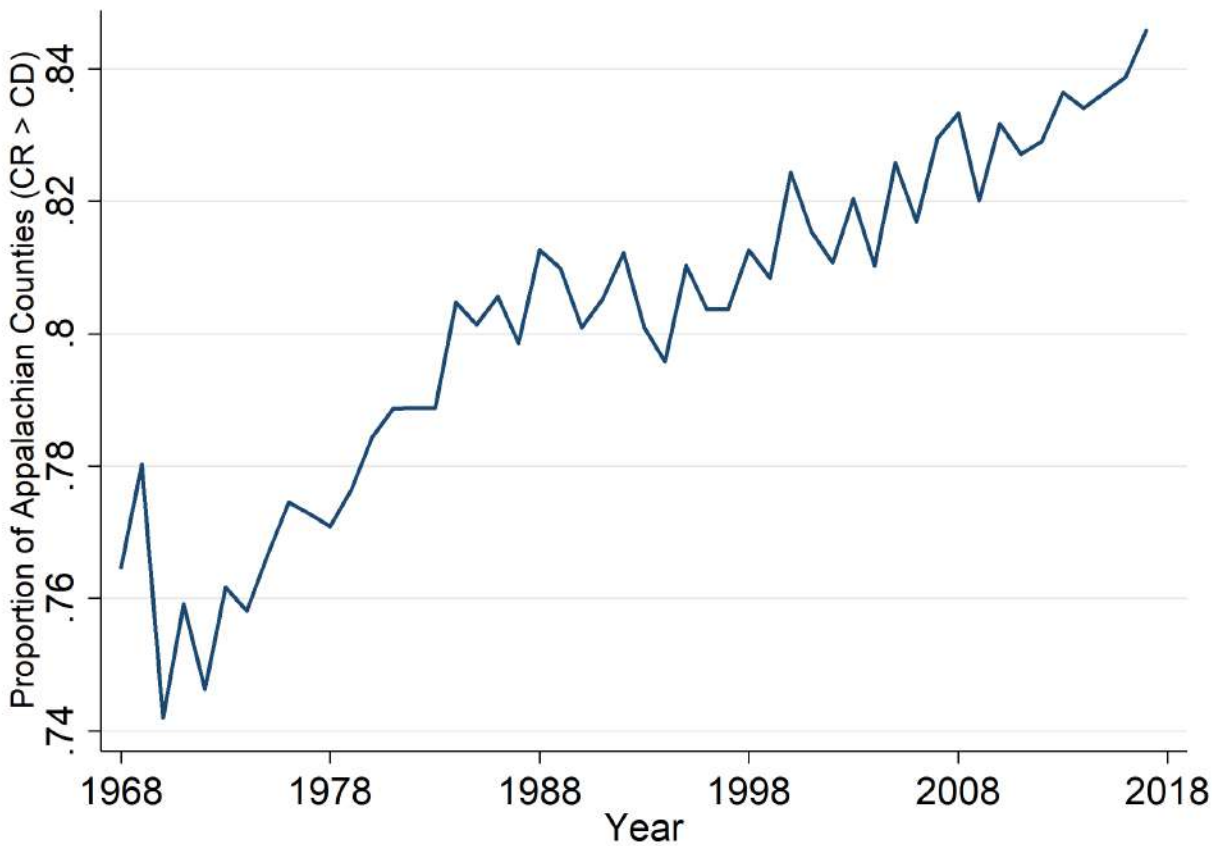


Panel B: Overdose Mortality Rate



Note: Panel A displays the car accident mortality rate in Appalachia. Panel B displays the accidental overdose mortality rate in Appalachia.

Figure 11: Proportion of Appalachian Counties with More Residents Dying Outside of the County



Note: Graph shows the proportion of Appalachian counties that have larger share of “county of residence” (CR) deaths compared to “county of death” (CD) deaths. In other words, this graph shows that more people in Appalachia over time died in a county that is not their county of residence, adding evidence of increased mobility in the region.

Table 1: Summary Statistics by Decade

	(1) Mean	(2) S.D.	(3) Min.	(4) Max.	(5) Count
Panel A: 1968-1978					
Distance to ADHS	47.4	38.00	0.29	191.91	3840
Distance to PARC Plan	48.5	53.95	0.25	250.42	3840
Hospital Count	1.2	2.48	0.00	39.00	3840
ARC Health Projects	0.4	0.89	0.00	8.00	3758
1960 Road Miles	192631.3	118629.67	32593.95	761721.75	3840
Panel B: 1978-1988					
Distance to ADHS	30.1	28.20	0.13	145.08	3916
Distance to PARC Plan	48.4	53.59	0.25	250.42	3916
Hospital Count	1.4	2.81	0.00	48.00	3916
ARC Health Projects	0.2	0.53	0.00	8.00	3821
1960 Road Miles	191554.0	117816.16	32593.95	761721.75	3916
Panel C: 1988-1998					
Distance to ADHS	28.1	25.86	0.13	145.08	3970
Distance to PARC Plan	48.4	53.34	0.25	250.42	3970
Hospital Count	1.6	2.89	0.00	43.00	3970
ARC Health Projects	0.0	0.23	0.00	4.00	3870
1960 Road Miles	190806.3	117247.65	32593.95	761721.75	3970
Panel D: 1998-2008					
Distance to ADHS	26.3	24.64	0.13	145.08	3970
Distance to PARC Plan	48.4	53.34	0.25	250.42	3970
Hospital Count	1.4	1.91	0.00	31.00	3964
ARC Health Projects	0.2	0.49	0.00	3.00	3870
1960 Road Miles	190806.3	117247.65	32593.95	761721.75	3970
Panel E: 2008-2017					
Distance to ADHS	24.4	21.89	0.06	145.08	3961
Distance to PARC Plan	48.4	53.34	0.25	250.42	3970
Hospital Count	1.3	2.09	0.00	46.00	3970
ARC Health Projects	0.3	0.58	0.00	5.00	3870
1960 Road Miles	190806.3	117247.65	32593.95	761721.75	3970

Note: Summary statistics for the county-year level, separated by decade, are shown above. Distance to ADHS is county centroid distance to nearest ADHS segment in miles. Distance to PARC plan is county centroid distance to nearest PARC planned segment. 1960 road miles is the total county road network in 1960 measured in miles.

Table 2: 2SLS Estimates of Appalachian Development Highway System on Total Mortality Rate With Controls

	(1) Mean Δ Mortality	(2) Reduced Form	(3) 1st Stage	(4) 2nd Stage
Panel A: 1968-1978 Δ in Total Mortality				
Distance to PARC 1964 Plan		0.340	-0.207***	
		(0.709)	(0.022)	
$\Delta\widehat{ADHS}$	-161.263			-1.642
	(954.674)			(3.415)
Counties	396	396	396	396
Kleibergen-Paap F				91.28
Panel B: 1978-1988 Δ in Total Mortality				
Distance to PARC 1964 Plan		0.191	-0.102***	
		(0.274)	(0.010)	
$\Delta\widehat{ADHS}$	37.413			-1.865
	(402.965)			(2.677)
Counties	396	396	396	396
Kleibergen-Paap F				103.81
Panel C: 1988-1998 Δ in Total Mortality				
Distance to PARC 1964 Plan		-0.248*	-0.035***	
		(0.143)	(0.009)	
$\Delta\widehat{ADHS}$	49.578			7.705
	(158.240)			(4.354)
Counties	406	406	406	406
Kleibergen-Paap F				14.76
Panel D: 1998-2008 Δ in Total Mortality				
Distance to PARC 1964 Plan		0.079	-0.041***	
		(0.143)	(0.011)	
$\Delta\widehat{ADHS}$	-12.176			-1.932
	(234.105)			(3.568)
Counties	427	427	427	427
Kleibergen-Paap F				13.67
Panel E: 2008-2017 Δ in Total Mortality				
Distance to PARC 1964 Plan		-0.304*	-0.003***	
		(0.162)	(0.001)	
$\Delta\widehat{ADHS}$	111.009			98.912
	(235.044)			(61.741)
Counties	427	427	427	427
Kleibergen-Paap F				8.13

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is change in total mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows the mean change in total mortality, with standard deviations in parentheses. Column 2 shows reduced form results (PARC distance on mortality), Column 3 shows first stage results (PARC distance on ADHS distance), and Column 4 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade, the total number of health-related ARC investment projects over the decade at the county level, and the length of existing road network in 1960 at the county level. County-clustered standard errors are used in every column and panel.

Table 3: 2SLS Estimates of Appalachian Development Highway System on Heart Disease Mortality Rate With Controls

	(1) Mean Δ Mortality	(2) Reduced Form	(3) 1st Stage	(4) 2nd Stage
Panel A: 1968-1978 Δ in Heart Disease Mortality				
Distance to PARC 1964 Plan		-0.049	-0.207***	
		(0.161)	(0.021)	
$\Delta\widehat{ADHS}$	-45.110			0.234
	(208.795)			(0.775)
Counties	396	396	396	396
Kleibergen-Paap F				91.28
Panel B: 1978-1988 Δ in Heart Disease Mortality				
Distance to PARC 1964 Plan		0.304**	-0.102***	
		(0.128)	(0.010)	
$\Delta\widehat{ADHS}$	-8.456			-2.974**
	(182.499)			(1.309)
Counties	396	396	396	396
Kleibergen-Paap F				103.81
Panel C: 1988-1998 Δ in Heart Disease Mortality				
Distance to PARC 1964 Plan		0.004	-0.035***	
		(0.066)	(0.009)	
$\Delta\widehat{ADHS}$	-27.219			-0.119
	(77.396)			(1.886)
Counties	406	406	406	406
Kleibergen-Paap F				14.76
Panel D: 1998-2008 Δ in Heart Disease Mortality				
Distance to PARC 1964 Plan		0.168**	-0.040***	
		(0.068)	(0.011)	
$\Delta\widehat{ADHS}$	-65.146			-4.132**
	(98.173)			(1.978)
Counties	427	427	427	427
Kleibergen-Paap F				13.67
Panel E: 2008-2017 Δ in Heart Disease Mortality				
Distance to PARC 1964 Plan		-0.084	-0.003***	
		(0.063)	(0.001)	
$\Delta\widehat{ADHS}$	2.984			27.157
	(85.988)			(23.015)
Counties	427	427	427	427
Kleibergen-Paap F				8.13

Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Dependent variable is change in heart disease mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows the mean change in heart disease mortality, with standard deviations in parentheses. Column 2 shows reduced form results (PARC distance on mortality), Column 3 shows first stage results (PARC distance on ADHS distance), and Column 4 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade, the total number of health-related ARC investment projects over the decade at the county level, and the length of existing road network in 1960 at the county level. County-clustered standard errors are used in every column and panel.

Table 4: 2SLS Estimates of Appalachian Development Highway System on Hypertension Mortality Rate With Controls

	(1) Mean Δ Mortality	(2) Reduced Form	(3) 1st Stage	(4) 2nd Stage
Panel A: 1968-1978 Δ in Hypertension Mortality				
Distance to PARC 1964 Plan		-0.007	-0.207***	
		(0.011)	(0.022)	
$\Delta\widehat{ADHS}$	-3.433			0.033
	(14.555)			(0.054)
Counties	396	396	396	396
Kleibergen-Paap F				91.28
Panel B: 1978-1988 Δ in Hypertension Mortality				
Distance to PARC 1964 Plan		-0.001	-0.102***	
		(0.004)	(0.010)	
$\Delta\widehat{ADHS}$	0.923			0.008
	(5.223)			(0.039)
Counties	396	396	396	396
Kleibergen-Paap F				103.81
Panel C: 1988-1998 Δ in Hypertension Mortality				
Distance to PARC 1964 Plan		0.017**	-0.035***	
		(0.007)	(0.009)	
$\Delta\widehat{ADHS}$	1.694			-0.474**
	(5.893)			(0.216)
Counties	406	406	406	406
Kleibergen-Paap F				14.76
Panel D: 1998-2008 Δ in Hypertension Mortality				
Distance to PARC 1964 Plan		0.000	-0.041***	
		(0.014)	(0.010)	
$\Delta\widehat{ADHS}$	3.508			-0.002
	(9.686)			(0.357)
Counties	427	427	427	427
Kleibergen-Paap F				13.67
Panel E: 2008-2017 Δ in Hypertension Mortality				
Distance to PARC 1964 Plan		-0.016	-0.003***	
		(0.014)	(0.001)	
$\Delta\widehat{ADHS}$	2.723			5.280
	(11.977)			(4.890)
Counties	427	427	427	427
Kleibergen-Paap F				8.13

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is change in hypertension mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows the mean change in hypertension mortality, with standard deviations in parentheses. Column 2 shows reduced form results (PARC distance on mortality), Column 3 shows first stage results (PARC distance on ADHS distance), and Column 4 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade, the total number of health-related ARC investment projects over the decade at the county level, and the length of existing road network in 1960 at the county level. County-clustered standard errors are used in every column and panel.

Table 5: 2SLS Estimates of Appalachian Development Highway System on Accident Mortality Rate With Controls

	(1) Mean Δ Mortality	(2) Reduced Form	(3) 1st Stage	(4) 2nd Stage
Panel A: 1968-1978 Δ in Total Accident Mortality				
Distance to PARC 1964 Plan		-0.003	-0.207***	
		(0.037)	(0.022)	
$\Delta\widehat{ADHS}$	-13.667			0.016
	(47.674)			(0.179)
Counties	396	396	396	396
Kleibergen-Paap F				91.28
Panel B: 1978-1988 Δ in Total Accident Mortality				
Distance to PARC 1964 Plan		0.070	-0.102***	
		(0.051)	(0.010)	
$\Delta\widehat{ADHS}$	-9.333			-0.686
	(62.190)			(0.496)
Counties	396	396	396	396
Kleibergen-Paap F				103.81
Panel C: 1988-1998 Δ in Total Accident Mortality				
Distance to PARC 1964 Plan		-0.027	-0.035***	
		(0.030)	(0.009)	
$\Delta\widehat{ADHS}$	-3.898			0.769
	(23.430)			(0.836)
Counties	406	406	406	406
Kleibergen-Paap F				14.76
Panel D: 1998-2008 Δ in Total Accident Mortality				
Distance to PARC 1964 Plan		-0.068***	-0.041***	
		(0.020)	(0.011)	
$\Delta\widehat{ADHS}$	7.073			1.666**
	(29.025)			(0.709)
Counties	427	427	427	427
Kleibergen-Paap F				13.67
Panel E: 2008-2017 Δ in Total Accident Mortality				
Distance to PARC 1964 Plan		-0.093***	-0.003***	
		(0.023)	(0.001)	
$\Delta\widehat{ADHS}$	15.812			30.343**
	(32.603)			(12.347)
Counties	427	427	427	427
Kleibergen-Paap F				8.13
Two-Step AR-CIs				[14.454, 95.118]

Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Dependent variable is change in accident mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows the mean change in accident mortality, with standard deviations in parentheses. Column 2 shows reduced form results (PARC distance on mortality), Column 3 shows first stage results (PARC distance on ADHS distance), and Column 4 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade, the total number of health-related ARC investment projects over the decade at the county level, and the length of existing road network in 1960 at the county level. County-clustered standard errors are used in every column and panel. Panel E includes two-step Anderson-Rubin confidence interval.

Table 6: 2SLS Estimates of Appalachian Development Highway System on Car Accident Mortality Rate With Controls

	(1) Mean Δ Mortality	(2) Reduced Form	(3) 1st Stage	(4) 2nd Stage
Panel A: 1968-1978 Δ in Car Accident Mortality				
Distance to PARC 1964 Plan		0.005	-0.207***	
		(0.012)	(0.022)	
$\Delta\widehat{ADHS}$	-0.974			-0.028
	(12.675)			(0.061)
Counties	396	396	396	396
Kleibergen-Paap F				91.28
Panel B: 1978-1988 Δ in Car Accident Mortality				
Distance to PARC 1964 Plan		0.026	-0.102***	
		(0.020)	(0.010)	
$\Delta\widehat{ADHS}$	18.177			-0.253
	(19.350)			(0.186)
Counties	396	396	396	396
Kleibergen-Paap F				103.81
Panel C: 1988-1998 Δ in Car Accident Mortality				
Distance to PARC 1964 Plan		-0.003	-0.035***	
		(0.019)	(0.009)	
$\Delta\widehat{ADHS}$	-4.623			0.071
	(16.572)			(0.534)
Counties	406	406	406	406
Kleibergen-Paap F				14.76
Panel D: 1998-2008 Δ in Car Accident Mortality				
Distance to PARC 1964 Plan		-0.001	-0.041***	
		(0.014)	(0.011)	
$\Delta\widehat{ADHS}$	-2.773			0.023
	(15.439)			(0.347)
Counties	427	427	427	427
Kleibergen-Paap F				13.67
Panel E: 2008-2017 Δ in Car Accident Mortality				
Distance to PARC 1964 Plan		0.026*	-0.003***	
		(0.014)	(0.001)	
$\Delta\widehat{ADHS}$	-1.035			-8.295
	(15.703)			(5.417)
Counties	427	427	427	427
Kleibergen-Paap F				8.13

Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Dependent variable is change in car accident mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows the mean change in car accident mortality, with standard deviations in parentheses. Column 2 shows reduced form results (PARC distance on mortality), Column 3 shows first stage results (PARC distance on ADHS distance), and Column 4 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade, the total number of health-related ARC investment projects over the decade at the county level, and the length of existing road network in 1960 at the county level. County-clustered standard errors are used in every column and panel.

Table 7: 2SLS Estimates of Appalachian Development Highway System on Accidental Overdose Mortality Rate With Controls

	(1) Mean Δ Mortality	(2) Reduced Form	(3) 1st Stage	(4) 2nd Stage
Panel A: 1968-1978 Δ in Overdose Mortality				
Distance to PARC 1964 Plan		0.001	-0.207***	
		(0.002)	(0.022)	
$\Delta\widehat{ADHS}$	0.206			-0.003
	(1.879)			(0.010)
Counties	396	396	396	396
Kleibergen-Paap F				91.28
Panel B: 1978-1988 Δ in Overdose Mortality				
Distance to PARC 1964 Plan		-0.002	-0.102***	
		(0.004)	(0.010)	
$\Delta\widehat{ADHS}$	1.434			0.026
	(2.994)			(0.035)
Counties	396	396	396	396
Kleibergen-Paap F				103.81
Panel C: 1988-1998 Δ in Overdose Mortality				
Distance to PARC 1964 Plan		-0.010***	-0.035***	
		(0.004)	(0.009)	
$\Delta\widehat{ADHS}$	1.346			0.292**
	(4.523)			(0.125)
Counties	406	406	406	406
Kleibergen-Paap F				14.76
Panel D: 1998-2008 Δ in Overdose Mortality				
Distance to PARC 1964 Plan		-0.037***	-0.041***	
		(0.010)	(0.011)	
$\Delta\widehat{ADHS}$	13.461			0.920**
	(15.332)			(0.362)
Counties	427	427	427	427
Kleibergen-Paap F				13.67
Panel E: 2008-2017 Δ in Overdose Mortality				
Distance to PARC 1964 Plan		-0.048***	-0.003***	
		(0.011)	(0.001)	
$\Delta\widehat{ADHS}$	6.724			15.622**
	(19.479)			(6.356)
Counties	427	427	427	427
Kleibergen-Paap F				8.13
Two-Step AR-CIs				[7.442, 50.228]

Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Dependent variable is change in accidental overdose mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows the mean change in overdose mortality, with standard deviations in parentheses. Column 2 shows reduced form results (PARC distance on mortality), Column 3 shows first stage results (PARC distance on ADHS distance), and Column 4 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade, the total number of health-related ARC investment projects over the decade at the county level, and the length of existing road network in 1960 at the county level. County-clustered standard errors are used in every column and panel. Panel E includes two-step Anderson-Rubin confidence interval.

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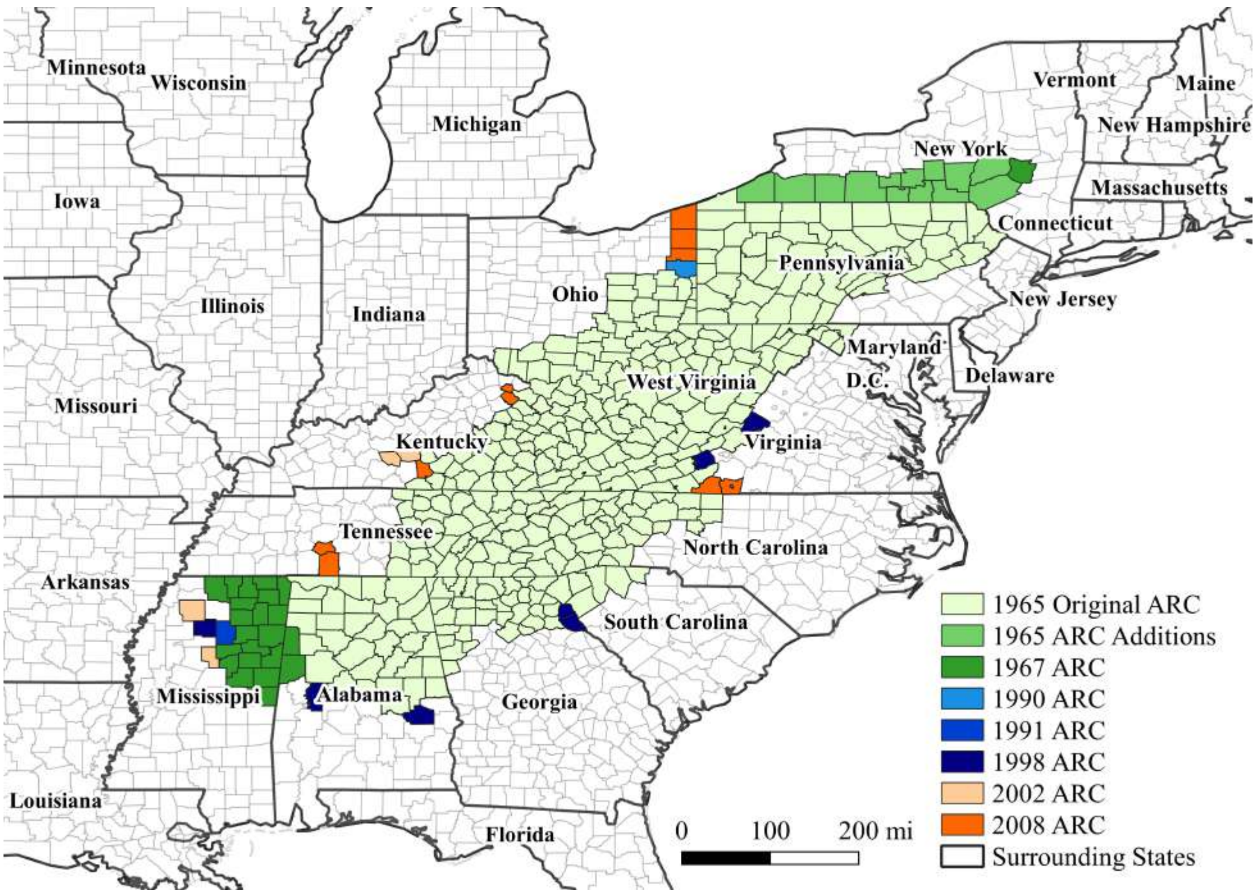
1

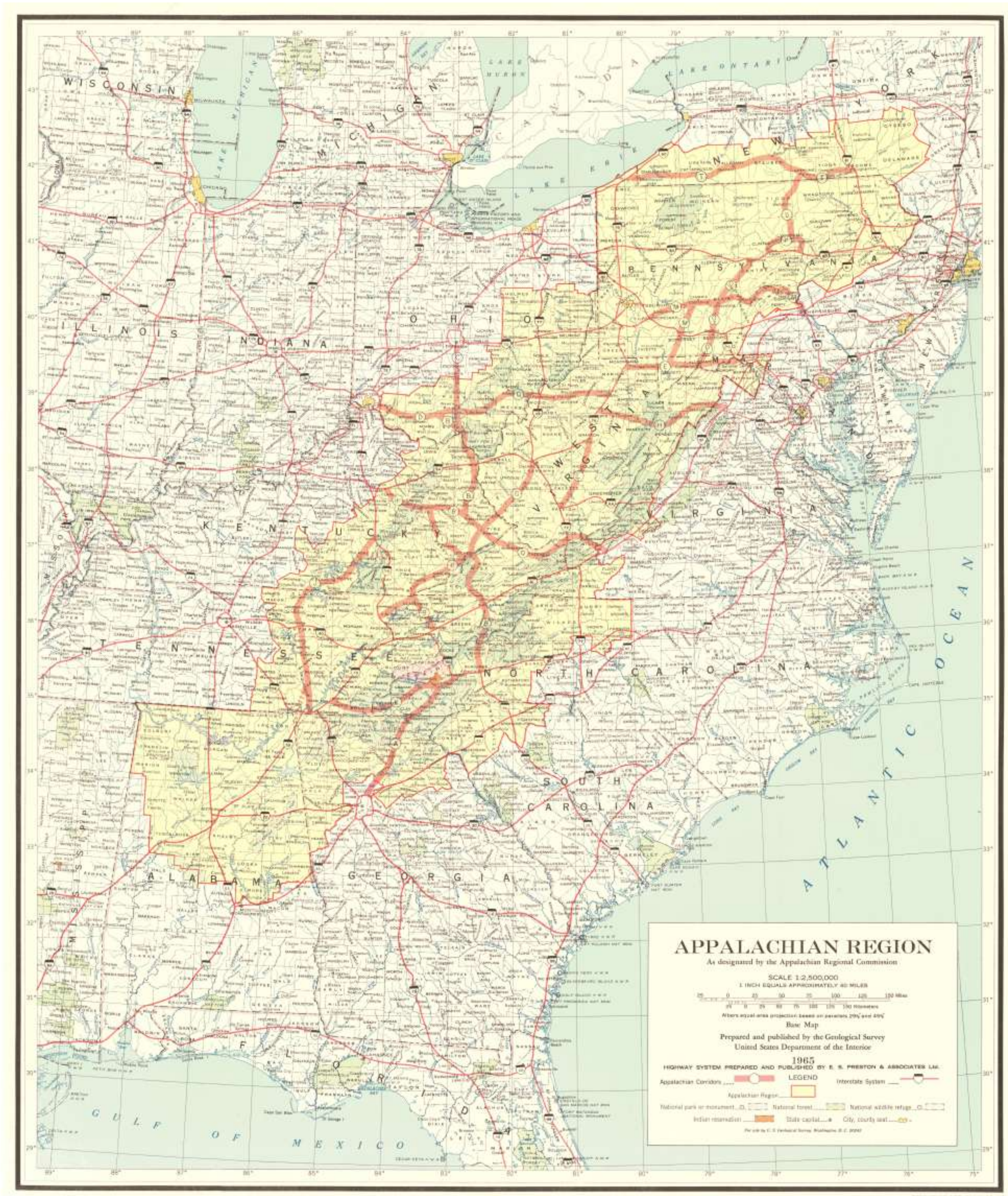
A Appendix Figures and Tables

Figure A.1: Appalachian Regional Commission (ARC) Counties Over Time



Note: This map shows the Appalachian Regional Commission (ARC) over time (1965-present). Each new color represents a year when a new county or counties were added to the ARC. The ARC remained relatively consistent in geography from 1967 until 1990. Throughout the 1990s-2000s, several counties were added, bringing the current total of ARC counties to 420. West Virginia is the only state with all of its counties in ARC. Figure was created using QGIS.

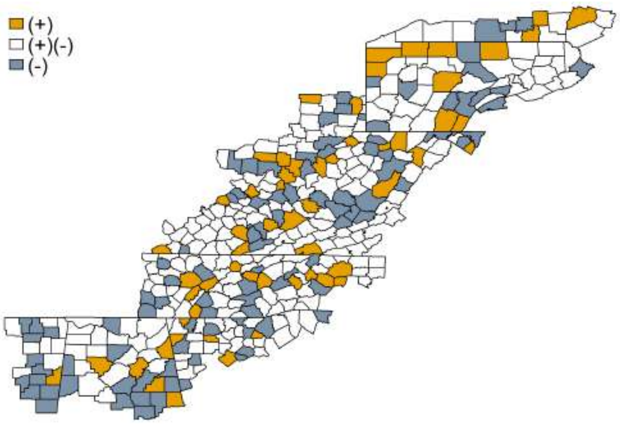
Figure A.2: 1966 ARC Plan for the ADHS



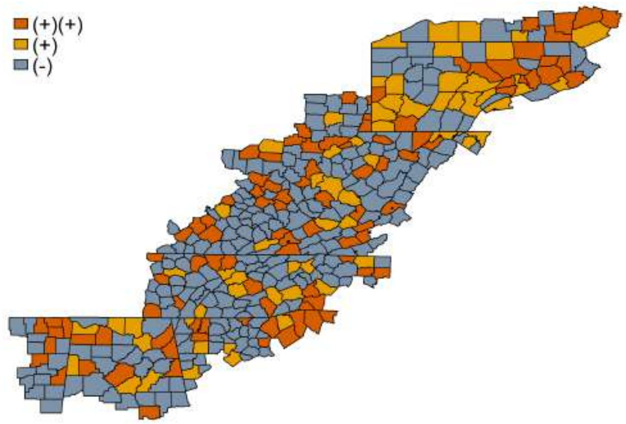
Note: This is a map of the 1966 planned ADHS route. Compared to Figure 1, this map was updated to include the larger extent of the Appalachian region under ARC.

Figure A.3: Appalachian County Change in Hypertension Mortality Rates: 1968-2017

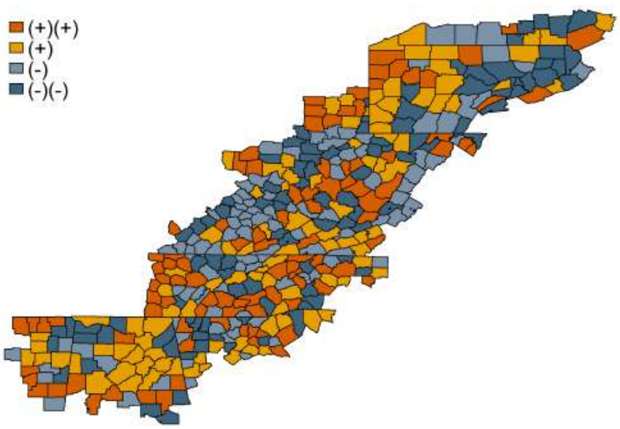
Panel A: Change in Hypertension Mortality:
1968-1978



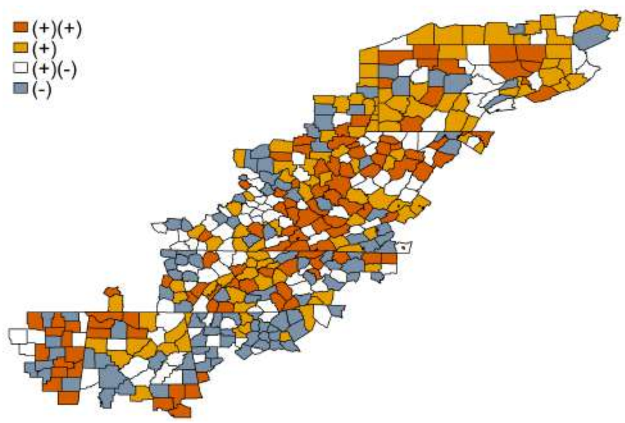
Panel B: Change in Hypertension Mortality:
1978-1988



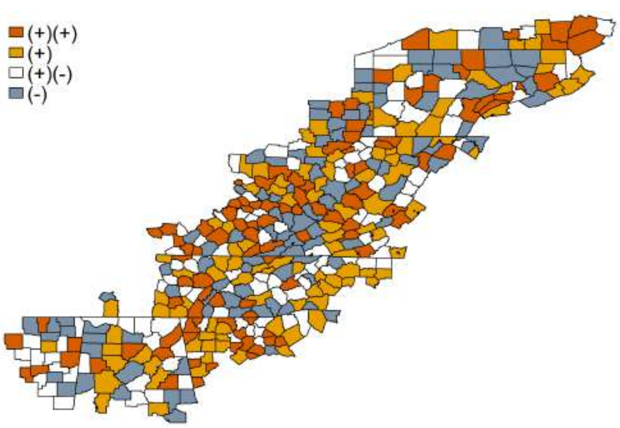
Panel C: Change in Hypertension Mortality:
1988-1998



Panel D: Change in Hypertension Mortality:
1998-2008



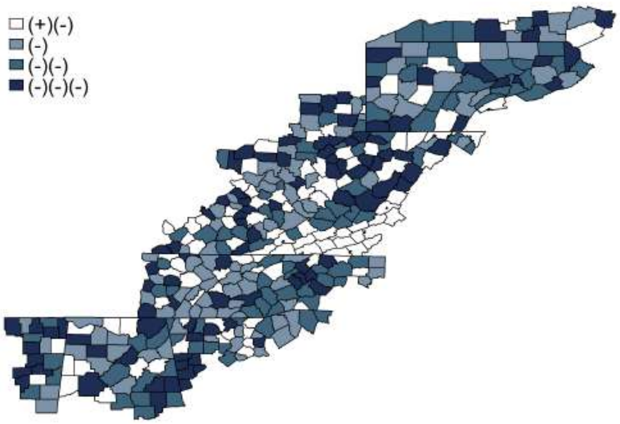
Panel E: Change in Hypertension Mortality:
2008-2017



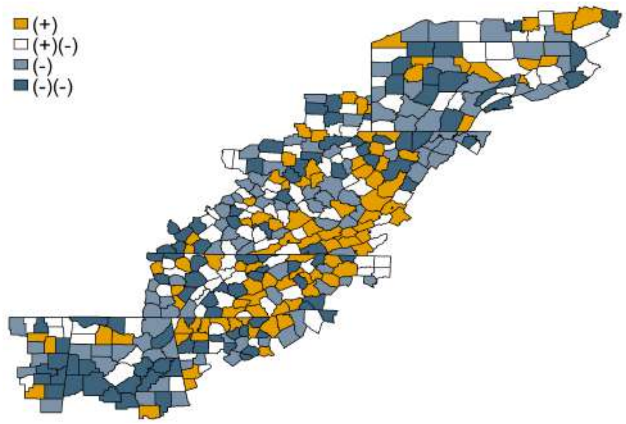
Note: Appalachian county changes in hypertension mortality rates are shown above. Darker shades of blue represent negative changes (improved mortality over the decade), while darker shades of orange represent positive changes (worse mortality over the decade). White counties represent no significant change. Counties grouped into equal quantiles per decade. County of death mapped.

Figure A.4: Appalachian County Change in Cerebrovascular Disease Mortality Rates: 1968-2017

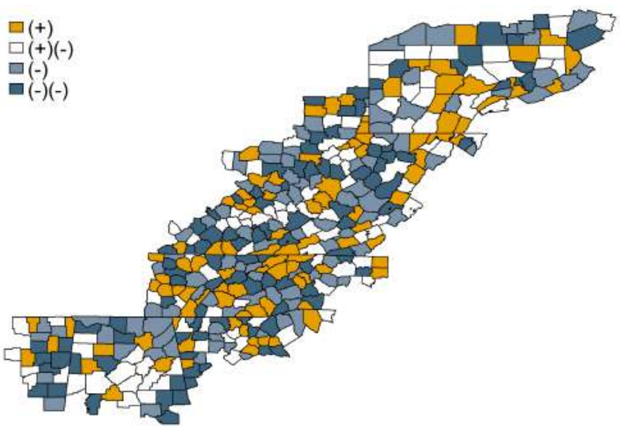
Panel A: Change in Cerebrovascular Disease Mortality: 1968-1978



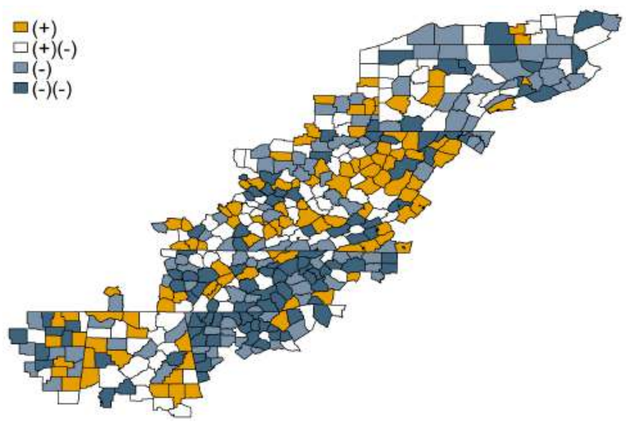
Panel B: Change in Cerebrovascular Disease Mortality: 1978-1988



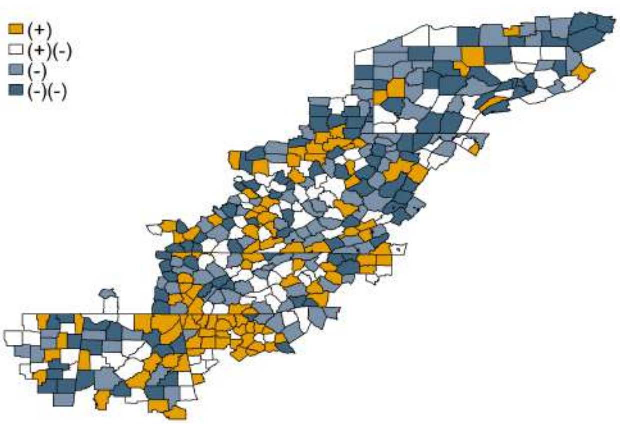
Panel C: Change in Cerebrovascular Disease Mortality: 1988-1998



Panel D: Change in Cerebrovascular Disease Mortality: 1998-2008



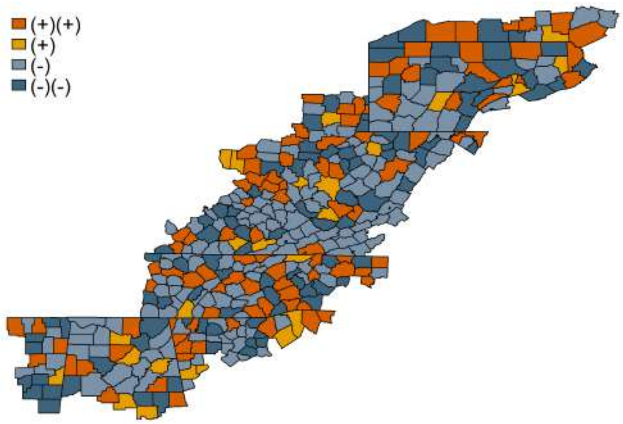
Panel E: Change in Cerebrovascular Disease Mortality: 2008-2017



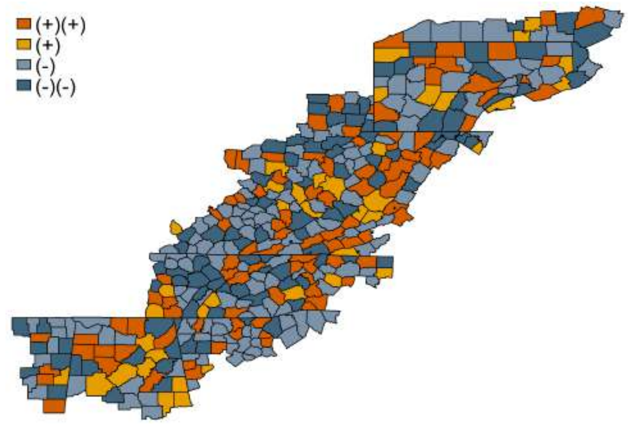
Note: Appalachian county changes in cerebrovascular disease mortality rates are shown above. Darker shades of blue represent negative changes (improved mortality over the decade), while darker shades of orange represent positive changes (worse mortality over the decade). White counties represent no significant change. Counties grouped into equal quantiles per decade. County of death mapped.

Figure A.5: Appalachian County Change in Aortic Aneurysm Mortality Rates: 1968-2017

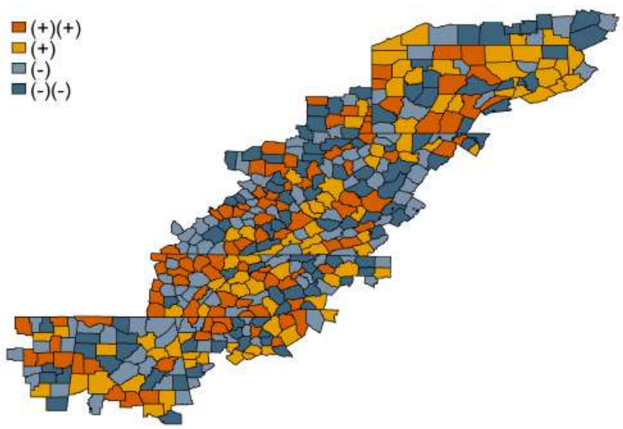
Panel A: Change in Aortic Aneurysm Mortality: 1968-1978



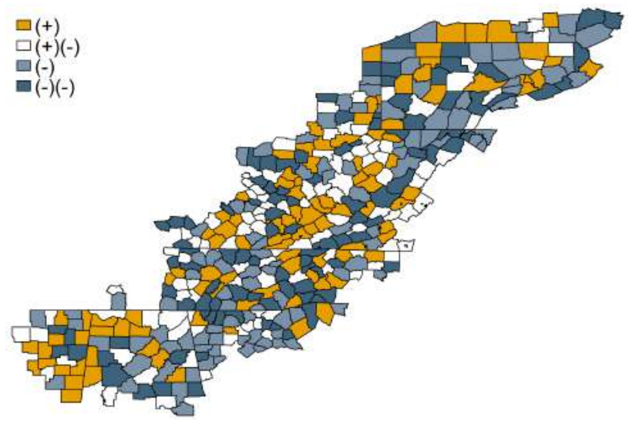
Panel B: Change in Aortic Aneurysm Mortality: 1978-1988



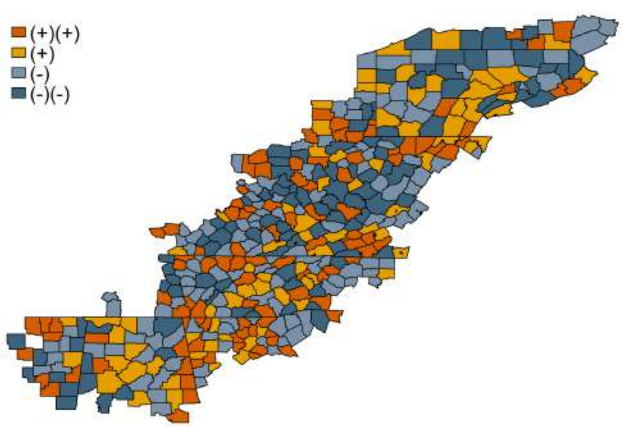
Panel C: Change in Aortic Aneurysm Mortality: 1988-1998



Panel D: Change in Aortic Aneurysm Mortality: 1998-2008



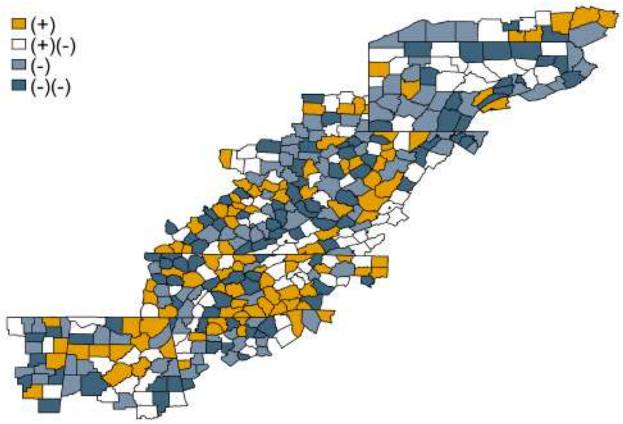
Panel E: Change in Aortic Aneurysm Mortality: 2008-2017



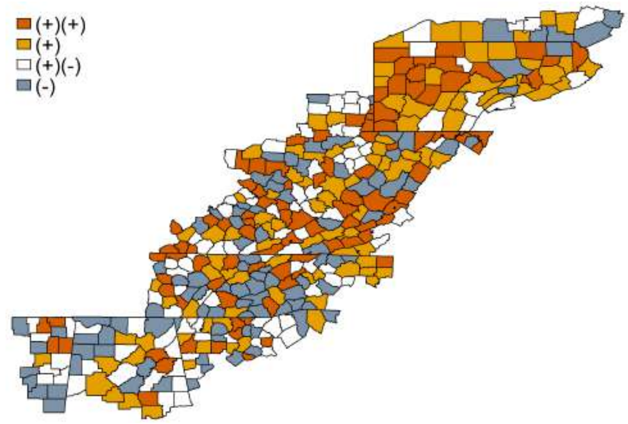
Note: Appalachian county changes in aortic aneurysm mortality rates are shown above. Darker shades of blue represent negative changes (improved mortality over the decade), while darker shades of orange represent positive changes (worse mortality over the decade). White counties represent no significant change. Counties grouped into equal quantiles per decade. County of death mapped.

Figure A.6: Appalachian County Change in Pneumonia and Influenza Mortality Rates: 1968-2017

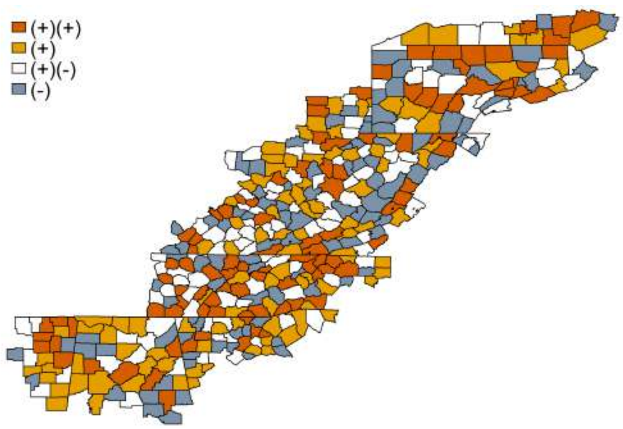
Panel A: Change in Pneumonia and Influenza Mortality: 1968-1978



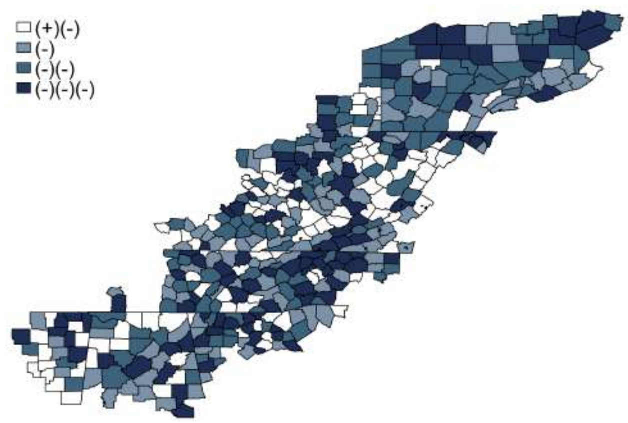
Panel B: Change in Pneumonia and Influenza Mortality: 1978-1988



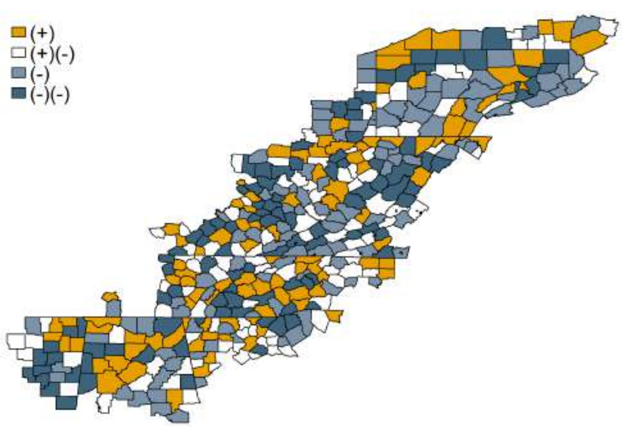
Panel C: Change in Pneumonia and Influenza Mortality: 1988-1998



Panel D: Change in Pneumonia and Influenza Mortality: 1998-2008

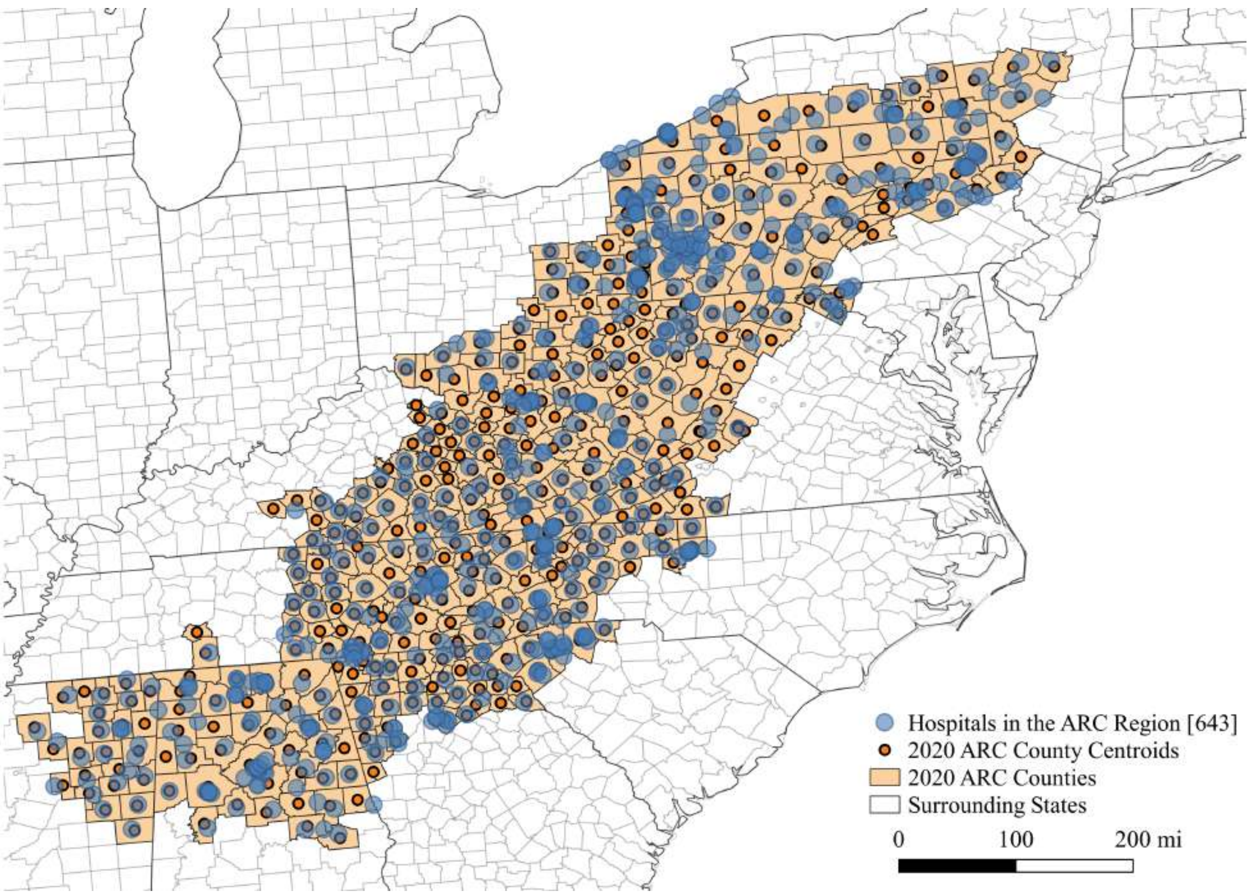


Panel E: Change in Pneumonia and Influenza Mortality: 2008-2017



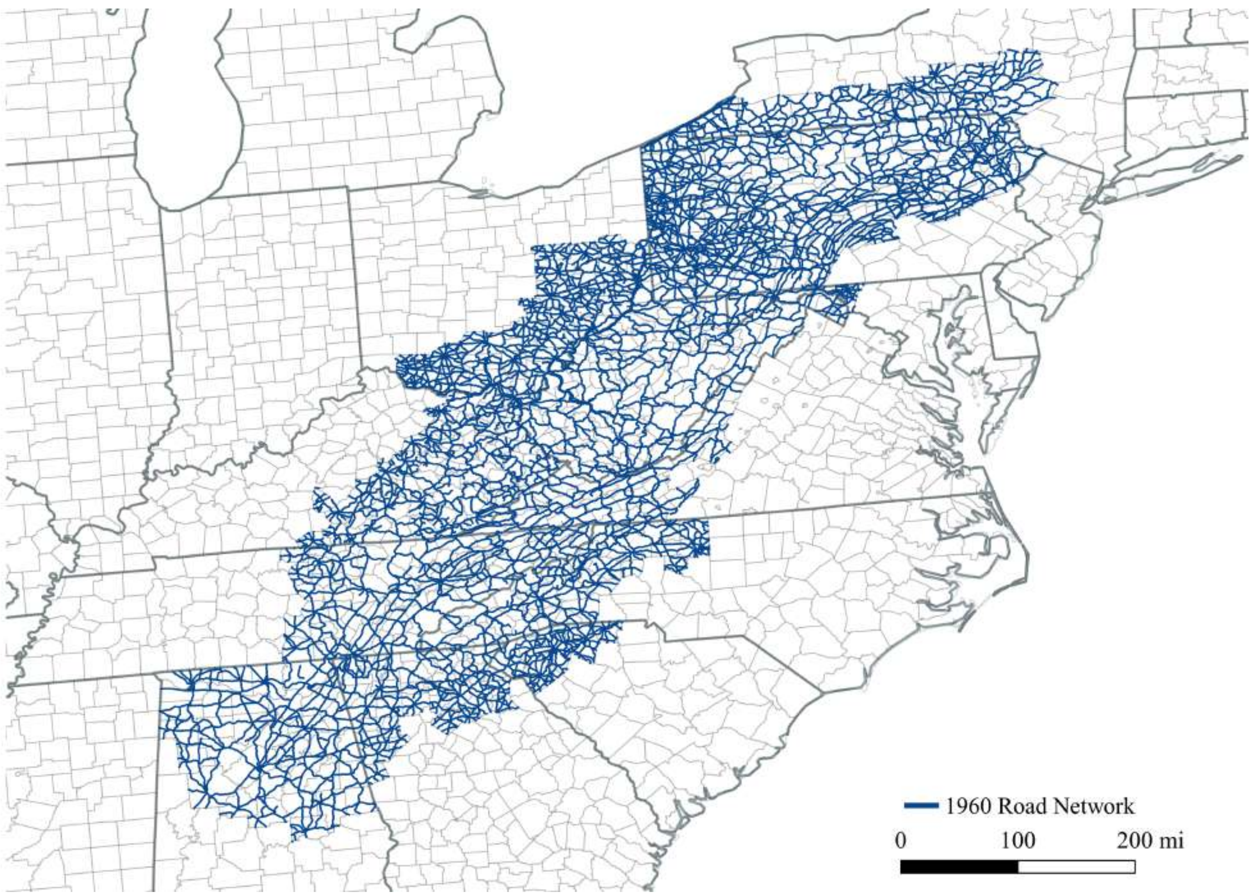
Note: Appalachian county changes in pneumonia and influenza mortality rates are shown above. Darker shades of blue represent negative changes (improved mortality over the decade), while darker shades of orange represent positive changes (worse mortality over the decade). White counties represent no significant change. Counties grouped into equal quantiles per decade. County of death mapped.

Figure A.7: Hospitals in Appalachia in 2020



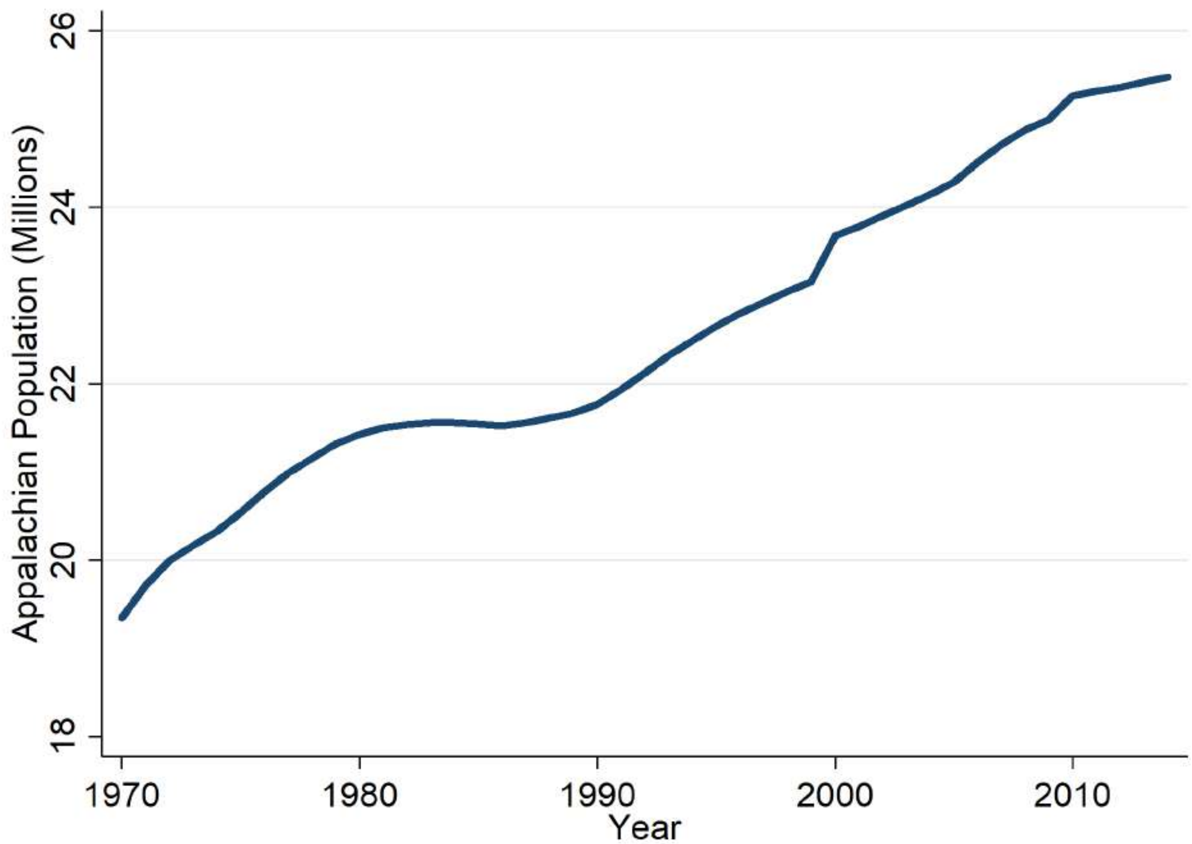
Note: Map displays the current ARC region and the hospitals currently open (as of 2020). A blue dot represents one open hospital. The orange dots show the county centroids. There are currently 643 open hospitals in the ARC region. Figure created using QGIS.

Figure A.8: Existing Road Network: 1960



Note: Map displays the 1960 road network in the Appalachian region. This includes interstates, U.S. routes, and state routes. Data sourced from Jaworski and Kitchens (2019). Figure created using QGIS.

Figure A.9: Appalachian Population: 1970-2014



Note: Graph displays Appalachian population in millions from 1970-2014. Estimates of county-level intercensal populations from 1970-2014 are available from Roth (2016).

Table A.1: ICD Code Definitions and Changes

Cause of Death	**ICD-8 (1968-1978)**	**ICD-9 (1979-1998)**	**ICD-10 (1999-present)**
Diseases of the Heart	390-398, 402, 404, 410, 429	390-398, 402, 404, 410-429	I00-I09, I11, I13, I20-I51
Hypertension without Heart Disease	400-401, 403	401, 403	I10-I12
Cerebrovascular Diseases	430-438	430- 438	I60-I69
Aortic Aneurysm	441	441	I71
Pneumonia and Influenza	470-474, 480-486	480-487	J09-J18
Complications of Pregnancy, Childbirth, Puerperium	630-678	630-676	A34, O00-O95, O98-O99
Accidents and Adverse Effects	E800-949	800-949	V01-X59, Y85-Y86
Car Accidents	E810-E823	E810-E823	V40-V89
Overdoses	E850-E859	E850-E859	X40-X44

Note: International Classification of Diseases (ICD) code changes throughout the length of the sample are shown above. The ICD codes used here arguably not exhaustive, but chosen to increase comparability across time. Overdoses – "accidental poisoning by drug and/or medicinal substance" – includes only overdoses classified as a non-intentional death. Online sources include: ICD-8 – http://www.wolfbane.com/icd/icd8.htm; ICD-9 – http://www.icd9data.com/; ICD-10 – http://www.icd10data.com/

Table A.2: ARC Investment Projects: 1968-2016

	Count of Projects	Percent of Projects
Asset-Based Development	180	0.60
Business Development	3,452	11.46
Child Development	2,133	7.08
Civic Entrepreneurship	107	0.36
Community Development	5,900	19.59
Education & Workforce Development	486	1.61
Education and Job Training	4,509	14.98
Environment and Natural Resources	431	1.43
Health	**4,179**	**13.88**
Highways & Access Roads	1,093	3.63
Housing	1,216	4.04
Leadership and Civic Capacity	704	2.34
Local Development Distric Planning & Admin.	3,676	12.21
Research & Evaluation	44	0.15
Research and Technical Assistance	1,488	4.94
State & LDD Administration	512	1.70
Total	30,110	100.00

Notes: Table displays types of ARC-funded investment projects from 1968-2016.

B Other Mortality Outcomes

Cerebrovascular Disease – Table B.1 display the 2SLS results for cerebrovascular disease mortality rates. In all decades considered, the second stage relationship is never significant.

Aortic Aneurysm – Table B.2 shows, similar to cerebrovascular disease, the second stage relationship is never statistically significant. This could be due to the relatively small mortality rate for aortic aneurysm in the Appalachian region, as shown in Figure 3e.

Pneumonia and Influenza – Table B.3 shows a non-significant relationship between ADHS construction and pneumonia and influenza mortality rates in Appalachia.

Complications with Pregnancy – Table B.4 shows, again, no significant relationship between ADHS construction and mortality rates from complications with pregnancy. Again, this could be due to the relatively small amount of recorded complications with pregnancy in Appalachia; this is shown in Figure 3g.

Table B.1: 2SLS Estimates of Appalachian Development Highway System on Cerebrovascular Disease Mortality Rate With Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	-0.003	-0.197***	
	(0.094)	(0.023)	
$\Delta \widehat{ADHS}$			0.015
			(0.474)
Counties	396	396	396
Kleibergen-Paap F			74.05
Panel B: 1978-1988			
Distance to PARC 1964 Plan	-0.041	-0.100***	
	(0.038)	(0.010)	
$\Delta \widehat{ADHS}$			0.407
			(0.383)
Counties	396	396	396
Kleibergen-Paap F			95.95
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.041	-0.034***	
	(0.031)	(0.009)	
$\Delta \widehat{ADHS}$			1.194
			(1.041)
Counties	406	406	406
Kleibergen-Paap F			14.12
Panel D: 1998-2008			
Distance to PARC 1964 Plan	-0.021	-0.040***	
	(0.026)	(0.010)	
$\Delta \widehat{ADHS}$			0.509
			(0.677)
Counties	427	427	427
Kleibergen-Paap F			13.91
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.009	-0.003***	
	(0.020)	(0.001)	
$\Delta \widehat{ADHS}$			2.971
			(6.252)
Counties	427	427	427
Kleibergen-Paap F			9.08

Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Dependent variable is change in cerebrovascular disease mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade and the total number of health-related ARC investment projects over the decade at the county level. County-clustered standard errors are used in every column and panel.

Table B.2: 2SLS Estimates of Appalachian Development Highway System on Aortic Aneurysm Mortality Rate With Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	0.007	-0.197***	
	(0.012)	(0.023)	
$\Delta\widehat{ADHS}$			-0.034
			(0.062)
Counties	396	396	396
Kleibergen-Paap F			74.05
Panel B: 1978-1988			
Distance to PARC 1964 Plan	-0.004	-0.100***	
	(0.009)	(0.010)	
$\Delta\widehat{ADHS}$			0.044
			(0.088)
Counties	396	396	396
Kleibergen-Paap F			95.95
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.004	-0.034***	
	(0.006)	(0.009)	
$\Delta\widehat{ADHS}$			0.118
			(0.180)
Counties	406	406	406
Kleibergen-Paap F			14.12
Panel D: 1998-2008			
Distance to PARC 1964 Plan	0.009	-0.040***	
	(0.006)	(0.010)	
$\Delta\widehat{ADHS}$			-0.214
			(0.172)
Counties	427	427	427
Kleibergen-Paap F			13.91
Panel E: 2008-2017			
Distance to PARC 1964 Plan	0.000	-0.003***	
	(0.007)	(0.001)	
$\Delta\widehat{ADHS}$			-0.088
			(2.157)
Counties	427	427	427
Kleibergen-Paap F			9.08

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is change in aortic aneurysm mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade and the total number of health-related ARC investment projects over the decade at the county level. County-clustered standard errors are used in every column and panel.

Table B.3: 2SLS Estimates of Appalachian Development Highway System on Pneumonia and Influenza Mortality Rate With Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	0.031	-0.197***	
	(0.054)	(0.023)	
$\Delta\widehat{ADHS}$			-0.159
			(0.273)
Counties	396	396	396
Kleibergen-Paap F			74.05
Panel B: 1978-1988			
Distance to PARC 1964 Plan	-0.013	-0.100***	
	(0.020)	(0.010)	
$\Delta\widehat{ADHS}$			0.126
			(0.200)
Counties	396	396	396
Kleibergen-Paap F			95.95
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.013	-0.034***	
	(0.019)	(0.009)	
$\Delta\widehat{ADHS}$			0.376
			(0.563)
Counties	406	406	406
Kleibergen-Paap F			14.12
Panel D: 1998-2008			
Distance to PARC 1964 Plan	0.019	-0.040***	
	(0.023)	(0.010)	
$\Delta\widehat{ADHS}$			-0.465
			(0.592)
Counties	427	427	427
Kleibergen-Paap F			13.91
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.003	-0.003***	
	(0.018)	(0.001)	
$\Delta\widehat{ADHS}$			1.032
			(5.740)
Counties	427	427	427
Kleibergen-Paap F			9.08

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is change in pneumonia and influenza mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade and the total number of health-related ARC investment projects over the decade at the county level. County-clustered standard errors are used in every column and panel.

Table B.4: 2SLS Estimates of Appalachian Development Highway System on Complications with Pregnancy Mortality Rate With Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	0.002	-0.197***	
	(0.002)	(0.023)	
$\Delta \widehat{ADHS}$			-0.012
			(0.010)
Counties	396	396	396
Kleibergen-Paap F			74.05
Panel B: 1978-1988			
Distance to PARC 1964 Plan	0.000	-0.100***	
	(0.001)	(0.010)	
$\Delta \widehat{ADHS}$			-0.004
			(0.013)
Counties	396	396	396
Kleibergen-Paap F			95.95
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.001	-0.034***	
	(0.001)	(0.009)	
$\Delta \widehat{ADHS}$			0.020
			(0.033)
Counties	406	406	406
Kleibergen-Paap F			14.12
Panel D: 1998-2008			
Distance to PARC 1964 Plan	0.001	-0.040***	
	(0.001)	(0.010)	
$\Delta \widehat{ADHS}$			-0.024
			(0.027)
Counties	427	427	427
Kleibergen-Paap F			13.91
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.002	-0.003***	
	(0.001)	(0.001)	
$\Delta \widehat{ADHS}$			0.549
			(0.605)
Counties	427	427	427
Kleibergen-Paap F			9.08

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is change in complications with pregnancy mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade and the total number of health-related ARC investment projects over the decade at the county level. County-clustered standard errors are used in every column and panel.

C IV Results without Controls

Table C.1: 2SLS Estimates of Appalachian Development Highway System on Total Mortality Rate Without Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	0.319	-0.198***	
	(0.740)	(0.023)	
$\Delta\widehat{ADHS}$			-1.611
			(3.742)
Counties	396	396	396
Kleibergen-Paap F			73.45
Panel B: 1978-1988			
Distance to PARC 1964 Plan	0.171	-0.099***	
	(0.291)	(0.010)	
$\Delta\widehat{ADHS}$			-1.725
			(2.940)
Counties	396	396	396
Kleibergen-Paap F			93.82
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.256*	-0.034***	
	(0.141)	(0.009)	
$\Delta\widehat{ADHS}$			7.437*
			(4.448)
Counties	406	406	406
Kleibergen-Paap F			14.80
Panel D: 1998-2008			
Distance to PARC 1964 Plan	0.129	-0.040***	
	(0.151)	(0.011)	
$\Delta\widehat{ADHS}$			-3.202
			(3.867)
Counties	427	427	427
Kleibergen-Paap F			13.77
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.381**	-0.003***	
	(0.164)	(0.001)	
$\Delta\widehat{ADHS}$			114.696*
			(61.145)
Counties	427	427	427
Kleibergen-Paap F			9.06
Two-Step AR-CIs			[23.9062, 362.855]

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is change in total mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). County-clustered standard errors are used in every column and panel. Panel E includes two-step Anderson-Rubin confidence interval.

Table C.2: 2SLS Estimates of Appalachian Development Highway System on Heart Disease Mortality Rate Without Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	-0.079	-0.198***	
	(0.166)	(0.023)	
$\Delta\widehat{ADHS}$			0.398
			(0.837)
Counties	396	396	396
Kleibergen-Paap F			73.45
Panel B: 1978-1988			
Distance to PARC 1964 Plan	0.291**	-0.099***	
	(0.134)	(0.010)	
$\Delta\widehat{ADHS}$			-2.934**
			(1.417)
Counties	396	396	396
Kleibergen-Paap F			93.82
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.021	-0.034***	
	(0.067)	(0.009)	
$\Delta\widehat{ADHS}$			0.607
			(1.900)
Counties	406	406	406
Kleibergen-Paap F			14.80
Panel D: 1998-2008			
Distance to PARC 1964 Plan	0.193	-0.040***	
	(0.071)	(0.011)	
$\Delta\widehat{ADHS}$			-4.797**
			(2.158)
Counties	427	427	427
Kleibergen-Paap F			13.77
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.102	-0.003***	
	(0.062)	(0.001)	
$\Delta\widehat{ADHS}$			30.663
			(21.835)
Counties	427	427	427
Kleibergen-Paap F			9.06

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is change in heart disease mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). County-clustered standard errors are used in every column and panel.

Table C.3: 2SLS Estimates of Appalachian Development Highway System on Hypertension Mortality Rate Without Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	-0.006	-0.198***	
	(0.012)	(0.023)	
$\Delta\widehat{ADHS}$			0.028
			(0.059)
Counties	396	396	396
Kleibergen-Paap F			73.45
Panel B: 1978-1988			
Distance to PARC 1964 Plan	-0.000	-0.099***	
	(0.003)	(0.010)	
$\Delta\widehat{ADHS}$			0.000
			(0.003)
Counties	396	396	396
Kleibergen-Paap F			93.82
Panel C: 1988-1998			
Distance to PARC 1964 Plan	0.017**	-0.034***	
	(0.007)	(0.009)	
$\Delta\widehat{ADHS}$			-0.503**
			(0.217)
Counties	406	406	406
Kleibergen-Paap F			14.80
Panel D: 1998-2008			
Distance to PARC 1964 Plan	-0.001	-0.040***	
	(0.014)	(0.011)	
$\Delta\widehat{ADHS}$			0.013
			(0.358)
Counties	427	427	427
Kleibergen-Paap F			13.77
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.015	-0.003***	
	(0.014)	(0.001)	
$\Delta\widehat{ADHS}$			4.531
			(4.421)
Counties	427	427	427
Kleibergen-Paap F			9.06

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is change in hypertension mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). County-clustered standard errors are used in every column and panel.

Table C.4: 2SLS Estimates of Appalachian Development Highway System on Cerebrovascular Disease Mortality Rate Without Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	-0.006	-0.198***	
	(0.093)	(0.023)	
Δ in Cerebrovascular Disease Mortality			0.032
			(0.469)
Counties	396	396	396
Kleibergen-Paap F			73.45
Panel B: 1978-1988			
Distance to PARC 1964 Plan	-0.037	-0.099***	
	(0.038)	(0.010)	
$\Delta\widehat{ADHS}$			0.368
			(0.390)
Counties	396	396	396
Kleibergen-Paap F			93.82
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.035	-0.034***	
	(0.031)	(0.009)	
$\Delta\widehat{ADHS}$			1.016
			(0.991)
Counties	406	406	406
Kleibergen-Paap F			14.80
Panel D: 1998-2008			
Distance to PARC 1964 Plan	-0.020	-0.040***	
	(0.026)	(0.011)	
$\Delta\widehat{ADHS}$			0.490
			(0.671)
Counties	427	427	427
Kleibergen-Paap F			13.77
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.010	-0.003***	
	(0.020)	(0.001)	
$\Delta\widehat{ADHS}$			3.009
			(6.086)
Counties	427	427	427
Kleibergen-Paap F			9.06

Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Dependent variable is change in cerebrovascular disease mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). County-clustered standard errors are used in every column and panel.

Table C.5: 2SLS Estimates of Appalachian Development Highway System on Aortic Aneurysm Mortality Rate Without Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	0.007	-0.198***	
	(0.012)	(0.023)	
$\Delta\widehat{ADHS}$			-0.034
			(0.062)
Counties	396	396	396
Kleibergen-Paap F			73.45
Panel B: 1978-1988			
Distance to PARC 1964 Plan	-0.004	-0.099***	
	(0.009)	(0.010)	
$\Delta\widehat{ADHS}$			0.044
			(0.089)
Counties	396	396	396
Kleibergen-Paap F			93.82
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.004	-0.034***	
	(0.006)	(0.009)	
$\Delta\widehat{ADHS}$			0.114
			(0.176)
Counties	406	406	406
Kleibergen-Paap F			14.80
Panel D: 1998-2008			
Distance to PARC 1964 Plan	0.009	-0.040***	
	(0.006)	(0.011)	
$\Delta\widehat{ADHS}$			-0.220
			(0.176)
Counties	427	427	427
Kleibergen-Paap F			13.77
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.000	-0.003***	
	(0.007)	(0.001)	
$\Delta\widehat{ADHS}$			0.027
			(2.045)
Counties	427	427	427
Kleibergen-Paap F			9.06

Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Dependent variable is change in aortic aneurysm mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). County-clustered standard errors are used in every column and panel.

Table C.6: 2SLS Estimates of Appalachian Development Highway System on Pneumonia and Influenza Mortality Rate Without Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	0.030	-0.198***	
	(0.053)	(0.023)	
$\Delta\widehat{ADHS}$			-0.153
			(0.270)
Counties	396	396	396
Kleibergen-Paap F			73.45
Panel B: 1978-1988			
Distance to PARC 1964 Plan	-0.014	-0.099***	
	(0.020)	(0.010)	
$\Delta\widehat{ADHS}$			0.142
			(0.198)
Counties	396	396	396
Kleibergen-Paap F			93.82
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.006	-0.034***	
	(0.019)	(0.009)	
$\Delta\widehat{ADHS}$			0.181
			(0.551)
Counties	406	406	406
Kleibergen-Paap F			14.80
Panel D: 1998-2008			
Distance to PARC 1964 Plan	0.019	-0.040***	
	(0.023)	(0.011)	
$\Delta\widehat{ADHS}$			-0.481
			(0.610)
Counties	427	427	427
Kleibergen-Paap F			13.77
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.004	-0.003***	
	(0.018)	(0.001)	
$\Delta\widehat{ADHS}$			1.138
			(5.536)
Counties	427	427	427
Kleibergen-Paap F			9.06

Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Dependent variable is change in pneumonia and influenza mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). County-clustered standard errors are used in every column and panel.

Table C.7: 2SLS Estimates of Appalachian Development Highway System on Complications with Pregnancy Mortality Rate Without Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	0.002	-0.198***	
	(0.002)	(0.023)	
$\Delta\widehat{ADHS}$			-0.01
			(0.010)
Counties	396	396	396
Kleibergen-Paap F			73.45
Panel B: 1978-1988			
Distance to PARC 1964 Plan	0.000	-0.099***	
	(0.001)	(0.010)	
$\Delta\widehat{ADHS}$			-0.004
			(0.013)
Counties	396	396	396
Kleibergen-Paap F			93.82
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.001	-0.034***	
	(0.001)	(0.009)	
$\Delta\widehat{ADHS}$			0.017
			(0.032)
Counties	406	406	406
Kleibergen-Paap F			14.80
Panel D: 1998-2008			
Distance to PARC 1964 Plan	0.001	-0.040***	
	(0.001)	(0.011)	
$\Delta\widehat{ADHS}$			-0.027
			(0.027)
Counties	427	427	427
Kleibergen-Paap F			13.77
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.002	-0.003***	
	(0.002)	(0.001)	
$\Delta\widehat{ADHS}$			0.492
			(0.489)
Counties	427	427	427
Kleibergen-Paap F			9.06

Notes: * $p<0.1$, ** $p<0.05$, *** $p<0.01$. Dependent variable is change in complications with pregnancy mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). County-clustered standard errors are used in every column and panel.

Table C.8: 2SLS Estimates of Appalachian Development Highway System on Accident Mortality Rate Without Controls

	(1) Reduced Form	(2) 1st Stage	(3) 2nd Stage
Panel A: 1968-1978			
Distance to PARC 1964 Plan	-0.006	-0.198***	
	(0.040)	(0.023)	
$\Delta \widehat{ADHS}$			0.031
			(0.201)
Counties	396	396	396
Kleibergen-Paap F			73.45
Panel B: 1978-1988			
Distance to PARC 1964 Plan	0.070	-0.099***	
	(0.052)	(0.010)	
$\Delta \widehat{ADHS}$			-0.700
			(0.530)
Counties	396	396	396
Kleibergen-Paap F			93.82
Panel C: 1988-1998			
Distance to PARC 1964 Plan	-0.034	-0.034***	
	(0.029)	(0.009)	
$\Delta \widehat{ADHS}$			0.973
			(0.837)
Counties	406	406	406
Kleibergen-Paap F			14.80
Panel D: 1998-2008			
Distance to PARC 1964 Plan	-0.065**	-0.040***	
	(0.021)	(0.011)	
$\Delta \widehat{ADHS}$			1.618**
			(0.719)
Counties	427	427	427
Kleibergen-Paap F			13.77
Panel E: 2008-2017			
Distance to PARC 1964 Plan	-0.099***	-0.003***	
	(0.023)	(0.001)	
$\Delta \widehat{ADHS}$			29.763**
			(11.742)
Counties	427	427	427
Kleibergen-Paap F			9.06
Two-Step AR-CIs			[14.6531, 86.716]

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is change in accident mortality in Appalachia. Each panel, A-E, shows the results for a different time period. Column 1 shows reduced form results (PARC distance on mortality), Column 2 shows first stage results (PARC distance on ADHS distance), and Column 3 shows second stage results (instrumented ADHS distance on mortality). County-clustered standard errors are used in every column and panel. Panel E includes two-step Anderson-Rubin confidence interval.

D Cumulative Effect of the ADHS on Mortality

Table D.1: Panel 2SLS Estimates of Appalachian Development Highway System on Mortality Rate With Controls

	(1) Mortality Mean	(2) Reduced Form	(3) 1st Stage	(4) 2nd Stage
Panel A: Total Mortality				
Distance to PARC 1964 Plan		-0.001*	0.000***	
		(0.709)	(0.000)	
$\widehat{ADHS}$	853.892			-2.480*
	(491.219)			(1.468)
Observations	19183	19183	19183	19183
Kleibergen-Paap F				130.99
Panel B: Heart Disease Mortality				
Distance to PARC 1964 Plan		-0.000*	0.000***	
		(0.000)	(0.000)	
$\widehat{ADHS}$	294.620			-0.772*
	(164.465)			(0.449)
Observations	19183	19183	19183	19183
Kleibergen-Paap F				131.22
Panel C: Hypertension Mortality				
Distance to PARC 1964 Plan		-0.000	0.000***	
		(0.000)	(0.000)	
$\widehat{ADHS}$	8.220			0.006
	(8.054)			(0.015)
Observations	19183	19183	19183	19183
Kleibergen-Paap F				123.22
Panel D: Accident Mortality				
Distance to PARC 1964 Plan		-0.000**	0.000***	
		(0.000)	(0.000)	
$\widehat{ADHS}$	52.565			-0.216*
	(37.689)			(0.112)
Observations	19183	19183	19183	19183
Kleibergen-Paap F				132.09
Panel E: Overdose Mortality				
Distance to PARC 1964 Plan		-0.000	0.000***	
		(0.000)	(0.000)	
$\widehat{ADHS}$	40.368			-0.155
	(38.811)			(0.101)
Observations	19183	19183	19183	19183
Kleibergen-Paap F				145.91

Notes: * p<0.1, ** p<0.05, *** p<0.01. Dependent variable is mortality rate in Appalachia. Each panel, A-E, shows the results for a different mortality outcome. Column 1 shows the mean mortality rate, with standard deviations in parentheses. Column 2 shows reduced form results (PARC distance on mortality), Column 3 shows first stage results (PARC distance on ADHS distance), and Column 4 shows second stage results (instrumented ADHS distance on mortality). Controls included in every panel are the count of hospital establishments in the last year of the decade, the total number of health-related ARC investment projects over the decade at the county level, and the length of existing road network in 1960 at the county level. Year and state fixed effects are used in every panel. County-clustered standard errors are used in every panel.