The Effect of Infrastructure Investment in a Low-Growth Environment: Evidence from the Great Depression*

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We inquire into the effects of infrastructure spending and road construction on the development of the manufacturing sector during the Great Depression. We use a novel dataset on road construction and manufacturing firms between 1930 and 1940. We distinguish between local effects, measured with the change in road mileage by county, and global effects, measured with the change in market access to all other counties through the road network. We also distinguish between the whole manufacturing sector and the least tradable industries. We find that global market access is correlated with an expansion of manufacturing (increase in number of firms, firm size, firm output, and a decrease in average labor productivity) for the whole manufacturing sector and not for the least tradable industries. We also find that the change in local market access has no correlation with manufacturing outcomes, either all of manufacturing or the least tradable industries.

Keywords: Great Depression; industrial development; road construction; global market access.

JEL codes: N12, N62, N72.

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1 Introduction

The painful and slow recovery from the Great Recession led economists to call for more infrastructure investment.[1] To shed light on this issue, we inquire in this paper into the effects of infrastructure spending on industrial development during a recession. Specifically, we take a historical perspective and consider the Great Depression over 1930-1940 and road construction, the big infrastructure investment at that time.

We consider two broad effects of infrastructure investment. The first is a local effect, whereby road construction spurs economic activity around that road and provides better access to the local market. We call this "local market access" and measure it with total road mileage within a county. The second is a global effect, whereby road construction also affects the travel distance of other counties whose roads now become connected. We call this "global market access" and measure this with the market size of all other counties weighted by the inverse of the travel distance. The data for the road network for all of the United States between 1930 and 1940 was digitized for the first time for this project, with a high level of detail that distinguishes between paved and unpaved roads.

We find a positive correlation between increased global market access and industrial development in manufacturing as a whole. Firms increase in number, in employment, and in value added. Average labor productivity decreases, which is consistent with firms needing to hire from a pool of labor that is less qualified than the workers inside the firm. We find no such results for the least tradable industries (beverages, ice cream, and concrete), which is plausible. Less plausible is that we do not find any correlation between the change in local market access and manufacturing outcomes, which the opposite of what a positive fiscal multiplier would predict. The data for the least tradable industries of beverages and ice cream was also digitized for the first time for this project.

[1]For example, Paul Krugman called for government borrowing to finance infrastructure spending on a New York Times column titled "Time to Borrow" on August 8, 2016.

The results in this paper are based on correlations and OLS results. We do not address the endogeneity of the measure of global market access as the instruments used in the literature (military plans of road construction and terrain ruggedness) were not relevant for this measure of global market access. Nevertheless, we note that change in this measure of global market access for a given county are driven by changes in road network and market size outside of that county. This research design excludes a range of endogeneity problems and lends credibility to the OLS results.

Related literature. This paper relates to two strans of the literature: the effect of road network expansion and the effect of government spending during the Great Depression. The effect of road network expansion on economic outcomes has been investigated by the following authors: Banerjee, Duflo and Qian (2012) on Chinese highways; Nathaniel Baum-Snow (2012) on transportation and city development in China; Michaels, Rauch and Redding (2013) on city specialization due to network expansion in transport and communications; and Duranton, Morrow and Turner ((forthcoming) on US highways and trade. The common finding is that more roads imply lower transport costs, lower trade costs, improved market access, and improved local economic outcomes compared to locations that did not receive roads. Building a road provides a global benefit to the entire economy which is widespread but weak due to limited spillovers, with most of the positive effect accruing locally. It generally is not the case that local road building provides a means through which previously trapped people can now leave, but rather a path for new activity to converge to one location more than others. Regarding effect of government spending during the Great Depression, we highlight in particular Fishback, Horrace and Kantor (2005), who use land area, the volatility of the Democratic vote, and church affiliation as instruments for public spending during the New Deal. They find that an additional dollar of spending in public works in the 1930s raises retails sales in 1939 by 44 cents.

Our contribution in this respect is three-fold. First, we use a novel dataset with the geographic location of roads in 1930 and 1940, which lets us compute the shortest travel times between any two counties, and also a novel dataset with the least tradable manufacturing industries of beverages and ice cream. Second, we study the heterogeneity of treatment with local and global market access. Third, we study the heterogeneity of treatment across sectors with manufacturing as a whole and the least tradable industries.

The remainder of the paper is organized as follows. Section 2 discusses the data sources and the definitions of local and global market access. Section 3 presents the results and discusses their robustness, validity, and limitations. Section 4 concludes.

2 Data and methods

The main data contribution of the paper consists of bilateral travel times between US mainland counties in 1930 and 1939. (We use travel time and distance interchangeably.) We obtained high resolution scans of archived road atlas maps from Rand McNally at the Library of Congress. These maps were digitized into GIS for the first time for this project.

We scanned each state individually to ensure sufficient quality, as a hypothetical driver in the 1930s might have used smaller roads which are absent from a map at the national level. The key features from the map images were the location of paved and unpaved roads. We had to ignore extraneous data and noise of visual artifacts such as city name labels and highway numbers that standard GIS packages may interpret as “fake roads”. We contracted with a third-party individual to write a script to filter and remove extraneous visual artifacts present in the raw map images before running the standard package in ArcGIS that translates scanned transport maps into GIS transport networks. The script has a number of arbitrary parameters that affect the filtering process and which we tuned with trial-and-error to obtain a satisfactory result on raw state-level maps. We applied the filtering separately for both paved and unpaved roads based on the color scheme of the original road atlas. We also ensured that paved roads are recognized as such instead of unpaved roads (and vice-versa). We experimented with the tuning parameters of the ArcGIS routine that translates maps into transport networks to obtain the best possible result given the fidelity of the original maps. We made numerous manual corrections to improve fidelity, accuracy, and overall connectivity (painstaking work that could only be done by hand). Based on visual inspection of the filtered maps, we are satisfied with the result and confident that the digitization is accurate.

We stitched together the state-level networks into a single nationwide coherent road network with rationalized edges and connections between states. We connected paved and unpaved roads together using an edge connection method, with paved roads having twice the maximum speed limit as unpaved: 60 vs. 30 miles per hour. Figure 1 shows one slice of the network data with the network of paved roads in mainland US in 1939. We assume that a vehicle always travels at maximum legal speed and between county centroids.[2] We added artificial "synthetic roads" at a penalized speed of 15 miles per hour to maintain connectivity between the county centroid and the rest of the combined paved-unpaved road network, and also to maintain the overal connectivity of the network. We computed minimum travel times between counties with the ArcGIS shortest path algorithm (which is standard in the literature) for mainland US in 1930 and 1939 separately. The original raw maps and the bilateral distance matrix are available online at the website of the corresponding author.

[FIGURE 1 HERE]

We used these digitized maps to compute two measures of market access. The change in "local market access" measures the gain from better road coverage within county i and defined as

$$\Delta LMA_i = \log \frac{Paved_{i,1939} + Unpaved_{i,1939}}{Paved_{i,1930} + Unpaved_{i,1930}},$$

where $Paved_{i,t}$ ($Unpaved_{i,t}$) is the mileage of paved (unpaved) roads in county i at time t.

[2]We used geographic centroids instead of population weighted centroids because population counts do not exist at a higher resolution than county level for these years.

The "global market access" measures the gain from the lower distance to all other counties, as in Donaldson and Hornbeck (2015):

$$GMA_{it} = \sum_{j \neq i} \frac{MS_{jt}}{d_{ijt}^{\gamma}}, \qquad \Delta GMA_i = \log\left(\frac{GMA_{i,1939}}{GMA_{i,1930}}\right),$$

where MS_{jt} is the market size in county j at time t, measured preferably as population and also retail sales; and d_{ijt} is the shortest time between counties i and j over entire network. We use a baseline exponent $\gamma = 2$ and consider robustness in a range of $\gamma \in [1, 4]$. Note that the time frame for these measures is the whole decade between 1930 and 1939.

The central estimating equation in this paper is:

$$\Delta Y_i = constant + \beta_1 \Delta LMA_i + \beta_2 \Delta GMA_i + \gamma X_i + \varepsilon_i,$$

where i indexes a cross-section of counties, Y_i denotes an outcome variable of interest, ΔLMA_i is the change in local market access of county i, ΔGMA_i is the change in global market access of county i, X_i are county-level controls, and ε_i is the regression residual. For robustness to outliers, we drop observations below the 1st and above the 99th percentile of all variables. We include as controls the county-level variables that are not balanced with respect to the change in global market access: initial road density, area, population, and proportion of blacks. We next discuss the construction of the market access variables and the outcome variables.

For outcome variables, we focus on crucial aspects of manufacturing structure: employment, sales, value added, labor productivity, wages, and number of firms. For manufacturing as a whole, we use the data from Haines et. al (2010, ICPSR 2896), who digitized the publications by the Census Bureau, which were aggregated from the firm-level Census of Manufactures. We focus on the 1929-1939 decade. We have two measures of output: the value of products and the value added (which equals the value of products minus the cost of materials, electricity, and contract work).

We are also interested in the effect on non-tradable manufacturing industries. Therefore, we also went to the source of the data, the Census of

Manufactures at the National Archives in Washington DC. We focus on the six years between 1929 and 1935 because these are the only surviving records of the Census of Manufactures in the interwar period. We selected the two least tradable industries as measured by the alignment of the state-level distribution of industry employees and the overall population.[3] These industries were digitized for the first time for this project and are also available at the website of the corresponding author. We also included concrete as it had been previously digitized by one of the authors. The county is the level of variation of the right-hand side of the regression and we aggregate the micro-level data at the county-level.

3 Results

Baseline results. Figure 2 presents the baseline results visually for the entire manufacturing sector over 1929-1939. Each line is a regression with a dependent variable among all eleven possible variables.[4] The left and right columns plot the value of the regression coefficient for the change in local market access and in global market access with the point estimate at the white diamond, the 90% confidence interval in dark blue, the 95% confidence interval in medium blue, and the 99% confidence interval in light blue. The red line in the background is the zero and serves for reference of statistical significance.

An increase in global market access is correlated with an increase in the number of manufacturing plants, in the level of manufacturing employment, the value added of plants, and the average size of a plant. It is also correlated with a decrease in labor productivity, as measured by the ratio of value added per worker. These results are consistent with manufacturing firms hiring from a ladder of workers by qualification and going down the

[3]This is measured by a Gini concentration coefficient (Holmes and Stevens, 2004, page 2810). Beverages has a coefficient of 16%; Ice cream has 24%.

[4]These are: number of firms, employment, wages, value of products, value added, labor productivity of the value of products, labor productivity of value added, average firm size in value of products, average firm size in value added, average firm size in employment, and average wage.

ladder of qualification to fulfill the demand from the new markets that became accessible with the decreased time taken to reach them. These results include county-level controls: proportion of blacks among males, proportion of men, proportion of rural population, proportion of manufacturing in population, initial road density, population, and area. An increase in local market access is not correlated with manufacturing outcomes. This seems counter-intuitive, if only because the change in local market access represents government investment and could trigger fiscal multiplier effects.

[FIGURE 2 HERE]

Figure 3 presents similar results for the aggregation of the least tradable industries over the period 1929-1935, along with the number of counties in the sample at the far right. The change in local market access is uncorrelated with the outcomes of non-tradable manufacturing. An increase in global market access is correlated with an increase in labor productivity and not with other outcomes.

[FIGURE 3 HERE]

Validity. We performed a balancing test of county characteristics and initial values in manufacturing. The following initial county characteristics do not predict the subsequent change in global market access: proportion of males, proportion of employment in agriculture, and proportion of employment in manufacturing. The following initial manufacturing values also do not predict the subsequent change in global market access: number of firms, employment, wage bill, value of products, value added. We included the variables that failed this balancing test as controls in the baseline regressions.

Another concern would be that the results are driven by spatial autocorrelation or by unobserved county characteristics. If that were the case, the least tradable manufacturing industries should also be affected, which they are not. We reiterate that the changes in global market access of a county are driven by changes that happen outside of the county, namely market size and the change in the duration of travel to all other counties. This methodology allays concerns on endogeneity.

Robustness. The baseline results are robust if we measure market size at destination with retails sales instead of population. The coefficients on employment, productivity, and average number of employees are similar in size and statistical significance for γ at 1, 3 or 4. They are similar if we drop the counties covered by the 10 largest Metropolitan Statistical Areas at the time. The difference between the results for non-tradable industries and all of manufacturing is not driven by the counties in the sample: the results on number, employment, and productivity for manufacturing as a whole are robust to restricting to the smaller sample of counties of the least-tradable industries (around 1,200 instead of 1,800). We excluded these results for brevity and they are available upon demand.

Limitations. These results have several limitations. First and foremost, the results we present here were "cherry-picked" among several possible specifications. They are weaker if we hold market size at destination fixed at the value in 1930 (instead of using the 1940 value for calculating global market access in 1940). Second, including state fixed effects causes all coefficients to lose statistical significance in the regressions for manufacturing. Third, we lack an instrument for the change in global market access. The instruments suggested by other researchers are not relevant in predicting the change in global market access: we tried the Pershing map, which outlined the priority of road construction for military purposes in 1921, and several measures of terrain ruggedness.[5]

We also obtained the data for the wholesale and retail sectors from the same source. The interpretation we provided for the results from manufacturing suggests that these two sectors are similar to the least tradable industries and do not benefit from an increase in global market access. In fact, the results for wholesale and the retail sector are similar to manufacturing as a whole.

[5] We tried four different measures of terrain ruggedness: the county-level average of the terrain's steepest slope, the county-level average of the steepest slope gradient, the county-level average of the standard deviation of elevation within an eight-cell neighborhood, and the county-level average of the standard deviation of slop within an eight-cell neighborhood. Each cell is a square of 200m.

4 Conclusion

This paper found that an increase in global market access is correlated with positive outcomes for manufacturing as a whole: an increase in the number of firms, in employment, and in value added; and a decrease in labor productivity. It is not correlated with outcomes for the least tradable industries. Our interpretation of these results is that road construction spurs the development of manufacturing sector: increased market access increases demand for products, firms hire more labor to satisfy demand, and newly hired labor less productive, so average labor productivity falls.

The paper also found no correlation between the change in local market access and manufacturing sector outcomes, either for the least tradable industries or for the sector as a whole. The latter result is surprising as manufacturing represented a third of economic activity and previous research on the fiscal multiplier suggests that this type of infrastructure investment should have a strong effect on economic activity.

Overall, the strongest contribution of this paper is the highly detailed dataset of the road network in the United States between 1930 and 1940, which allows other researchers to use the shortest path distance between any two counties in mainland US. Another contribution is the firm-level dataset for the least tradable manufacturing industries between 1929 and 1935. Both datasets are freely available at the webpage of the corresponding author. We will remember the tepid results on the measure of global market access and the lack of results on the measure of local market access as an instance of professional curiosity where the resulting satisfaction was an exception to the hypothesis of rational expectations.

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Figures

Figure 1: Digitized network of paved roads in 1939.

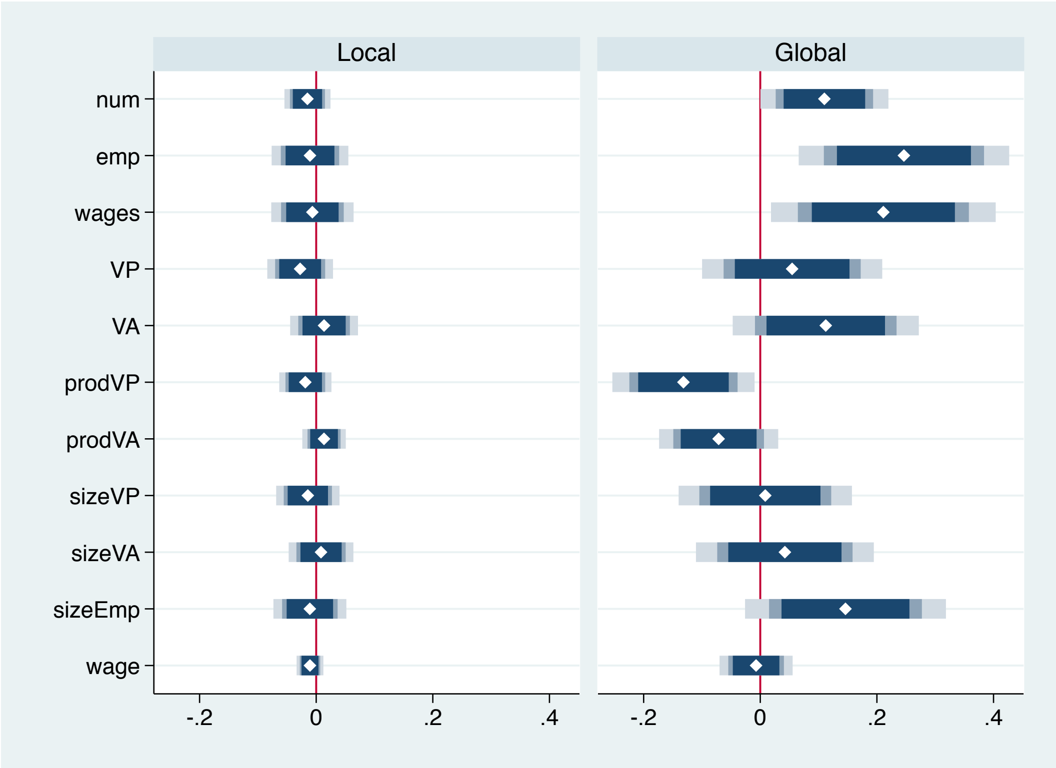

Figure 2: Plot of the coefficients and confidence intervals for the baseline results of outcomes for the entire manufacturing sector over 1929-1939 and local and global market access over 1930-1939.

Each line is a separate regression of the outcome from the left on the variables at the top, e.g. the change in the number of firms by county on the change in local market access and global market access. Segments are 1%, 5%, and 10% confidence levels. Variables: num (number of firms), emp (employment), VP (sales), VA (value added), prodVP (labor productivity of sales), prodVA (labor productivity of value added), sizeVA (value added per firm). All outcomes in changes.

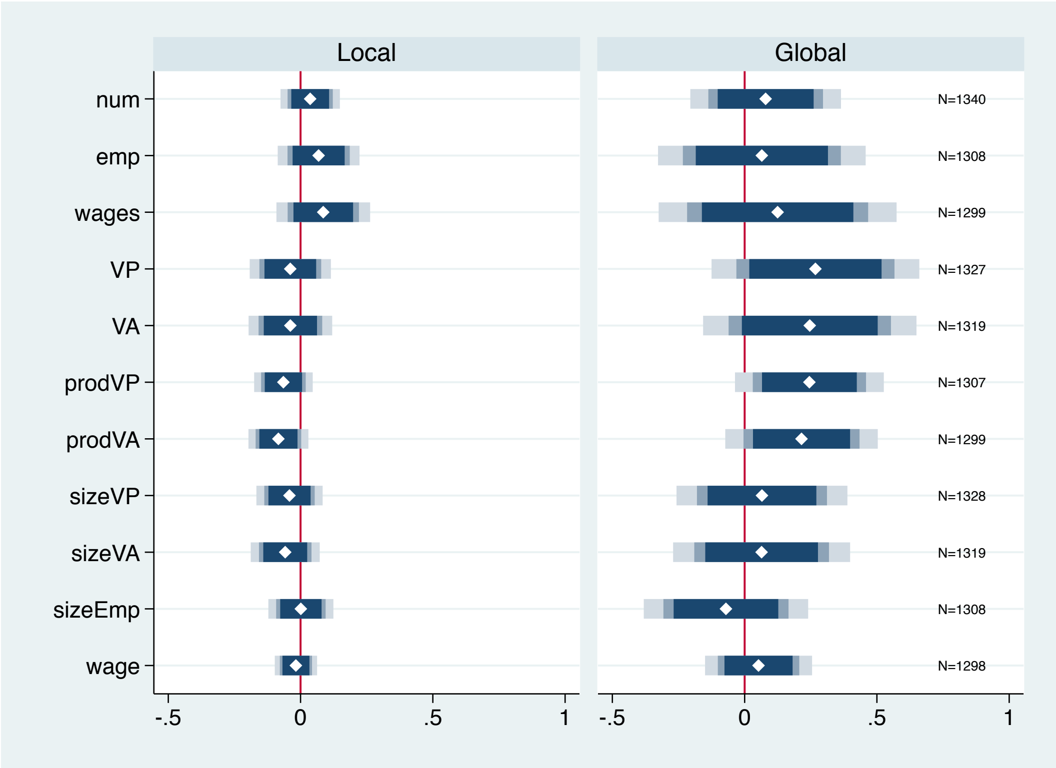

Figure 3: Plot of the coefficients and confidence intervals for the baseline results of outcomes for the least tradable manufacturing industries (beverages, ice cream, and concrete) over 1929-1935 and local and global market access over 1930-1939.

Notes: see Figure 2.