NBER WORKING PAPER SERIES

NATIONAL POLICY FOR REGIONAL DEVELOPMENT: EVIDENCE FROM APPALACHIAN HIGHWAYS

Taylor Jaworski
Carl T. Kitchens

Working Paper 22073
http://www.nber.org/papers/w22073

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 2016

We thank Nate Baum-Snow, Shawn Kantor, Ian Keay, Alex Whalley and conference/seminar participants at the 2015 Canadian Network for Economic History meetings, McGill, and York for comments that improved the paper. The authors also thank Queens University, Florida State University, and the Economic History Association for financial support. All remaining errors are our own. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

National Policy for Regional Development: Evidence from Appalachian Highways
Taylor Jaworski and Carl T. Kitchens
NBER Working Paper No. 22073
March 2016
JEL No. N12,O18,O2,R13

ABSTRACT

How effective are policies aimed at integrating isolated regions? We answer this question using the construction of a highway system in one of the poorest regions in the United States. With construction starting in 1965, the Appalachian Development Highway System (ADHS) ultimately consisted of over 2,500 high-grade road miles. Motivated by a model of inter-regional trade we estimate the elasticity of total income with respect to market access, which we then use to evaluate the overall impact of the ADHS. We find that removing the ADHS would have reduced the total income by $45.9 billion or, roughly, 1 percent. Ultimately, the population response to improvements in transportation infrastructure reduced the gains in income per capita, which were equal to $515 (1.4 percent) in the poorest counties. Today, the region's performance relative to the national average is similar to its position in the 1960s. Thus, despite substantial investment in transportation and some gains in income per capita the region continues to lag behind the rest of the country.

Taylor Jaworski
Queen's University
94 University Avenue
Dunning Hall, 209
Kingston, Ontario K7L 3N6
Canada
tjaworski@gmail.com

Carl T. Kitchens
Department of Economics
Florida State University
239 Bellamy Building
Tallahassee, FL 32306
and NBER
ckitchens@fsu.edu

1 Introduction

In *Night Comes to the Cumberlands*, Harry Caudill painted a grim picture of economic conditions in Eastern Kentucky and, more broadly, Appalachia circa 1960. Caudill highlighted the poverty, isolation, exploitation, and destruction of natural resources as well as political backwardness within the region. These views were supported in 1964 after the President's Appalachian Regional Commission reported that incomes were three-quarters of the national average–less than half in Kentucky–which was reinforced by high unemployment relative to the rest of the country.

This stark contrast led the governors of Appalachian states to lobby the federal government for relief. In 1965, President Johnson signed the Appalachian Regional Development Act, creating the Appalachian Regional Commission–a federal-state partnership aimed at integrating the region–and fulfilling promises made by the Kennedy Administration. To date, over $34 billion (in 2015 dollars) of federal expenditures have gone to the region, with the bulk of funding going to the construction of the nearly 2,500 miles of the Appalachian Development Highway System.[1] The new highway system aimed to integrate Appalachia with industrial markets to both the east and west and complement the new Interstate Highway System, which largely bypassed the most isolated areas within Appalachia.

In this paper, we examine the impact of the Appalachian Development Highway System (ADHS) on regional development. Following recent work by Donaldson and Hornbeck (forthcoming) we use a model of inter-regional trade together with newly digitized network data of the Appalachian, interstate, and state highway systems in 1960 and 2010. The model guides

[1]The federal portion of expenditures under the Appalachian Regional Commission (ARC) is similar in size to the Tennessee Valley Authority (TVA), a large-scale development project initiated as part of Franklin Roosevelt's New Deal. Total spending on the TVA was approximately approximately $27.5 billion between 1930 and 2000; its impact on regional development was recently studied by Kitchens (2014) and Kline and Moretti (2014). There was also a state and local matching component of the ARC that was up to an additional 30 percent of federal expenditures depending on the year over the program's history.

the interpretation of our main variable of interest, "market access," which measures each county's proximity to other counties based on travel time through the highway network as well as market size.[2] This approach provides a straightforward way to capture how changes at a particular point in the highway network influence *all* counties. In this way, our measure of market access incorporates network-wide improvements in transportation infrastructure so that our estimates of the effect on total income reflect these general equilibrium effects.

For the empirical analysis we restrict our sample to approximately 1,000 counties in and around the program area of the Appalachian Regional Commission, although we compute market access to *all* counties in the contiguous United States. This ensures that our estimate of the elasticity of income with respect to market access reflects the structure of the Appalachian region.[3] Importantly, changes in the measure of market access used in the empirical analysis reflect changes in transportation costs due to improvements in the highway network as well as changes in a county's underlying productivity. We use county fixed effects to address concerns about highway placement with respect to time-invariant local productivity and include additional variables to control for differences in access to ARC funds as well as convergence across counties. We also 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.[4] This allows us to focus on changes in market access due to reduction in travel time over a fixed distance, which we combine with lagged market size.

We then estimate the relationship between total income and market access using instrumental variables and obtain estimates similar to recent work on the impact of railroads in

[2]To proxy for market size we use total income, which closely corresponds with the theory, and check that our results are not sensitive to alternative measures of market size.

[3]In footnote 70, Donaldson and Hornbeck (forthcoming) report some differences in the estimated relationship between their main outcome of interest, agricultural land values, and market access across regions.

[4]Physical distance is the straight-line distance between county-centroid pairs and average speed is the the total travel time divided the distance travel along each route using the complete highway network.

the United States in the second half of the nineteenth century (Donaldson and Hornbeck, forthcoming) and modern-day highways in India (Alder, 2015). A key advantage of this approach is the ability to perform counterfactual exercises using alternative changes in the transportation network that may alter access to markets. For example, we can ask: Would total income have been lower in the absence of the ADHS (i.e., using only the Interstate Highway System) and, if so, by how much? Or, how much of the losses associated with removing the ADHS could have been mitigated by a proposed, but never built smaller highway system?

To answer the first question, we calculate the market access that would have prevailed in 2010 incorporating growth in the highway network from 1960 but removing the ADHS. The counterfactual change in market access together with our estimate of the elasticity implies losses without the ADHS of $45.9 billion in annual total income with changes in the program area of the ARC equal to $32.5 billion relative to $13.4 billion in counties outside of the ARC. Importantly, changes in market access also lead to changes in population. Taking into account population movement, annual income per capita in ARC counties would have been $515 lower in the absence of the ADHS relative to just $64 lower in non-ARC counties.

To answer the second question, we consider replacing the ADHS with a smaller highway system than was ultimately built. This is motivated by the fact that large infrastructure projects are often the outcome of a process that involves politicking to obtain benefits for concentrated interests (e.g., states or congressional districts) in exchange for support in passing legislation. In the context of the Appalachian Regional Commission, several counties in New York, Mississippi, and elsewhere were added to the initial counties targeted in the earlier plan of the President's Appalachian Regional Commission (PARC) during the Kennedy administration. The highway system that was eventually built had almost 1,000 miles that were not included in the first-draft plan. To assess the impact of the deviation from the

PARC plan, we recalculate market access replacing the ADHS with PARC and find losses of \$22.0 billion.

Relative to overall costs–including federal, state and local expenditures–the aggregate benefits of the ADHS imply a rate of return between 3.1 and 8.4 percent annually. This is lower than the 9 percent Allen and Arkolakis (2014) find for the Interstate Highway System or the 11 to 25 percent Alder (2015) finds for highways in India. Compared to historical infrastructure projects, earlier improvements in the transportation network due to the construction of railroads were larger for the United States (Donaldson and Hornbeck, forthcoming) and India (Donaldson, forthcoming). Overall, the reduction in transportation costs associated with the ADHS increased economic activity in Appalachian counties, although the reallocation of population mitigated some of these gains.

In addition to recent work by Allen and Arkolakis (2014), our paper contributes to a substantial literature focused on quantifying the impact of highway infrastructure in the United States (Isserman and Rephann, 1994; Chandra and Thompson, 2000; Baum-Snow, 2007; Michaels, 2008; Duranton and Turner, 2012; Duranton, Morrow, and Turner, 2014) and in developing countries (Banerjee, Duflo, and Qian, 2012; Baum-Snow, Brandt, Henderson, Turner, and Zhang, 2012; Faber, 2014; Ghani, Goswami, and Kerr, 2015). Importantly, the Appalachian Development Highway System is still maintained today and the expansion of similar systems elsewhere is ongoing (e.g., under the Delta Regional Administration). Our results provide evidence on the size of the potential long-run benefits as well as a comparison with the costs and policy alternatives.

A related literature focuses on the combined impact of all programs associated with the Appalachian Regional Commission (Bradshaw, 1992; Black and Sanders, 2004, 2007; Glaeser and Gottlieb, 2008; Haaga, 2004; Widener, 1990; Ziliak, 2012). We focus exclusively on the impact of the new highway infrastructure associated with the ARC, which we believe requires special attention given (i) the high share of appropriated funds going to the ADHS relative to other programs, (ii) the region's limited integration internally and with the rest of the country, and (iii) the theoretical and empirical issues that arise in assessing interventions with potentially general equilibrium impacts.

The remainder of the paper is organized as follows. Section 2 gives an overview of the region's history and background for the creation of the Appalachian Regional Commission. Section 3 describes the highway network and county-level data used in the empirical analysis. Section 4 discusses the model of trade among counties, empirical specification, and identification concerns that arise in our setting. Section 5 presents our estimates of the market access elasticity, which we use to quantify the overall impact of Appalachian highways. Section 6 concludes.

2 Historical Background

In the early 1960s average household income in Appalachia was \$5,706 compared to \$7,349 nationwide. In addition, one-third of families in the region lived on less than \$3,000 per year compared to one-fifth in the rest of the country and unemployment in the region was pervasive (Appalachian Regional Commission, 1964; Pollard, 2003). Over the next several decades differences with the rest of the country in terms of income, poverty, and unemployment narrowed. Despite these gains, policymakers and scholars remained concerned about the strength of the labor market, deteriorating infrastructure, rate of structural transformation, and lack of opportunity and mobility.

To combat poverty in the region, individual states initially used their own welfare systems to provide for displaced workers and promote growth. For example, Kentucky created the Agricultural and Industrial Development Board in 1946.[5] This and similar programs at

[5] This program was modeled after Mississippi's Balance Agriculture with Industry program established in 1936. Cobb (1982) provides an excellent overview of state-level policies for industrial recruitment starting during the Great Depression.

the state level attempted to promote local development and provide subsidies to recruit industry from the North. In 1956, Kentucky created the Action Plan for Eastern Kentucky, which emphasized the need for a regional development authority to improve infrastructure, particularly through new highway construction (Eller, 2008, p. 47). In 1959, the same group established Program 60 to provide education, job training, health, and transportation investments, although the proposal failed to receive support from the state legislature.

In 1960, governors from several Appalachian states attended the Conference of Appalachian Governors, to develop strategies to lobby the federal government for assistance and cooperate in setting their own development goals. In the same year, then Senator John F. Kennedy visited West Virginia during a campaign stop and witnessed the poverty of the region first hand. This led to campaign promises to revitalize and invigorate Appalachia. After his election, Kennedy promoted the passage of the Area Redevelopment Act in 1961, which promised relief funds for distressed regions. While the Conference of Appalachian Governors was eager to receive some funding, it became apparent these funds would not reach Appalachia due to strict matching requirements. This was true even though 76 percent of Appalachian counties qualified as "distressed."

The Conference of Appalachian Governors continued to lobby President Kennedy and, following severe flooding in the region in 1963, the President's Appalachian Regional Commission (PARC) was created.[6] The commission was to provide recommendations to develop and integrate the region with the nation by January 1, 1964. The PARC report highlighted the lack of transportation infrastructure within the region as well as the absence of education and health services.

Following Kennedy's assassination, Johnson promised to continue efforts begun under the

[6]The US Geological Survey estimated that the damages associated with the flood totaled $755 million in real 2015 dollars (USGS, 1968 p. B-56).

previous administration. In the spring of 1964, the Appalachian Regional Development Act (ARDA) was proposed in Congress. At first the ARDA failed to receive sufficient support, however, the bill was resubmitted to Congress in 1965 following a few changes, the addition of Ohio and South Carolina as beneficiaries, and promises to Senator Robert F. Kennedy of New York to add 13 counties in New York at a later date. The modified ARDA was signed into law on March 9, 1965.[7]

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. Figure 1A shows the program area of the ARC, including counties in Mississippi and New York that were added in 1967. The largest portion of funds, \$840 million, was earmarked to create the Appalachian Development Highway System (ADHS) and remainder to be spent on education, health, and job training programs. The new highway system was intended to complement the expansion of the Interstate Highway System by providing connections to major population centers outside the region. Figure 1B shows the aggregate federal ARC spending separately for highway and non-highway programs. By 2010, over \$34 billion had been spent on ARC projects with \$23 billion going to highways.

The initial PARC report highlighted the perceived importance of new transportation infrastructure: "Developmental activity in Appalachia cannot proceed until the regional isolation has been overcome. Its cities and towns, its areas of natural wealth and its areas of recreations and industrial potential must be penetrated by a transportation network which provides access to and from the rest of the Nation and within the region itself" (Appalachian Regional Commission, 1964, p. 32). In the initial authorization, over \$489,000 per mile was authorized to transform steep, winding, narrow two-lane roads into highways with a straight

[7]In 1967, the ARC boundary expanded to include additional counties in Mississippi, New York, and others in states already in the program area.

alignment, low grade, additional lanes, and average travel speeds of 50 miles per hour or more (E.S. Preston & Associates, 1965, pp. 2-4). Many of the proposed segments were four lane roads that could handle vehicle speeds of up to 70 miles per hour (E.S. Preston & Associates, 1965).[8]

3 Data

The data for in the empirical analysis are drawn from several sources. We use a newly digitized maps of the highway network in 1960 and 2010 to compute the travel time between all county pairs in the contiguous United States in each year. In this section we discuss our representation of the highway network using geographic information system software and the details of calculating travel time. For the empirical analysis we combine the information on travel times with county-level data on income, population, and employment to examine the impact of the ADHS.

3.1 Using the Highway Network to Calculate Travel Time

To calculate travel times we start by identifying each county as a point in space using the latitude and longitude of the county centroid. We then create a set of access roads that link the county centroids to neighboring counties with straight line connections. These two parts of the network are fixed in 1960 and 2010 and a constant speed of 10 miles per hour is assigned to all travel on access roads in both years. Next, we overlay the highway network–including the Appalachian, interstate, national, and state highway systems–corresponding to either 1960 or 2010. The relative importance of each portion of the network for a given route will depend on the distance to be travelled and the assigned speed on each road type. Figure 2 shows the extent of the highway system in 1960 and 2010.

For 1960, we start with a Shell Oil Company (1956) map for the non-interstate highway

[8]Ultimately, improvements were substantial enough that three of the ADHS corridors were fully integrated as part of the Interstate Highway System: Corridor T in New York (I-86), Corridor E in Maryland and West Virginia (I-68), and Corridor X traversing Alabama and Mississippi (I-22).

system. This map reports major travel routes 1956, which we use to proxy for the highway network prior to the Interstate system. In addition to indicating routes, the map gives estimated travel times between points of interest and we use these to assign speeds to different segments of the network. For the IHS in 1960, we obtained paper maps from the Annual Report Bureau of Public Roads (Bureau of Economic Analysis, 1960). These are shown in Figure 2A.

For 2010, we use a shapefile obtained by the National Transportation and Highway Safety Administration.[9] Figure 2B shows digitized highway network (excluding the ADHS). In each year, we assign IHS segments a speed of 65 mph, primary highways a speed of 40 mph, secondary highways a speed of 30 mph, tertiary roads have speeds of 25 mph, and quaternary roads have a speed of 20 mph. In our initial specifications we fix these speed limits in each year and in robustness checks adopt modern speeds from the National Highway Travel Safety Administration's National Traffic Speeds Survey II (2009).

Finally, from the annual reports of the Appalachian Regional Commission (ARC) we digitized the network of the ADHS in 2010, shown in Figure 2C. For our baseline travel time calculation we assign a speed of 55 miles per hour when using the ADHS. Our main empirical analysis combines the network of time invariant access roads together with the Appalachian, interstate, national, and state highway systems. We then compute the travel time between all county pairs in each year, which we use to calculate our measure of market acces for the empirical analysis.[10]

[9] Download the shapefile at `http://www.fhwa.dot.gov/planning/processes/tools/nhpn/2011/`.

[10] We compute the travel time between all counties in the contiguous United States. The time involved in so many (over 9 million) routes is reduced by applying Dijkstra (1959)'s algorithm, which we implement using the network analyst tool in ArcGIS.

3.2 County-level Income, Population, and Employment

We use county-level data on total income, population, and employment in 1960 and 2010 from Bureau of Economic Analysis (2015). In some specifications we report the impact on income per worker, which we compute by dividing total income by employment in each county in a given year. We adjust county-level variables to reflect county boundaries in 2010 following the procedure in Hornbeck (2010) and merge independent cities in Virginia with the surrounding county to give a total of 3,080 observations in each year.

Although our measure of market access takes into account the change in access to all counties in the contiguous United States, we restrict the sample used in estimation to 1,070 counties in states with at least one county in the ARC. Importantly this does not introduce bias into our measure of market access, rather our estimates reflect the structure of the economy in and around Appalachia. This is so our empirical analysis quantifies the effect of particular improvements in transportation infrastructure that are most relevant for evaluating counterfactuals in the region.

Table 1 provides summary statistics for all sample counties as well as counties included in the ARC and counties not included in the ARC, separately. Columns 2 through 4 show the (log) change in market access, total income, and total population, respectively, between 1960 and 2010. Market access across sample counties increased by 2.43 log points, with larger gains in ARC relative to non-ARC counties (i.e., 2.39 versus 2.43 log points). Average total income increased by 1.73 log points: growth was lower for ARC counties at 1.64 log points than for non-ARC counties at 1.79 log points. Finally, population growth was smaller in ARC counties than non-ARC counties (i.e., 0.34 versus 0.43 log points).

4 Theoretical Framework

We use a model of inter-regional trade to derive our main estimating equation and inform our identification strategy. This model produces a relationship between total income and access to markets. In this context, market access provides a straightforward way to summarize the impact of a change in transportation costs *anywhere in the highway network* on total income. Empirically, we exploit changes in market access due to improvements in the interstate and Appalachian highways. We use an instrumental variables strategy to isolate changes in transportation costs that are unrelated to changes in local productivity. This ensures that our estimate of the relationship between total income and market access is not confounded with the region's low growth potential, which motivated the passage of the Appalachian Regional Development Act and the placement of the associated highways. The model in the remainder of this section follows closely the exposition in Donaldson and Hornbeck (forthcoming).

4.1 Model Setup

In the model counties are indexed by c if they are the origin of trade and d if they are the destination. Consumers have CES preferences over a continuum of differentiated goods varieties, where the elasticity of substitution between varieties is given by σ. Producers in each county combine a fixed factor land (L_c) and mobile factors labor (N_c) and capital (K_c) using a Cobb-Douglas technology to produce varieties. The marginal cost of each variety j is:

$$MC_c(j) = \frac{q_c^{\alpha} w_c^{\gamma} r_c^{1-\alpha-\gamma}}{z_c(j)}$$

where q_c is the land rental rate, w_c is the wage, r_c is the interest rate, and $z_c(j)$ is local productivity shifter drawn from a Fréchet distribution with CDF $F_c(z) = \exp(-T_c z^{-\theta})$. We assume that output markets are perfectly competitive.

Trade costs between an c and d take the "iceberg" form: for each unit to arrive at d from c, $\tau_{cd} \geq 1$ must be shipped. That is, if a variety is produced and sold in the same county the price is $p_{cc}(j)$, while the same variety sold in a different county has price $p_{cd}(j) = \tau_{cd} p_{cc}(j)$. In equilibrium, consumers in counties that are farther away from producers will pay higher prices and, in turn, producers that are farther away from consumers will charge lower prices. Empirically, we measure bilateral travel costs as the lowest travel time (in hours) between c and d using the highway network.

The land available for production is assumed to be constant in each year. Capital is purchased in national, perfectly competitive markets so the returns on capital are the same in all counties with $r_c = r$. To the extent that this assumption is violated in our setting, our empirical analysis controls for state-year fixed effects to adjust for variation over time at the state level as well as additional county-level variables that capture within-state variation in geography, climate, etc. Finally, workers are perfectly mobile and reallocate across counties until nominal wages and utility (adjusted for the local price index) are equalized: $w_c = \bar{U} P_c$.

4.2 Prices and the Gravity Equation

Assuming perfect competition so that prices and marginal costs (including trade costs) are equal and letting consumers buy from the cheapest origin county, Eaton and Kortum (2002) give an expression for the price index at d:

$$P_d = \mu \sum_c \left[T_c (\tau_{cd} q_c^{\alpha} w_c^{\gamma} r_c^{1-\alpha-\gamma})^{-\theta} \right]^{-\frac{1}{\theta}}$$

with $\mu = [\Gamma(\frac{\theta+1-\sigma}{\theta})]^{\frac{1}{1-\sigma}}$, where Γ is the Gamma function. Using the assumption that $r_c = r$, Donaldson and Hornbeck (forthcoming) define $\kappa_1 = \mu^{-\theta} r^{(1-\alpha-\gamma)\theta}$. We can then use the expression for the price index above to write:

$$P_d^{-\theta} = \kappa_1 \sum_c \left[T_c(q_c^{\alpha} w_c^{\gamma})^{-\theta} \tau_{cd}^{-\theta}\right] \tag{1}$$

which is the trade cost-weighted sum of consumers' access in d to the technology and inputs of other counties. This is referred to as "consumer market access."

Eaton and Kortum (2002) also give the following expression for the value of exports from c to d:

$$X_{cd} = \underbrace{T_c(q_c^{\alpha} w_c^{\gamma})^{-\theta}}_{\text{(i)}} \times \underbrace{Y_d \tau_{cd}^{-\theta}}_{\text{(ii)}} \times \underbrace{\kappa_1 CMA_d^{-1}}_{\text{(iii)}}$$

This expression says that trade flows from c to d are increasing in (i) local productivity of c weighted by input costs, (ii) market size of d weighted by trade costs, and (iii) competition from firms with access to d.

4.3 Total Income and Market Access

To derive a relationship between total income and market access we assume total income in c is equal to the sum of all expenditures purchased from d:

$$Y_c = \sum_d X_{cd} = \kappa_1 T_c(q_c^{\alpha} w_c^{\gamma})^{-\theta} \times \sum_d \left[\tau_{cd}^{-\theta} CMA_d^{-1} Y_d\right] \tag{2}$$

The interpretation of the final term on the right-hand side, called "firm market access," is the access of firms at c to all consumers in the economy. With the assumption that trade costs are symmetric (i.e., $\tau_{cd} = \tau_{dc}$) the relationship between consumer and firm market access at c must satisfy $FMA_c = \rho CMA_c$. Following Donaldson and Hornbeck (forthcoming), we define $MA_c \equiv FMA_c = \rho CMA_c$ for use in our empirical work. A suitable measure of market access solves the system of non-linear equations given by $MA_c = \rho \sum_d \tau_{cd}^{-\theta} MA_d^{-1} Y_d$. The approximation used in our empirical analysis is $MA_c = \sum_d \tau_{cd}^{-\theta} Y_d$.

From equation (2), the final steps are to replace $\sum_d \left[\tau_{cd}^{-\theta} CMA_d^{-1} Y_d\right]$ with MA_c, substitute the income share for the immobile factor land, apply the assumption that workers move until they are indifferent across locations, take logs and rearrange:[11]

$$\log Y_c = \kappa_2 + \frac{1}{1+\alpha\theta} \log T_c + \frac{\alpha\theta}{1+\alpha\theta} \log L_c + \frac{1+\gamma}{1+\alpha\theta} \log MA_c \tag{3}$$

Total income will be higher if a county has higher productivity, more land, or better market access. The increase in total income due to changes in market access may reflect firms' improved access to large markets or consumers with more access to low-cost producers. The relationship between total income and market access may also reflect effects outside of the model, for example, due to existing agglomeration economies that are reinforced by lower trade costs.

4.4 Estimating Equation and Identification

To assess the impact of the Appalachian Development Highway System (ADHS), we exploit variation in market access due to the expansion of the highway network from 1960 to 2010. Specifically, we estimate:

$$\log Y_{ct} = \beta \log MA_{ct} + X_c \delta_t + \phi_c + \phi_{st} + \epsilon_{ct} \tag{4}$$

where Y_{ct} is the total income in county c and year t. Standard errors are clustered at the state level to allow correlation across counties in the same state over time.

The main variable of interest is (log) market access, which summarizes the proximity of a

[11] $\kappa_2 \equiv \frac{1}{1+\alpha\theta} \log \kappa_1 - \frac{\gamma}{1+\alpha\theta} \log \rho - \frac{\alpha\theta}{1+\alpha\theta} \log \alpha - \frac{\gamma\theta}{1+\alpha\theta} \log \bar{U}$.

county to all other markets in the United States in terms of travel time. We calculate market access as: $MA_{ct} = \sum_{d \neq c} \tau_{cdt}^{-\theta} Y_{dt}$, where τ_{cdt} is the travel time between c and d in year t, θ is the trade elasticity, and Y_{dt} is the income other counties.[12] The trade elasticity, θ, is assumed to have a value of 8 in our baseline measure of market access. We present several robustness checks based on alternative measures of market access, including different values of θ and different travel speeds on each portion of the highway network. We exclude a county's own contribution when constructing market access to avoid the mechanical relationship between market access and market size, although our results are not sensitive to this choice.

In X_c, we include a second-order polynomial in the latitude and longitude of a county's centroid interacted with year fixed effects. This controls for the relationship between the outcome variable and smooth changes in county geography. This may be particularly useful in addressing the role of topography, climate, etc., in shaping the economic development of Appalachia, which is stressed by Eller (1982, 2008). All control variables included in X_c are interacted with year fixed effects. As robustness, we also consider specifications that control for local (i.e., within county) access to the highway network.

County (ϕ_c) and state-year (ϕ_{st}) fixed effects control for county characteristics that are fixed over the sample period and changes over time that are shared by all counties in the same state in a given year. County fixed effects adjust for differences in the productivity and physical size of counties that are time invariant. Productivity and the land used in production may vary over time in ways that are both unobserved and correlated with market access. This would be the case, for example, if improvements in highway infrastructure were targeted to integrate counties with high (low) growth potential and would suggest upward (downward) bias for estimates of β based on equation (4). Specifically in our setting, the locations that received ADHS connections may have had low growth potential between 1960 and 2010. The

[12] We transform travel time into the "iceberg form" by dividing τ_{cdt} by the average travel time in 1960 and adding one.

1968 annual report of the ARC indicated, "[the ARC] has given priority to upgrading the less adequate sections and deferring more serviceable, but still inadequate sections" (p. 41). Our empirical strategy of focusing on changes over several decades mitigates concerns about the endogeneity of the ADHS rollout since our estimates do not exploit this variation.

More broadly, from equation (1), market access is a function of the travel time-weighted sum of access to the technology and inputs of other counties. As described above, fixing market size in a given year is one approach to addressing concerns about the endogenous reallocation of economic activity due to changes in productivity that are targeted for highway improvements. Another approach is to isolate variation in market access that only reflects changes in transportation costs. To do this we exploit variation due to the change in travel time from a given county c to all other counties. In particular, we compute the average travel time from county c to all other counties according to:

$$\text{travel time}_{ct} = \sum_{d \neq c} \frac{\text{physical distance}_{cd}}{\text{average speed}_{cdt}} \times \frac{\text{population}_{d,t-50}}{\sum_d \text{population}_{d,t-50}} \tag{5}$$

The portion due to $\frac{\text{physical distance}_{cd}}{\text{average speed}_{cdt}}$ focuses on changes in travel time due to highway improvements that translate into increased average speed holding the distance travelled constant (i.e., the physical distance).[13] The portion due to $\frac{\text{population}_{d,t-50}}{\sum_d \text{population}_{d,t-50}}$ gives more weight to historically important markets–which may have remained important–but do not reflect changes between 1960 and 2010 that may have been targeted by policymakers.[14]

5 Results

In this section we present our estimates for the elasticity of total income with respect to market access. In addition, we present several robustness checks controlling for local

[13]We use the `geodist` command in Stata (Picard, 2010) to calculate the physical distance between county centroid pairs given latitude and longitude

[14]We use population to construct the instrument because county-level data on total income lagged to 1910 are not available.

measures of highway access, alternative definitions of market access, and instrumenting for market access using the change in travel time weighted by historical market sizes. We then use the estimated elasticity to quantify the overall gains due to the ADHS on entire 13 state sample area and consider the robustness to several alternatives for construction market access. After discussing the aggregate benefits, we then ask how the benefits were distributed across the ARC and non-ARC counties within our sample area and the impact on income per capita.

Before discussing our results it is useful to provide evidence for two conditions given by Donaldson and Hornbeck (forthcoming) for the validity of the counterfactual exercises reported in Section 5.2. First, for some counties removing the the ADHS or replacing the ADHS with an alternative proposal results in large changes in market access. Thus, our counterfactual exercises require the elasticity estimated in Section 5.1 to be based on similarly large changes in market access. Figure 4A shows a histogram for the residual change in market access controlling for a second-order polynomial in latitude and longitude and state-year fixed effects. There is substantial variation in residualized market access: the difference between the 90$^{\text{th}}$ and 10$^{\text{th}}$ percentiles of the change in (log) market access is 0.459. Second, the relationship between changes in (log) market access and (log) total income is linear in Figure 4B, which provides some support for the functional form used in the estimation and counterfactuals.

5.1 The Impact of Market Access

Table 2 shows the baseline results for estimating equation (4). These results focus on the sample of 1,070 Appalachian counties. Column 1 gives the impact on total income from estimating equation (4) weighted by total income in 1960, column 2 reports results from an unweighted version, and column 3 shows the second-stage results when using instrumental variables. Column 4 provides the first-stage coefficient on the excluded instrument, which is highly statistically significant and implies that a 1 percent increase in the predicted travel time decreases market access by 3.29 percent.

In columns 1 and 2, the coefficient on market access is statistically significant at the 5 percent level. In column 3, the coefficient on market access is statistically significant and larger in magnitude than the OLS estimates. This suggest that transportation infrastructure may be targeted at low income and slow growth locations. The magnitude of the IV estimate suggests that that a 1 percent increase in market access increases total income by 0.814 percent. Overall, the estimates are in line with results obtained in the recent literature for nineteenth century railroads in the United States (Donaldson and Hornbeck, forthcoming) and highways in India (Alder, 2015).

Recall that the measure of market access was calculated by assuming a value of θ equal to 8. Based on the theoretical relationship between (log) total income and (log) market access from equation (3), we can solve for the implied value of θ.[15] Doing this, we find a value of θ that is approximately equal to 8. The consistency between the implied and assumed value of trade elasticity is comforting. It is also comforting, as we show below, that the results of our counterfactual exercises are not sensitive to using alternatives values of θ.

Table 3 shows the results from several robustness checks for the estimated relationship in Table 2. Column 1 reports our estimate using instrumental variables (Table 2, column 3). Subsequent columns control for whether a county has direct access to a highway (column 2), IHS and ADHS miles in each county (column 3), whether a county is within 50 miles of an IHS or ADHS connection (column 4), whether a county is 100, 200, and 500 or more miles from an IHS or ADHS connection (column 5), as well as all controls for local access (column 6). When we include all covariates, the elasticity decreases to 0.616, which is the estimate

[15] To do this, note that the estimate of β from equation (4) corresponds to $\frac{1+\gamma}{1+\alpha\theta}$ from equation (3). Based on Caselli and Coleman (2001), we calibrate the share of land (α) and labor (γ) in total income to be 0.2 and 0.6, respectively, and obtain a value for θ of 8.38, which is in line with our assumed value.

we use in our baseline counterfactual exercise.

In Table 4 we include additional robustness checks for assigned highway network parameters and alternative definitions of market access. In Column 1, we allow the speeds of all roads in 1960 to increase by 5 mph and increase the speeds in 2010 to their modern speeds as reported by the National Highway Transportation Safety Administration. In Column 1, we allow the speed of the ADHS segments to increase from 55 to 65 mph to capture the incorporation of some segments into the interstate system (e.g., I-22, I-68, I-86). Estimates remain statistically significant.

The remaining columns consider alternative definitions of the market access variable. In our baseline market size is measured using data from 1960 and 2010. In column 3, we let national income increase but fix the distribution in each year to the distribution of income in 1960. In column 4, we compute market access replacing total income with population. Finally, when computing market access, we use θ equal to 8 based on the previous literature (Donaldson and Hornbeck, forthcoming, see). Columns 5 and 6 report estimates of the market access elasticity using θ equal to 4 or 12 (see Anderson and van Wincoop, 2004; Simonovska and Waugh, 2014); differences reflect a scaling of market access variable so that, as we see in section 5.2, the results of the counterfactual exercises are not affected. Columns 7 and 8 reports similar estimates based on a measure of market access that excludes counties within 100 and 200 miles of the origin county, respectively. In general, results are not sensitive to alternative highway network parameters and definitions of market access.

Finally, Table 5 shows the results of replacing the outcome variable with different measures of (log) employment. Column 1 shows the results for total employment: a 1 percent increase in market access leads to a 0.859 percent increase in total employment. In column 2, the response of employment in agriculture to market access is negative but not statistically significant. The estimated coefficients in the remaining columns are positive and statistically significant. In the case of manufacturing (column 4) and trade (column 5), the gains may reflect the role of improved market access in making Appalachia more attractive for new plant location or relocation.

5.2 Overall Gains from Appalachian Highways

Together with the estimated elasticity between total income and market access, the model provides a natural way to evaluate the aggregate impact of alternative transportation infrastructure policies on the development of the Appalachian region. In particular, this approach provides a straightforward way to capture how changes at a point in the highway network influence *all* counties. In this way, we are able to quantify the aggregate impact of improvements due to the ADHS throughout the entire 13 state area. We consider two counterfactual policies.

First, we remove the ADHS from the highway network in 2010, but let the highway network grow as it actually did between 1960 and 2010. We then recompute market access exactly as before. That is, we only consider the impact of the change in market access due to moving from Panel A to Panel B of Figure 2 plus the fixed access road network. Figure 5 shows the difference between the counterfactual scenario of removing the ADHS relative to actual market access. The figure, which denotes counties with less market access in the absence of the ADHS with lighter shades, shows that counties in center of Appalachia (i.e., those included in the ARC) would have experienced a decline in market access while those on the periphery continue to be well-served by the rest of the highway system.

Second, we replace the ADHS in 2010 with the smaller highway network initially planned under the President's Appalachian Regional Commission and continue to allow the IHS network to expand as it actually did. The PARC plan was approximately 1,000 miles smaller than the prevailing ADHS network. Many of those miles were added to gain political support or were patronage for eventual supporters of the ARC. For example, Senator Robert

Kennedy added an amendment to the 1965 legislation to include 14 counties in New York in the ARC region, which ultimately paved the way for the construction of Corridor T from Binghamton, NY to Erie, PA and Corridor U from Elmira, NY to Williamsport, PA. These added approximately 280 miles to the ADHS. The construction of Corridors V, X, and X-1 in Alabama and Mississippi added more than 400 miles, despite Alabama being purposefully excluded from the initial plan due to substantial coverage by the IHS (Preston and Associates, 1965).

The rows of Table 6 show the results for each counterfactual. In Column 2, we calculate the aggregate impact of removing the ADHS by multiplying the counterfactual change in market access for all counties (both in the ARC and outside of the ARC) with our baseline estimate of the elasticity of total income with respect to market access. Moving down the table, we show how the estimated income loss changes under alternative definitions of the market access variable. For example, we allow the speeds of the roads in the network to increase to their modern speeds and the income loss associated with the ADHS falls from \$45.9 billion to \$23.8 (row 1) and \$27.7 (row 2) billion. Fixing the distribution of income (row 3) or using population (row 4) to construct market access, leads to losses of \$37.6 billion and \$50.4 billion, respectively. Replacing θ with alternative values (rows 5 and 6) or excluding counties within 100 or 200 miles (rows 7 and 8) when constructing market access does not alter the counterfactual estimates. To provide a sense of the magnitude of this effect, we compare it to the aggregate income of the region. In 2010, total income was \$4.43 trillion in our sample of 1,070 counties. Thus, losses of \$45.9 billion associated with removing the ADHS represents approximately 1 percent of the region's total income.

In Column 3, we calculate the loss in income of using the PARC network in lieu of the ADHS network. In each row the results in column 3 are roughly half the results reported in column 2, which suggests that PARC would have mitigated half of the losses from removing the ADHS. In some cases, the confidence intervals of the ADHS income loss and PARC income loss overlap, suggesting that it is possible that some of the income gains could have been achieved with a network smaller than the ADHS.

The last issue we examine is whether the people targeted by the program were the actual recipients of the benefits. Our sample includes all counties in the states that have at least one county in the ARC. It is possible that some share of the benefits accrued to locations outside the targeted area. In Table 7 we examine the distribution of the counterfactual effect between the ARC and non-ARC counties. In Panel A, the first row reports the decrease in income associated due to the removal of the ADHS (column 1) as well as the distribution of losses across ARC and non-ARC counties (columns 2 and 3). From this exercise we see that approximately 70 percent of the benefits are concentrated in counties that are part of the ARC and the remainder to people outside of the ARC.

The loss of \$32.5 billion–approximately 3.7 percent of total income–is large given the lower total income in ARC counties relative to non-ARC counties. Importantly, workers are mobile and so endogenously reallocate across counties in response to a change in transportation infrastructure. To the extent that Appalachian counties looked more attractive due to improved market access, some of the potential gains in income per capita will be mitigated by population change. The second row of Table 7 shows that across all counties the average person would have earned \$171 less in the absence of the ADHS. This effect was larger in the ARC counties (i.e., \$515) relative to non-ARC counties (i.e., \$63). This is roughly 1.4 percent of income per capita in ARC counties or, alternatively, approximately one-third the value of current food stamp benefits. In Panel B, we find similar effects given the size and corresponding change in market access under the PARC plan.

In addition to our estimated benefits we also collected information on the fiscal costs of the ADHS, which allows us to calculate a back-of-the-envelope rate of return. We start with benefits of \$45.9 billion (in 2015 dollars). The fiscal costs of the ADHS reflect expenditures from two sources. The federal government provided roughly 70 percent of funds for the ADHS, while state and local government provided the remainder. Together, expenditures on highway from federal and non-federal sources were \$35.1 billion (in 2015 dollars). Applying a 7.5 percent cost of capital (i.e., equal to the average market return over the period), adding costs of maintenance, and compounding annually gives annualized costs of \$10.9 billion.[16] Taken together this suggests a rate of return of 8.4 percent ($\frac{45.9-10.9}{415.8}$) annually. When we allow for modern travel speeds the rate of return decreases to 3.1 percent. This rate is just below the 9 percent Allen and Arkolakis (2014) find for the Interstate Highway System and the 11 to 25 percent Alder (2015) finds for highways in India.

When the ADHS is replaced with the highway network proposed by PARC the losses in total income were \$22.0 billion. The PARC plan included 1,500 highway miles instead of the 2,500 miles in the ADHS. We assume that the cost of PARC would have been proportional (in miles) to the ADHS, i.e., the marginal benefit of each additional mile is the same, and obtain a counterfactual rate of return on PARC of approximately 7.5 percent. Alternatively, assuming an increasing cost or a decreasing benefit of additional miles would increase the rate of return of PARC relative to the ADHS.

6 Conclusion

In 1965, President Johnson signed legislation creating the Appalachian Regional Commission, which aimed to reduce poverty in isolated pockets of West Virginia, Kentucky, and the surrounding states. Central to the Commission's approach to improving economic conditions in the region was the construction of high quality highways to complement the Interstate Highway System. Between 1965 and 2010, \$35.1 billion in federal and state funds

[16] We let maintenance costs equal \$535,000 per mile based the Office of Highway Policy Information estimates at https://www.fhwa.dot.gov/policyinformation/pubs/hf/pl11028/chapter1.cfm.

were spent to construct approximately 2,500 highway miles. In this paper, we examine the impact of the Appalachian Development Highway System (ADHS) on regional development. We use a model of inter-regional trade together with newly digitized data of the Appalachian and interstate highway systems in 1960 and 2010.

Due to the ADHS, Appalachia has experienced a substantial decrease in transportation costs over the last 50 years. In this paper, we estimate the aggregate and per capita income benefits associated with the ADHS. We find that removing the ADHS would have reduced the total income by $45.9 billion, i.e., roughly 1 percent, and approximately two-thirds of this effect were concentrated in counties included in the ARC. The benefits of the ADHS relative to federal, state, and local expenditures suggest a rate of return up to 8.4 percent.

In addition to the increase in total income, the ADHS created new employment opportunities and attracted new residents to region. To some extent this mitigated gains in income per capita. We find that income per capita would have been $171 lower without the ADHS and this effect was $515 in the ARC counties versus $63 in non-ARC counties. Still, aggregate indicators today are similar to those that prevailed in the recent past; income per capita (including transfers) was 75 percent of the national average in the ARC and just 50 percent of the national average in Kentucky in 2010. For the same geographies, the comparable figures were 74 and 44 percent in 1965. Thus, despite improvements in transportation infrastructure and some gains in income per capita the region continues to lag behind the rest of the country.

Overall, our findings contribute to an ongoing debate in urban and regional economics regarding the impact of transportation infrastructure (Redding and Turner, 2015). In addition, we contribute to a recent literature examining the impact of the Appalachian Regional Commission (see Bradshaw, 1992; Ziliak, 2012) and, more generally, War on Poverty era programs (see Bailey and Danziger, 2013). Our results are the first to address the transportation portions of federal government spending on regional development during this period. Finally, the results are useful for understanding the long-run implications of place-based policies in underdeveloped regions in the United States and provide a starting point for evaluating the efficacy of ongoing policies (i.e., the Delta Regional Administration).

References

Simon Alder. Chinese Roads in India: The Effect of Transport Infrastructure on Economic Development. *Working Paper*, 2015.

Treb Allen and Costas Arkolakis. Trade and Topography of the Spaital Economy. *Quarterly Journal of Economics*, 1085:1139, 2014.

James E. Anderson and Eric van Wincoop. Trade Costs. *Journal of Economic Literature*, 42(3):691–751, 2004.

Appalachian Regional Commission. *Appalachia: A Report by the President's Appalachian Regional Commission*. Government Printing Office, Washingotn, DC, 1964.

Martha Bailey and Sheldon Danziger, editors. *Legacies of the War on Poverty*. Russell Sage Foundation, New York, NY, 2013.

Abhijit Banerjee, Esther Duflo, and Nancy Qian. On the Road: Access to Transportation Infrastructure and Economic Growth in China. Technical report, National Bureau of Economic Research, 2012.

Nathaniel Baum-Snow. Did Highways Cause Suburbanization? *Quarterly Journal of Economics*, pages 775–805, 2007.

Nathaniel Baum-Snow, Loren Brandt, J. Vernon Henderson, Matthew A Turner, and Qinghua Zhang. Roads, Railroads and Decentralization of Chinese Cities. 2012.

Dan A. Black and Seth G. Sanders. *Labor Market Performance, Poverty, and Income Inequality*. Appalachian Regional Commission, Washington, DC, 2004.

Dan A. Black and Seth G. Sanders. *Standards of Living in Appalachia, 1960-2000*. Population Reference Bureau, Washington, DC, 2007.

Michael Bradshaw. *The Appalachian Regional Commission: Twenty-five years of government policy*. University Press of Kentucky, 1992.

U.S. Department of Commerce Bureau of Economic Analysis. *Annual Report, Bureau of Public Roads*. Office of Government Printing, Washington DC, 1960.

U.S. Department of Commerce Bureau of Economic Analysis. *Regional Economic Accounts*. 2015.

Francesco Caselli and Wilbur John Coleman. The U.S. Structural Transformation and Regional Convergence: A Reinterpretation. *Journal of Political Economy*, 109(3):584–616, 2001.

Amitabh Chandra and Eric Thompson. Does Public Infrastructure Affect Economic Activity?: Evidence from the Rural Interstate Highway System. *Regional Science and Urban Economics*, 30(4):457–490, 2000.

James C. Cobb. *The Selling of the South: The Southern Crusade for Industrial Development, 1936-90*. Louisiana State University Press, Baton Rouge, LA, 1982.

Edsger W Dijkstra. A note on two problems in connexion with graphs. *Numerische mathematik*, 1(1):269–271, 1959.

Dave Donaldson. Railroads of the Raj: Estimating the Impact of Transportation Infrastructure. *American Economic Review*, forthcoming.

Dave Donaldson and Richard Hornbeck. Railroads and American Economic Growth: 'A Market Access' Approach. *Quarterly Journal of Economics*, forthcoming.

Gilles Duranton and Matthew Turner. Urban Growth and Transportation. *Review of Economic Studies*, 79(4):1407–1440, 2012.

Gilles Duranton, Peter M. Morrow, and Matthew A. Turner. Roads and Trade: Evidence from the US. *Review of Economic Studies*, 81(2):681–724, 2014.

Jonathan Eaton and Samuel Kortum. Technology, geography, and trade. *Econometrica*, pages 1741–1779, 2002.

Ronald Eller. *Miners, Millhands, and Mountaineers: Industrialization of the Appalachian South, 1880-1930*. University of Tennessee Press, 1982.

Ronald Eller. *Uneven Ground: Appalachia since 1945*. University Press of Kentucky, 2008.

E.S. Preston & Associates. *Appalachian Highway Planning Report : Appalachian Development Highways and Access Roads as Authorized by the Appalachian Regional Development Act of 1965*. E.S. Preston Associates, Columbus, OH, 1965.

Benjamin Faber. Trade Integration, Market Size, and Industrialization: Evidence from China's National Trunk Highway System. *Review of Economic Studies*, 81(3):1046–1070, 2014.

Ejaz Ghani, Arti Grover Goswami, and William R. Kerr. Highway to Success: The Impact of the Golden Quadrilateral Project for the Location and Performance of Indian Manufacturing. *Economic Journal*, 2015.

Edward L. Glaeser and Joshua D. Gottlieb. The Economics of Place-Making Policies. *Brookings Papers on Economic Activity*, 39(1):155–253, 2008.

John Haaga. *Educational Attainment in Appalachia*. Appalachian Regional Commission, Washington, DC, 2004.

Richard Hornbeck. Barbed Wire: Property Rights and Agricultural Development. *Quarterly Journal of Economics*, 125(2):767–810, 2010.

Andrew Isserman and Terance Rephann. New Highways as Economic Development Tools: An Evaluation using Quasi-Experimental Matching Methods. *Regional Science and Urban Economics*, 24(6):723–751, 1994.

Carl Kitchens. The Role of Publicly Provided Electricity in Economic Development: The Experience of the Tennessee Valley Authority, 19291955. *Journal of Economic History*, 74 (2):389–419, 2014.

Patrick Kline and Enrico Moretti. Local Economic Development, Agglomeration Economies and the Big Push: 100 Years of Evidence from the Tennessee Valley Authority. *Quarterly Journal of Economics*, 129(1):275–331, 2014.

Guy Michaels. The Effect of Trade on the Demand for Skill: Evidence from the Interstate Highway System. *Review of Economics and Statistics*, 90(4):683–701, 2008.

Robert Picard. GEODIST: Stata module to compute geodetic distances. Statistical Software Components, Boston College Department of Economics, April 2010. URL `https://ideas.repec.org/c/boc/bocode/s457147.html`.

Kelvin M. Pollard. *Appalachia at the Millennium: An Overview of Results from Census 2000*. Population Reference Bureau Washington, DC, 2003.

Stephen Redding and Matthew A. Turner. Transportation Costs and the Spatial Organization of Economic Activity. In Gilles Duranton, J. Vernon Henderson, and William Strange, editors, *Handbook of Urban and Regional Economics*, volume 5, pages 1339–1398.

North-Holland, Amersterdam, 2015.

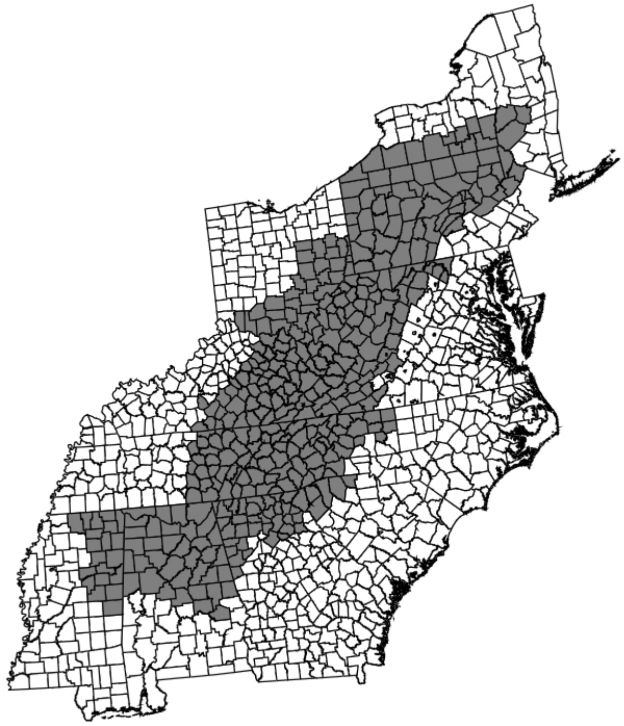
Shell Oil Company. *Shell Highway Map of United States*. Chicago, IL, 1956.

Ina Simonovska and Michael E. Waugh. The elasticity of trade: Estimates and evidence. *Journal of International Economics*, 92(1):34–50, 2014.

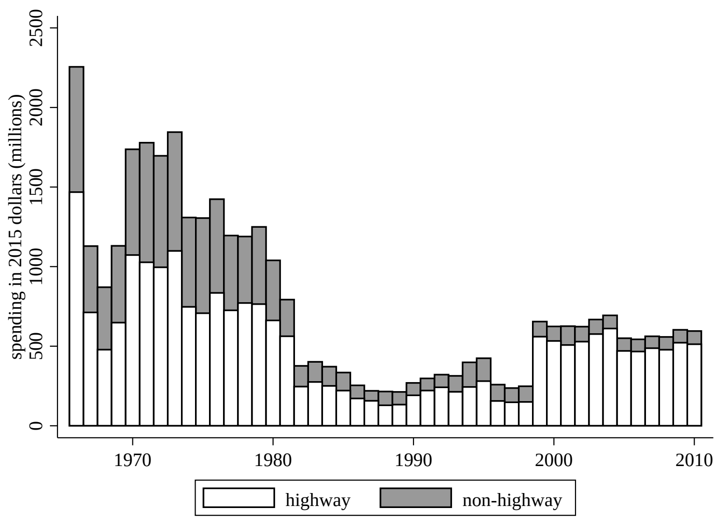
Ralph Widener. Appalachian Development after 25 Years: An Assessment. *Economic Development Quarterly*, 4(4):291–312, 1990.

James P. Ziliak. *Appalachian Legacy: Economic Opportunity after the War on Poverty*. Brookings Institution Press, 2012.

Figure 1: Appalachian Regional Commission Program Area and Spending



A. Program Area



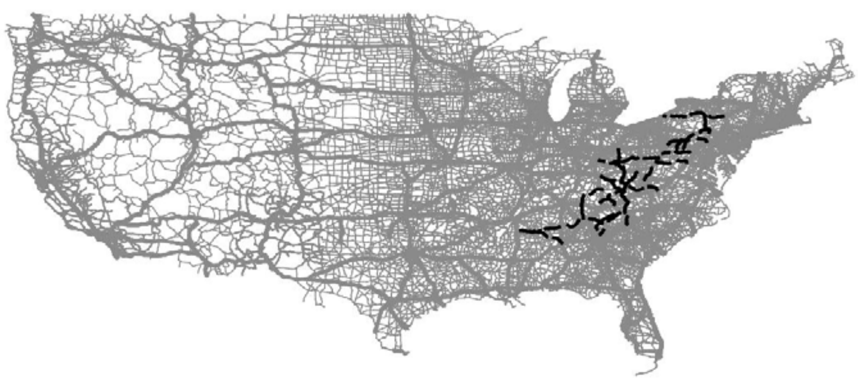
B. Aggregate Spending

Notes: Panel A shows the counties included in the Appalachian Regional Commission as of 1967. Panel B shows aggregate spending by the Appalachian Regional Commission in 2015 dollars separately by the highway (unshaded) and non-highway (shaded) components from 1965 to 2010.

Figure 2: Interstate and Appalachian Highways, 1960-2010

A. Highways in 1960

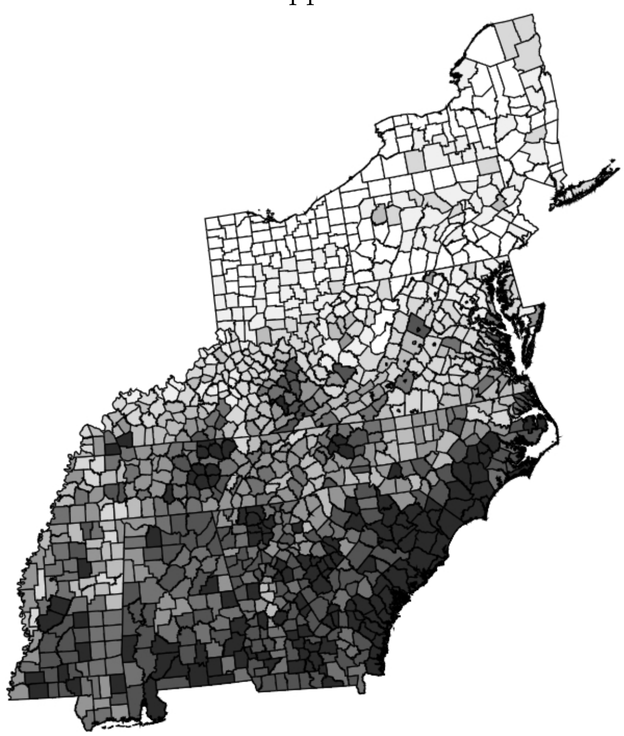
B. Highways in 2010, without ADHS



C. Highways in 2010, with ADHS

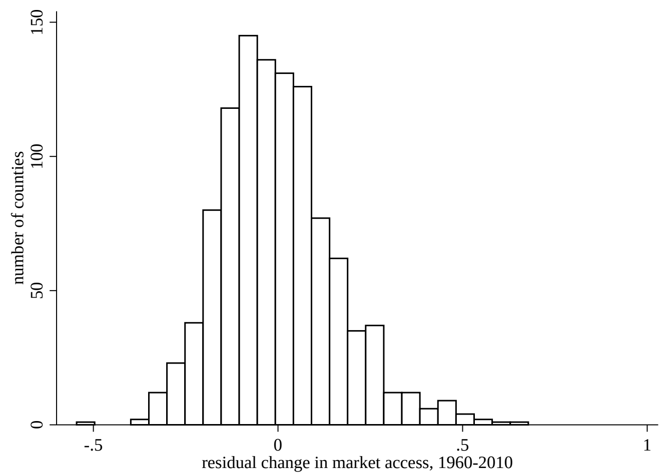
Notes: The figure shows growth of the highway network between 1960 and 2010. In panels A and B, the solid black lines show the IHS in 1960 and 2010, respectively, and the gray lines show the other portions of the highway network. In Panel C, the gray lines are the high network (including the IHS) in 2010 and the dotted black line shows the ADHS.

Figure 3: Change in Market Access in Appalachian Counties between 1960 and 2010

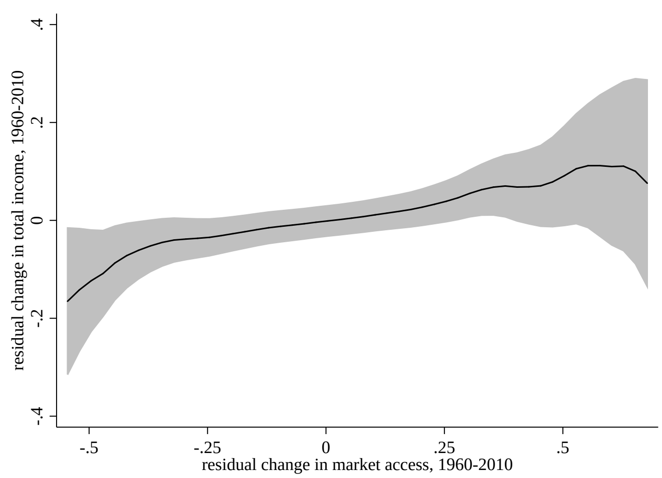


Notes: The figure shows the change in market access between 1960 and 2010 for the 1,070 counties in states with at least one county in the Appalachian Regional Commission. The change in market access is calculated between each county shown and all counties in the contiguous United States. In the empirical analysis, independent cities in Virginia observations are merged with the surrounding county. Darker shades indicate larger changes in market access.

Figure 4: Changes in Market Access and Relationship to Changes in Total Income



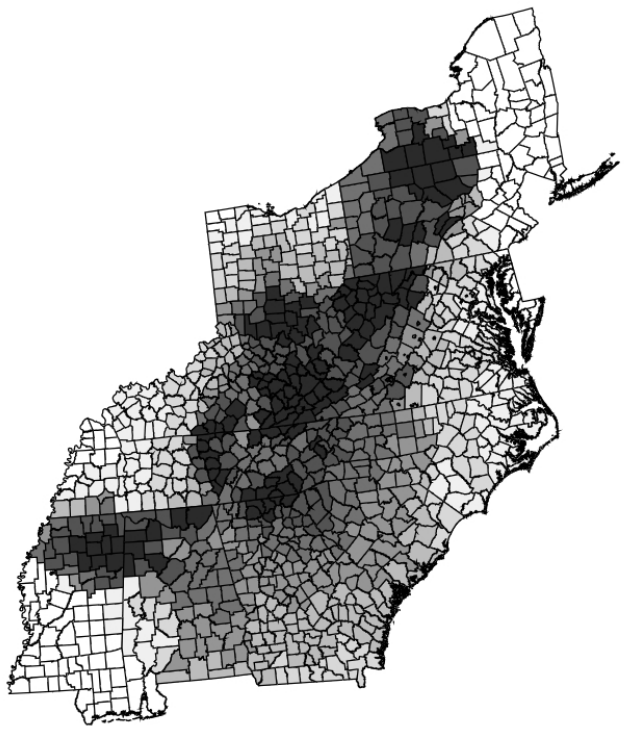
A. Changes in market access



B. Changes in market access and total income

Notes: Panel A shows a histogram for the residual changes in market access between 1960 and 2010 after controlling for a second-order polynomial of latitude and longitude, lagged values of total income and population, and an indicator for whether the county is included in the ARC. Panel B shows the results of a local polynomial regression for the relationship residual changes in total income and market access between 1960 and 2010.

Figure 5: Counterfactual Change in Market Access in Appalachian Counties without ADHS



Notes: The figure shows the difference between the actual change in market access between 1960 and 2010 and the counterfactual change in the absence of the ADHS. In each scenario, the change in market access is calculated between each county shown and all counties in the contiguous United States. Darker shades indicate counties that have relatively larger market access in the absence of the ADHS.

Table 1: Summary Statistics for Change in Market Access, Income, and Population

	All Counties (1)	ARC Counties (2)	Non-ARC Counties (3)
Market Access	2.43	2.39	2.45
	[0.36]	[0.33]	[0.38]
Total Income	1.73	1.64	1.79
	[0.58]	[0.57]	[0.58]
Total Population	0.39	0.34	0.43
	[0.51]	[0.48]	[0.52]
Sample Counties	1070	397	673

Notes: The table shows summary statistics for the change in market access, total income, and total population from 1960 to 2010 for all sample counties and stratified by whether counties were included in the Appalachian Regional Commission program area. Standard deviations are in parentheses.

Table 2: Results for Impact of Market Access on Total Income, 1960-2010

	OLS, weighted (1)	OLS, unweighted (2)	2nd IV, weighted (3)	1st IV, weighted (4)
log(market access)	0.442	0.290	0.814	
	(0.175)	(0.151)	(0.191)	
log(travel time)				-3.287
				(0.940)
First Stage F-stat				12.23

Notes: The table shows the results from estimating equation (4). The first two columns are estimated using ordinary least squares and the last two columns present second- and first-stage results using instrumental variables. In columns 1 through 3 the outcome variable is (log) total income and in column 4 the outcome is (log) market access. Column 1, 3 and 4 are weighted by total income in 1960. Standard errors (in parentheses) are clustered at the state level. The number of counties is 1,070.

Table 3: Impact of Market Access on Total Income with Local Controls, 1960-2010

	2nd IV, weighted (1)	direct connection (2)	highway mileage (3)	"near" highway (4)	"far" highway (5)	all local variables (6)
log(market access)	0.814	0.813	0.837	0.751	0.810	0.616
	(0.191)	(0.196)	(0.194)	(0.208)	(0.218)	(0.222)

Notes: The table shows results using instrumental variables and additional controls for local market access. Column 1 is the main result from column 1 of Table 2. The remaining columns add an indicator if any portion of the interstate or Appalachian highways is within a county's border (column 2), the interstate or Appalachian highway mileage (column 3), whether a county is within 50 miles of an IHS or ADHS connection (column 4), whether a county is 100, 200, and 500 or more miles from an IHS or ADHS connection (column 5), and all controls for local access (column 6). All columns are weighted by total income in 1960 and include county and state-year fixed effects as well as a second-order polynomial in latitude and longitude. Standard errors (in parentheses) are clustered at the state level. The number of counties is 1,070.

Table 4: Robustness for Impact of Market Access on Total Income, 1960-2010

	increase IHS speed (1)	increase ADHS speed (2)	fixed income (3)	adjusted population (4)
log(market access)	0.502	0.384	0.473	0.617
	(0.178)	(0.146)	(0.207)	(0.225)
	set $\theta = 4$ (5)	set $\theta = 12$ (6)	exclude $<$ 100 miles (7)	exclude $<$ 200 miles (8)
log(market access)	0.418	1.194	0.519	0.511
	(0.160)	(0.397)	(0.165)	(0.178)

Notes: The table shows results using instrumental variables and alternative definitions of market access. Column 1 increases the IHS speed and Column 2 increases the ADHS speed. Column 3 fixes the distribution of total income in 1960 to compute market access. Column 4 uses population instead of total income in each year to calculate market access. Columns 5 and 6 use alternative values of θ. Columns 7 and 8 excludes counties with 100 and 200 miles of the origin county, respectively, when calculating market access. All columns are weighted by total income in 1960 and include county and state-year fixed effects, a second-order polynomial in latitude and longitude, and local controls from Table 3. Standard errors (in parentheses) are clustered at the state level. The number of counties is 1,070.

Table 5: Results for Impact of Market Access on Employment by Sector

	Employment (1)	Agriculture (2)	Construction (3)	Manufacturing (4)	Trade (5)	Other (6)
log(market access)	0.859	-1.650	2.033	1.728	1.235	0.637
	(0.3997)	(1.8981)	(0.6856)	(1.0127)	(0.3385)	(0.3763)

Notes: The table shows the results of equation (4) replacing (log) total income as the outcome with (log) employment by sector. Column 1 shows the results for total employment and columns 2 through 6 show the results for the sector given in the heading. In Column 6, "Other" includes the broad category of services, mining, and miscellaneous employment. All columns are weighted by total income in 1960 and include county and state-year fixed effects, a second-order polynomial in latitude and longitude, and local controls from Table 3. Standard errors (in parentheses) are clustered at the state level. The number of counties is 1,070.

Table 6: Counterfactual Impact of Market Access on Total Income

	Market Access Coefficient	Counterfactual (in billions, 2015 \$):	
		w/o ADHS	w/ PARC
	(1)	(2)	(3)
2nd IV, weighted	0.616	-45.9	-22.0
	(0.222)	(15.7)	(7.5)
1. increase IHS speed	0.502	-23.8	-12.6
	(0.178)	(8.3)	(4.4)
2. increase ADHS speed	0.384	-27.7	-12.4
	(0.146)	(10.3)	(4.6)
3. fixed 1960 income	0.473	-37.6	-17.8
	(0.207)	(15.8)	(7.5)
4. adj. 1960, 2010 pop.	0.617	-50.4	-23.9
	(0.225)	(17.6)	(8.3)
5. set θ equal to 4	0.418	-44.8	-22.1
	(0.160)	(16.2)	(8.0)
6. set θ equal to 12	1.194	-44.3	-20.8
	(0.397)	(14.1)	(6.6)
7. exclude counties <100 miles	0.519	-41.8	-19.5
	(0.165)	(12.7)	(5.9)
8. exclude counties <200 miles	0.511	-38.1	-16.7
	(0.178)	(12.8)	(5.6)

Notes: The table shows the results and robustness for the impact of counterfactual changes in market access. Each row shows the estimated market access coefficient (column 1) as well as the results under the two counterfactual scenarios for all sample counties (columns 2 and 3). Estimates in Column 1 are weighted by total income in 1960 and include county and state-year fixed effects, a second-order polynomial in latitude and longitude, and local controls from Table 3. Standard errors (in parentheses) are clustered at the state level.

Table 7: Distribution of Counterfactual Impact of Market Access on Income

	All Counties (1)	ARC Counties (2)	Non-ARC Counties (3)
A. Counterfactual w/o ADHS, in 2015 $			
total income (billions)	-45.9	-32.5	-13.4
	(15.7)	(10.9)	(4.8)
income per capita	-170.5	-514.6	-63.5
	(69.1)	(207.2)	(26.2)
B. Counterfactual w/ PARC, in 2015 $			
total income (billions)	-22.0	-15.0	-7.0
	(7.5)	(5.0)	(2.5)
income per capita	-81.4	-236.9	-33.1
	(33.1)	(95.5)	(13.6)

Notes: The table shows results from the two counterfactual scenarios. We use the estimate of the elasticity of total income with respect to market access from Table 3, column 6. Column 1 shows the counterfactual change in total income for counties in the ARC and column 2 shows the change for counties not in the ARC. Column 3 shows the counterfactual change in total income for all sample counties. Standard errors (in parentheses) are clustered at the state level.