The Interstate Highway System and the Development of the American Economy∗

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Abstract

The construction of the Interstate Highway System reduced travel times and the cost of moving freight in the United States over the second half of the twentieth century. From 1960 to 2010 travel times fell by one-third across all US counties. We use a theoretical framework that combines many domestic and foreign locations—respectively, US counties and foreign countries—and sectors together with newly digitized data on internal trade costs in the United States to understand the role improvements in highway infrastructure played in the development of US regions. In particular, we focus on the aggregate contribution of each segment of the Interstate Highway System to labor income, the distributional impact across counties, and the relative importance of access to domestic and international markets. In this version of the paper, we present results for the aggregate and spatial distributional effect of removing each segment of the Interstate Highway System in 2010. We also present results for the aggregate effect for the ten largest segments (in 2010 miles) for each decade from 1970 to 2010.

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1 Introduction

The United States has undergone two important changes in the determinants of internal trade costs—the costs of moving goods (or people) within the country—over the last 200 years. First, in the nineteenth century, canals and railroads were added to a transportation system that previously relied on oceanic shipping between domestic ports, the use of inland waterways, and a crude road network. Second, in the twentieth century, a vast system of local, state, and national highways provided greater flexibility in business and residential location decisions and eventually came to dominate domestic freight. In turn, each period of falling internal trade costs was accompanied by great national integration with the rest of the world, i.e., globalization. This suggests an important role for internal trade costs in shaping regional development by intermediating exposure to the benefits and costs of globalization across regions.

In the second half of the twentieth century, the Interstate Highway System was a massive national undertaking that reduced internal travel times. Today, a majority of the Interstate Highway System is paved with concrete 11 inches thick and uses 1.5 billion metric tons of aggregates, 35 million metric tons of asphalt, 48 metric tons of cement, and 6 metric tons of steel. From the passage of the Federal Aid Highway Act in 1956, nearly 50,000 miles of limited access and high-grade highways were added to the 4 million miles constructed by local, state, and national projects over the same period. This improvement in the number of miles, grading of certain segments for higher speeds, and fewer interruptions together combined to lower travel times between US counties by 30 percent from 1960 to 2010.

In this paper, we make several contributions to understanding the role of internal trade costs in determining the spatial distribution of economic activity in the United States. In particular, we focus on the role of internal improvements in road infrastructure—including each segment of the Interstate Highway System, individually—in providing better access to domestic and international markets and, thus, the impact on national and regional growth over the second half of the twentieth century. To do this, we use a theoretical framework that incorporates domestic locations (i.e., counties) and foreign locations (i.e., countries). In particular, following Caliendo, Dvorkin and Parro (2017) we aim to calculate counterfactuals
that quantify the value of each segment of the Interstate Highway System, the distributional impact across counties in the United States, and the relative importance of access to domestic and international markets.

The first step of this paper is to quantify county-to-county trade costs for all county pairs using newly digitized maps of the US highway network. Specifically, we use Rand McNally’s *Road Atlas of the United States* and shapefiles from the Federal Highway Administration to calculate county-to-county travel times for nearly 4.8 million county pairs each decade from 1960 to 2010. The second step uses these new data to understand the role of internal trade costs in shaping access to national and international markets and the subsequent impact on regional development. We will conduct counterfactuals to quantify the aggregate contribution of each segment of the Interstate Highway System as well as decompose this effect into portions due to improved internal versus external integration. With this approach, we demonstrate the important joint role that transportation infrastructure and globalization played in determined the size and spatial distribution of economic activity in the United States over the second half of the twentieth century. In this version of the paper, we present results for the aggregate and spatial distributional effect of removing each segment of the Interstate Highway System in 2010. We also present results for the aggregate effect for the ten largest segments (in 2010 miles) for each decade from 1960 to 2010.

This paper contributes to several different literatures. First, there is a large literature that examines the impact of changes in transportation infrastructure within the United States. Isserman and Rephann (1994) find positive effects on counties with more urbanization or counties closer to large cities from 1963 to 1975 and Chandra and Thompson (2000) document differential effects across industries as well as reallocation of economic activity away from counties with no highway access from 1969 to 1993. Michaels (2008) shows that counties with a segment of the Interstate Highway System experiences relative increases in trade-related activities and that the demand for skilled labor increases in skill-abundant counties.1 Closely related to our focus on highways is work by Duranton, Morrow and

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1For China, Faber (2014) identifies a similar effect: locations not targeted within National Trunk Highway System see relative decreases in industrial output.
Turner (2014), which finds that more highways increase the weight and specialization in heavier goods but have minimal effect on the value of exports at the city-level in the United States. More recently, Donaldson and Hornbeck (2016) quantify the aggregate effect of the railroads on agricultural development between 1870 and 1890, while Jaworski and Kitchens (2018) examine the national and regional effects of highway-building in Appalachia.\textsuperscript{2}

Second, recent research in international trade allows connections between domestic locations and the rest of the world to be affected by internal trade costs. For example, Atkin and Donaldson (2015) use information on spatial price gaps to quantify internal trade costs within each of Ethiopia, Nigeria, and the United States. Their results suggest substantial variation in internal trade costs across countries and this has implications for the distribution of the gains from globalization within countries. In addition, Baum-Snow et al. (2017), Coşar and Fajgelbaum (2016), Ramondo, Rodríguez-Clare and Saborío-Rodríguez (2016), Redding (2012), Agnosteva, Anderson and Yotov (2014), Du, Wei and Xie (2013), and Fajgelbaum and Redding (2014), provide evidence that suggests an important role for internal trade costs in understanding the impact of greater openness to international trade.

In this paper, we measure internal trade costs directly using detailed data on changes in the distance and speed of travel through the US highway network between all US counties and ports of entry. We will provide an assessment of the contribution of the Interstate Highway System to US economic growth over the second half of the twentieth century that incorporates the effects of both greater internal and external integration. In this way, we build on work in macroeconomics by Fernald (1999), economic geography by Allen and Arkolakis (2014, 2016), and the interaction between trade costs, growth, and the spatial distribution of economic activity more broadly (Redding and Turner, 2015; Redding and Rossi-Hansberg, 2017).

The remainder of the paper is organized as follows. Section 2 provides historical background on the development of transportation infrastructure in the United States, including the growth of highway network and construction of the Interstate Highway System after

\textsuperscript{2}In addition, Donaldson (forthcoming) finds large gains associated with railroad construction in India during the late nineteenth and early twentieth centuries. Alder (2017) and Baum-Snow et al. (2017) quantify the aggregate effects of highways in India and China, respectively.
1956. In Section 3 we provide details of a theoretical framework that integrates the United States with the rest of the world and show how the framework can be used to conduct counterfactuals. Section 4 describes digitized maps of the US highway network and how this network is combined with the rest of the world. We then describe how we use this network to calculate internal and international trade costs for all US counties. Section 5 presents our results, including counterfactuals that quantify the aggregate impact of removing each segment of the Interstate Highway System. Section 6 concludes.

2 Historical Background

The extent and types of transportation infrastructure in the United States underwent dramatic changes over the course of the twentieth century. In 1920, there were approximately 3.1 million miles of road in the United States, most of which were unpaved and only suited for local travel. From 1920 to 2015 over 1 million high-grade road miles were constructed, which permitted substantially faster travel between faraway cities. There are approximately 227,000 miles of federal-aid highways; with nearly 50,000 of these miles designated as part of the Interstate Highway System. As highways improved and became more expansive, Americans subsequently increased the number of vehicle miles traveled by a factor of more than 50. Better roads and advances in driving technology also enabled faster speeds and reduced travel times; in 1945 the average speed was 45 miles per hour and by 1970 speeds had increased to 60 miles per hour. Today, average travel speeds on interstates routinely top 70 miles per hour, with certain sections permitting speeds of 85 miles per hour.

As a concrete example of the gains achieved between the beginning and end of the twentieth century, consider travel between Washington, DC, and San Francisco, CA. In 1919, the US Army’s First Transcontinental Convoy traversed the nation between the coasts—with future president, Dwight Eisenhower, as a member of the convoy. The trip took 62 days at an average speed of just 6 miles per hour and over 10 hours per day. The official report from the convoy reveals there were “no transcontinental highways” and over half of the trip (1,778 miles) were traveled on dirt roads.

By 1960, approximately one third of all road miles were paved in the United States and, most importantly, the vast majority of highways were paved. Using the newly digitized
maps of the US highway network that underlie the quantitative exercises in this paper, we estimate that it took 66 hours of continuous driving at an average speed of 42 miles per hour to complete the same journey (between Washington, DC, and San Francisco, CA) in 1960, 47 hours (at 62 miles per hour) in 1985, and 42 hours (at 65 miles per hour) in 2010. This represents a 36 percent reduction in travel time over the second half of the twentieth century.

Eventually, the federal government was heavily involved in the financing and construction of the major highway projects of the twentieth century. At the beginning, however, its initial role was unclear. Starting in the second half of the nineteenth century, long distance freight was mainly carried out on railroads, while roads primarily facilitated local travel. The first federal intervention came in 1893 as a result of lobbying efforts by the bicycle club, League of American Wheelman (LAW), on behalf of the “Good Roads” movement. At the LAW’s urging Congress provided funding to create the Office of Road Inquiry as part of the Department of Agriculture, which was charged with investigating best practices to construct and extend roads throughout the country. The role of the Office of Road Inquiry was limited–its first publication simply summarized existing state laws in reference to road construction (Department of Agriculture, 1894). The volume highlighted New Jersey’s approach to financing highway construction by providing counties with one third of the necessary funds; this approach was later adopted by the federal government.

The highway network continued to grow in late nineteenth and early twentieth centuries, but was still not designed for high-speed travel and safety. Many of the roads funded by federal legislation during this period were either dirt or gravel. In 1938, the federal government expressed interest in creating a high-speed highway network and the 1938 Federal Highway Act appropriated funds to study the feasibility of such a network. The Department of Agriculture’s report entitled, Toll Roads and Free Roads, was submitted to Congress in 1939 and outlined a plan to construct a series of transcontinental highways. The network, shown in Figure 1, proposed six superhighways–three running East-West, three running North-South–with a total of 14,000 miles and was expected to cost $2.9 billion. The report also discussed the potential for a larger network with 26,000 miles that would connect principal US cities.
Notes: The figure shows six highway routes from a 1939 proposal: the north-south routes are numbered routes are 1, 3, and 5, from east to west, respectively; the three east-west routes are numbered 2, 4, and 6 from north to south, respectively. The diagonal route from Salt Lake City to the north is designated 4N and similarly to the south is 4S. The route 4 branch connecting Washington, DC, is designated 4A.

During World War II, President Roosevelt authorized a second report carried out by the Commissioner of the Bureau of Public Roads, Thomas MacDonald. The report was submitted to Congress in 1944 and included proposals for networks starting at nearly 40,000 miles (depicted in Figure 2). Routes were selected to connect population centers with over 50,000 people and to integrate regions with significant manufacturing, high-value agriculture, and military bases taking into account motor vehicle registrations, existing congestion, and topography.

The Federal Aid Highway Act of 1944 authorized the construction a highway network of up to 40,000 miles. While the size and specifications of the network were generally approved, additional funding to construct the network was not provided by Congress. The 1944 Act maintained the 50-50 state-federal matching grant following the appropriation rules established in the Federal Aid Highway Act of 1916. However, because funds were not allocated
Figure 2: Interregional Highways from 1944 Proposal

Notes: The figure shows a 1944 proposal for an interregional highway system with 33,920 miles and passing through all cities with at least 300,000 population. 
Source: US House, *Interregional Highways*, 19, Figure 1.

for highway construction, states had a choice to construct expensive interstate highways or continue to use more locally-oriented roads. Many chose to continue building smaller highways. In 1952, $25 million was appropriated for highway construction, but this amount was too small and states were still responsible for 50 percent of funding. After Eisenhower took office, the Federal Aid Highway Act of 1954 was passed: including $175 million for construction, which was too small to complete the entire network, but increased the federal share to 60 percent. After this initial success, the Eisenhower administration continued to push for more funding.

Initial plans to design a funding system were studied by the Clay Commission during 1954-55, which estimated approximately $27 billion to construct the Interstate Highway System and suggested that the federal government cover $25 billion of the funds. In addition, to funding construction, the Clay Commission suggested that a government-owned corporation be authorized to issue bonds to raise revenue. The bonds were to be repaid from revenue generated by a gasoline tax. In the Senate, there was opposition to the creation of
a government corporation that would issue such a large debt outside of direct Congressional oversight and the Clay bill was defeated.

Soon thereafter, Senator Albert Gore (D-TN) submitted a bill that expanded the Federal-Aid Highway bill to include appropriations for the Interstate Highway System, a federal share up to 75 percent, and funded on a pay-as-you-go basis. The Senate passed the Gore bill. In the House, Representative George Fallon (D-MD) proposed the federal government cover 90 percent of the cost and pay for this with revenues from user fees. Opposition from the trucking lobby killed the Fallon bill. In 1956, a revised version altered the funding structure to rely on changes in the federal gasoline tax. The modified bill, which was to apportion funds based on the cost share was passed in the House during the 1956 session. President Eisenhower signed the Federal Aid Highway Act of 1956 into law on June 29, 1956.

The two pieces of legislation that enabled the construction and funding of the interstates—the Federal Aid Highway Act of 1956 and the Highway Revenue Act of 1956—authorized just over 40,000 miles of highways with over $25 billion to be spent between 1957 and 1969. The federal government would provide 90 percent of the funds to states from gasoline tax revenues and initial funds were allocated on the basis of mileage, land area, and population, but would later be allocated on the basis of a given state’s cost share of the entire system. Therefore, states knew from the outset how much federal money would be allocated regardless of when construction on their segments began.

Between 1956 and 1960, approximately 10,000 miles of existing highways and new construction were integrated into the Interstate Highway System and from 1960 to 1970 an additional 21,000 miles were constructed and opened to traffic. Another 10,000 miles were built between 1970 and 1980. Today, the Interstate Highway System comprises nearly 50,000 miles of limited-access highways, graded for heavy loads and speeds up to 85 miles per hour.

The construction of the interstate highway system had several goals. Publicly, Eisenhower touted the benefits of improved national defense, congestion relief, public safety and reduced litigation, and efficiency in the transportation of goods and services. Politically the creation of a massive construction program also served as a peacetime stimulus that would put to work many idle hands (Ambrose, 1984). Given the amount of spending on the Interstate
Highway System—nearly 0.5 percent of gross domestic production in 1961—it was possible to increase spending to offset minor economic fluctuations.

Figure 3: Relationship Between Interstate Highway Mileage and 1960 Population Rank

Notes: The figure shows the number of highway miles per capita \((y\text{-axis})\) plotted against the population rank of each state \((x\text{-axis})\).

Source: The number of highway miles is calculated from the Federal Highway Administration (2017) shapefiles for 2010. The population is for 1960 and is from Haines (2010).

In aggregate, the system is huge, as previously noted, almost 50,000 miles cross the contiguous states, with over 1.5 billion tons of aggregate and 35 million tons of asphalt, and 48 million tons of cement. While enormous in scale, the construction of the IHS overwhelmingly directed funds towards sparsely populated states. Figure 3 shows the relationship between Interstate Highway mileage per capita and 1960 population rank. From this figure it is clear that Western and Southern states gained relatively more from the system. Wyoming received 276 miles per 100,000 in population, more than 25 times the mileage in Massachusetts on a per capita basis. Nine of the top 10 states in mileage per capita are in the West.

In locations that were initially isolated, such as the Great Plains, reduced internal trade costs have facilitated more integrated supply chains, lowering production costs. For example,
John Deere, based in Molina, Illinois was able to utilize a just in time inventory system to reduce the costs of producing large farm equipment for an increasingly global market. This permitted Deere to acquire intermediate inputs from a wider variety of sources. At the same time, Deere was better able to compete in international markets; and today exports account for more than a quarter of Deere’s revenue.

3 Theoretical Framework

Following Caliendo, Dvorkin and Parro (2017), this section provides an overview of a theoretical framework for the world economy with \( N \) locations and \( J \) sectors. Locations in the model are both domestic (i.e., counties) and foreign (i.e., countries). Markets (including labor markets) are a combination for a location and sector; below we refer to locations using the subscripts \( c \) for origin or \( d \) for destination and sectors using the subscripts \( j \) and \( k \).

There are a continuum of firms producing for perfectly competitive markets with a constant returns to scale Cobb-Douglas technology using labor, a location-specific factor (i.e., land or fixed capital), and intermediate goods from all sectors. Firms draw productivity from a Fréchet distribution with a sector-specific dispersion parameter, \( \theta_j \).

In section 3.1 we first describe the problem faced by individuals choosing where to live and work (including a “not employed” category), which gives rise to an expression for transitions between locations and sectors based on the costs of moving as well as the value of living and working in a particular location. Next, in section 3.2, we describe the problem of firms in each location and sector, which produces a gravity equation for domestic and international trade flows in each sector based on trade costs, productivity, and the price of intermediate inputs. Section 3.3 briefly describes how the model can be used to solve for counterfactuals under alternative configurations of the US highway network.

3.1 Labor

The economy is populated with a continuum of individuals, \( L_{dj,t} \), in each destination \( d \), sector \( j \) (including non-employment, i.e., \( j = 0 \)), and period \( t \), and inelastically supply a unit of labor to perfectly competitive labor markets and receive wage \( w_{dj,t} \). For consumption,
individuals have logarithmic preferences over a bundle of final local goods,

\[
U(C_{dj,t}) = \ln \left( \prod_{k=1}^{J} (c_{dj,k,t})^{\alpha_k} \right),
\]

where \(c_{dj,k,t}\) reflects the consumption bundle at destination \(d\) and sector \(j\) from all \(k\) sectors in period \(t\). Let denote \(\alpha_k\) the final consumption share with \(\sum_{k=1}^{J} \alpha_k = 1\). The price index at destination \(d\) in period \(t\) is given by

\[
P_{d,t} = \prod_{k=1}^{J} (P_{dk,t}/\alpha_k)^{\alpha_k}.
\]

Finally, following Dvorkin (2014), individuals in non-employment consume from household production so that \(C_{d0,t} = b_d > 0\).

Individuals are forward-looking and face location-sector mobility costs \(\kappa_{dj,ck} \geq 0\) to move from sector \(k\) at origin \(c\) to sector \(j\) at destination \(d\) and receive additive idiosyncratic shocks for each choice and year, \(\epsilon_{ck,t}\), which we assume is zero-mean from a Type-I Extreme Value distribution. Individuals begin each year in a location and sector, observe economic conditions in all labor markets, receive their idiosyncratic shocks, and consume based on their market wage if they are employed or receive home production if they are in non-employment. Then individuals choose the destination \(d\) and sector \(j\) in period \(t\) in order to maximize lifetime utility:

\[
v_{dj,t} = U(C_{dj,t}) + \max_{\{c,k\}_{c=1,k=0}^{J}} \left\{ \beta E[v_{dj,t+1}] - \kappa_{dj,ck} + \nu \epsilon_{ck,t} \right\}
\]

where \(C_{dj,t}\) is equal to \(b_d\) for \(j = 0\) and \(w_{dj,t}/P_{d,t}\) if \(j = 1, \ldots, J\). The parameter \(\nu\) scales the variance of the idiosyncratic shocks. In this setup, individuals choose the location and sector that maximizes lifetime utility minus the costs of moving or changing sectors.

Given the assumption that \(\epsilon_{ck,t}\) are zero-mean draws from a Type-I Extreme Value dis-
tribution, the expected value for choosing location \( n \) and sector \( j \) in period \( t \) is:

\[
E[v_{nj,t}] = V_{nj,t} = U(C_{nj,t}) + \nu \log \left( \sum_{c=1}^{N} \sum_{k=0}^{J} \exp \left( \beta V_{nj,t+1} - \kappa_{nj,ik} \right) \right)
\]

where the first term captures the current-period utility and the second term reflects the option value of future decisions. Equation (1) describes the mean utility obtained by individuals in location \( n \) and sector \( j \) in period \( t \), and can then be used to write the share of individuals that make transitions from the location-sector combination \( ck \) to \( dj \) in each period \( t \) as

\[
\mu_{dj,ck}^t = \frac{\exp(\beta V_{ck}^{t+1} - \kappa_{dj,ck})^{1/\nu}}{\sum_{m=1}^{N} \sum_{h=0}^{J} \exp(\beta V_{mh}^{t+1} - \kappa_{dj,mh})^{1/\nu}}.
\]

Combining equation (2) with the current location and sector of all individuals, \( L^t_{ik} \), shows how the distribution of labor will evolve over time (i.e., \( L_{dj,t+1} = \sum_{c=1}^{N} \sum_{k=0}^{J} \mu_{dj,ck,t} L_{ck,t} \)).

Next, we describe the static production problem that firms solve, the resulting equilibrium wage, and pattern of domestic and international trade.

### 3.2 Firms

Each location \( d \) and sector \( j \) in the model has representative firms that produce a continuum of intermediate goods varieties (Caliendo and Parro, 2015; Caliendo, Parro, Rossi-Hansberg and Sarte, forthcoming). Intermediate goods producers use a constant returns to scale technology that combines labor \( (l_{dj,t}) \), a fixed supply of structures \( (h_{dj,t}) \), and materials \( (M_{dj,dk,t}) \) purchased from sector \( k \) by sector \( j \) in location \( d \) to produce output \( q_{dj,t} \). Formally,

\[
q_{dj,t} = z_{dj} \left( A_{dj,t}(h_{dj,t})^{\xi_d}(l_{dj,t})^{1-\xi_d} \right)^{\gamma_{dj}} \prod_{k=1}^{J} (M_{dj,dk,t})^{\gamma_{dj,dk}},
\]

where \( A_{dj,t} \) is the time-varying component of productivity common to all varieties for each location and sector and \( z_{dj} \) is the time-invariant component of productivity specific is each variety. The parameter \( \gamma_{dj} \geq 0 \) is the share of value-added from sector \( j \) in location \( d \) and \( \gamma_{dj,dk} \geq 0 \) is the share of materials for sector \( j \) from sector \( k \) in location \( d \). Because we assume
constant returns to scale, \( \gamma_{dj} + \sum_{k=1}^{J} \gamma_{dj,dk} = 1 \). Finally, the parameter \( \xi_d \) is the share of value-added due to structures, while the corresponding \( 1 - \xi_d \) is the share due to labor.

Let \( P_{dj,t} \) denote the price of materials, \( r_{dj,t} \) the rental rate for structures, and recall that \( w_{dj,t} \) is the competitive wage in each location \( d \) and sector \( j \) at time \( t \). Then we can write the unit price of an input bundle as:

\[
x_{dj,t} = B_{dj} \left( (r_{dj,t})^{\xi_d} (w_{dj,t})^{1-\xi_d} \right) \prod_{k=1}^{J} (P_{dj,dk,t})^{\gamma_{dj,dk}},
\]

where \( B_{dj} \) is a constant. This implies that the unit cost of an intermediate good at time \( t \) is \( x_{dj,t} \times [z_{dj} \times (A_{dj,t})^{\eta_j}]^{-1} \). Trade costs take the “iceberg” form and are denoted by \( \tau_{dj,cj,t} \).

For one unit of any intermediate good variety \( j \) to arrive at location \( n \) requires producing \( \tau_{dj,cj} \geq 1 \) at location \( c \). A good is not tradable if \( \tau = \infty \). The price of variety \( j \) in destination \( d \) is given by,

\[
p_{dj,t}(z_j) = \min_c \left\{ \tau_{dj,cj}^t x_{cj,t}^{\theta_j} (A_{cj,t})^{\gamma_{cj}} \right\},
\]

where \( z_j \) is the vector of productivity draws for each location.

Let \( Q_{dj,t} \) denote the local sectoral output in each location \( d \) and sector \( j \) at time \( t \). We obtain an expression for \( Q_{dj,t} \) by aggregating over all local intermediate goods demanded from the lowest cost supplier, which is given by \( \tilde{q}_{dj,t}(z_j) \). That is,

\[
Q_{dj,t}^* = \left( \int (\tilde{q}_{dj}^t(z_j))^{1-1/\eta_{dj}} d\phi_j(z_j) \right)^{\eta_{dj}/(\eta_{dj} - 1)}
\]

where \( \phi_j(z_j) = \exp\{-\sum_{d=1}^{N} (z_{dj})^{-\theta_j}\} \).\(^3\) In the absence of fixed costs or entry and exit barriers at all levels of production competition implies zero profits.

From the properties of the Fréchet distribution for local productivity, we can derive the price of the sectoral aggregate good \( j \) in location \( n \) at time \( t \) as

\[
P_{dj,t} = \Gamma \left( \sum_{c=1}^{N} (x_{cj,t} \tau_{dj,cj,t})^{-\theta_j} (A_{cj})^{\theta_j \gamma_{cj}} \right)^{-1/\theta_j}
\]

where \( \Gamma \) is the value of the Gamma function evaluated at \( 1 + (1 - \eta_{nj}/\theta_j) \). Then we can solve

\(^3\)This is the joint distribution over the vector \( z_j \) with a marginal distribution \( \phi_{dj}(z_{dj}) = \exp\{-z_{dj}^{-\theta_j}\} \).
for the expenditure share in destination $d$ and sector $j$ for goods from origin $c$. That is,

$$\pi_{dj,cj,t} = \frac{(x_{cj,t} r_{dj,cj,t})^{-\theta_j} (A_{cj,t})^{\theta_j \gamma_{cj}}}{\sum_{m=1}^{N} (x_{mj,t} r_{dj,mj,t})^{-\theta_j} (A_{mj,t})^{\theta_j \gamma_{mj}}}.\quad (3)$$

This expression says that trade flows for each sector $j$ from origin $c$ to destination $d$ will be higher if the costs of production in $c$ are lower and trade costs between $c$ and $d$ are lower or if productivity is $c$ is higher.

Importantly, we follow Caliendo, Dvorkin and Parro (2017) to account for observed trade imbalances. To do this, assume a unit mass of rentiers in each region that cannot relocate and receives a constant $\iota_d$ share from a global portfolio with $\sum_{d=1}^{N} \iota_d = 1$. Imbalances may arise from the difference between remittances and income received by rentiers, given by $\sum_{k=1}^{J} r_{ik,t} H_{ck} - \iota_d \chi_t$ where $\chi_t$ is total revenue form the global portfolio.

For goods market clearing, let $X_{dj,t}$ be the total expenditure in destination $d$ on goods from sector $j$, so that

$$X_{dj,t} = \sum_{k=1}^{J} \gamma_{dk,dj} \sum_{c=1}^{N} \pi_{dk,ck,t} X_{ck,t} + \alpha_j \left( \sum_{k=1}^{J} w_{dk,t} L_{dk,t} + \iota_d \chi_t \right).$$

On the right-hand side, the first term is the value of total demand for intermediate goods from sector $j$ used in all other locations and sectors and the second term is the value of final consumption from sector $j$ at destination $d$. Finally, the conditions for market clearing for labor and structures for destination $d$ and sector $j$, respectively, are

$$L_{dj,t} = \frac{\gamma_{dj} (1 - \xi_d)}{w_{dj,t}} \sum_{c=1}^{N} \pi_{cj,nj,t} X_{cj,t},$$

$$H_{dj,t} = \frac{\gamma_{dj} \xi_d}{r_{dj,t}} \sum_{c=1}^{N} \pi_{dj,cj,t} X_{dj,t}.$$

### 3.3 Counterfactuals

For the model described above, Caliendo, Dvorkin and Parro (2017) show how to solve for the equilibrium allocation in $t + 1$ given information on the equilibrium allocation in
without information on levels of fundamentals (i.e., productivity, endowments of local structures, non-employment income, and trade and mobility costs) in \( t \). They also show how to solve for counterfactual equilibrium allocations relative to an economy with constant fundamentals using only cross-sectional data for a single time period or relative to an economy with changing fundamentals using cross-section data for each time period of interest. This is particularly useful in our setting where we observe trade costs for each decade from 1960 to 2010, but only observe migration and trade flows since 1990. Section 4 describes the availability of the data needed to calibrate the model described in the previous section and conduct counterfactuals with alternative configurations of the US highway network. Section 5 presents preliminary results for aggregate and regional changes in total income using a simplified version of the model.

4 Data

This section describes the data available to calibrate the model and solve for counterfactuals. The key data are newly digitized maps of the US highway network each decade from 1960 to 2010. These data allow us to compute counterfactuals under alternative configurations for the US highway network. In addition, we need data by industry on migration and trade flows within the United States and trade flows between the United States and other countries.\(^4\) We also need data by industry on production and employment.

*Trade costs for 1960 to 2010*

The main data for this paper are newly digitized maps of the US highway network, which we use to construct internal trade costs for the United States for each decade from 1960 to 2010. The map for 1960 is from previous research by Jaworski and Kitchens (2018). Maps for 1970, 1980, and 1990 are from Rand McNally’s Rand McNally (1970, 1980, 1990). These maps were created by scanning each detailed state or regional map from the Rand McNally’s *Road Atlas of the United States* and hand-tracing each type–state, national and interstate highway–and tag each segment in the network with information on the surface type–dirt, gravel, or paved–in ArcGIS. Maps for 2000 and 2010 are taken from the National Highway Planning Network shapefiles of the Federal Highway Administration (2017). We then assign

\(^4\)For the quantitative exercises in this paper we do not for international migration.
each segment a speed based on the type and surface based on *Rand McNally Road Atlas of the United States*, which included information on mileage and estimated travel time, for each year.\(^5\)

To calculate travel times and the distance between counties, we start by representing each county in the network by its centroid latitude and longitude.\(^6\) To ensure that each county is connected to the highway network, we construct a set of access roads that are straight line connections from a given county to all neighboring counties.\(^7\) We then overlay each decade’s highway network and merge the shapefiles to create the network that allows for travel between all county pairs in the contiguous United States. Finally, we use the network analyst tool in ArcGIS to find the lowest travel time path through the highway network for all county pairs, which results in travel time (in hours) and distance (in miles) for approximately 4.8 million unique routes in each decade. Let \(\text{hours}_{d,c,t}\) and \(\text{miles}_{d,c,t}\), respectively, denote the travel time and distance, from origin county \(c\) to destination county \(d\) in year \(t\).

To measure trade costs origin \(c\) to destination \(d\) in year \(t\), which we denote \(\tau_{d,c,t}\), we first calculate the lowest travel time route and then multiply the distance (in miles) by the domestic freight rate for trucking. As robustness, we also consider two alternatives. First, we use the reimbursement rate given by the federal government (or the American Automobile Association for years that predate the federal reimbursement guidelines). Second, we follow Combes and Lafourcade (2005) and use \(\text{hours}_{d,c,t}\) and \(\text{miles}_{d,c,t}\) together with information on the wage of a trucker, national diesel price, and the fuel efficiency of a truck in each year to determine the labor cost and fuel cost of transporting goods for each route.

To connect counties in the United States to the rest of the world we use information on the location of ports of entry—by land between the United States and Canada or Mexico and by water—from the US Geological Survey (2017). Specifically, we calculate the distance from

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\(^5\)We assigned speeds of 65 miles per hour for segments in the Interstate Highway System and toll roads, 40 miles per hour to paved segments of the US highways, and 30 miles per hour for state highways. We also consider alternatives based legislated speeds for each surface and year as robustness to our main results.

\(^6\)We baseline results use geographic country centroid. As an alternative we also consider population-weighted centroids constructed.

\(^7\)We fix the travel speed on these access roads at 10 miles per hour in each decade.
Figure 4: US Highway Network, 1960-2010

Notes: This figure shows the progress of the Interstate Highway System and US highways. To calculate trade costs we also use the state highway system (not shown).

each county to each port of entry and multiply by the domestic freight rate, as described above. Next, we calculate the distance from each port of entry to each country and multiply the international freight rate. Finally, we find the least cost route between each county-country pair. Taken together, we are able to construct a matrix of bilateral trade costs between all domestic locations in the United States and foreign locations in the rest of the world.

Trade Flows

We draw on data from the Commodity Flow Survey to construct trade flows within the United States by industry for 2002 and 2012. In each case, we match the year in the Commodity Flow Survey that is closest to the year of the trade cost data described in the previous subsection. We also use data from the World Input-Output Database to construct trade flows between the United States and the rest of the world by industry for 2000 and 2010. Bilateral trade flows between locations within the United States and countries in the rest of the world are drawn from the USA Trade database available from the US Census Bureau. We use this information to construct a matrix of bilateral trade flows for all locations in the model.

Income, Production, Population, and Employment

We draw on Haines (2010), the Bureau of Economic Analysis, U.S. Department of Commerce (2015), and the County Business Patterns for information on local income or production, population, and employment by industry for each decade from 1960 to 2010. We follow Hornbeck (2010) and adjust the county level variables to 2010 boundaries. We drop locations in Alaska and Hawaii. Finally, we draw on the Integrated Public Use Microdata Samples to calculate migration flows by location and sector within the United States.

5 Results

In this section we results results for a simplified version of the model presented in Section 3. The simplified model restricts focus to US counties and assumes perfect mobility, one sector, and no intermediate inputs. To calibrate the model, we follow the previous literature
in picking values for the land and labor shares of income and the trade elasticity. To conduct counterfactuals we use the information on the total income, population and trade costs to recover the level of productivity and amenities every ten years from 1960 to 2010. Then, in each year, we fix the level of productivity and amenities and solve counterfactual income and population for each county given alternative trade costs and holding constant the level of utility. We also consider counterfactuals in which we fix the level of productivity, amenities, as well the total population in the United States and solve for the counterfactual national utility.

We present several counterfactuals at the national, state, and county levels to show removing a given highway segment impacts the aggregate and spatial distribution of economic activity. Specifically, our counterfactuals focus on the impact of removing each numbered segment (and the associated loops and spurs) of the Interstate Highway System in 2010 as well as the impact of removing each of the largest ten numbered segments (in terms of vehicle miles traveled) between 1970 and 2010.

In Figure 5, we present the counterfactual income loss associated with removing each numbered segment of the Interstate Highway System in 2010. In the first panel Figure 5, we report the aggregate losses associated with the removal of a particular segment. The results show that the most valuable interstates are those that traverse the nation and are routed through major metropolitan areas. For example, we estimate that if I-95, the main thoroughfare along the eastern seaboard, and its numbered loops and spurs were eliminated, aggregate income would $277 billion lower in 2010. Similarly, the removal of I-70, which traverses the nation from Philadelphia, PA to its terminus in Utah via Columbus, OH, Indianapolis, IN, St. Louis, MO, Kansas City, KS, and Denver, CO would reduce income by $116 billion in 2010. Overall, the ten most valuable segments in 2010 were transcontinental, either via east-west corridors (I-10, I-40, I-70, I-80, I-90, I-94) or south-north routes (I-5, I-35, I-75, and I-95).

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8We let the land and labor shares of income be equal to 0.2 and 0.6, respectively. We let the trade elasticity be equal to 8.

9Note that because we assume perfect mobility welfare is the same in each location in equilibrium. In future work, we will relax this assumption.
Figure 5: Counterfactual Income for Removing Each Numbered Highway Segment in 2010

Notes: This figure shows the counterfactual impact of removing each numbered segment of the Interstate Highway System.
Source: Authors’ calculations.
While transcontinental routes are by far the most valuable in aggregate, some of the shorter routes are highly valuable on a per mile basis. In the second panel of Figure 5, we report the loss per mile associated with each interstate segment in 2010. On a per mile basis, I-78 connecting New York, New Jersey, and Pennsylvania is the most valuable. This is not surprising given that I-78 connects the ports of New York and New Jersey, and links with major interior routes such as I-95 and I-81. We estimate that I-78 has an annual value of $294 million per mile: more than twice the value of I-95 on a per mile basis. Similarly, I-45—connecting the port of Galveston, TX with Houston, TX and Dallas, TX—is one of the most valuable routes on a per mile basis.

Next, we examine how the losses associated with removing a given numbered segment effect the spatial distribution of income. Figure 6 shows the effects for I-5, I-70, and I-95 in 2010. The figure shows that the largest losses are concentrated in the western half of the United States for I-5, in and around the state of Colorado for I-70, and close to the East Coast for I-95. In general, the extent and location of the losses shown in Figure 6 are determined by the segment’s proximity economic activity and availability of substitutes via other segments of the Interstate Highway System as well as the state and other national portions of the highway system.

To understand the quantitative significance of these changes in trade costs, Figure 6 aggregates the losses depicted in Figure 6 as a share of each state’s total income. Unsurprisingly, the largest losses from removing I-5 fall on California, Oregon, and Washington. Among these three states Oregon’s loss is the largest at nearly 15 percent of total income; this effect is substantial and reflects the paucity of close substitutes relative to the other states, especially California. After removing I-70, the largest losses are in Colorado, Kansas, and Missouri; each state losses close to 5 percent of total income. The losses in income from removing I-95 are more than 15 percent in Maine and close to 5 percent in Delaware, Maryland, Pennsylvania, and Virginia.

Up to this point the discussion of the counterfactuals has focused on conditions in 2010 after the completion of the Interstate Highway System. However, importantly, our data also allow us to consider counterfactuals over time. In particular, we examine the impact of
Figure 6: Counterfactual Loss in Income for Removing I-5, I-70, and I-95 in 2010 by County

Notes: This figure shows the difference between the actual and counterfactual income after removing the given highway segment in 2010 by county.

Source: Authors’ calculations.
Figure 7: Counterfactual Loss in Income for Removing I-5, I-70, and I-95 in 2010 by State

Notes: This figure shows the difference between the actual and counterfactual income (as a share of total income in each state) after removing the given highway segment in 2010 by state. 
Source: Authors’ calculations.
Figure 8: Counterfactual Income for Removing Ten Most Traveled Segments, 1970-2010

*Notes:* This figure shows the counterfactual impact (in billions $) of removing the ten most traveled numbered segments of the Interstate Highway System between 1970 and 2010.  
*Source:* Authors’ calculations.
removing the ten most traveled interstates (in terms of vehicle miles traveled as of 2010) in each decade from 1970 to 2010. Over this period each segment was in a different stage of construction. In addition, over this period, the federal government and state governments made improvements to other portions of the network. In doing so, other portions of the highway network became better substitutes increasingly for the segments of the Interstate Highway System over time.

Figure 8 shows the impact of removing I-5, I-10, I-15, I-35, I-40, I-70, I-75, I-80, I-90, and I-95 between 1970 and 2010. The results show that despite the higher quality of viable substitutes—due to the expansion of state and US highways—the losses of removing each segment are increasing over time. In a few cases, the losses associated with removing specific segments increase more rapidly in the 1990s, which is perhaps due to free trade agreements between the United States, Canada, and Mexico. For example, consider I-5 running though California, Oregon, and Washington between the Mexican and Canadian borders, construction began in 1956 and was completed in 1979. When I-5 was initially completed, removing it would have reduced total income by roughly $80 billion in 1980. Most of the IHS was completed by 1980. After North American Free Trade Agreement, which reinforced the connections that I-5 formed with neighboring countries and the interior United States, was enacted in 1994 the losses associated with removing I-5 double to $160 billion. Today, one million trucks cross the US-Mexico border in San Diego, making it the second busiest land port of entry for goods arriving from Mexico. Meanwhile, Blaine, WA is the fourth largest port of entry for goods hauled by truck arriving from Canada (over 350,000 trucks annually). Similarly, I-95 has become increasingly important as ports in Jacksonville, FL, Savannah, GA, New York, and New Jersey have expanded.

6 Conclusion

Over the twentieth century, the United States experienced dramatic changes in internal trade costs due to the vast system of local, state, and national highways, which provided greater flexibility in business and residential location decisions. Following the passage of the Federal Aid Highway Act in 1956, nearly 50,000 miles of limited access and high-grade highways were added to the 4 million miles constructed by local, state, and national projects
over the same period. Improved roads and the substantial increase in the number of miles with fewer interruptions together combined to lower travel times between US counties by 30 percent from 1960 to 2010.

In this paper, we develop a theoretical framework that incorporates domestic locations (i.e., counties) and foreign locations (i.e., countries) following Caliendo, Dvorkin and Parro (2017). Together with newly digitized maps of the US highway network we calculate county-to-county trade costs for all US county pairs and use a simplified version of the model to evaluate the aggregate and regional impacts of removing different segments of the Interstate Highway System. The results indicate a substantial impact of removing key interstate segments. Moreover, the timing and geographic distribution of counterfactuals impacts suggest an important role of access to both domestic and international markets.
References


