Local Economic Development, Agglomeration Economies and the Big Push: 100 Years of Evidence from the Tennessee Valley Authority

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Abstract

We study the long run effects of one of the most ambitious place based economic development policies in U.S. history: the Tennessee Valley Authority. We first conduct an evaluation of the dynamic effects of the TVA on local economies in the six decades since its inception. We find that TVA led to short run gains in agricultural employment that were eventually reversed, while impacts on manufacturing employment continued to intensify well after the program had scaled down. This pattern is potentially consistent with the presence of strong agglomeration economies and multiple steady states in the manufacturing sector. However, it is also consistent with models with a unique steady state and slow adjustment. To differentiate between these two possibilities, we estimate a simple dynamic county level model of agglomeration that allows for multiple steady states. We find clear evidence of agglomeration effects, but no sign that these effects are strong enough to generate multiple steady states, suggesting that the gains to the TVA region will eventually be reversed. Moreover, we find little evidence of nonlinearity in agglomeration economies, implying the aggregate productivity effects of place based development policies are probably limited.

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1 Introduction

Like most countries, the United States exhibits vast differences in income across cities and regions. For example, after adjusting for differences in skill composition, average wages in the highest and lowest paying U.S. metropolitan areas differ by a factor of approximately three (Moretti, 2011). Such disparities have prompted governments to create a variety of place based economic development policies aimed at reducing regional inequality (see Glaeser and Gottleib, 2008 and Duranton, 2011 for recent reviews). These programs, which target public resources towards disadvantaged geographic areas rather than towards disadvantaged individuals, are widespread. In the U.S., it is estimated that state and local governments spend $30-40 billion per year on such programs, while the federal government spends $8-12 billion per year.[1] Place based policies are also widespread in Europe in the form of generous European Union regional transfers and in Asia in the form of Special Economic Zones.[2]

Despite their popularity with policy makers, the economic motivation for place based policies is often unclear. Although they are frequently touted as a means of reaching disadvantaged populations, this equity rationale is weak if, in the long run, households are very mobile, so that utility levels are eventually equalized across space.[3] An alternative justification relies on the argument that large investments in disadvantaged areas tend to make good national investments. This could be true if, for example, households face credit constraints, capital flows slowly to the most disadvantaged areas, or there are significantly nonlinear forms of increasing returns, external effects, or other forces of agglomeration. A popular version of this argument holds that economic development exhibits nonlinear threshold effects whereby investments beyond some critical level generate self-sustaining economic activity (e.g. Azariadis and Drazen, 1991). If such nonlinearities are present, a “big push” strategy of large scale public investment in particular areas may yield long run returns dramatically outweighing the initial costs of investment (Rosenstein-Rodan, 1943; Murphy, Shleifer, and Vishny, 1989).

The presence of such non-linearities is crucial for evaluating the aggregate efficiency of place based policies, as they may allow the gains in areas that benefit from such a policy to outweigh the losses in areas from which activity is being diverted. In the

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[1] Bartik (1991) provides a comprehensive taxonomy and discussion of place based policies. In addition to the direct provision of subsidies, states often compete on income and corporate taxes and labor and environmental regulations. The U.S. federal government has promoted and currently promotes several location-based policies, including the Tennessee Valley Authority, the Appalachian Regional Commission, and Empowerment Zones.

[2] Important place based policies have recently been studied in China (Wang, 2010), Europe (Wren and Taylor, 1999), and Canada (Albouy, 2010)

[3] As Kline (2010) and Moretti (2011) point out, the local benefits of place based policies need not be entirely arbitraged away by migration if workers exhibit heterogeneous preferences. Busso, Kline, and Gregory (2010) find that the short run incidence of the federal Empowerment Zone program fell, in part, on local workers.

absence of non-linearities, such policies could be beneficial at the local level but a zero-sum game in the aggregate, simply shifting economic activity from one locality to another without any corresponding increase in national output. For this reason, many economists argue that national governments are unlikely to succeed in crafting efficient place based policies, as doing so requires determining which areas are likely to benefit most from infusions of public capital and the resulting agglomeration of economic activity. For example, in their influential review, Glaeser and Gottlieb (2008) conclude that "without a better understanding of nonlinearities in these externalities, any government spatial policy is as likely to reduce as to increase welfare."

The possibility that certain large scale investments might have long run growth effects on particular industries or areas has intrigued economists and policymakers for decades, however empirical evidence on the existence of such mechanisms remains thin (Azariadis and Stachurski, 2005 provide a review). Notably, there is little direct evidence on the long run effects of large place based policies explicitly intended to foster long run growth.[4]

In this paper we contribute to the literature by examining the long run effects of one of the most ambitious place based economic development policies in the history of the United States: the Tennessee Valley Authority (TVA). Charged by President Roosevelt with "touching and giving life to all forms of human concerns" the program was intended to modernize the economy of the Tennessee Valley region, which at the time of the program's inception in 1933 was among the poorest areas in the United States. The Authority sought to improve economic activity in the region by investing in large scale infrastructure programs, particularly large electricity generating dams, and an extensive network of new roads, canals, and flood control systems. At the program's peak in 1950, the annual federal subsidy to the region amounted to $625 for the typical household (roughly 10% of household income). By 1960 however, that figure had become negligible, as Congress made the TVA a fiscally self-sustaining entity.

The TVA makes for a particularly interesting case study for at least two reasons. First, because of its size, ambitious goals, and the targeting of a severely underdeveloped region, the TVA program is perhaps the best example of a big push development strategy in the history of the United States. If the Authority failed to shift regional growth equilibria, it is hard to imagine what programs may succeed.

Second, because the TVA began in the 1930's, it is possible to evaluate not just the contemporaneous effects of the program but also its dynamic, long run consequences. A finding that areas receiving a large inflow of federal investment dollars experience an

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[4] Recent studies on the short run effects of place based policies include Busso, Kline, and Gregory (2010), Ham et al. (2011), and Neumark and Kolko (2010). In related work, Duflo and Pande (2007) evaluate the short run impact of Indian dams on local communities. Finally, though perhaps not explicitly intended as place based policies, there has been a resurgence of work on the long run effects of transportation infrastructure (Baum-Snow, 2007; Michaels, 2008; Donaldson, 2010).

increase in the level of economic activity in the years during and immediately after the investment takes place is not necessarily informative about the ultimate effectiveness of those investments. At a minimum, one expects the construction jobs associated with building roads and dams to benefit the local economy in the years of construction. In order to assess the long run social return of local development policies, it is important to have an idea of what occurs when public subsidies lapse. In the case of TVA, the dramatic scaling down of federal transfers after 1960 provides the opportunity to examine whether a lapsed development policy may have persistent effects. In the presence of agglomeration economies and multiple equilibria, the positive effects of the initial subsidy on the local economy may be long lasting, provided the initial investment is large enough.

Our analysis provides two key contributions. First, using a rich panel dataset of counties, we conduct an evaluation of the dynamic effects of the TVA on local economies in the seventy year period following its inception. We examine the manufacturing and agricultural sectors separately, since there is a long standing presumption in the literature that manufacturing may exhibit agglomeration economies but little reason to expect such effects in agriculture. Comparing TVA counties to observationally similar controls, we find that between 1930 and 1960 – the period during which federal transfers were greatest – the TVA led to gains in both agricultural and manufacturing employment. However, between 1960 and 2000 – during which time federal transfers were scaled down – the gains in agriculture were completely reversed, while the gains in manufacturing employment continued to intensify. These facts are qualitatively consistent with the presence of multiple steady states in the manufacturing sector and a single steady state in agriculture. However, they are also consistent with simple momentum in manufacturing employment changes of the sort that might arise from weaker dynamic agglomeration effects.

In our second contribution, we attempt to distinguish between these two interpretations by estimating a dynamic county level model of agglomeration that admits the possibility of multiple steady states. In practice, this procedure consists of estimating a panel threshold autoregressive model of manufacturing activity allowing for endogeneity due to serially correlated productivity and amenity shocks. An important feature of our analysis is that it allows us to estimate the strength and shape of agglomeration forces, if they exist.

Estimates from our model point to two main conclusions. First, like many recent studies (Ellison and Glaeser, 1999; Ellison, Glaeser, and Kerr, 2010; Greenstone, Hornbeck and Moretti, 2011), we find evidence of important agglomeration effects in the manufacturing sector. However, we find little evidence that these effects are sufficiently strong to generate multiple steady states. Our estimates indicate that the effect of the TVA is best described as a shift in the location of a single equilibrium. Hence the gains to the TVA region are likely temporary, and will eventually (albeit slowly) be reversed.

Second, we find no evidence of sharp nonlinearities in manufacturing agglomeration of the sort that have been proposed to justify big push policies. Our estimates suggest that an increase in the density of local manufacturing activity has roughly the same external effect on productivity in counties with a low density of manufacturing activity as in counties with a high density. This finding is policy relevant, as it implies that the aggregate productivity effects of shifting manufacturing activity from one locality to another are likely to be small.

Our findings are consistent with previous studies pointing to the existence of a unique steady state in economic development. For example, Davis and Weinstein (2002, 2008) find that Japanese cities bombed in World War II, recover their population, their share of aggregate manufacturing, and their prior industry mix in the decades following the bombings. Miguel and Roland (2011) find similar results for towns bombed in the Vietnam war. Likewise, Barro and Sala-i-Martin (1991, 1992a, 1992b) empirically document the convergence of a variety of economies, measured at various levels of aggregation, to apparently unique steady states determined by locational fundamentals.

We caution, however, that our findings do not necessarily contradict recent studies which find indirect evidence of multiple steady state growth equilibria in other contexts (Bleakley and Lin, 2010; Graham and Temple, 2006; Redding, Sturm, and Wolf, 2011). As we have argued, the likelihood of multiplicity depends on the strength and shape of agglomeration economies, which may well vary across industries, periods and levels of aggregation.[5]

The remainder of the paper is organized as follows. Section 2 describes the program and the criteria used to determine selection into the program. Section 3 provides estimates of the impact of the TVA on the region's economy over various time periods. Section 4 develops and estimates our model of county manufacturing growth. Section 5 discusses the implications of our findings and concludes.

2 The Tennessee Valley Authority Program

The TVA is a federally owned corporation created by Congress on May 18, 1933 with the passage of the Tennessee Valley Authority Act. At the time of its inception, the Authority's primary objective was to invest in, and rapidly modernize, the Tennessee Valley's economy. The TVA service area, pictured in Figure 1, includes 163 counties spanning several states, including virtually all of Tennessee, and substantial portions

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[5] As pointed out by Bleakley and Lin (2010) the likelihood of multiplicity may also depend on the degree of heterogeneity in natural advantage among the areas under study.

of Kentucky, Alabama, and Mississippi.[6] The federal effort to modernize the TVA region's economy entailed one of the largest place based development programs in U.S. history. Large investments were made in public infrastructure projects including a series of hydroelectric dams, a 650-mile navigation canal, and an extensive road network, with additional money flowing to the construction of new schools and flood control systems. Funds were also spent on a hodgepodge of smaller programs including malaria prevention, soil erosion mitigation programs, educational programs, health clinics, the distribution of cheap fertilizers to farmers, reforestation and forest fire control, and provision of federal expertise for local economic development.

Probably the most salient changes prompted by the TVA came from the electricity generated by the Authority's dams. Electricity was intended to attract manufacturing industries to what was a heavily agricultural region. While, in principle, electricity could have been exported outside the region, the Authority primarily sold to municipal power authorities and cooperatives *inside* its service area at reduced rates.

Between 1934 and 2000, federal appropriations for the TVA totalled approximately \$30 billion (2009 dollars). The size of these transfers varied significantly across decades. As a federal regulatory agency, the Authority initially relied on government subsidies to conduct its operations. During the Eisenhower administration, however, it was given more freedom to issue its own bonds in exchange for substantial reductions in subsidies. A time series of federal transfers to the Authority is shown in Figure 2.[7] Only a small fraction of total federal appropriations were actually used in the program's first five years. The effectiveness of the Authority was initially hampered by infighting within the three-member TVA board who held differing ideas about the agency's goals. The battle between the three administrators went on from 1933 until March 1938, when Roosevelt dismissed one of the members for his public criticisms of the program.

The bulk of federal investment occurred over the period 1940-1958, during which time approximately 73% of federal transfers took place. This manifested in a correspondingly frenzied pace of TVA activity over this interval. Construction of the navigation canal began in 1939, and was completed in 1945, while most of the roads were built during the 1940s and 1950s. With the onset of World War II, construction of the dams became a national priority due to the increased demand for aluminum; by 1942, 12 dams were under construction. By the end of the war, the Authority had become the largest single supplier of electricity in the country. Due to the Authority's gener-

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[6] A handful of counties were only partially covered by the TVA service area. For the purpose of our analysis below, we include these counties in the list of TVA counties. The service area expanded over time, though by 1940 TVA already served most of its final area. In our analysis below we use the most recent and therefore most comprehensive definition of the TVA service area.

[7] The figure plots "Appropriation Investment" defined as appropriations by Congress plus property transfers from other Federal agencies minus repayments to General Fund of the U.S. Treasury. These figures come from an analysis of the financial statements contained in TVA Annual Reports to Congress between 1934 and 2000. (See the data Appendix for more details on sources.)

ous subsidies, electricity rates in the TVA region were approximately half the national average.

In 1959, Congress passed legislation making the TVA power generation system self-financing. From that year on, federal subsidies declined sharply. Figure 2 shows that the magnitude of the overall federal transfer dropped significantly in the late 1950's and remained low in the following four decades. Currently, TVA no longer receives a substantial net federal transfer. The post 1960 dropoff in federal appropriations is even more pronounced when per-capita figures are considered. Appendix Figure 1 shows yearly per-capita federal transfers to the TVA. At the peak of the program in the mid-1950's, the federal government was effectively transferring $125 to each resident in each year in the form of subsidies to TVA (2009 dollars). Since, at the time, the typical household in TVA counties had 5 members, the per household transfer was $625 per year, or about 10% of average household income.

Selection into TVA and Data

In order to understand the sorts of selection bias that might plague an evaluation of the TVA, it is important to understand how the geographic scope of the program was determined. Arthur E. Morgan (the Authority's first chairman) and other contemporary sources list several criteria that were used to determine the TVA service region (Morgan, 1934; Barbour, 1937; Boyce, 2004; Kimble, 1933; Menhinick, and Durisch, 1953; Satterfield, 1947). These criteria prioritized counties which:

- Were heavily rural and required additional electric power;
- Experienced severe flooding and/or had misguided land use;
- Lacked public facilities such as libraries, health services and schools;
- Experienced heavy deficits;
- Were willing to receive technical and advisory assistance from the TVA;
- Had planning agencies and enabling legislation;[8]
- Agreed to experiment with new fertilizers;
- Were within reasonable transmission distance of power plants; and possessed enough natural resources for development in tourism and economy;
- Had strong municipal cooperatives and regulatory agencies;

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[8] In the case of North Carolina, counties were excluded from the jurisdiction of the Authority as the state did not have enabling legislation.

The list of counties to be included in the service region was first drafted by geographers at the Division of Land Planning and Housing based on the above criteria and later approved by the TVA Board of Directors.[9]

Based on these criteria, it is reasonable to expect TVA counties to have been less developed than other parts of the country. The data generally confirm this impression. Our data come from a county-level panel covering the years 1900 to 2000 which we constructed using both microdata and published tables from the Population Census, the Manufacturing Census and the Agricultural Census. We also use topographic variables collected by Price Fishback, Haines, and Kantor (2011). Details on data construction are provided in the Appendix.[10]

The quality of some of the key variables is not ideal. Substantial measurement error is likely to be present at the beginning of our sample period. Moreover, in early years, direct data on workers wages are unavailable at the county level. As an expedient, we proxy for the average wage in manufacturing by dividing the total wage bill in manufacturing by the estimated number of workers in the industry. This is unlikely to provide a perfect measure of the marginal product of labor as it fails to account for differences in the number of hours worked and quality of workers. Moreover, in some counties, the wage bill is missing. For agriculture, the county wage bill is not available, so there is no good way to compute an average agricultural wage.

With these important limitations in mind, in Table 1 we compare the average mean county characteristics in 1930 for TVA counties (Column 1), all non-TVA counties (Column 2), and non-TVA counties in the South (Column 3). All monetary values are in constant 2000 dollars. Based on 1930 levels, TVA counties appear to have had worse economic outcomes than other U.S. counties and other Southern counties. In particular, in 1930 the economies of TVA counties were significantly more dependent on agriculture and had a significantly smaller manufacturing base, as measured by the share of workers in the two sectors. Manufacturing wages, housing values and agricultural land values were all lower, pointing to lower local productivity. TVA counties also tended to be less urbanized, had lower literacy rates and, in contrast with the rest of the country, had virtually no foreign immigrants. The lower fraction of households with a radio likely reflects both the lower local income level and the lack of electricity. TVA counties had a higher fraction of white residents than the rest of the South.

TVA also exhibited somewhat different trends over the 1920s than the rest of the country. The lower panel of Table 1 reports the average 10-year percentage changes

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[9] The Authority eliminated some counties from its jurisdiction to which supplying electricity would be too costly.

[10] To avoid issues with county splits and merges we drop areas with more than a three percent change in square mileage between 1930 and 2000 and we drop the state of Virginia where splits and merges are common. We also drop counties in Hawaii or Alaska and underpopulated counties with population less than 1,000 in any decade in the 20th century.

between 1920 and 1930 for our covariates. Population growth in TVA counties was similar to growth in other counties, but slower than growth in Southern counties. Employment growth and housing growth were slower in TVA counties than both the rest of the South and the rest of the United States. Manufacturing wages, urbanization and literacy were growing at a significantly slower rate than in the rest of the country, although land values were declining at a significantly slower pace. The fraction of immigrants, which was essentially zero to begin with remained unchanged, while it was declining in the rest of the country. Due to data limitations, we can not compute the change in value of agricultural output.

Overall, Table 1 confirms the impression that the Tennessee Valley was, at the time of the Authority's inception, an economically lagging region, both relative to the rest of the nation and, to a lesser extent, the South. This backwardness in levels coincides with some trend differences consistent with simple models of regional convergence. The TVA region exhibited greater growth in manufacturing share than the rest of the country accompanied by a faster rate of retrenchment in agriculture, issues which we are careful to address in the next section's empirical evaluation of TVA's long run impact.

We turn now to our empirical analysis. We proceed in two steps. In section 3 we conduct a reduced-form evaluation of the effect of TVA on the region's economy. In section 4, we develop and estimate a simple model of growth aimed at explaining the economic forces underlying the reduced-form results.

3 Long Run Effects of the TVA on Local Economies

The literature evaluating the effects of place based economic development policies has typically focused on credibly identifying *short run* effects on job creation and investment.[11] Establishing that subsidies which target an area raise contemporaneous employment is a useful first step. But, as we argued in the introduction, the contemporaneous effects of these policies are likely to provide an incomplete assessment of the costs and benefits of such an intervention. Our interests center on estimating the *long run* effects of the TVA. The existing evidence on the long run effects of location

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[11] In the case of the TVA, evaluation of the program started almost immediately. In 1938, the Tennessee Valley Authority Social and Economic Research Division conducted a comprehensive evaluation of the economic effects of the newly constructed Norris Dam on the regional economy. The first dam built by the TVA, it was named after Nebraska Senator George W. Norris, who was among the earliest and strongest supporters of the Authority. The final report (TVA, 1938) describes in detail the short run positive effect of the project on county finances, basic infrastructure, population, labor market outcomes, and spillover effects on neighboring counties. More recently, Kitchens (2011) focuses on electricity contracts for TVA municipalities, and seeks to determine the effect of publicly provided electricity on local economies. His strategy is to compare the economic outcomes of TVA counties near TVA dams and counties further away from TVA dams. He finds that proximity to a TVA dam does not significantly improve economic outcomes of a county relative to otherwise similar counties further away from the dam.

based policies is scant, which may be one of the reasons why such programs tend to be so controversial. Critics argue that these policies are a waste of public money, while officials of localities that receive transfers are often supportive. In 1984, the influential urban thinker Jane Jacobs published a scathing critique of the Authority – and, by extension, of many similar programs – with an unambiguous title: "Why TVA Failed." However, we are not aware of any existing systematic empirical evaluation of the TVA program's long run effects on economic activity.

In this section, we compare the long run economic performance of TVA counties with the performance of otherwise similar counties outside of the TVA region. We account for possible differences between TVA counties and other U.S. counties by controlling for a rich set of pre-program economic, demographic and geographical characteristics, including: a quadratic in 1920 and 1930 log population and interactions; 1920 and 1930 urban share; 1920 and 1930 log employment; a quadratic in 1920 and 1930 agricultural employment share; a quadratic in 1920 and 1930 manufacturing employment share; 1920 and 1930 log wages in manufacturing; 1920 and 1930 log wages in trade (retail + wholesale); dummies for 1920 and 1930 wages in manufacturing or trade being missing; 1920 and 1930 farm values, owner occupied housing values and rental rates; a quadratic in 1920 and 1930 white share; the share of the population age 5+ that are illiterate in 1920 and 1930; the 1920 and 1930 share of whites who are foreign born; the 1930 share of households with a radio; the 1930 unemployment rate, maximum elevation and elevation range (to capture mountainous terrain).

Our vector of covariates controls not only for some of the key differences in levels between TVA and non-TVA counties in 1930, but also for some differences in trends. In addition, we also drop from the analysis two sets of non-TVA counties. First, we drop control counties which, based on their pre-program characteristics, appear to be substantially different from TVA counties. Specifically, we estimate a logit model of the probability of being included in the TVA service area based on the aforementioned vector of regressors. We drop from the analysis all non-TVA counties with a predicted probability of treatment in the bottom 25 percent. This criterion leads us to drop 584 non-TVA counties (25% of the total–by construction), 16 of which are located in the South (2% of the Southern total).

Second, we also drop all non-TVA counties that border the TVA region. We take this step because the economies of border counties may be directly affected by the program.[12] Appendix Figure 2a provides a map of counties in our trimmed estimation sample, and Columns 4 to 6 in Table 1 show the unconditional averages in the trimmed

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[12] This spillover effect could be positive or negative. On the one hand, border counties may benefit from higher demand for labor because of demand leakages from infrastructure construction inside TVA. On the other hand, border counties may experience a decline in labor demand if the program induces firms that would have located there to locate in the TVA region instead.

estimation sample. While the exclusion of counties with low probability of treatment reduces some of the differences with TVA counties, other important differences remain, both in levels and trends.

To adjust for these remaining differences, we estimate counterfactual changes for TVA counties via Oaxaca-Blinder regressions. This is, we first fit regression models to the non-TVA counties of the form:

$$(y_{it} - y_{it-1}) = \alpha + \beta X_{it_0} + (\epsilon_{it} - \epsilon_{it-1}) \quad (1)$$

where $(y_{it} - y_{it-1})$ is the change in the relevant dependent variable between year $t-1$ and t for county i and X_{it_0} is the vector of preprogram characteristics listed above. We then use the vector $\hat{\beta}$ of estimated coefficients to predict the counterfactual mean for the treated counties. The Oaxaca-Blinder regression has the advantage over standard regression methods of identifying the average treatment effect on treated counties in the presence of treatment effect heterogeneity.[13]

Another appealing characteristic of the Oaxaca-Blinder estimator is its dual interpretation as a propensity score reweighting estimator (see Kline, 2011 for discussion).[14] Each control county is implicitly assigned a weight in providing an estimate of the counterfactual TVA mean: counties that look more similar to TVA counties in the years before TVA receive more weight. This weight is proportional to an estimate of the odds of treatment. Appendix Figure 2b provides a map of the control counties in our estimation sample and their affiliated weights. The map indicates that in generating a counterfactual, our estimates place more weight on Southern counties, which tend to be substantially more comparable to TVA counties in terms of their pre-intervention characteristics.[15]

3.1 A Test of the Research Design

In order to evaluate the effectiveness of our controls in matching the pre-treatment growth patterns of the TVA region, Table 2a shows the results of a "placebo analysis,"

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[13] In practice, standard regression models yield generally similar results and are available upon request.

[14] Relative to a propensity score reweighting estimator, the Oaxaca-Blinder regression has the additional advantage that it allows for a relatively simple computation of standard errors that allow for spatial correlation of the residuals.

[15] Of course, the TVA was not the only economic intervention conducted by the federal government over our sample period. Since the 1930's, the federal government has adopted a wealth of policies that affect the geography of economic activity. This is obviously true of explicitly location based policies like Empowerment Zones but also of other federal interventions that affect local labor demand, like the construction of the federal highway system or the opening and closing of military bases. More generally a variety of government policies may have had uneven geographic impacts including federal taxation (Albouy, 2010), environmental regulation (Chay and Greenstone, 2003, 2005) or labor regulation. Thus, our estimates are to be interpreted as the difference between the TVA region and other parts of the country, allowing for other type of federal interventions in the rest of the country.

where we estimate the effect of TVA on 1900-1940 changes in population, employment, housing units, manufacturing wages, industry structure and agricultural land values conditioning on our controls. This false experiment tests whether, conditional on our controls, our outcome variables are trending differently in TVA counties and non-TVA counties in the decades leading up to the policy intervention. Because the period 1900-1940 is temporally prior to the TVA treatment, the finding of significant differences between TVA counties and controls would be evidence of selection bias. (All our controls are measured in 1920 and 1930. We focus on the 1900-1940 change in order to avoid the possibility of a spurious mechanical correlation between the regressors and outcomes due to measurement error.)

Through the paper, we show decadalized growth rates to make the interpretation of our estimates comparable across tables. In Table 2, for example, the 1900-1940 changes are divided by four. Thus, entries are to be interpreted as average differences in 10-year growth rates experienced by TVA counties relative to non-TVA counties in the four decades between 1900 and 1940.[16] Column 1 shows the unconditional difference between TVA counties and non-TVA counties in the 1900-1940 decadalized change in the relevant outcome. Column 3 shows the difference conditioning on our vector of controls. Columns 2 and 4 report standard errors clustered by state. These variance estimates allow for unrestricted spatial correlation across counties within each state, but assume no correlation across states. Column 5 reports standard errors obtained from a spatial Heteroscedasticity and Autocorrelation Consistent (HAC) variance estimator based upon the method of Conley (1999), which allows for correlation between counties that are geographically close but belong to different states.[17]

A comparison of Columns 1 and 3 highlights the importance of our controls in the sample of all U.S. counties. Column 1 indicates that while trends in population, employment, housing units and manufacturing wages are similar in TVA and non-TVA counties, statistically different trends are present in manufacturing and agricultural share and the value of agricultural land. Though they are statistically significant, the differential trends in manufacturing and agricultural share are relatively small. The trend in agricultural land values however is quite large. These differences may be evidence that, in the absence of treatment, TVA counties would have caught up with the rest of the country, at least along some dimensions. However, Column 3 shows that, after conditioning on 1920 and 1930 covariates, all of these differences become statistically indistinguishable from zero.

Table 2b reports analogous figures for the sample of Southern counties. In this

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[16] For example, the first entry in the first row indicates that between 1900 and 1940, the average ten year rate of growth of population was 0.7 percentage point higher in TVA counties than among control counties.

[17] In computing our HAC estimates we use a bandwidth of 200 miles.

case, both the unconditional differences and the conditional differences are statistically indistinguishable from zero. Notably, the small estimated pre-trend differences in this sample of southern counties exhibit a different pattern than those found in the sample of all U.S. counties. Agricultural values, for instance, grow slower in TVA than the rest of the south over the 1900-1940 period. As shown in Column 3 of Table 2b, conditioning on 1920 and 1930 covariates substantially reduces the small imbalances present in the unconditional comparisons.

We interpret the evidence in Tables 2a and 2b as broadly supportive of the notion that our controls capture the bulk of the selectivity biases associated with a comparison of TVA to non-TVA counties. While we can not completely rule out the possibility that TVA counties experienced unique unobserved shocks between 1940 and 2000, we think it unlikely that both sets of comparison groups (the U.S. vs South only) would suffer from identical selection biases. Hence, we focus on conclusions that appear robust across both sets of comparison groups.

3.2 Impact Estimates

We now turn to our estimates of the effect of TVA on local economies. In this subsection we describe our empirical findings. In the next subsection we interpret these results in more depth.

Table 3a provides estimates of the effect of TVA on long run growth rates. Column 1 reports the unconditional difference between TVA counties and non-TVA counties in the 1940-2000 decadalized change in the relevant outcome. Column 3, our preferred specification, shows the corresponding conditional difference. As was the case in Table 2, the substantial differences between our unconditional and conditional estimates illustrate the importance of controlling for pre-treatment characteristics in the entire U.S. sample. The TVA region appears to have been poised for greater growth, along several dimensions, even in the absence of the program. Many of these effects, however, are eliminated by our covariate adjustments.

After conditioning, the most pronounced effects of the TVA appear to be on the sectoral mix of employment. TVA is associated with a sharp shift away from agriculture toward manufacturing. Specifically, Column 3 in Table 3a indicates that the 1940-2000 growth rate of agricultural employment was significantly smaller and the growth rate of manufacturing employment was significantly larger in TVA counties than non-TVA counties. These estimated impacts on growth rates are economically large, amounting to 5.6% and 5.9% per decade, respectively.

Perhaps surprisingly, manufacturing wages and wages in retail and wholesale trade do not respond significantly to the TVA intervention. These small wage effects suggest that, in the long run, workers are quite mobile across sectors and space, allowing the employment mix to change without large corresponding changes in the price of labor. The estimated effect on median family income (available only since 1950) is statistically insignificant, but quantitatively sizable. It implies that the impact of TVA on growth between 1950 and 2000 yielded median family incomes roughly 10% higher in 2000 than would have obtained in the absence of treatment. Taken at face value, this estimate together with the limited increase in hourly wages points to an increase in family labor supply. We fail to find any statistically (or economically) significant effects on population, value of farm production, agricultural land values or housing values. The lack of an effect on housing prices is not surprising, given that there are few, if any, geographical or legal constraints to adding new housing units in this region.

Table 3b, conducts this same exercise in the sample of southern counties. Again, we find evidence that selection is less of a concern in this sample, as our conditional and unconditional estimates are substantially more similar. Reassuringly, the estimated impacts of Table 3b, are similar to those of Table 3a. In this case however the effects on family income and retail-wholesale wages are statistically significant at conventional levels, while the effect on agricultural employment falls to marginal significance and that on manufacturing wages to statistical (and economic) insignificance.

In Table 4, we estimate Oaxaca-Blinder regressions analogous to those in Column 3 of Table 3a, separately for the period 1940-1960 and 1960-2000. Recall that 1940-1960 is the period of maximum generosity of the federal subsidies to TVA. By contrast, the decades after Congress makes TVA financially self-sustaining in 1959 are characterized by limited federal transfers to TVA.

Empirically, the differences in the two periods are striking. In the earlier period the 10-year growth rate of employment in both agriculture and manufacturing is more than 10 percentage points larger in the TVA region than in the rest of the US and the rest of the South. This is a remarkably large effect, most likely explained by the rapid electrification of the region and the addition of new transportation infrastructure. The growth rates of population, non-farm non-manufacturing employment, farm land values and farm production also appear to substantial, however the estimates are very imprecise.

In the later period the estimated impacts on manufacturing and agricultural employment are quite different. Consistent with the end of federal investment, and the lack of important agglomeration economies, employment growth in agriculture falls behind, reversing the gains of the previous period. By contrast, even after the cessation of federal outlays, manufacturing employment grows significantly faster in TVA counties. We see little evidence of an impact on population during this period.

Finally, we turn to models designed to uncover possible heterogeneity across counties in the effect that TVA has on local economies. Table 5 presents estimates of the effect of TVA separately for counties in the lowest, middle and top tercile of 1930 manufacturing density.[18] Manufacturing density, a proxy for the agglomeration of manufacturing activity which we will study more carefully in the next section, is measured as the number of manufacturing workers in 1930 per square mile. In the earlier period (top panel), the effect of TVA on manufacturing and agricultural employment appears to be strongest for counties with moderate initial manufacturing density. Counties in the middle tercile experienced a rate of growth in manufacturing and agricultural jobs roughly 15 percent higher than the rest of the country. By contrast, in the later period (bottom panel), the reversal experienced by agricultural employment is strongest in the middle tercile, but remains large and negative in the bottom and top terciles. For manufacturing jobs, the pattern is more nuanced, with the strongest additional growth in the middle tercile, and the smallest in the bottom tercile. The effect of TVA on median family income (which is not available in the first period) declines in initial manufacturing density. On net, these estimates suggest that TVA disproportionately benefitted counties with a critical base level of manufacturing activity.

3.3 Discussion

In 1930, the counties of the TVA service area were largely agricultural and their share of manufacturing was significantly lower than the corresponding share in non-TVA counties. The reduced-form evidence indicates that the Authority deeply affected the local economy of treated counties by dramatically increasing the speed of industrialization, shifting employment out of agriculture and into manufacturing, over and above the trends experienced by similar counties outside TVA. This seems to have been accomplished with limited long run impact on local wage rates, which suggests a large population of potential workers capable of moving to the region or switching out of local agriculture and into manufacturing.[19]

Importantly, our analysis uncovered a striking degree of temporal heterogeneity in this employment response. Over the period 1930-1960 – when TVA enjoyed large federal transfers – we find strong evidence of a sharp increase both in manufacturing and agricultural employment. While over the period 1960-2000 – when the TVA subsidies were scaled back – we find evidence of retrenchment in agriculture. Manufacturing employment, by contrast, continues to grow even after the end of federal investment. Finally, this second period growth in manufacturing appears to be concentrated among counties with a non-trivial base level of manufacturing activity.

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[18] Because our tercile specific samples are much smaller, these treatment effect estimates are computed via simple OLS rather than a Oaxaca-Blinder regression.

[19] Unfortunately, we lack the data necessary to determine whether the manufacturing jobs created by TVA were initially occupied by local residents who had previously been working in agriculture or new migrants to the area. Of course, because our estimated long run impacts take place over the course of sixty years, it must be the case that the new jobs are occupied by members of subsequent generations.

Different economic models can generate these temporal and sectoral patterns of effects. On the one hand, these findings are qualitatively consistent with simple models of sectoral poverty traps,[20] where the manufacturing sector is characterized by highly non-linear agglomeration economies yielding multiple steady states, while agriculture exhibits a constant returns to scale technology yielding a single employment steady state. To see why, consider what this scenario would imply for the employment dynamics after 1960 in the two sectors:

- Agricultural employment should decline in the later period as the direct effects of the program begin to wane. While the stock of TVA dams and public infrastructure does not disappear immediately with the end of federal transfers, it does depreciate over time. Indeed, our finding that agricultural employment reverts back to its pre-program levels is consistent with the notion that, without maintenance, the infrastructure put in place between 1930 and 1959 would have fully depreciated by 2000. If true, this would imply a depreciation rate for dams, roads and canals of about 2% per year.[21] We find this degree of depreciation quite reasonable. If anything, it is somewhat lower than the degree of deprecation actually used by planners and governmental agencies in the South – which is often closer to 4% or 5%.[22]

- Manufacturing employment ought to keep growing in the later period if, in the first period, local manufacturing activity reaches a level sufficient to generating self-reinforcing behavior. If this happens, the agglomeration effects of increased manufacturing density may outweigh the productivity decreases associated with depreciation of the stock of local infrastructure, in which case the gains to manufacturing employment would likely be permanent. That is, the inflow of federal investment would have succeeded in permanently shifting the region's manufacturing sector from a "bad" equilibrium to a "good" equilibrium.

However, steady state multiplicity is not the only possible explanation of the facts. The most obvious alternative is that the manufacturing sector possesses a unique steady state but exhibits sluggish adjustment. For example, it is possible that it takes some time for plants to be built or, more relevant we think, that agglomeration forces may

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[20] See Azariadis and Stachurski (2005) for examples.

[21] The exact implied depreciation rate depends on the exact timing of the public investment. 2% per year would be the correct rate if all the investment were put in place in 1950.

[22] See for example, Mississippi State Auditor (2002). In practice, of course, infrastructure capital was not allowed to fully depreciate. But while the original construction was paid for by the federal taxpayer, its maintenance since 1959 was paid for by local taxpayers and local users of electricity. Effectively, by 2000, local taxpayers and local users of electricity financed an infrastructure investment similar to the one initially provided by the federal government, and this cost brought agricultural employment back to were it was before TVA (relative to the rest of the country).

themselves take time to develop. Such lags can yield momentum in employment changes even if agglomeration forces are so weak that the model possesses a unique steady state. Under such a scenario one would expect the second period gains in manufacturing to eventually be reversed. In the next section, we make these statements more precise and seek to distinguish between these alternative interpretations of the facts.

4 Do Multiple Steady States Exist?

We turn now to an investigation of whether the pattern of treatment effects found in the previous section is most readily explained by a shift between dynamic steady state equilibria or a shift in the location of a unique steady state equilibrium.

Figure 3 provides a plot of the density of log manufacturing per square mile across three decades in the sample. The graphs display clear evidence of convergence, with the bottom tail of the distribution increasing much faster than the upper tail. This general compression of the distribution, along with its unimodal shape, casts doubt on the multiplicity hypothesis, as one would generally expect multiple persistent modes in the distribution corresponding to equilibrium points of attraction. However, it is possible for heterogeneity in economic fundamentals to prevent clear modes from arising and heterogeneity in initial conditions to allow a narrowing of the cross-sectional distribution despite the presence of multiplicity. Indeed, the standard interpretation of growth facts is that regions exhibit *conditional* convergence to what may be distinct (but typically unique) steady states.

We investigate this process of local growth through the lense of a model with agglomeration effects where the TVA serves as an exogenous driver of local productivity. A hallmark sign of models with multiple steady states is that they will exhibit ranges of behavior over which changes are self-reinforcing. Detecting this process of reinforcement empirically is difficult as it requires separating true state dependence from unobserved heterogeneity. We develop a simple econometric model incorporating both cross-sectional and temporal heterogeneity and allowing for rich forms of state dependence. We then discuss an instrumental variables approach to identification of the model's parameters and provide estimates and an assessment of the plausibility of the multiplicity hypothesis.

4.1 A Model of Growth with Agglomeration Economies

We model U.S. counties as small open economies with price taking behavior on capital, labor, and output markets. Heterogeneity in county level outcomes results from two fundamental sources: unobserved locational productivity advantages and endogenous agglomeration externalities. Multiplicity emerges when these agglomeration externalities become strong enough for shocks to be self-reinforcing over some regions.

Capital and labor are assumed to be perfectly mobile across counties at decadal frequencies.[23] Likewise, workers are assumed to be mobile and to possess homogenous tastes as in the classic models of Rosen (1979) and Roback (1982).[24] The mobility and homogeneity assumptions imply that utility, which we model as a Cobb-Douglas function of wages w_{it} and amenity levels M_{it}, is equalized across counties in each year. Hence we have that:

$$\ln w_{it} + M_{it} = \overline{u}_t \tag{2}$$

where $\overline{u}_t$ varies only across years.

Manufacturing output (Y_{it}) is produced in each county using capital, labor, and a fixed factor via a Cobb-Douglas production technology,

$$Y_{it} = A_{it} K_{it}^{\alpha} F_i^{\beta} L_{it}^{1-\alpha-\beta}$$

where A_{it} is a local productivity level, L_{it} is the number of manufacturing workers, K_{it} is the local capital stock, and F_i is a fixed factor leading the derived demand for labor to slope down each period. The nonreproducable factors in F_i might include land, navigable rivers, and other natural features of the environment.

We assume perfectly integrated capital markets so that capital in any county may be rented at national price r_t. Normalizing the price of output to 1, price taking behavior on the part of firms implies the usual first order conditions and the following inverse demand curve:

$$\ln w_{it} = C - \frac{\beta}{1-\alpha} \ln L_{it} + \frac{\beta}{1-\alpha} \ln F_i - \frac{\alpha}{1-\alpha} \ln r_t + \frac{1}{1-\alpha} \ln A_{it} \tag{3}$$

where $C \equiv \ln(1-\alpha-\beta) + \frac{1}{1-\alpha} \ln \alpha$.

Consistent with much of the growth and urban economics literature on agglomeration economies, we assume that the productivity of firms in a county reflects both exogenous productivity differences across counties and endogenous agglomeration effects. Specifically, we assume that the log productivity level ($\ln A_{it}$) may be decomposed into a locational advantage component, a component due to agglomeration effects, an effect

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[23] This assumption is supported by evidence from Blanchard and Katz (1992) which suggests that labor and capital adjustment to local shocks completes within a decade.

[24] These are strong assumptions which, in many cases, would not be appropriate for modeling place based policies (Kline 2010; Moretti, 2011). We employ them here because our focus is on long run changes – so that the process of regional adjustment may in fact span generations – and, especially, because we found little empirical evidence of wage impacts in our evaluation despite large effects on manufacturing employment.

of TVA, and a transitory shock as follows:

$$\ln A_{it} = g\left(\frac{L_{it-1}}{R_i};\theta\right) + \delta_t D_i + \eta_i + \gamma_t + \varepsilon_{it} \tag{4}$$

where D_i is a dummy for whether a county is exposed to TVA and δ_t is a measure of the flow investment in local communities deriving from TVA in year t. TVA raised local productivity both by reducing the cost of electricity and providing investments in local infrastructure. The fixed effect η_i captures the time invariant suitability of the county for manufacturing due to, for example, proximity to a body of water. Heterogeneity in this factor leads manufacturing steady states to differ across counties based upon locational fundamentals. The effect ε_{it} represents time varying shocks to the local business environment due for example to unobserved changes in local infrastructure or to unobserved changes in local regulations. The decade effect γ_t is meant to capture national changes in productivity.

The term $g\left(\frac{L_{it-1}}{R_i};\theta\right)$ captures the local agglomeration effects of manufacturing activity. Different mechanisms have been proposed in the urban economics and growth literatures that may generate such agglomeration economies.[25] This specification is consistent with many of the models proposed in the literature. The variable R_i is the square mileage of the county. Hence, we assume agglomeration effects vary as a function of the density of manufacturing employment per square mile and operate with a decade lag. This timing assumption is convenient and, we think, realistic. As discussed in a similar context by Adsera and Ray (1998), allowing the agglomeration effect to operate with a lag, no matter how short, ensures that the model yields deterministic predictions each period. This determinism is desirable as it rules out models that imply a given county could, given its history, take on wildly different levels of manufacturing activity by chance (see Krugman, 1991 for further discussion). While non-deterministic models (e.g. Morris and Shin, 1998) may provide a useful description of certain financial markets where behavior is primarily governed by expectations about the future, we feel they are unlikely to apply to the growth of counties where agglomeration operates through interactions that take time to develop. Our choice to allow agglomeration to operate through the density of manufacturing employment per square mile is consistent with our view that agglomeration effects are likely mediated through social interactions and learning (Glaeser, Kallal, Schienkman, Schliefer, 1992).

Note that in this model we are attributing all state dependence in manufacturing activity to agglomeration effects. This is obviously an oversimplification. Even without agglomeration, we would not necessarily expect all counties of the United States to converge to their steady states in ten years. However, our goal here is not to disentangle the various sources of state dependence in manufacturing activity. Rather, it is to

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[25] See for example Henderson (1995, 1997, 2003). Henderson (2005) provides a survey.

uncover whether that dependence is strong enough to yield multiple steady states for a given county.

4.2 Comparative Dynamics: A Graphical Analysis

Our model allows for both direct and indirect effects of TVA on manufacturing employment. The direct effects operate through the impact of TVA on productivity as captured by the δ_t coefficients. The indirect effects operate through the agglomeration channel, as increases in employment may feed back into further increases in productivity. If these feedback effects are strong enough, TVA may push the county to a new steady state.

The long run effects then hinge crucially on the nature of the agglomeration function $g(.;\theta)$. The panels of Figure 4a depict a hypothetical county's behavior when $g(.;\theta)$ is linear. Our assumption of perfect labor mobility yields a horizontal county labor supply locus at the going wage w. The SR curve depicts the standard short run inverse demand curve given in (3), when A_{it} is taken as given. This curve has slope $-\frac{\beta}{1-\alpha}$. The slope is negative because of the fixed factor F_i. The long run inverse demand curve LR incorporates the agglomeration effects of changes in local manufacturing activity given in (4). The slope of the LR curve is smaller than the slope of the SR curve because the agglomeration economies dampen the effects of the fixed factor on labor productivity.

The first panel depicts the initial equilibrium: the intersection of the LR curve with the horizontal labor supply curve determines the steady state level of manufacturing employment which, in this setting, is unique. The second panel shows what happens with the introduction of TVA. Because the new infrastructure makes firms in TVA more productive, the new LR curve is to the right of the initial LR curve. Specifically, the Authority shifts both the SR and LR curves up by an amount δ_t, which motivates a series of employment increases as manufacturing employment converges towards its new steady state. The one period lag in agglomeration yields geometric adjustment to the steady state, depicted in the final panel of Figure 4a. Hence, the model exhibits conditional convergence of the sort found in traditional growth models (Barro and Sala-i-Martin, 2004).[26]

In such a setting, the TVA can have only temporary effects on employment. Once the direct productivity effects of TVA lapse, the steady state reverts to its prior level. As infrastructure depreciates over time, LR slowly reverts back to its original position and the employment gains are gradually reversed. When infrastructure is fully depreciated, this local economy is back in the equilibrium depicted in the first panel.

By contrast, Figure 4b depicts the case where $g(.;\theta)$ is non-linear and exhibits

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[26] Convergence is conditional because each county may possess a different intercept for its LR demand curve based upon locational fundamentals (η_i in our setting).

strong threshold effects so that productivity increases rapidly once the sector reaches some critical level of density but begins to decrease afterwards due to the presence of the fixed factor. As depicted, this nonlinearity is strong enough to generate multiple steady state equilibria, two of which are stable and one of which is an unstable tipping point. Thus, in this case, the system exhibits locally, but not globally, convergent dynamics.

Consider the prospects of a county stuck in the low employment "poverty trap". If the direct productivity effects of the TVA are sufficiently large, manufacturing employment will fall within the basin of attraction of the developed equilibrium. In such a case, the TVA will yield permanent effects on manufacturing employment provided the program is kept in place long enough for the tipping point depicted in the final panel of Figure 4b to be crossed.

Our empirical analysis centers on determining whether Figure 4a or 4b provides a better approximation to the dynamics of county growth. The key distinction between these two models has to do with whether there exist regions of manufacturing activity over which agglomeration effects are strong enough that the long run inverse demand curve slopes up. Over such regions, employment adjustment will not dampen geometrically; rather, employment changes will be self-reinforcing – e.g. a productivity driven increase in employment will, on average, generate an even larger increase next period due to agglomeration effects. This makes our empirical task one of determining the degree of state dependence in manufacturing employment. Multiplicity is possible if and only if such locally explosive regions of manufacturing activity exist.

4.3 Identification and Estimation

Identification of the parameters of our model is hindered by a variety of endogeneity problems. It is natural to suspect, for example, that M_{it} might be correlated with ε_{it} because more manufacturing employment increases pollution. Likewise, M_{it} and η_i may be correlated if, say, areas with particularly rugged terrain are both less productive and less hospitable. We will solve these problems by differencing the data across decades in order to eliminate the time invariant county effects and then using cross sectional instruments to resolve problems of correlation with time varying shocks.

Before proceeding, it is natural to rewrite (3) in terms of the direct demand relationship:

$$\ln\left(L_{it}\right) = -\frac{1-\alpha}{\beta}\ln w_{it} + \frac{1}{\beta}g\left(\frac{L_{it-1}}{R_i};\theta\right) + \frac{\delta_t}{\beta}D_i + \widetilde{\eta}_i + \widetilde{\gamma}_t + \widetilde{\varepsilon}_{it} \tag{5}$$

since the errors in this equation define $\ln\left(L_{it}\right)$. Note that $\frac{1-\alpha}{\beta} > 1$, so the model places a lower bound of one on the slope of the contemporaneous derived demand relationship.

To remove the county fixed effects we take a long difference as follows:

$$\begin{aligned}\ln\left(L_{i2000}\right)-\ln\left(L_{i70}\right) &= -\frac{1-\alpha}{\beta}\left(\ln w_{i2000}-\ln w_{i70}\right)+\frac{1}{\beta}\left[g\left(\frac{L_{i90}}{R_i};\theta\right)-g\left(\frac{L_{i60}}{R_i};\theta\right)\right] \\ &\quad +\frac{\delta_{2000}-\delta_{70}}{\beta}D_i+\widetilde{\gamma}_{2000}-\widetilde{\gamma}_{70}+\widetilde{\varepsilon}_{i2000}-\widetilde{\varepsilon}_{i70}\end{aligned}$$

Covariates are introduced to the model by assuming the productivity shocks may be written as: $\widetilde{\gamma}_{2000}-\widetilde{\gamma}_{70}+\widetilde{\varepsilon}_{i2000}-\widetilde{\varepsilon}_{i70}=X_i'\lambda+\xi_{i2000}$, where X_i contains the set of 1920 and 1930 covariates used in our earlier reduced form analysis of TVA plus region fixed effects. This yields the following estimating equation:

$$\begin{aligned}\ln\left(L_{i2000}\right)-\ln\left(L_{i70}\right) &= -\frac{1-\alpha}{\beta}\left(\ln w_{i2000}-\ln w_{i70}\right)+\frac{\delta_{2000}-\delta_{70}}{\beta}D_i \\ &\quad +\frac{1}{\beta}\left[g\left(\frac{L_{i90}}{R_i};\theta\right)-g\left(\frac{L_{i60}}{R_i};\theta\right)\right]+X_i'\lambda+\xi_{i2000}\end{aligned} \tag{6}$$

The exact functional form of $g\left(.;\theta\right)$ is unknown, and there is little guidance from the theoretical literature on its shape. In our analysis, we begin by assuming that the function is well approximated by a 4 segment piecewise linear spline in $\ln(\frac{L_{it-1}}{R_i})$, so that:

$$g(L_{it-1};\theta)=\sum_{k=1}^{4}\theta_k\ln(\frac{L_{it-1}}{R_i})I\left[c_{k-1}<\frac{L_{it-1}}{R_i}<c_k\right]$$

where $c_0=-\infty$ and $c_4=\infty$. We choose c_1,c_2,c_3 to equal the 25th, 50th, and 75th percentiles of $\frac{L_{it-1}}{R_i}$ in 1970. The spline basis is particularly convenient for assessing the number of steady state equilibria since the slope of each segment may be used to assess local stability of the system. Multiplicity requires explosive regions exhibiting a slope $\frac{\theta_k}{\beta}$ greater than one where shocks to employment are locally self-reinforcing. To probe the sensitivity of our findings to this functional form assumption, we also re-estimate our model assuming that $g\left(.;\theta\right)$ is a polynomial.

Although equation (6) has eliminated the time invariant heterogeneity, two endogeneity problems remain. First, $\ln w_{i2000}-\ln w_{i70}$ might be correlated with ξ_{i2000} if amenity shocks are contemporaneously correlated with productivity shocks. And since our measure of manufacturing wages is formed as the ratio of manufacturing earnings to manufacturing workers, measurement errors in manufacturing workers will also lead to upward biases in estimation of $-\frac{1-\alpha}{\beta}$. Second, the changes in the time varying component of productivity ξ_{i2000} might themselves be serially correlated and hence correlated with $g\left(\frac{L_{i90}}{R_i};\theta\right)-g\left(\frac{L_{i60}}{R_i};\theta\right)$, which will tend to lead us to understate the degree of structural state dependence in the data (Nickell, 1981). To solve these problems, we follow Arellano and Bond (1991) in developing an instrumental variables strategy predicated on the assumption that productivity shocks die out over long horizons.

Specifically, we use $\left[\ln \frac{L_{i40}}{R_i}, \ln\left(\frac{L_{i40}}{R_i}\right)^2, \ln\left(\frac{L_{i40}}{R_i}\right)^3, \ln\left(\frac{L_{i40}}{R_i}\right)^4\right]$ and $\ln w_{i40}$ as instruments for $g\left(\frac{L_{i90}}{R_i};\theta\right) - g\left(\frac{L_{i60}}{R_i};\theta\right)$ and $(\ln w_{i2000} - \ln w_{i70})$. These instruments are valid under the assumption that measurement errors in wages are serially uncorrelated and that idiosyncratic changes in the time varying component of productivity between 1970 and 2000 are not correlated with the 1940 level of productivity $(E\left[\xi_{i2000}\widetilde{\varepsilon}_{i40}\right] = 0)$ or with 1940 amenity levels $(E\left[\xi_{i2000}M_{i40}\right] = 0)$. Thus we require that productivity shocks not be persistent beyond a horizon of three decades and that amenity changes not lead to delayed improvements in productivity, assumptions we think are plausible in our setting. As a further check on this approach, we exploit the prior restriction that $\frac{1-\alpha}{\beta} > 1$, to assess the sensitivity of our estimates of agglomeration effects to different assumed values of this nuisance parameter. Conditional on an assumed value of $\frac{1-\alpha}{\beta}$, the model is overidentified and hence provides a test of instrument validity.

4.4 Results

Table 6 provides OLS and two stage least squares (2SLS) estimates of the structural parameters in (6). The first Column reports OLS estimates assuming $g(\frac{L_{it-1}}{R_i};\theta)$ is log-linear. We find evidence of reasonably strong persistence in manufacturing changes – a 10% increase in manufacturing density is associated with a 7.5% increase in density in the following decade. In the context of our model, this suggests strong, but not explosive, agglomeration effects. The coefficient on wages has the wrong sign which, as already discussed, can emerge from measurement error or correlation between amenity and productivity shocks. The negative coefficient on the TVA dummy indicates that the direct productivity effects of TVA scaled down between 1970 and 2000 which is in keeping with our earlier discussion of the program's history. The second Column of Table 6 looks for nonlinearities in the process of agglomeration using the spline approximation to $g(\frac{L_{it-1}}{R_i};\theta)$. Little evidence of nonlinearity presents itself and an F-test fails to reject the null hypothesis that slopes are equal across spline segments.

Estimates in the the third Column address endogeneity by instrumenting changes in manufacturing density and wages using 1940 levels of manufacturing density and wages assuming a linear model. First stage partial F-statistics of the sort proposed by Angrist and Pischke (2009) are given in brackets for each endogenous variable. As expected, instrumenting raises the estimated degree of persistence in manufacturing changes. Now a 10% increase in manufacturing density is associated with a roughly 8% increase the next decade. Though the standard errors increase somewhat, we can still rule out explosive behavior at conventional significance levels. Moreover, we cannot reject the linear specification via a Hansen-Sargan test despite our use of a fourth order polynomial in 1940 manufacturing density as instruments. Consistent with our concerns regarding endogeneity, the sign of the coefficient on wage changes reverses when instrumented and achieves a magnitude consonant with the level prescribed by theory. However, the first stage F for wage changes is very low, suggesting the large standard error associated with this coefficient may actually underestimate its sampling variability.

The fourth specification searches for the presence of nonlinear dynamics by instrumented the spline in lagged manufacturing activity using 1940 manufacturing density. The first stage partial F statistics in each spline segment are large suggesting the model is well identified. As was true with OLS, we cannot reject the null hypothesis that the slopes in each spline segment are equal. This is in keeping with our earlier inability to reject the linear model via an overidentification test using the same instruments. Moreover, our point estimates suggest nearly linear agglomeration effects.

Columns five through eight conduct the same exercises while controlling for the 1920 and 1930 characteristics used in our earlier evaluation of the effects of TVA. The addition of these controls weakens the predictive power of our instruments somewhat which serves to inflate the standard errors of our 2SLS estimates. Column seven, for instance, finds the greatest level of persistence and cannot decisively rule out explosive behavior. We again find little evidence of nonlinear state dependence either from an overidentification test of specification seven or a Wald test of equality of slopes in Column eight. However, the point estimates of Column eight do exhibit some signs of nonlinearity, with the slope in the second quartile above that in the third quartile, however this relationship is not statistically significant. Also of note is that the coefficient on wages falls below the minimal theoretically prescribed magnitude of one which may well be an artifact of the weak identification of that parameter.

To assess the sensitivity of our agglomeration estimates to issues with the weak identification of the coefficient on wage changes, in Table 7 we try fixing $-\frac{1-\alpha}{\beta}$ at various values and re-estimating the model via two stage least squares using our same set of instruments and adjusting for controls.[27] By fixing the coefficient on wage changes, the model becomes overidentified, allowing us to trace out the set of values for $-\frac{1-\alpha}{\beta}$ that are not rejected by the data and assess the resulting patterns of agglomeration effects. Evidence of nonlinearity begins to emerge as we fix $-\frac{1-\alpha}{\beta}$ at theoretically plausible values in the neighborhood of -1.5. At such values we find the strongest agglomeration effects in the lowest quartile of manufacturing density with effects decreasing monotonically at higher quartiles. These differences are significant at conventional levels. In all cases, manufacturing activity appears globally convergent, though we cannot reject the null that changes are explosive at bottom quartiles. Appendix Figure 3b plots estimates of the resulting inverse demand curve when $-\frac{1-\alpha}{\beta}$ is calibrated at -1.5.

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[27] This is accomplished by subtracting the assumed coefficient times the wage change from the dependent variable and running a 2SLS regression with this residual as the dependent variable and employment change spline components as endogeneous variables.

To assess the sensitivity of our findings to the assumption on the functional form of $g(.;\theta)$, in Appendix Tables 1 and 2 we report estimates from models where $g(.;\theta)$ is assumed to be a quadratic function of manufacturing density. In all cases, we fail to reject that the quadratic term is equal to zero, lending additional credibility to our conclusion that the function is linear. Estimates based on higher order polynomials yield the similar result.

4.5 Discussion

The estimates of Tables 6 and 7 yield two main conclusions. First, we find evidence of substantial agglomeration economies. Using, for instance, the linear 2SLS estimates in Column 3 of Table 6, a 10% increase in the density of manufacturing employment is estimated to yield somewhere between a $6.5\beta\%$ and $10\beta\%$ increase in TFP. If one takes the major fixed factor to be land, then we can calibrate β using the Census of Manufacturers, which yields land cost shares of about .07, implying productivity-density elasticities in the range $[.46, .7]$. The magnitude of these productivity effect is sizable, but somewhat smaller than the corresponding estimates in Greenstone, Hornbeck and Moretti (2010), who find productivity elasticities in the interval $[2, 6]$.[28] While there is no particular reason to expect the magnitude of agglomeration economies to be exactly the same in the two contexts, this does suggest that our estimates are not particularly large compared with previous estimates.

Second, and crucially, our estimates imply the data are best rationalized by a shift in the location of a single steady state. Our baseline estimates suggest linear agglomeration economies. When allowing for controls, we find some evidence of potential nonlinearities, particularly in Table 7 where we account for weak identification of the coefficient on wage changes. But in no case do we find evidence that these nonlinearities are strong enough to yield actual multiplicity. A visual assessment of the results is provided in Appendix Figures 3a and 3b, which plot the inverse demand functions implied by the estimates from Column 8 of Table 6 and Column 3 of Table 7. These figures are the empirical equivalent of our theoretical Figure 4. Clearly, the data indicate that Figure 4a is a better description of this economy than Figure 4b.

If one takes our estimates from Table 6 at face value, they suggests the manufacturing gains of the TVA region will eventually subside, though this may take several decades.[29] On the other hand, our estimates also suggest that low density counties

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[28] This calculation assumes that million dollar plant openings in Greenstone, Hornbeck and Moretti result on average in an 18% increase in the density of manufacturing activity in winner counties relative to loser counties. Note that this figure includes both the direct effect of the million dollar plant as well as any contemporaneous indirect employment effect, excluding of course the effect that occurs due to the productivity increase.

[29] If one works with the estimates from Column 3 of Table 3, the half-life of a shock to manufacturing employment is roughly 50 years.

may differentially benefit from interventions, though the magnitude of this differential benefit appears to be relatively small.

5 Conclusions

While the persistent impact of the TVA on regional manufacturing growth uncovered in Section 3 appears consistent with simple models of poverty traps, the evidence from our empirical analysis of county growth dynamics is not supportive of the multiplicity hypothesis. Consistent with the presence of agglomeration effects, we find substantial evidence of state dependence in manufacturing employment. But this dependence is not strong enough to generate persistent poverty traps or convergence clubs of the sort discussed in the macroeconomics and development economics literatures.

Our estimates suggest that the TVA region will eventually revert back to its original steady state. We note, however, that the practical distinction between models exhibiting multiplicity and those with a unique steady state, but substantial persistence, may be limited. If the TVA improves manufacturing employment growth for several decades, it can still be said to have made a lasting impact, with long run benefits very different from those likely to emerge from the subsidization of agriculture or other sectors that lack agglomeration effects. We interpret the evidence as suggesting that local productivity levels can meaningfully be impacted by place based policies for substantial periods of time. However the relatively modest nonlinearities uncovered in our empirical analysis of manufacturing growth dynamics suggest that the aggregate productivity effects of investing in disadvantages areas, while probably positive, are also likely to be relatively small.

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Table 1: Summary Statistics for TVA Counties vs. Rest of U.S.

	Overall			Estimation Sample		
	TVA	Non-TVA	Non-TVA (South)	TVA	Non-TVA	Non-TVA (South)
<u>1930 Characteristics</u>						
Log Population	9.991	9.977	9.989	9.991	9.905	9.979
Log Employment	8.942	8.967	8.959	8.942	8.881	8.947
Log # of Houses	8.445	8.508	8.455	8.445	8.442	8.445
Log Average Manufacturing Wage	1.406	1.802	1.545	1.406	1.728	1.538
Manufacturing Employment Share	0.075	0.090	0.080	0.075	0.080	0.078
Agricultural Employment Share	0.617	0.455	0.541	0.617	0.487	0.547
% White	0.813	0.885	0.722	0.813	0.863	0.724
% Urbanized	0.153	0.280	0.233	0.153	0.242	0.215
% Illiterate	0.088	0.045	0.092	0.088	0.051	0.092
% of Whites Foreign Born	0.002	0.059	0.013	0.002	0.030	0.011
Log Average Farm Value	5.252	5.646	5.386	5.252	5.579	5.370
Log Median Housing Value	9.271	9.581	9.360	9.271	9.516	9.358
Log Median Contract Rent	8.574	9.030	8.679	8.574	8.934	8.672
% Own Radio	0.079	0.296	0.114	0.079	0.256	0.112
Max Elevation (meters)	1576.190	2364.531	1068.943	1576.190	2044.656	1070.334
Elevation Range (Max-Min)	1127.761	1521.322	712.336	1127.761	1251.074	715.253
% Counties in South	1.000	0.342	1.000	1.000	0.447	1.000
<u>Changes 1920-1930</u>						
Log Population	0.051	0.049	0.067	0.051	0.037	0.060
Log Employment	0.082	0.096	0.111	0.082	0.083	0.103
Log # of Houses	0.078	0.092	0.108	0.078	0.078	0.100
Log Average Manufacturing Wage	0.117	0.217	0.108	0.117	0.197	0.103
Manufacturing Employment Share	-0.010	-0.035	-0.018	-0.010	-0.026	-0.018
Agricultural Employment Share	-0.047	-0.036	-0.047	-0.047	-0.042	-0.047
% White	0.012	-0.011	-0.010	0.012	-0.006	-0.004
% Urbanized	0.047	0.064	0.080	0.047	0.054	0.069
% Illiterate	-0.030	-0.014	-0.029	-0.030	-0.015	-0.028
% of Whites Foreign Born	-0.001	-0.023	-0.016	-0.001	-0.015	-0.012
Log Average Farm Value	-0.013	-0.076	0.025	-0.013	-0.102	0.013
# of Observations	163	2326	795	163	1744	779
# of States	6	46	14	6	43	14

Table 2a: Decadalized Growth Rates in TVA Region vs. Rest of U.S. 1900-1940

	Outcome	Point Estimate (Unadjusted)	Clustered S.E.	Point Estimate (Controls)	Clustered S.E.	Spatial HAC	N
(1)	Population	0.007	(0.016)	0.010	(0.012)	(0.012)	1776
(2)	Total Employment	-0.009	(0.016)	0.005	(0.013)	(0.013)	1776
(3)	Housing Units	-0.006	(0.015)	0.007	(0.011)	(0.011)	1776
(4)	Average Manufacturing Wage	0.009	(0.018)	0.010	(0.021)	(0.021)	1428
(5)	Manufacturing Share	0.007*	(0.004)	0.005	(0.004)	(0.004)	1776
(6)	Agricultural Share	-0.007*	(0.004)	-0.001	(0.005)	(0.005)	1776
(7)	Average Agricultural Land Value	0.078***	(0.021)	0.025	(0.018)	(0.018)	1746

Table 2b: Decadalized Growth Rates in TVA Region vs. U.S. South 1900-1940

	Outcome	Point Estimate (Unadjusted)	Spatial HAC	Point Estimate (Controls)	Spatial HAC	N
(1)	Population	-0.018	(0.018)	0.003	(0.016)	850
(2)	Total Employment	-0.028	(0.018)	0.001	(0.016)	850
(3)	Housing Units	-0.025	(0.016)	0.005	(0.013)	850
(4)	Average Manufacturing Wage	0.001	(0.015)	0.001	(0.016)	687
(5)	Manufacturing Share	0.005	(0.005)	0.005	(0.005)	850
(6)	Agricultural Share	0.003	(0.004)	-0.002	(0.005)	850
(7)	Average Agricultural Land Value	-0.009	(0.020)	-0.007	(0.017)	839

Note: Point estimates obtained from regression of 1900-1940 change in outcomes divided by four on TVA dummy. All outcomes besides share variables are transformed to logarithms before taking difference. In specification titled controls, counterfactual change in TVA sample computed via Oaxaca-Blinder regression as in Kline (2011). Clustered S.E. column provides standard errors estimates clustered by state. Spatial HAC column provides standard error estimates based upon technique of Conley (1999) using bandwidth of 200 miles. Stars based upon clustered standard errors. Legend: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 3a: Decadalized Impact of TVA on Growth Rate of Outcomes (1940-2000)

	Outcome	Point Estimate (Unadjusted)	Clustered S.E.	Point Estimate (Controls)	Clustered S.E.	Spatial HAC	N
(1)	Population	0.004	(0.021)	0.007	(0.020)	(0.018)	1907
(2)	Average Manufacturing Wage	0.027***	(0.006)	0.005	(0.004)	(0.005)	1172
(3)	Average Retail/Wholesale Wage	0.015	(0.012)	0.029	(0.020)	(0.020)	1814
(4)	Agricultural Employment	-0.130***	(0.026)	-0.056**	(0.024)	(0.027)	1907
(5)	Manufacturing Employment	0.076***	(0.013)	0.059***	(0.015)	(0.023)	1907
(6)	Other Employment	0.063**	(0.026)	0.020	(0.023)	(0.020)	1905
(7)	Value of Farm Production	-0.028	(0.028)	0.002	(0.032)	(0.026)	1903
(8)	Median Family Income (1950-2000 only)	0.072***	(0.014)	0.021	(0.013)	(0.011)	1905
(9)	Average Agricultural Land Value	0.066***	(0.013)	-0.002	(0.012)	(0.016)	1906
(10)	Median Housing Value	0.040**	(0.017)	0.005	(0.015)	(0.015)	1906
(11)	Median Rent	0.063***	(0.014)	0.004	(0.009)	(0.006)	1905
(12)	Manufacturing Employment Share	0.012***	(0.003)	0.009***	(0.003)	(0.004)	1906
(13)	Agricultural Employment Share	-0.023***	(0.006)	-0.004	(0.006)	(0.006)	1906

Note: Point estimates obtained from regression of 1940-2000 change in outcomes divided by six on TVA dummy. All outcomes besides share variables are transformed to logarithms before taking difference. In specification titled controls, counterfactual change in TVA sample computed via Oaxaca-Blinder regression as in Kline (2011). Clustered S.E. column provides standard errors estimates clustered by state. Spatial HAC column provides standard error estimates based upon technique of Conley (1999) using bandwidth of 200 miles. Stars based upon clustered standard errors. Legend: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 3b: Decadalized Impact of TVA on Growth Rate of Outcomes (1940-2000, South Only)

	Outcome	Point Estimate (Unadjusted)	Spatial HAC	Point Estimate (Controls)	Spatial HAC	N
(1)	Population	-0.007	(0.018)	0.014	(0.019)	942
(2)	Average Manufacturing Wage	0.003	(0.006)	0.001	(0.005)	610
(3)	Average Retail/Wholesale Wage	0.009	(0.019)	0.048**	(0.022)	866
(4)	Agricultural Employment	-0.097***	(0.030)	-0.051*	(0.027)	942
(5)	Manufacturing Employment	0.079***	(0.023)	0.063***	(0.024)	942
(6)	Other Employment	0.032	(0.022)	0.026	(0.021)	942
(7)	Value of Farm Production	-0.005	(0.025)	-0.006	(0.026)	939
(8)	Median Family Income (1950-2000 only)	0.041***	(0.012)	0.024**	(0.011)	942
(9)	Average Agricultural Land Value	0.031*	(0.018)	-0.003	(0.017)	942
(10)	Median Housing Value	0.019	(0.017)	0.007	(0.016)	942
(11)	Median Rent	0.016	(0.010)	0.003	(0.006)	942
(12)	Manufacturing Employment Share	0.012***	(0.004)	0.008**	(0.004)	942
(13)	Agricultural Employment Share	-0.015**	(0.006)	-0.003	(0.006)	942

Note: Point estimates obtained from regression of 1940-2000 change in outcomes divided by six on TVA dummy. All outcomes besides share variables are transformed to logarithms before taking difference. In specification titled controls, counterfactual change in TVA sample computed via Oaxaca-Blinder regression as in Kline (2011). Spatial HAC column provides standard error estimates based upon technique of Conley (1999) using bandwidth of 200 miles. Stars: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 4: Decadalized Impact of TVA on Growth Rate of Outcomes Over Two Sub-Periods

	Outcome	Entire U.S. (1940-1960)	South Only (1940-1960)	Entire U.S. (1960-2000)	South Only (1960-2000)
(1)	Population	0.037	0.042	-0.008	-0.000
(2)	Average Manufacturing Wage	-0.005	-0.003	0.014*	0.010
(3)	Average Retail/Wholesale Wage	-0.011	-0.006	0.039	0.065**
(4)	Agricultural Employment	0.106***	0.106***	-0.134***	-0.130***
(5)	Manufacturing Employment	0.114***	0.116***	0.033**	0.035*
(6)	Other Employment	0.060	0.063	-0.000	0.006
(7)	Value of Farm Production	0.076*	0.081**	-0.030	-0.044
(8)	Median Family Income	N/A	N/A	0.017	0.016
(9)	Average Agricultural Land Value	0.027	0.018	-0.017	-0.015
(10)	Median Housing Value	0.019	0.010	-0.003	0.005

Note: Point estimates obtained from Oaxaca-Blinder regression of 1940-1960 or 1960-2000 change in outcomes divided by two or four respectively on TVA dummy and interacted controls as in Kline (2011). All outcomes besides share variables are transformed to logarithms before taking difference. Stars based on standard errors clustered by state (entire U.S.) or spatial HAC estimates (South Only) using technique of Conley (1999) with bandwidth of 200 miles. Legend: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 5: Decadalized Impact of TVA on Growth Rate of Outcomes Over Two Sub-Periods by 1930 Manufacturing Density

		1940-1960		
	Outcome	Bottom Tercile	Middle Tercile	Top Tercile
(1)	Average Manufacturing Wage	-0.013	0.002	-0.002
(2)	Agricultural Employment	0.099***	0.150***	0.088**
(3)	Manufacturing Employment	0.086**	0.155***	0.103**
(4)	Median Family Income	N/A	N/A	N/A

		1960-2000		
	Outcome	Bottom Tercile	Middle Tercile	Top Tercile
(1)	Average Manufacturing Wage	0.016	0.014	0.002
(2)	Agricultural Employment	-0.110***	-0.144***	-0.145***
(3)	Manufacturing Employment	-0.011	0.069***	0.029**
(4)	Median Family Income	0.008	0.028***	0.006

Note: Point estimates obtained from regression of 1940-1960 or 1960-2000 change in outcomes divided by two or four respectively on TVA dummy and controls. All outcomes are transformed to logarithms before taking difference. Stars based on standard errors clustered by state. Legend: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 6: Structural Estimates of Labor Demand

	Dependent Variable: Change in Log Manufacturing (1970-2000)							
	(1) OLS – Linear	(2) OLS – Spline	(3) 2SLS – Linear	(4) 2SLS – Spline	(5) OLS – Linear	(6) OLS – Spline	(7) 2SLS – Linear	(8) 2SLS – Spline
Change in Log Manufacturing Density (1960-1990)	0.750 (0.039)		0.817 (0.086) [53.49]		0.699 (0.034)		0.870 (0.163) [10.56]	
Change in Log Manufacturing Density (1960-1990), Bottom Density Quartile		0.867 (0.114)		0.868 (0.389) [177.34]		0.777 (0.105)		0.767 (0.302) [83.63]
Change in Log Manufacturing Density (1960-1990), Second Density Quartile		0.750 (0.048)		0.781 (0.290) [53.82]		0.687 (0.046)		0.837 (0.175) [37.44]
Change in Log Manufacturing Density (1960-1990), Third Density Quartile		0.689 (0.051)		0.852 (0.259) [46.86]		0.658 (0.042)		0.665 (0.259) [28.58]
Change in Log Manufacturing Density (1960-1990), Top Density Quartile		0.740 (0.030)		0.895 (0.153) [40.72]		0.714 (0.032)		0.667 (0.245) [10.45]
TVA	-0.087 (0.041)	-0.068 (0.040)	-0.028 (0.073)	-0.025 (0.081)	-0.093 (0.025)	-0.081 (0.024)	-0.091 (0.058)	-0.046 (0.059)
Change in Log Manufacturing Wage (1970-2000)	0.028 (0.047)	0.040 (0.046)	-2.133 (1.374) [2.00]	-2.519 (1.690) [2.76]	0.063 (0.037)	0.067 (0.036)	-0.465 (0.786) [3.83]	-0.519 (0.778) [2.30]
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	No	Yes	Yes	Yes	Yes
N	1224	1224	1224	1224	1224	1224	1224	1224
Equality of Slopes p-value		0.388		0.885		0.440		0.335
Overid p-value			0.878				0.488	

Note: Instruments used in 2SLS specifications are 1940 wages and fourth order polynomial in 1940 manufacturing density. Standard errors clustered by state in parentheses. Angrist-Pischke cluster robust F-stats in brackets. Manufacturing density is manufacturing employment per square mile. Density quartiles defined based upon 1970 distribution.

Table 7: Sensitivity Analysis -- Structural Estimates of Labor Demand Given Different Assumed Short Run Elasticities of Demand

	Dependent Variable: Change in Log Manufacturing (1970-2000)				
	(1) 2SLS – Linear	(2) 2SLS – Linear	(3) 2SLS – Spline	(4) 2SLS – Spline	(5) 2SLS – Spline
Change in Log Manufacturing Density (1960-1990), Bottom Density Quartile	0.779	0.788	0.797	0.806	0.815
	(0.305)	(0.349)	(0.395)	(0.443)	(0.493)
Change in Log Manufacturing Density (1960-1990), Second Density Quartile	0.870	0.803	0.736	0.670	0.603
	(0.171)	(0.200)	(0.233)	(0.271)	(0.310)
Change in Log Manufacturing Density (1960-1990), Third Density Quartile	0.677	0.676	0.674	0.673	0.672
	(0.260)	(0.298)	(0.343)	(0.393)	(0.445)
Change in Log Manufacturing Density (1960-1990), Top Density Quartile	0.716	0.622	0.527	0.432	0.337
	(0.185)	(0.203)	(0.230)	(0.263)	(0.301)
TVA	-0.050	-0.027	-0.005	0.018	0.041
	(0.048)	(0.055)	(0.063)	(0.073)	(0.084)
Change in Log Manufacturing Wage (1970-2000) **Calibrated Coefficient**	**-0.5**	**-1**	**-1.5**	**-2**	**-2.5**
Region Effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
N	1224	1224	1224	1224	1224
Equality of Slopes p-value	0.317	0.178	0.095	0.061	0.046
Overid p-value	0.342	0.214	0.155	0.124	0.106

Note: Instruments used in 2SLS specifications are 1940 wages and fourth order polynomial in 1940 manufacturing density. Standard errors clustered by state in parentheses. Manufacturing density is manufacturing employment per square mile. Density quartiles defined based upon 1970 distribution.

Figure 1: The TVA Service Area

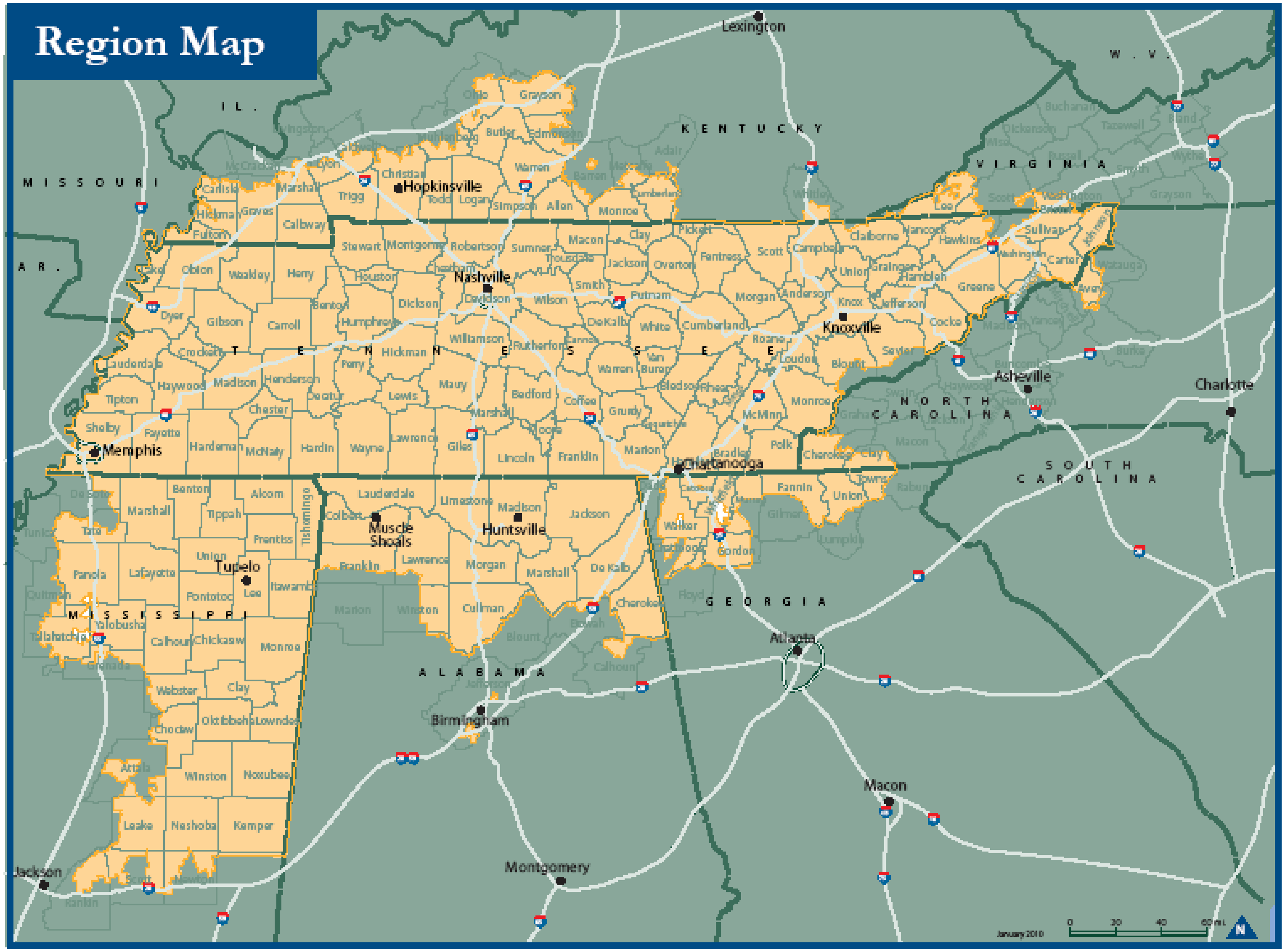
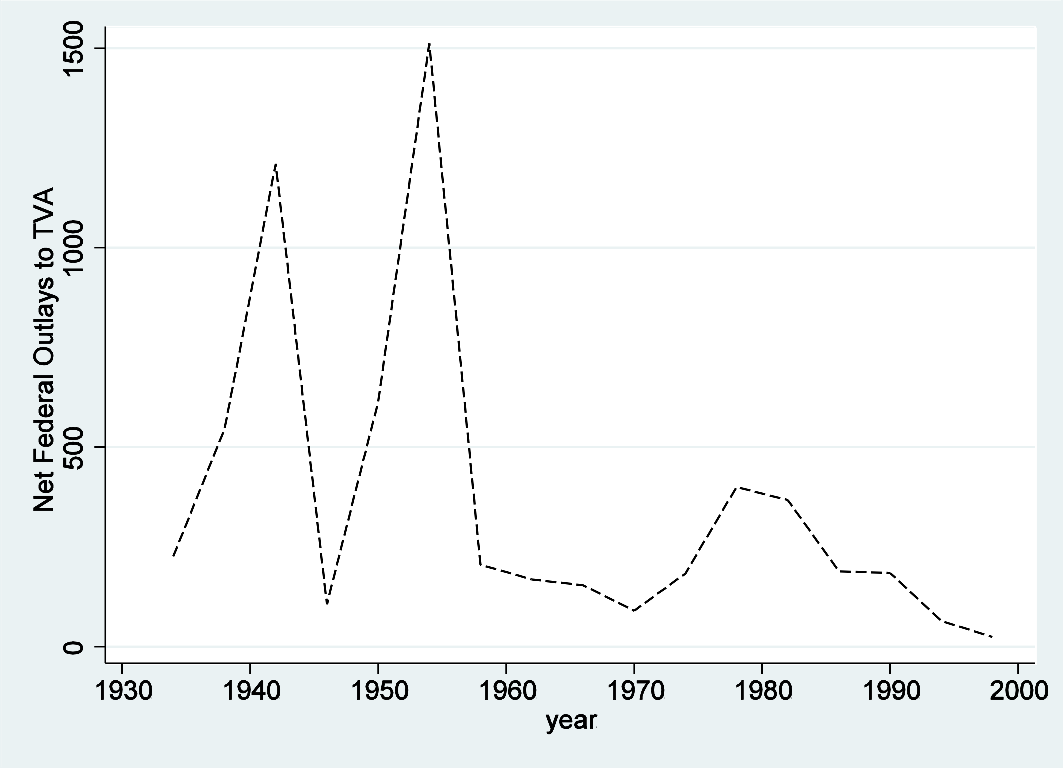


Figure 2: Net Federal Outlays to TVA by Year



Note: Figure provides four year centered averages (see Data Appendix for source).

Figure 3: Convergence in Manufacturing Density Across Four Decades

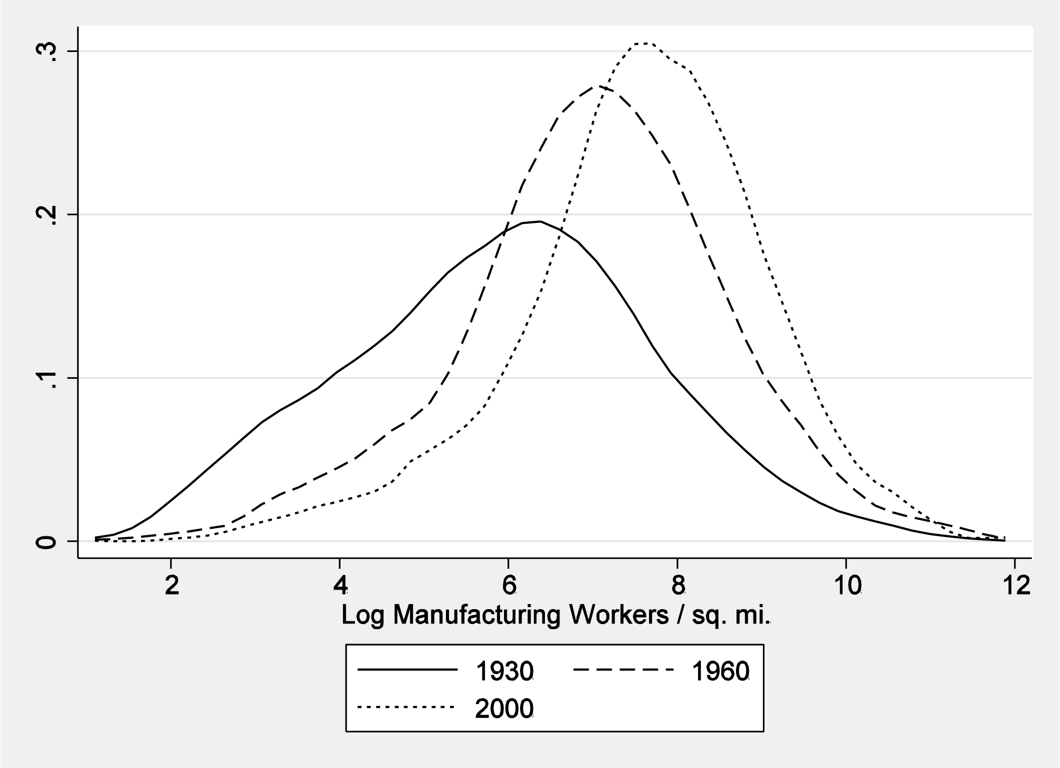


Figure 4a: Linear Agglomeration

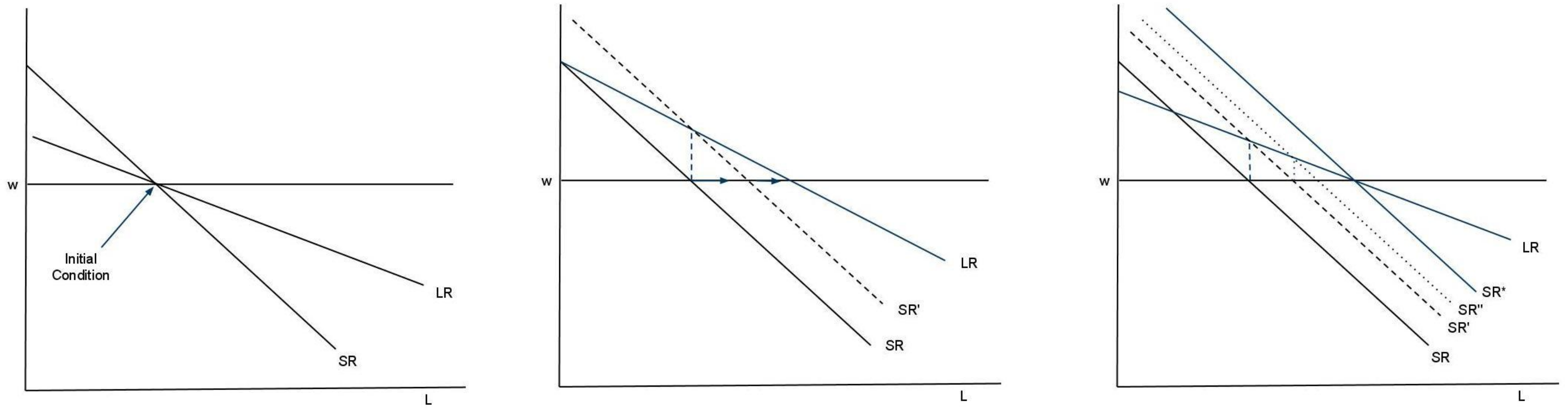
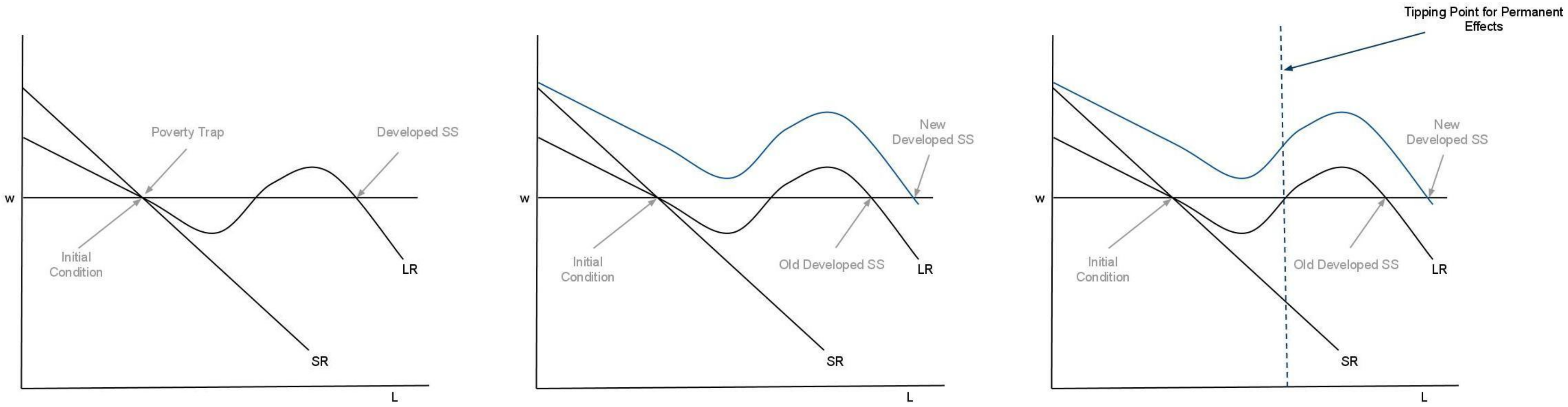


Figure 4b: Nonlinear Agglomeration



Notes: The x-axis is log manufacturing density and the y-axis is the log manufacturing wage. SR and LR refer to short run and long run inverse demand curves respectively (see section 4.2 of text). Figure 4a depicts convergence from initial condition to the new unique steady state under linear agglomeration after a permanent productivity shift. Figure 4b depicts effects of transitory productivity shift on steady state in the presence of nonlinear agglomeration effects.

Data Appendix

1. Data on TVA Appropriations

Data on federal appropriations for the TVA was collected using financial statements from the TVA's Annual Reports. From 1934 to 1976, these are Reports to Congress. From 1977 onwards, they are the usual reports released by corporations in the U.S. The comparison of balance sheets between consecutive years provides the values for each variable present in the table. The actual names of those reports changed over time as follows:

- 1934/1939: Annual Report of the Tennessee Valley Authority for the Fiscal Year Ended June 30, of the relevant year.
- 1945: Audit of Tennessee Valley Authority for Fiscal Year Ended June 30, 1945. It contains information from 1938 until 1945.
- 1946-47: Report on the Audit of Tennessee Valley Authority for the Fiscal Year Ended June 30, 1946 and 1947.
- 1948-1950: Report on the Audit of Tennessee Valley Authority for the Fiscal Year Ended on June 30 pof the relevant year.
- 1951-1957: Audit Report of Tennessee Valley Authority for the Fiscal Year Ended June 30 of the relevant year.
- 1958: Audit Report of Tennessee Valley Authority Fiscal Year 1958.
- 1959-1962: Report on Audit of the Tennessee Valley Authority.
- 1963: Report on Audit of Financial Statements of Tennessee Valley Authority Fiscal Year 1963.
- 1964: Report on Audit of the Financial Statements of the Tennessee Valley Authority, Fiscal Year Ended June 30, 1964.
- 1965: Report on the Examination of Financial Statements, Tennessee Valley Authority, Fiscal Year 1965.
- 1966: An Audit of the Tennessee Valley Authority, Fiscal Year 1966.
- 1967: An Examination of Financial Statements of the Tennessee Valley Authority, Fiscal Year 1967.
- 1968-1969: An Examination of Financial Statements Tennessee Valley Authority.
- 1970-1976: Examination of Financial Statements of the Tennessee Valley Authority.
- 1977-1986: Annual Report of the Tennessee Valley Authority, Volume II ? Appendix, For the Fiscal Year Ending September 30 of the relevant year.
- 1987-1989: Tennessee Valley Authority, Financial Statements for the Fiscal Year Ended September 30 of the relevant year.

- 1991-1993: Annual Report TVA.

- 1994: Tennessee Valley Authority 1994 Annual Report.

- 1995: We did not find report for this year, but we recovered the information for it using the reports of 1994 and 1996. That was possible because each of those reports presents information comparing the financial situation in the current and in the previous year.

- 1996: 1996 Annual Report, Tennessee Valley Authority.

- 1997: Tennessee Valley Authority Financial Statements 1997.

- 1998-1999: We did not find report for these years, but we got the information for them in the Amended 2002 Information Statement Tennessee Valley Authority. This amendment provides annual information for the period 1998-2002.

- 2000: TVA Annual Report 2000.

2. Data Used in the Empirical Analysis

We work with county level data for all US states excluding Alaska, Hawaii and Virginia, for the years 1900 to 2000. The data for the years 1900 to 1930 was obtained from Historical, Demographic, Economic, and Social Data: The United States, 1790-2000, ICPSR 2896 (Parts 20, 22, 24, 26 29 and 85 which correspond to the 1900 Census, 1910 Census, 1920 Census, 1930 Census Part I, 1930 Census Part IV Families and the 1910 Census of Agriculture) with the exception of the variables manuf, const, agr, trade and other, which were built from individual level data from IPUMS from a 1% extract from the 1900, 1910, 1920 and 1930 Census respectively.

For 1940 to 1970 each variable was built from two alternative data sources: the County and City Data Book [United States] Consolidated File: County Data, 1947-1977, from ICPSR 7736; and from Historical, Demographic, Economic, and Social Data: The United States, 1790-2000, ICPSR 2896 (Parts 70, 72, 74 and 76, which correspond to the 1947 County Data Book, the 1952 County Data Book, the 1962 County Data Book and the 1972 County Data Book). In most cases the variable definitions are the same using these two alternative data sources. When the definitions are different, we use the one from ICPSR 2896.

The data for year 1980 to 2000 was obtained from census extracts from the National Historical Geographic Information System (NHGIS), with the exception of variables mwage and vfprod, which were obtained from ICPR 2896 (Parts 79, 80 and 81, which correspond to the 1988 County Data Book, the 1994 County Data Book and the 2000 County Data Book).

Additionally, we use data on county topography and demographics from the paper "Data Set for Births, Deaths, and New Deal Relief During the Great Depression" by Price Fishback, Michael Haines, and Shawn Kantor generously made available on Price Fishback's website.

The key variables used in this study are the following:

- Pop: Total population of each county.

- Popurb: Urban population in each county. For 1900 to 1920 it was calculated as population residing in places of 2,500 or more persons. For 1930, 1940, 1950 and 2000, calculated directly as total urban population. For 1960 and 1970, defined as percentage urban times the total population. For 1980 and 1990 it was calculated as urban population inside urbanized areas plus urban population outside urbanized area.

- Poprrl: Rural Population in each county. Calculated as total population minus urban population

- White: Share of Population of White Race. For 1900-1940 and 1970-2000 defined as total white population over total population. For 1950 and 1960, it was defined as 1 minus the share of black and races other than white.

- Emp: Total Employment. Missing for 1900-1920. For 1930, defined as the number of "gainful workers" in a county, for 1940 and 1950 defined as the total employed workers, for 1960 and 1980 defined as the total civilian labor force employed and for 1970 defined as the total civilian force aged 16 or more employed. For 1990, defined as the male civilian labor force employed plus the female labor force employed. For 2000, defined as the population 16 and over who worked in 1999.

- Manuf: Share of employment in manufacturing. For 1900 to 1920 defined from individual level data as the number of individuals who reported working on manufacturing over the total number of individuals with reported industry. For 1930, defined as the average number of wage earners in manufacturing in 1929 over total employment. For 1940 defined as workers in manufacturing over total employment. For 1950-1970, defined both directly as share of employment in manufacturing and also as workers in manufacturing over total employment for 1950, as labor force employed in manufacturing of durable goods plus labor force employed in manufacturing of nondurable goods over total employment for 1960, and as civilian labor force aged 16+ employed in manufacturing for 1970. For 1980-1990, defined as workers in manufacturing of durable goods plus workers in manufacturing of nondurable goods, over total employment. For 2000, defined as female workers in manufacturing plus male workers in manufacturing, over total employment.

- Manuftot: Manufacturing total employment. For 1900-1940 it was defined as the average number of manufacturing wage earners and for 1947-1997 as manufacturing production workers.

- Const: Share of employment in construction. For 1900 to 1930 defined from individual level data as the number of individuals who reported working on construction over the total number of individuals with reported industry. For 1940-1960 it was defined as the number of workers in constructions over total employment. For 1970-1990 it was defined directly. For 2000, defined as the sum of male and female in construction.

- Agr: Share of employment in agriculture. For 1900 to 1930 defined from individual level data as the number of individuals who reported working on agriculture over the total number of individuals with reported industry. For 1940-1960, defined as workers in agriculture over total employment. Missing for 1970. For 1980 and 1990 it was defined as the number of workers employed in agriculture, forestry and fisheries over total employment. For 2000, defined as the sum of males and females employed in agriculture, forestry, fisheries and hunting and mining over total employment

- Trade: Share of employment in trade (trade defined as wholesale plus retails). For 1900 to 1920 defined from individual level data as the number of individuals who reported working on trade over the total number of individuals with reported industry. For 1930, defined as total employees in wholesale plus retail proprietors plus total employees in retail over total employment. For 1940-1960, defined as workers in trade over total employment. For 1970, defined directly as percentage of the civilian labor force aged 16 or more employed in trade. For 1980-1990, defined as workers in wholesale trade plus workers in retail trade over total employment. For 2000 defined as female workers in wholesale trade plus workers in retail trade plus male workers in wholesale trade plus workers in retail trade over total employment.

- Other: Share of workers not in manufacturing, construction, agriculture or trade. Defined as 1 minus shares in those industries. Missing for 1930 and 1970.

- Medfaminc: Median family income. Missing for 1900 to 1940. For 1980 defined as Median family income in 1979. For 1990 defined as Median family income in 1989. For 2000 defined as Median income in 1999.

- Mwage: Total county level manufacturing wages in thousands of dollars. For 1900, 1920, 1930, given in dollars, so divided by 1,000. For 1940 defined as 1939 wages. For 1950 defined as 1954 wages. For 1960 defined as 1963 wages. For 1970 defined as 1972 wages, given in millions of dollars, so multiplied by 1,000. For 1980 defined 1982 wages, given in millions of dollars, so multiplied by 1,000. For 1990 defined as 1987 wages, given in millions of dollars, so multiplied by 1,000. For 2000, defined as 1997 wages.

- Pcmwage: per capita county level manufacturing wage. Defined as mwage over manuftot

- Twage: Total county level trade wages in thousands of dollars. Defined as total payroll in retail stores plus total payroll in wholesale establishments. For 1930, wages are given in dollars, so divided by 1,000. For 1950-2000 we use wages in 1954, 1963, 1972, 1982, 1987 and 1997.

- Pctwage: Per capita county level trade wage. Defined as twage over total employees in retail stores and wholesales establishments for 1930 and 1940, over retail and wholesale paid employees on the workweek 11/15/54 for 1950, over retail and wholesale paid employees on the workweek 11/15/58 for 1960, over retail and wholesale paid employees on the workweek 3/12/67 for 1970, over retail and wholesale paid employees in 1982 for 1980, over retail and wholesale paid employees in 1987 for 1990, and over retail and wholesale paid employees in 1997 for 2000.

- House: Total number of housing units. For 1900-1930 defined as total dwellings. For 1940-2000 defined as total housing units.

- Ohouse: Number of occupied housing units. Missing for 1900-1930. Defined directly for 1940-1990. For 2000 defined as total housing units minus vacant housing units.

- Vhouse: Number of vacant housing units. Missing for 1900-1930. For 1940-90, defined as total housing units minus occupied housing units. Defined directly for 2000.

- Vfprod: Value of farm products in thousands of dollars. Total value of farm products for each county in thousands of dollars. For 1900, defined as the value of miscellaneous crops with acreage reported in 1899 plus the value of miscellaneous crops without acreage reported in 1899. For 1910-1930, defined as value of all crops divided by 1,000. For 1940, defined as value of all farm products sold, traded or used. For 1950-1960, defined as value of all farm products sold, in thousands of dollars. For 1970, we use the value of farm products sold in farms with sales of $2,500 or more in 1969. For 1980, defined as value of farm products sold in 1982 in millions of dollars, so multiplied by 1000. For 1990, defined as value of farm products sold in 1987 in thousands of dollars. For 2000, defined as value of farm products sold in 1997 in thousands of dollars.

- Vfland: Value of land. For 1900-1910 defined directly as average value of land per acre. For 1920 and 1930 defined as value of land in farms divided the number of acres in farms. For 1940-1970, value of farmland in 1945, 1954, 1959 and 1969.

Appendix Table 1: Structural Estimates of Labor Demand (Polynomial Basis)

	Dependent Variable: Change in Log Manufacturing (1970-2000)							
	(1) OLS – Linear	(2) OLS – Spline	(3) 2SLS – Linear	(4) 2SLS – Spline	(5) OLS – Linear	(6) OLS – Spline	(7) 2SLS – Linear	(8) 2SLS – Spline
Change in Log Manufacturing Density (1960-1990)	0.750	0.772	0.817	0.816	0.699	0.707	0.870	0.804
	(0.039)	(0.058)	(0.086)	(0.093)	(0.034)	(0.058)	(0.163)	(0.169)
			[53.49]	[66.09]			[10.56]	[13.04]
Change in Squared Log Manufacturing Density (1960-1990)		-0.010		0.004		-0.003		-0.019
		(0.011)		(0.032)		(0.011)		(0.021)
				[78.11]				[21.02]
TVA	-0.087	-0.082	-0.028	-0.029	-0.093	-0.091	-0.091	-0.046
	(0.041)	(0.038)	(0.073)	(0.072)	(0.025)	(0.024)	(0.058)	(0.060)
Change in Log Manufacturing Wage (1970-2000)	0.028	0.033	-2.133	-2.193	0.063	0.064	-0.465	-0.908
	(0.047)	(0.046)	(1.374)	(1.645)	(0.037)	(0.037)	(0.786)	(0.804)
			[2.00]	[2.59]			[3.83]	[2.32]
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	No	Yes	Yes	Yes	Yes
N	1224	1224	1224	1224	1224	1224	1224	1224
Overid p-value			0.878	0.941			0.488	0.831

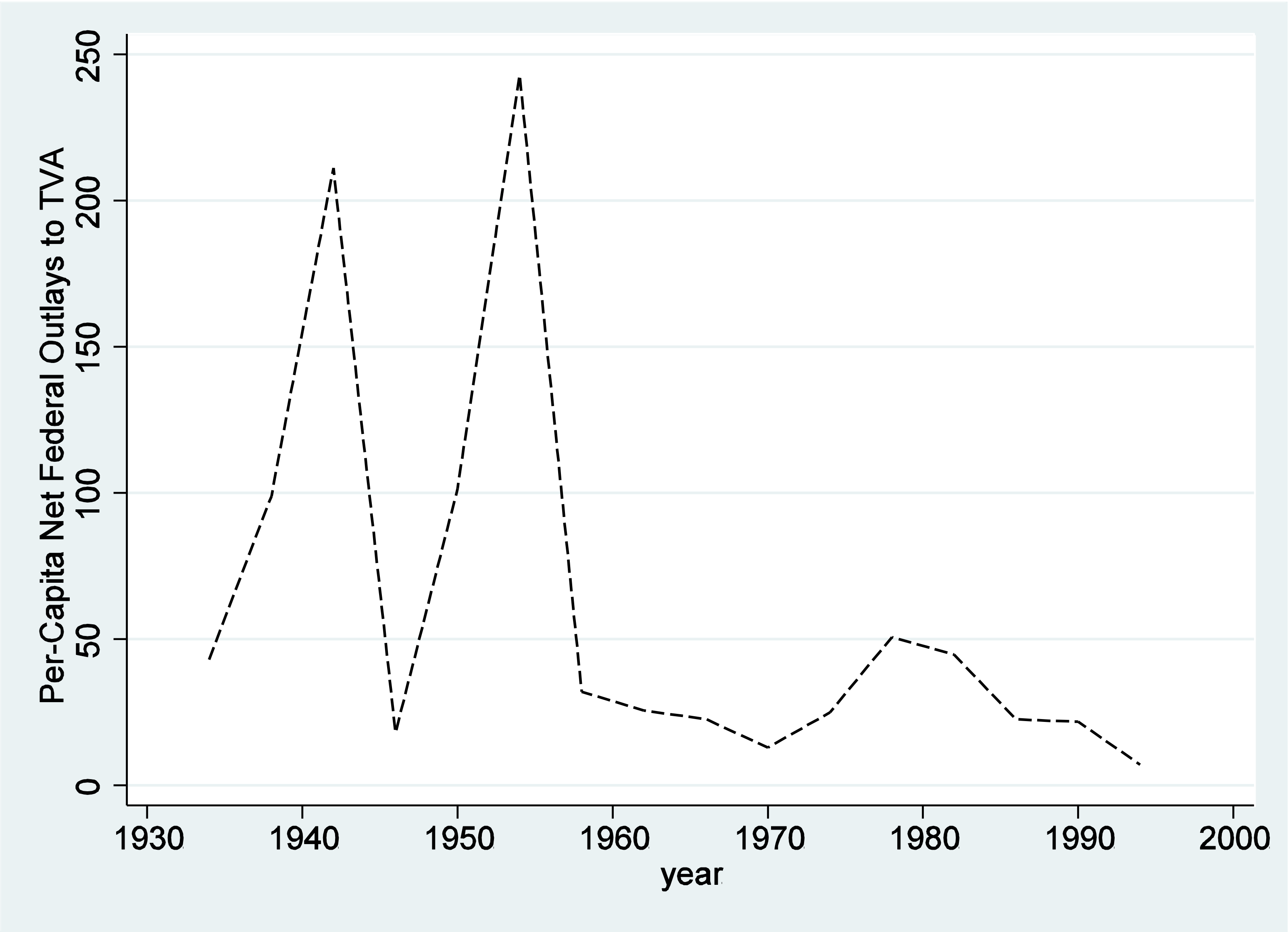
Note: Instruments used in 2SLS specifications are 1940 wages and fourth order polynomial in 1940 manufacturing density. Standard errors clustered by state in parentheses. Angrist-Pischke cluster robust F-stats in brackets. Manufacturing density is manufacturing employment per square mile.

Appendix Table 2: Sensitivity Analysis -- Structural Estimates of Labor Demand Given Different Assumed Short Run Elasticities of Demand (Polynomial Basis)

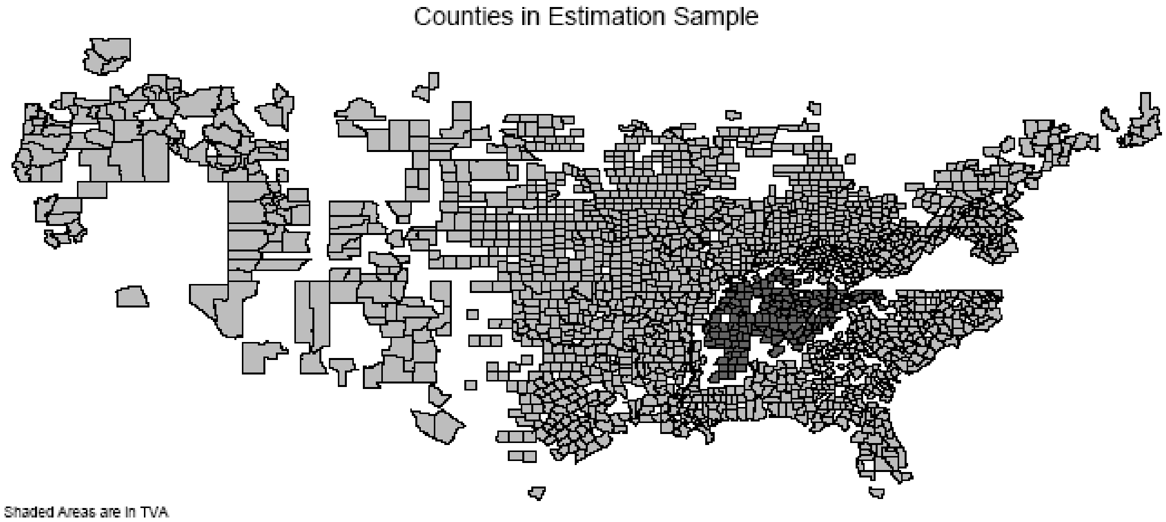
	Dependent Variable: Change in Log Manufacturing (1970-2000)				
	(1) 2SLS – Linear	(2) 2SLS – Linear	(3) 2SLS – Spline	(4) 2SLS – Spline	(5) 2SLS – Spline
Change in Log Manufacturing Density (1960-1990)	0.848 (0.149)	0.819 (0.172)	0.790 (0.199)	0.761 (0.229)	0.732 (0.261)
Change in Squared Log Manufacturing Density (1960-1990)	-0.011 (0.021)	-0.018 (0.023)	-0.026 (0.026)	-0.033 (0.030)	-0.041 (0.033)
TVA	-0.079 (0.033)	-0.047 (0.040)	-0.015 (0.049)	0.017 (0.059)	0.049 (0.069)
Change in Log Manufacturing Wage (1970-2000) **Calibrated Coefficient**	**-0.5**	**-1**	**-1.5**	**-2**	**-2.5**
Region Effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
N	1224	1224	1224	1224	1224
Overid p-value	0.622	0.624	0.565	0.498	0.442

Note: Instruments used in 2SLS specifications are 1940 wages and fourth order polynomial in 1940 manufacturing density. Standard errors clustered by state in parentheses. Manufacturing density is manufacturing employment per square mile.

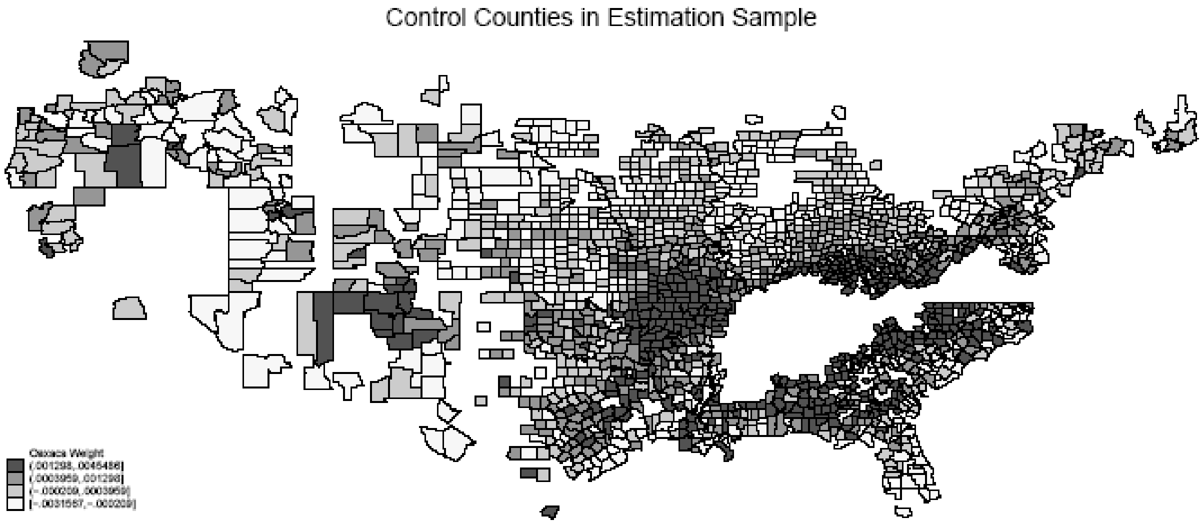
Appendix Figure 1: Per-Capita Net Federal Outlays to TVA by Year



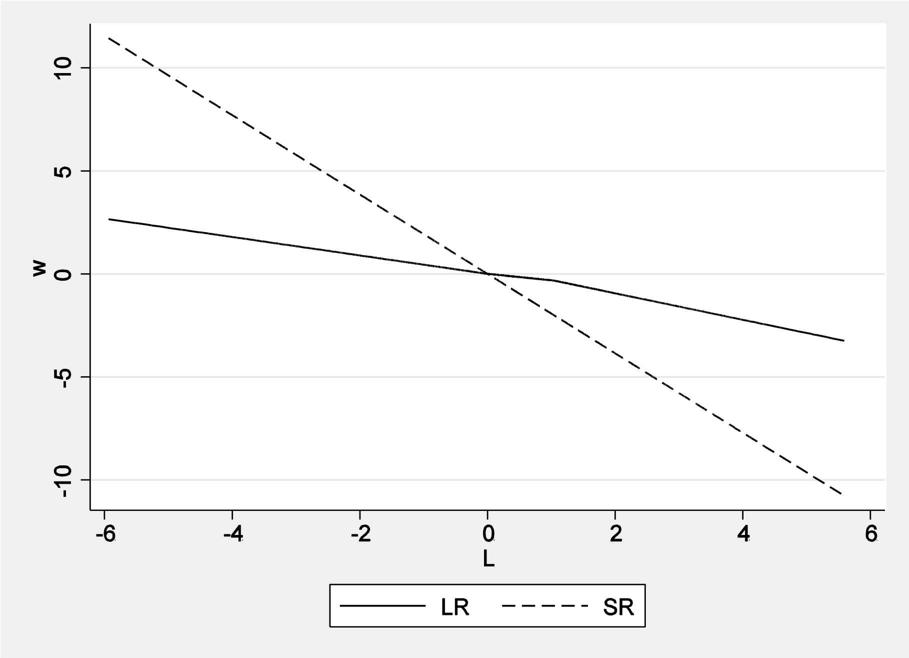
Appendix Figure 2a – Estimation Sample



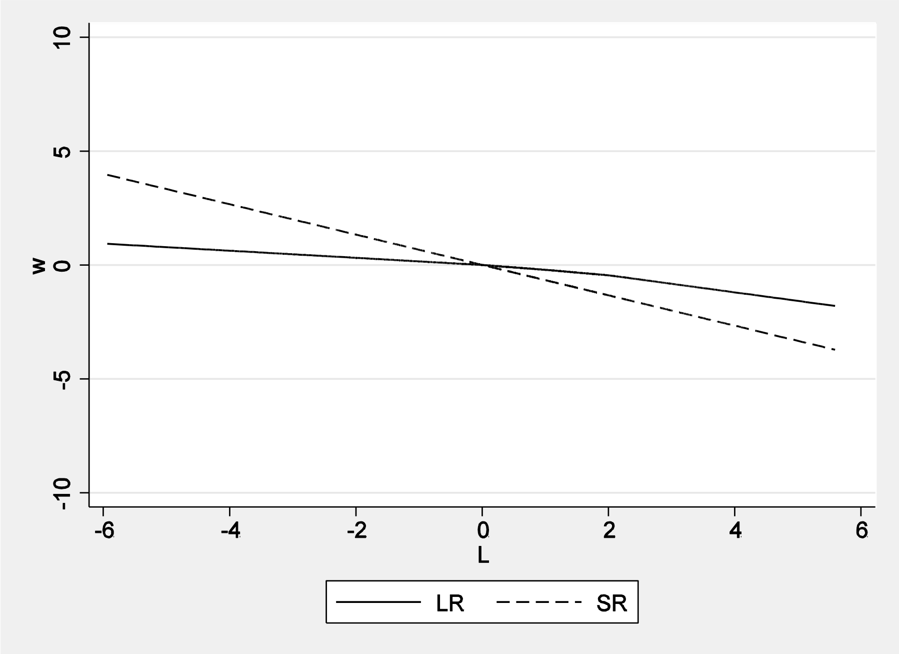
Appendix Figure 2b – Weight on Untreated Counties



Appendix Figure 3a – Estimated Inverse Demand Functions



Appendix Figure 3b – Estimates w/ Calibrated SR Demand Elasticity of -3/2



Notes: In the figures above, the x-axis is log manufacturing density and the y-axis is the log manufacturing wage. SR and LR refer to short run and long run inverse demand curves respectively (see section 4.2 of text). Plots correspond to estimates from column 8 of Table 6 and column 3 of Table 7 respectively.