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. Using a rich panel dataset of counties, we conduct an evaluation of the dynamic effects of the TVA on local economies in the seventy years following the program's inception. We find that the 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's subsidies had lapsed – a pattern consistent with the presence of strong agglomeration economies in the manufacturing sector. Economists have long cautioned that the local gains created by place based policies may be offset by losses elsewhere, yielding ambiguous effects on the U.S. as a whole. Building on the framework in Glaeser and Gottlieb (2008), we develop a novel approach to assessing the aggregate consequences of shifting the spatial distribution of manufacturing employment. Our findings suggest the aggregate productivity gains associated with relocating manufacturing activity to the TVA region were probably minimal.

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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 nominal wages in the highest and lowest paying U.S. metropolitan areas differ by a factor of two to three (Moretti, 2011). Such disparities have prompted governments to create a variety of place based economic development policies aimed at reducing regional inequality (Bartik, 1991; Glaeser and Gottlieb, 2008; Duranton, 2011). 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 federal and local governments spend $40-50 billion per year on such programs, more than Unemployment Insurance in a typical year.[1] Many place based policies in the U.S. involve attempts to retain or attract manufacturing plants to a specific jurisdiction. Indeed, it is rare that a large manufacturing establishment opens today without the provision of generous public subsidies. Such programs have become the de-facto industrial policy in the United States, with similar policies widespread in Canada, Europe and Asia (Albouy, 2012; Criscuolo, Martin, Overman, and Van Reenen, 2012; Wang, 2011; Wren and Taylor, 1999).

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. In the extreme case of perfect mobility, the primary beneficiaries of such policies may be local land owners.[2] An alternative justification relies on the existence of some type of market failure due, for example, to agglomeration economies. In such a case, attracting economic activity to an area through public subsidies benefits all firms in the area through productivity spillovers or other forms of agglomeration externalities.

But even if localized externalities are present, place based policies are not necessarily

[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] However, 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 (2012) find that the short run incidence of the federal Empowerment Zone program fell, in part, on local workers.

beneficial for the country as a whole. As pointed out by Glaeser and Gottlieb (2008) in their influential review, unless the agglomeration forces sustaining a place based policy are substantially nonlinear, spatially reallocating employment is unlikely to be welfare enhancing. If agglomeration economies are linear, the productivity gains in areas that benefit from a policy are offset by the losses in areas from which activity is being diverted. In such a case, targeted policies may 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.[3]

If, on the other hand, agglomeration economies are substantially nonlinear, the gains in targeted areas may outweigh the losses in areas from which activity is being diverted, and large public investments in disadvantaged areas would tend to make good national investments. A popular version of this argument holds that economic development exhibits threshold effects whereby investments beyond some critical level generate self-sustaining economic activity (e.g. Azariadis and Drazen, 1990; Azariadis and Stachurski, 2005). In this type of setting, the economy may exhibit multiple equilibria, with some localities enjoying a "good" equilibrium characterized by high economic density, high productivity and high wages, and other localities trapped in a "bad" equilibrium with low density, low productivity and low wages. 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). While this possibility has tantalized economists and policymakers for decades, direct empirical evidence on big push policies is scarce.[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 "touch-

[3]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. 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."

[4]A recent study by Ziliak (2011) on the Appalachian Regional Development Act is one important exception. Ziliak finds that ARDA reduced poverty in Appalachia between 1960 and 2000 by 7.6 percentage points relative to the rest of the U.S., with the majority of the effect occurring in the first five years of the program. Recent studies on the *short run* effects of place based policies include Busso, Kline, and Gregory (2012), Ham et al. (2011), and Neumark and Kolko (2010). In addition, 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; Donaldson and Hornbeck, 2012).

ing 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 might succeed.

Second, the short and long run effects of the program are likely to be quite different (Hornbeck, 2012a). 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 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 an opportunity to examine whether a lapsed development policy may have persistent effects.[5] 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.

We proceed in two steps. In the first part of the paper, we use a rich panel dataset of counties to conduct a program evaluation of the dynamic effects of the TVA on local economies in the seventy year period following its inception. We examine the manufacturing

[5]This is to be contrasted with a related literature that has studied the long run effects of large spatially targeted disasters (e.g. Davis and Weinstein, 2002, 2008; Miguel and Roland, 2011).

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.

To identify the effect of TVA on the regional economy, we use two alternative identification strategies. First, we compare the TVA area to observationally similar controls, both in the South and the rest of the U.S.. Placebo tests indicate that our covariates are successful at balancing trends in observable characteristics of TVA and control counties in the two decades before the program. Second, we use the fact that in the years following the inception of TVA, Congress considered creating six additional regional authorities modeled upon TVA. Due to political infighting, these additional authorities were never approved. We compare TVA counties to the areas of these authorities that were proposed but never implemented.

We find that between 1930 and 1960 – the period during which federal transfers were greatest – the TVA generated gains in both agricultural and manufacturing employment. This likely reflects the increase in transportation infrastructure and the reduction in electricity prices, both of which were financed by federal transfers. 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. In 2000, forty years after TVA became financially self-sufficient, manufacturing employment in the region was still growing at a significantly faster pace than the comparison group. Our interpretation is that the TVA program successfully unleashed a self-reinforcing process of economic development strong enough to sustain a larger manufacturing base for several decades. Because the manufacturing sector paid higher wages than agriculture, this shift raised aggregate income in the TVA region for an extended period of time.

Though our results suggest the TVA program benefitted the TVA region, they do not allow us to conclude that the gains in that region outweighed the potential losses to the rest of the United States from which manufacturing jobs may have been diverted. Indeed, one of the fundamental concerns raised by economists about the efficacy of place based policies is the potential for a business stealing effect, whereby the benefits enjoyed by the target locality come at the expenses of other localities, with no aggregate benefits for the nation as a whole. In the case of TVA, it is possible that the program failed to raise national income, or even lowered it, if the regional productivity gains were smaller than the corresponding losses in the rest of the country.

In the second part of the paper, we develop a novel approach to assessing the aggregate impact of manufacturing reallocations by examining the dynamic responses of counties to representative shocks to their manufacturing base. Building on the framework in Glaeser and Gottlieb (2008), we develop an empirical model that yields a transparent approach to identifying the shape and strength of local agglomeration forces.

Estimates from our model point to three main conclusions. First, like many recent studies (Ellison and Glaeser, 1999; Ellison, Glaeser, and Kerr, 2010; Rosenthal and Strange, 2004; Greenstone, Hornbeck and Moretti, 2011), we find evidence of important agglomeration effects in the manufacturing sector. The estimated agglomeration forces are smaller than the ones uncovered by Greenstone, Hornbeck and Moretti (2011), but are economically and statistically meaningful.

Second, we find no evidence of multiple equilibria and/or poverty traps of the sort discussed in the macroeconomics and development economics literatures (e.g. Graham and Temple, 2006; Redding, Sturm, and Wolf, 2011). 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. 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.

Finally, and most importantly, 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. Thus, to the extent that the TVA region's manufacturing jobs came at the expense of manufacturing jobs elsewhere, we estimate that the productivity effects of TVA were a zero sum game and that the program had no effect on national income. Indeed, if one also takes into account the traditional dead weight losses from taxation, it is reasonable to expect a net loss in national income.

We caution, however, that some of the regional gains in manufacturing employment induced by the TVA may have come at the expense of agricultural jobs. Since this sector is unlikely to exhibit agglomeration, diverting employment from it would entail fewer offsetting costs. We conclude that a priority for future research on place based policies is determining the strength of employment diversion effects within and between sectors.

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 agglomeration forces in manufacturing. Section 5 discusses the implications of our findings and concludes.

2 The Tennessee Valley Authority Program

2.1 Brief History

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 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

[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.

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 generous 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

[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.)

(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.

2.2 Selection into TVA and Summary Statistics

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;

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]

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

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

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 (i.e. before the start of the program) 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.

The TVA region 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 between 1920 and 1930 for our covariates. Population growth in TVA counties was similar

[10] We drop the state of Virginia where county splits and merges are common. We also drop counties in Hawaii and Alaska.

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 and urbanization 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 cannot compute the change in the value of agricultural output.

Overall, Table 1 confirms 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 (e.g. Barro and Sala-i-Martin, 1991). In particular, 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 agglomeration in the manufacturing sector aimed at explaining the economic forces underlying the reduced-form results and their implications for aggregate efficiency of the program.

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

[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.

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. After all, finding employment growth in a region benefitting from substantial federal investment is not particularly surprising. Our interests center on estimating the *long run* effects of the TVA. In particular, we wish to learn what happened to the TVA regional economy after the federal subsidies associated with program lapsed.

The existing evidence on the long run effects of location 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, systematic empirical evidence on the long run effects of the TVA program on economic activity is limited.[12]

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. In subsections 3.1 and 3.2 we describe two alternative ways to identify a plausible counterfactual for the TVA region. In subsection 3.3 we report program impacts, and in subsection 3.4 we discuss how to interpret the findings.

3.1 First Research Design

We begin by comparing long run *changes* in TVA counties with long run *changes* in counties outside the TVA that before the inception of the program had similar economic, social, demographic and geographical characteristics.

We control 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

[12]As mentioned above, Ziliak (2011) studies the impact of the Appalachian Regional Development Act. Bateman, Ros and Taylor (2009) study of the effect of public investments during the Great Depression and World War II on economic development in the South. Using surveys of industrial firms that moved to the South after the War, they find evidence consistent with big-push dynamics.

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.

To further increase comparability of TVA and non-TVA counties, we drop from our models control counties which, based on their pre-program characteristics, appear to be substantially different from TVA counties (see Angrist and Pischke, 2009 for a general discussion of the merits of this procedure). 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).

We present two sets of results: estimates based on the entire U.S. and estimates that focus on the South only. One potential concern is that the economies of counties outside but near TVA may be directly affected by the program.[13] To address this concern, we drop all non-TVA counties that border the TVA region.

Figure 3a provides a map of counties in our trimmed estimation sample, and columns 5 through 7 in Table 1 show the unconditional averages in the trimmed 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:

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

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

[13] In principle, this spillover 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.

of identifying the average treatment effect on treated counties in the presence of treatment effect heterogeneity.[14]

Another appealing characteristic of the Oaxaca-Blinder estimator is its dual interpretation as a propensity score reweighting estimator (see Kline, 2011 for discussion).[15] 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.

To give an exact idea of what areas are used as a counterfactual by our estimator, Figure 3b 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.

The residual in equation 1 is likely to spatially correlated. We deal with this possibility by presenting two sets of standard errors. First, we compute standard errors clustered by state. These variance estimates allow for unrestricted spatial correlation across counties within each state, but assume no correlation across states. Second, we use 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.

Of course, the TVA was not the only spatially biased intervention occurring 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 (Busso, Gregory, and Kline, 2012) but also of other federal interventions that affect local labor demand, like the construction of the federal highway system (Michaels, 2008) or military expenditures (Blanchard and Katz, 1992). More generally a variety of government policies may have had uneven geographic impacts including federal taxation (Albouy, 2009), environmental regulation (Chay and Greenstone, 2003, 2005) or labor regulation (the Taft-Hartley Act, for example, effectively allowed Southern states to become right-to-work states). Thus, our estimates are to be interpreted as the impact of the TVA on the TVA region, allowing for the potentially endogenous response of

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

[15] 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.

other federal and local policies that might have occurred over the time period in question.

A Test of the 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, where we estimate the "effect" of TVA on 1900-1940 changes in population, employment, housing units, manufacturing wages, industry structure and agricultural land values. 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.[16] (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.)

Throughout the paper, we report decadalized growth rates to aid comparability 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.[17] 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. Column 5 reports standard errors obtained from a spatial Heteroscedasticity and Autocorrelation Consistent (HAC) variance estimator (Conley, 1999), where we use a bandwidth of 200 miles.

A comparison of Columns 1 and 3 in Table 2a 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

[16] As we argued before, the vast majority of the program took place after 1940.

[17] 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.

along some dimensions. However, column 3 shows that, after conditioning on 1920 and 1930 covariates, all of these differences become statistically indistinguishable from zero. Notably, this is due to the point estimates shrinking substantially rather than an increase in the standard errors.

Table 2b reports analogous figures for the sample of Southern counties. In this table, we focus on spatial HAC standard errors because state clustered standard errors are unlikely to be valid when considering just one region of the country. In this case, both the unconditional differences and the conditional differences are statistically indistinguishable from zero. In other words, even before controlling for any covariates, the economic and demographic trends in TVA counties are not different from the rest of the South. This suggests that Southern counties may represent a good counterfactual for the TVA region.[18]

3.2 Second Research Design

As an alternative design, we use the failed attempts by members of Congress to create several additional Authorities to construct a set of control regions. From the beginning, TVA was supposed to be the first of many regional Authorities. In a 1933 message to Congress urging passage of the Tennessee Valley Authority legislation, President Roosevelt stated that: "If we are successful here we can march on, step by step, in a like development of other great natural territorial units within our borders." In the next few years, reports of the alleged success of the TVA moved many members of Congress and regional leaders – especially Senator George W. Norris of Nebraska – to support the creation of additional Authorities in other parts of the United States. This effort culminated in the introduction by Senator Morris on June 3, 1937 of a Senate bill that envisioned the creation of seven new Authorities, one for each region of the country.

At the time, the bill was considered likely to pass. In his detailed account of the events, Leuchtenburg (1952) notes that "throughout the spring of 1937, newspaper dispatches left little reason to conclude anything but that Roosevelt and Norris were one in attempting to extend the TVA pattern to several other regions" and that Congress appeared generally

[18] 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. The point estimates for population, for instance, is negative for the South, while it is positive for the entire U.S.. In neither case are these estimates statistically different from zero. For agricultural land values, the point estimate is positive for the U.S. and negative for the South.

supportive. But a split within the FDR administration on the exact nature of the power to be granted to the Authorities lead to delays, postponements and the ultimate failure of the bill.[19]

In the three following years, several attempts were made to resuscitate the proposal, but the changing balance of power between liberals and conservatives in Congress prevented quick action. The push for new authorities, suspended by the onset of World War II, gathered new momentum towards the end of the war. In 1945, ten bills proposing the establishment of "valley authorities" comparable to the Tennessee Valley Authority were before Congress. Contemporary accounts suggest that approval was again considered likely. For example, Clark (1946) observes that "it seems almost a certainty that within a few years the regional authority idea which has received so much publicity as a result of the success of the TVA will be given further impetus by the enactment of additional valley authority laws." But none of the bills mustered enough support for final approval and they were ultimately dropped.

In our second design, we compare TVA counties to counties located within the local economic development Authorities that were proposed but not implemented. Relative to the first research design, this strategy has both advantages and disadvantages. On one hand, these authorities offer a credible counterfactual because they were modeled on TVA, and were therefore likely to be economically similar by design. Moreover, the proposed authorities had a reasonable ex-ante chance of getting implemented but ultimately failed due to largely exogenous political reasons. Thus, economic changes in these regions may be informative of the changes that might have occurred to the TVA regional economy had TVA not been implemented. On the other hand, the proposed authorities never reached the implementation phase. While the proposed legislation identified the general geographical scope of the regional authorities, it did not specify exactly which counties were going to belong to each authority. This limitation requires us to make some assumptions on their

[19]Specifically, Leuchtenburg (1952) reports that Agriculture Secretary Henry Wallace, who administered the Soil Conservation Service, and War Secretary Harry Woodring, who administered the Corps of Engineers, objected to the plan. Wallace and Woodring told Roosevelt and Interior Secretary Harold Ickes that they would approve of regional planning authorities only if they were limited to a planning role. In particular, they opposed the empowerment of new agencies to administer soil conservation and water projects for fear of demoralizing existing agencies. In addition, planners in Roosevelt's advisory National Resources Committee opposed features of the Norris bill that conflicted with their own proposals, which they never introduced as legislation. Power companies and Senator Copeland of New York opposed power production by valley authorities. Roosevelt asked his staff to redraft Norris's bill with the watered-down planning features that Wallace and Woodring had suggested. Senator Joseph J. Mansfield, chair of the House Rivers and Harbors Committee, introduced a competing watered down bill with a different set of provisions. Ultimately, the Norris bill and the Mansfield bills failed to overcome opposition.

exact geographical definition.

In practice, to identify the geographical scope of the proposed authorities, we rely on the historical account of the deliberations in Leuchtenburg (1952, 1997) and on bill HR 1824, titled "The Conservation Authorities Act," introduced on Jan. 29, 1945, by Representative John E. Rankin of Mississippi.[20] We end up using the six Authorities listed by Leuchtenburg, and their geographical borders as specified in HR 1824: an Atlantic Seaboard Authority, a Great Lakes-Ohio Valley Authority, Missouri Valley Authority, Arkansas Valley Authority, Columbia Authority, and a Western authority.[21] We assume that within each region, the exact boundaries of each authority would have have been identified using the same criteria used by TVA geographers and listed in Section 2.2 above. In the Appendix, we provide more details on the regions and on the exact algorithm used.

In total, the six counterfactual authorities include 828 counties in 25 states. A map of the counterfactual authorities is provided in Figure 4. We again fit models of the form given in equation 1, estimated on the sample of counties that belong either to TVA or one of the proposed authorities. Unlike with the first identification strategy, we do not drop counties with low propensity scores because we want this identification strategy to be based mainly on the historical accident of the failed authorities. Like for the models that include only Southern counties, we rely on a HAC variance estimator for inference due to the limited number of states in this sample.

Columns 4 and 8 in Table 1 presents summary statistics for counties belonging to these regions.[22] Since the proposed authorities are from all regions of the country, but were chosen with criteria similar to TVA, they have pre-program characteristics generally closer to the TVA counties than the average U.S. county. Among the key variables of interest, a comparison of columns 1 and 4 reveals that 7.7% and 7.5% of workers are employed in manufacturing in 1930 in the proposed authorities and in the TVA region, respectively. The corresponding figure for the average U.S. county outside the TVA region is significantly higher at 9%. In the case of agricultural employment share, the means in TVA, proposed authorities, and the non-TVA U.S. are 61%, 51% and 45%, respectively. More importantly, the change over time in the manufacturing share between 1920 and 1930 in the proposed

[20]Among the 10 bills in front of Congress in 1945, HR 1824 appears to be the most detailed.

[21]HR 1824 splits the Western authority into three separate authorities: Great Basin Authority, California Authority, and Colorado Authority, but Leuchtenburg presents as more likely the scenario where these three authorities are merged into one.

[22]Because we do not drop counties with low propensity scores, columns 4 and 8 are identical.

authorities and in the TVA is respectively -.010% and -018%, vs. a nationwide change of -0.035%. However, other trends in the counterfactual authorities are not always identical to trends in the TVA. For example, population, employment and housing units in proposed authorities grew significantly more slowly than in TVA counties between 1920 and 1930, while farm values declined significantly faster.

A Test of the Design. Table 2c presents the result of a placebo experiment based on the proposed authorities. Only the change in agricultural land values appears to be statistically different before conditioning (column 1).[23] Like for the model with all U.S. counties in Table 2a, the difference in land value trends is economically very large. However, the difference becomes considerably smaller and statistically insignificant after conditioning on our controls (column 3). In general, we find no statistically significant differences with TVA counties after conditioning on controls.

Overall, we interpret the evidence in Tables 2a, 2b and 2c 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. In the case of the South, TVA counties seems comparable even before conditioning on our controls. Of course, the tests in Tables 2a, 2b and 2c are based on features of local economies that we can observe. They cannot tell us whether there are unobserved features of the TVA region that differ from our comparison groups. Thus we can not completely rule out the possibility that TVA counties experienced unique unobserved shocks between 1940 and 2000. However, we think it unlikely that the three sets of comparison groups (the U.S., the South, and the proposed authorities) would suffer from identical selection biases. Hence, we focus on conclusions that appear robust across the three sets of comparison groups.

3.3 Estimates of the Effect of the Program

We now turn to our estimates of the effect of TVA on local economies. In this subsection, we describe our empirical findings. In subsection 3.4 we discuss the economic interpretation of these results in more depth.

[23]Compared to the South (Table 2b), counties in proposed authorities are further apart from TVA. This is probably to be expected, since proposed authorities are in all regions of the country.

(A) Long Run Estimates. Table 3a provides estimates of the effect of TVA on long run growth rates, using all U.S. counties as a comparison group. 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. Similarly, the lack of an effect on housing prices may reflect the lack of supply constraints. The estimated effect on median family income (available only since 1950) is statistically insignificant, but quantitatively sizable.

Table 3b provides estimates of the effect of TVA on long run growth rates, using only Southern counties as a comparison group. Consistent with the findings in Table 2b, we find evidence that selection is less of a concern in this sample, as our conditional and unconditional estimates are more similar. Reassuringly, many of the estimated impacts in column 3 are similar to those in the corresponding column of Table 3a. The estimated impact on agricultural employment and manufacturing employment are -0.51 and .063, respectively. Unlike Table 3a, however, the effect on family income is 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.

Table 3c provides estimates of the effect of TVA on long run growth rates using proposed authorities as a comparison group. The conditional estimates in column 3 appear to be similar to the ones in Table 3a and, especially, the ones in Table 3b. The estimated impact on agricultural employment is -0.071, while the estimated impact on manufacturing employment is 0.053. Like in Table 3b, median family income in the TVA region appears to increase faster than in the counterfactual areas.

In general, results based on a comparison of TVA with the rest of the U.S., the rest of the South, and the proposed authorities all yield a consistent picture. The strongest effect of the program was on jobs in agriculture and manufacturing. There is little evidence that local prices, particularly manufacturing wages and housing prices, changed significantly. But median family income seems to have improved, driven presumably by the replacement of agricultural jobs with better paying manufacturing jobs.

(B) Estimates by Period. In Table 4, we present separate estimates for the period 1940-1960 and 1960-2000. Specifically, we estimate Oaxaca-Blinder models analogous to those in column 3 of Table 3a, 3b and 3c. We report estimates based on the comparison of TVA counties with all other U.S. counties in columns 1 and 2; with Southern counties in columns 3 and 4; and with counties in proposed authorities in columns 5 and 6.

Recall that 1940-1960 is the period of maximum generosity of the federal subsidies to TVA. In this period, the TVA region experienced a major increase in transportation infrastructure and electricity supply relative to the rest of the country, paid for by federal funds. By contrast, the four decades after Congress makes TVA financially self-sustaining in 1959 are characterized by limited federal transfers to TVA.

Empirically, the differences between the two periods are striking. In the earlier period the 10-year growth rate of employment in both agriculture and manufacturing is 10.6 - 11.6 percentage points larger in the TVA region than in the rest of the U.S. and the rest of the South. When estimated relative to the proposed authorities, these figures are 11.9 and 9.7 percentage points respectively. These are remarkably large employment effects, probably explained by an increase in labor demand due to the rapid electrification of the region and the addition of new transportation infrastructure. The impacts on growth rates of population and farm land values also appear substantial, however the estimates are very imprecise and preclude definitive conclusions.[24] The value of farm production increases significantly.

[24] For example, the point estimate for population are .037, .042, and 0.028 depending on the exact comparison group, pointing to a much faster population growth in the TVA region relative to the rest of the country.

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. Estimates range between -13 and -16 percentage points, depending on the comparison group.

By contrast, even after the cessation of federal outlays, manufacturing employment keeps growing significantly faster in TVA counties (although less fast than in the early period). Estimates that use as a comparison group the entire U.S., the South or the proposed authorities, are 3.3, 3.5 and 3.2 percentage points, respectively. We see little evidence of an impact on population or agricultural land values during this period.

3.4 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 accelerating the pace 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. Consistent with existing historical evidence on labor mobility in the South,[25] this suggests a large population of potential workers capable of moving to the region or switching out of local agriculture and into manufacturing.[26] The effect on housing values and agricultural land prices also appears to be rather modest. This is consistent with an elastic supply of housing and land – certainly plausible in a region characterized by limited legal and political constraints to development and very permissive land use regulations.

Importantly, our analysis uncovered a striking degree of temporal heterogeneity in this employment response. Over the period 1940-1960 – when TVA enjoyed large federal transfers

However, given the magnitude of the standard errors, these estimates are not statistically significant.

[25] See, for example, recent work by Hornbeck (2012b and 2011c) and Hornbeck and Naidu (2012) on labor reallocation following historical localized shocks to Southern counties.

[26] 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 eventually occupied by members of subsequent generations.

– we find a sharp increase both in manufacturing and agricultural employment. While over the period 1960-2000 – when the TVA subsidies were scaled back – we find a retrenchment in agriculture. Manufacturing employment, by contrast, continued to grow even after the end of federal investment.

Of course, the TVA dams and public infrastructure did not disappear when transfers to the region stopped. Rather, the value of these investments gradually depreciated. 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. This interpretation would imply a depreciation rate for dams, roads and canals of roughly 2% per year.[27] In practice, of course, the TVA infrastructure was not allowed to fully depreciate. But from 1959 onward maintenance of the TVA capital stock was paid for by local taxpayers and local users of electricity.

The resilience of manufacturing employment in the face of this depreciation of the initial capital infusion indicates that firms in the region enjoyed a competitive advantage even after the subsidies lapsed, presumably because of agglomeration effects induced by the initial TVA investment. On a cursory level then, our interpretation of the estimated impacts is that the TVA program successfully generated a self-reinforcing process of economic development strong enough to sustain a larger manufacturing base in the long run. Because the manufacturing sector paid higher wages than agriculture, this shift raised aggregate income in the TVA region for an extended period of time.

But even if this interpretation is correct, we cannot necessarily conclude that TVA was a beneficial investment from the standpoint of the entire nation, as it may have destroyed agglomerations elsewhere. That is, the TVA may have simply reallocated manufacturing activity across space without raising national income. As pointed out by Glaeser and Gottlieb (2008), unless the agglomeration forces sustaining a place based policy are substantially nonlinear, reallocating employment is unlikely to be welfare enhancing. Linear agglomeration forces imply that shifting economic activity from one part of the country to another yields productivity gains in receiving areas that are perfectly offset by the productivity losses elsewhere. By contrast, with nonlinear agglomeration forces, shifting economic activity from

[27] 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. We find this degree of depreciation quite reasonable. In fact, this figure is somewhat lower than the rate of depreciation for roads, dams and other public capital actually used by planners and governmental agencies in the South, which is often closer to 4% or 5%. See for example, Mississippi State Auditor (2002).

one part of the country to another has the potential to improve aggregate welfare, as the gains in the region that receives the transfer may exceed the losses in the region that pays for it.

The policy evaluation exercises conducted thus far allow us to isolate the impact of TVA on the regional economy, but cannot be used to identify the effect of TVA on the entire U.S. economy. Put simply, we cannot construct a credible counterfactual for the entire U.S. economy in the absence of TVA. In particular, we cannot estimate how many manufacturing jobs outside the TVA region were diverted by the TVA program, nor can we directly assess the impact of the program on national income.

In order to make progress on these important questions, in the next section we develop an approach to estimating the shape of local agglomeration forces in manufacturing based upon examining the dynamic responses of counties to representative shocks to their manufacturing base. Our estimation strategy relies on an equilibrium model that, while simple, yields a transparent approach to identifying the shape of local agglomeration forces. Our findings provide a structural interpretation of TVA's partial equilibrium effects and shed light on the potential for any TVA induced reallocations of manufacturing activity to be efficiency enhancing in the aggregate.

Our approach allows us to address the original questions posed by Glaeser and Gottlieb regarding the welfare impacts of pure geographic reallocations of production, which are an important component of the employment effects of the TVA. We note, however, that in partial equilibrium models like that of Glaeser and Gottlieb (2008), all employment gains in a region necessarily come at the expense of employment elsewhere because labor supply is fixed. A full employment benchmark is not unreasonable when considering long run growth patterns. However, in the case of TVA – and any other place based policy targeting the manufacturing sector – it is possible that many of the local manufacturing jobs created come at the expense of employment in other sectors exhibiting substantially weaker agglomeration forces, and hence entail fewer offsetting social costs.[28] Our estimates also inform discussion of the potential gains from such intersectoral reallocations by deducing the strength of agglomeration in the manufacturing sector.

[28] In the case of the TVA, one expects some of the manufacturing workers to have been diverted from working in agriculture which is unlikely to exhibit agglomeration effects.

4 Did TVA Raise Aggregate Productivity?

In this section, we assess whether reallocations of manufacturing activity across space may affect aggregate manufacturing productivity by examining the dynamic responses of counties to shocks to their manufacturing base. We develop a simple partial equilibrium model to frame our empirical strategy and formalize our discussion of the potential efficiency consequences of reallocation. To introduce our approach, consider the response of a typical U.S. county to a permanent increase in local manufacturing productivity brought on, say, by an improvement in the local transportation infrastructure. With higher productivity, more manufacturing jobs will be created, thereby attracting more manufacturing workers. But if agglomeration forces are important, this inflow will feed back into further increases in local productivity, thereby generating more jobs and attracting even more workers.

To isolate the strength of the agglomeration channel then, one must be able to separate a county's initial employment response to a shock from the feedback effects of that response – the stronger the feedback, the stronger the agglomeration. To detect any nonlinearities in the agglomeration forces, one must additionally be able to infer whether these feedback effects are stronger in underdeveloped counties than in counties with more established manufacturing bases.

Ideally, one would like to be able to investigate this question by randomly assigning manufacturing plants to counties and measuring how many additional workers are subsequently attracted to areas awarded plants. Recent research by Greenstone, Hornbeck and Moretti (2010) attempts to approximate such an experiment by examining the consequences of the siting decisions of million dollar manufacturing plants. Though the authors find evidence of substantial agglomeration effects, they lack the statistical power necessary to detect subtle nonlinearities of the sort necessary for setting policy. Moreover, their study restricts attention to a small subset of U.S. counties that bid for manufacturing plants, which may not tell us much about the effects of *losing* plants in counties with more developed industrial bases.

To address these shortcomings, we analyze four decades worth of observational changes in manufacturing employment in the baseline sample of U.S. counties considered in our earlier analysis. The fundamental difficulty confronting such an exercise is that the shocks leading county manufacturing to change in the first place may be persistent across decades, in which case we may mistake the persistence of the shocks for the feedback effects of increases in manufacturing density. Thus, we face the traditional econometric challenge of separating state dependence from serial correlation in unobservables.

To address this problem, we rely on an instrumental variables strategy to isolate variation in manufacturing employment unlikely to directly induce manufacturing changes in subsequent decades. To preview the results, we find that employment changes lead to subsequent changes in employment, but that the relationship is roughly linear, which suggests the aggregate effects of reallocating manufacturing activity are likely to be small. Although the estimation strategy in this section uses sources of identification that are different from the previous section, and makes stronger assumptions on the process of economic growth, the model's predictions turn out to be roughly consistent with the reduced form impacts on manufacturing employment uncovered in the previous section.

4.1 A Model of Manufacturing Reallocation 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 three fundamental sources: amenity differences, unobserved locational productivity advantages, and endogenous agglomeration externalities. Capital and labor are assumed to be perfectly mobile across counties at decadal frequencies. This assumption is in keeping with evidence from Blanchard and Katz (1992) who find that labor and capital adjustment to local shocks completes within a decade. Likewise, workers are assumed to possess homogenous tastes as in the classic models of Rosen (1979) and Roback (1982) and labor supply is presumed to be fixed.[29,30] 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:

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

[29]The homogeneity assumption is a strong one and, in many cases, would not be appropriate for modeling place based policies as argued by Kline (2010) and Moretti (2011). We employ it 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.

[30]Fixed labor supply is a standard assumption in spatial equilibrium models but in our context implies that employment gains in an area must come at the expense of employment losses elsewhere. We return to the importance of this assumption in the conclusion.

where $\overline{u}_t$ varies only across years.[31]

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 depends upon both fixed locational fundamentals 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 of TVA, and an idiosyncratic component 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,

[31] By treating $\overline{u}_t$ as a fixed constant, we are taking a partial equilibrium approach to the modeling of county responses to shocks. This is in line with our focus on understanding the productivity impacts of *reallocations* of manufacturing activity between counties conditional on the state of aggregate demand. To study the full national impact of a large intervention like TVA which might add to national aggregate demand, one would want to adopt a general equilibrium framework with variable labor supply where $\overline{u}_t$ would be a function of the state of all county economies. This would necessitate a different empirical approach with much stronger assumptions about the structure of the aggregate economy.

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 decade effect γ_t captures national changes in productivity common to all counties.

The error ε_{it} represents the idiosyncratic component of county productivity. Following the evidence in Blanchard and Katz (1992) on the persistence of local employment changes, we assume ε_{it} contains a unit root, so that:

$$\varepsilon_{it} = \varepsilon_{it-1} + \xi_{it} \tag{5}$$

where ξ_{it}, which may itself be serially or spatially correlated, represents unobserved shocks to productivity. Such shocks could include unobserved changes in local infrastructure, shifts in the preferences of consumers, changes in the regulatory environment, or technological innovations.

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.[32] 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. 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.[33] This determinism is desirable as it rules out implausible situations where a given county could take on in any given period wildly different levels of manufacturing activity by chance (see Krugman, 1991; Matsuyama, 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 a slow-moving process that takes time to develop. Our choice to allow agglomeration to operate through the density of manufacturing employment per square mile is consistent with the view that agglomeration effects may arise through social interactions and learning (Glaeser, Kallal, Scheinkman, and Schleifer, 1992) or through thick market

[32] See for example Henderson (1995, 1997, 2003) and Ahlfeldt et al. (2012). Duranton and Puga (2004) and Henderson (2005) provide reviews.

[33] Duranton (2007) explores the effects of a similar timing assumption in his model of urban growth.

effects (Moretti, 2011).

4.2 Comparative Dynamics: An Interpretation of the Reallocative Effects of the TVA

The elements of our model developed so far allow for a more precise discussion of the dynamic effects of place based policies such as TVA.[34] The 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 of TVA hinge crucially on the nature of the agglomeration function $g(.;\theta)$. Figure 5 contrasts a hypothetical county's behavior when $g(.;\theta)$ is linear with that when it is substantially nonlinear. Consider first the panels of Figure 5a, which depict the linear case. 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 LR curve is flatter than 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.[35] 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

[34] The dynamic effects of the productivity shocks ξ_{it} can also be graphically analyzed in this framework. Since those shocks are assumed permanent and do not involve a depreciation component, they yield a permanent response regardless of the shape of the agglomeration function.

[35] Note however that this "steady state" is in fact conditional on the idiosyncratic component of productivity ε_{it}. Because ε_{it} contains a unit root, the intercept of the LR curve is itself nonstationary.

period lag in agglomeration yields geometric adjustment to the steady state, depicted in the final panel of Figure 5a. Hence, the model exhibits conditional convergence of the sort found in traditional growth models (Barro and Sala-i-Martin, 2004).[36]

In this setting, linearity has two implications. First, given positive depreciation, the TVA can have only temporary effects on employment. Once the direct productivity effects of TVA lapse, the LR curve slowly reverts back to its original position as the initial infrastructure investment depreciates (the δ_t coefficients go negative) and the employment gains are gradually reversed.

Second, there can be no aggregate effect of TVA on manufacturing productivity other than through the direct effects of the TVA infrastructure. That is, there are no aggregate productivity gains associated with the influx of workers from other communities. Because of the linearity in $g(.;\theta)$, the agglomeration based productivity gains to this region associated with the additional workers must equal the losses in the counties from which those workers came.

Contrast this setting with Figure 5b, which shows the case where $g(.;\theta)$ is nonlinear. Here $g(.;\theta)$ exhibits 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.

Two key differences emerge here relative to the linear case. First, and most importantly for our purposes, the influx of workers to the TVA region can have a positive effect on aggregate productivity. Due to the nonlinearity, the productivity gains to the TVA region may be much larger than the losses in the rest of the country. In fact, if workers come from developed regions on the downward sloping portion of the LR curve, productivity in those areas may actually rise as they lose workers because outmigration alleviates crowding of the fixed factor.

Because we are ultimately interested in understanding the aggregate effects of reallocations of manufacturing activity, our empirical analysis in the next subsection centers on estimating the shape of the function $g(.;\theta)$. Our goal is to determine whether Figure 5a or 5b (or some intermediate case) provides a better approximation to the dynamics of county growth.[37]

[36]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) and the current state of the idiosyncratic component ε_{it}.

[37]Though not depicted here, it is clearly possible to have nonlinearity but a single steady state equilibrium.

Uncovering the the shape of the function $g(.;\theta)$ is critical to understanding whether place based policies like TVA can be welfare improving for the U.S. as a whole.

The second difference with the linear case is that multiple steady state equilibria are present, two of which are stable and one of which is an unstable tipping point.[38] 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 5b to be crossed.

4.3 Identification and Estimation

To estimate the model's parameters we consider four decades of changes in log manufacturing density as measured in the Decennial Census.[39] Identification 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 may increase disamenties like pollution. Likewise, M_{it} and η_i may be correlated if, say, areas with particularly rugged terrain or bad weather 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 use 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:

$$\ln(L_{it}) = -\frac{1-\alpha}{\beta}\ln w_{it} + \frac{1}{\beta}g\left(\frac{L_{it-1}}{R_i};\theta\right) + \frac{\delta_t}{\beta}D_i + \widetilde{\eta}_i + \widetilde{\gamma}_t + \widetilde{\varepsilon}_{it} \qquad (6)$$

where tilde's over variables indicate they have been renormalized by $-\frac{1-\alpha}{\beta}$. 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.[40]

[38]That is, the system exhibits locally, but not globally, convergent dynamics.

[39]Specifically, we construct a pooled county level panel from the 1960-1970, 1970-1980, 1980-1990, and 1990-2000 changes in the counties considered in section 3.

[40]This restriction is an artifact of the Cobb-Douglas functional form which imposes a unitary elasticity of substitution between capital and labor.

To remove the county fixed effects we take decade level differences as follows:

$$\begin{aligned}\ln\left(L_{it}\right)-\ln\left(L_{it-1}\right) &= -\frac{1-\alpha}{\beta}\left(\ln w_{it}-\ln w_{it-1}\right)+\frac{1}{\beta}\left[g\left(\frac{L_{it-1}}{R_i};\theta\right)-g\left(\frac{L_{it-2}}{R_i};\theta\right)\right]\\ &\quad+\frac{\delta_t-\delta_{t-1}}{\beta}D_i+\widetilde{\gamma}_t-\widetilde{\gamma}_{t-1}+\widetilde{\xi}_{it}\end{aligned}$$

Covariates are introduced into the model by assuming the productivity shocks may be written:

$$\widetilde{\xi}_{it}=X_i'\lambda+\nu_{it}, \tag{7}$$

where X_i contains the vector of 1920 and 1930 covariates used in our earlier reduced form analysis of TVA.

The 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 assume that the function is well approximated by a third order polynomial in the log of manufacturing density, so that:

$$g\left(\frac{L_{it}}{R_i};\theta\right)=\theta_1\ln\left(\frac{L_{it}}{R_i}\right)+\theta_2\ln\left(\frac{L_{it}}{R_i}\right)^2+\theta_3\ln\left(\frac{L_{it}}{R_i}\right)^3. \tag{8}$$

Note that the intercept of this function has been normalized to zero as it is not separately identified from η_i.

With these assumptions, we obtain the following estimating equation:

$$\begin{aligned}\ln\left(L_{it}\right)-\ln\left(L_{it-1}\right) &= -\frac{1-\alpha}{\beta}\left(\ln w_{it}-\ln w_{it-1}\right)+\frac{\delta_t-\delta_{t-1}}{\beta}D_i\\ &\quad+\frac{\theta_1}{\beta}\left[\ln\left(\frac{L_{it}}{R_i}\right)-\ln\left(\frac{L_{it-1}}{R_i}\right)\right]\\ &\quad+\frac{\theta_2}{\beta}\left[\ln\left(\frac{L_{it}}{R_i}\right)^2-\ln\left(\frac{L_{it-1}}{R_i}\right)^2\right]\\ &\quad+\frac{\theta_3}{\beta}\left[\ln\left(\frac{L_{it}}{R_i}\right)^3-\ln\left(\frac{L_{it-1}}{R_i}\right)^3\right]\\ &\quad+X_i'\lambda+\widetilde{\gamma}_t-\widetilde{\gamma}_{t-1}+\nu_{it}\end{aligned} \tag{9}$$

A key impediment to estimation of (9) is that ν_{it} may be serially correlated, which would lead to bias in OLS estimates of the θ coefficients (Nickell, 1981; Arellano and Bond, 1991). This bias emerges because a regression will attribute all of the serial correlation in employment changes to state dependence (agglomeration) when some of it is actually the result of additional shocks. If the ν_{it} are positively correlated any agglomeration effects will be overstated. If, on the other hand, the shocks are negatively correlated, OLS will yield an underestimate of the degree of state dependence.[41]

While some interpretations of the distribution of city sizes (e.g., Gabaix, 1999; Eeckhout, 2004) suggest that local growth may be the result of a series of uncorrelated permanent shocks, we think it prudent to consider seriously the possibility that shocks are mildly positively correlated. That is, that the sources of change in one decade are somewhat similar to the sources of change in the subsequent decade. To address this problem, we employ an instrumental variables strategy relying on lagged manufacturing changes.

Our instruments are of the form:

$$Z_{it}^{(k)} \equiv \ln(L_{it-2})^{(k)} - \ln(L_{it-3})^{(k)} \tag{10}$$

for $k \in \{1, 2, 3\}$. That is, the instruments are changes in polynomials of log manufacturing employment lagged by two decades.[42] To avoid any mechanical correlation with the elements of $g\left(\frac{L_{it-1}}{R_i};\theta\right) - g\left(\frac{L_{it-2}}{R_i};\theta\right)$ that might result from measurement errors in L_{it-2}, we construct these instruments using manufacturing employment data from the Economic Census while the endogeneous variables are measured using employment data from the Decennial Census.[43]

The instruments are valid under the assumption that shocks to productivity are uncorrelated over a horizon of 20 years, so that:

$$E[\nu_{it}\nu_{it-2}] = 0. \tag{11}$$

Note that this condition is essentially equivalent to assuming that counties lack idiosyncratic trends in productivity. The main reason for why trends might be present is if counties exhibit convergence in manufacturing activity for reasons having little to do with agglomeration (e.g., as in the capital mobility arguments in Barro and Sala-i-Martin (1991, 1992a, 1992b)).[44]

We account for this possibility in three ways. First, we condition on the vector of baseline

[41]Negative correlation could result, for example, if instead of (5) the idiosyncratic component of productivity ε actually followed a stationarity autoregressive process.

[42]Note that this functional form mirrors that of the endogenous variables in (9).

[43]Because the manufacturing Census is conducted irregularly and in off years, the instrument is typically an 18 year lag rather than a exact 20 year lag.

[44]Michaels, Rauch, and Redding (2012) argue that local convergence patterns are driven by initial agricultural share although the dynamics of their model are actually generated in part by a static agglomeration force in manufacturing.

controls X_i, which include 1920 and 1930 population and quadratics in 1920 and 1930 agricultural and manufacturing shares. These variables ought to absorb much of the variation in initial conditions giving rise to convergence based heterogeneity in growth rates. Second, in some specifications we also condition on 1940 manufacturing density which will be a negative predictor of growth if conditional convergence is present. Third, we also examine the robustness of our results to the inclusion of fixed regional trends. While these approaches do not guarantee that all trend heterogeneity has been removed, we believe that the general robustness of our results to their inclusion suggests that our results are not spurious.

A second, unrelated problem is the potential endogeneity of $\ln w_{it} - \ln w_{it-1}$ which might be correlated with ν_{it} if amenity shocks are contemporaneously correlated with productivity shocks. This regressor also faces a potential division bias (Borjas, 1980) due to measurement errors in manufacturing employment which are used as the denominator in our manufacturing wage measure. To deal with this potential correlation, in some specifications we calibrate $-\frac{1-\alpha}{\beta}$, which represents the (short-run) elasticity of labor demand. In his review of empirical estimates, Hamermesh (1993) points to 1.5 as the most plausible estimate of the relevant labor demand elasticity. We use this as our starting point, and then assess the sensitivity of our estimates to different values of the elasticity.

4.4 Results

Table 5 provides OLS and two stage least squares (2SLS) estimates of the structural parameters in (9). The first column reports OLS estimates assuming $g(\frac{L_{it-1}}{R_i}; \theta)$ is log-linear. We find evidence of persistence in manufacturing changes – a 10% increase in manufacturing density is associated with a 0.82% increase in density in the following decade. In the context of our model, this would suggest modest agglomeration effects consistent with a single steady state equilibrium. The coefficient on the TVA dummy is statistically indistinguishable from zero. This suggests the direct productivity effects of TVA were constant over the sample period, which is consistent with the notion that the TVA infrastructure exhibited a constant rate of depreciation from 1970-2000.

Columns 2 and 3 of Table 5 examine the effect of introducing controls for 1940 manufacturing density and regional trends which might capture forces outside of the model giving rise to convergence. Notably, these controls yield only small reductions in the estimated strength of the agglomeration effects – the qualitative results are essentially unchanged.

This lends some credibility to the notion that unobserved area-specific trends may not be very important.

Estimates in the the fourth column address endogeneity by instrumenting changes in manufacturing density using lagged changes in manufacturing density. As expected, instrumenting raises the estimated degree of persistence in manufacturing changes. Now a 10% increase in manufacturing density is associated with a roughly 2.2% increase the next decade. Though the standard errors increase somewhat, we can still easy rule out both the absence of agglomeration effects and explosive behavior (a coefficient great than 1) at conventional significance levels. Columns 5 and 6 show that these findings are robust to the inclusion of controls for heterogeneous trends and 1940 manufacturing density.

Specifications in columns 7 through 12 allow for nonlinearities by including a full third order polynomial for the agglomeration function. To give a sense of the implied curvature, at the bottom of the table we report the marginal effect of an increase in manufacturing employment at various percentiles of the 1980 cross-sectional distribution of employment density. The null hypothesis of linearity is easily rejected when the OLS estimator is used in columns 7 to 9. Surprisingly, the coefficients suggest a convex agglomeration function, with the marginal effect of an increase in manufacturing employment at the 20th percentile of the density distribution estimated to be substantially smaller than that at the 50th or 80th percentiles.

The specifications in columns 10 through 12 are estimated by 2SLS. First stage partial F-statistics of the sort proposed by Angrist and Pischke (2009) are given in brackets for each endogenous variable and suggest a reasonably strong first stage relationship for each polynomial term. As before, instrumenting increases the magnitude of the estimated agglomeration effects.

Importantly, our point estimates again suggest an agglomeration function that is convex in log manufacturing density. To see the shape of the agglomeration function more clearly, Figure 6 shows the estimated agglomeration function and its 95% confidence interval. The figure is based on the specification in column 11, but specifications in other columns provide a similar picture. As was the case with OLS, we can reject the null hypothesis that the structural relationship is linear.

A troubling feature of these estimates is the incorrect sign on wages which, if taken literally, would imply that the short run inverse demand curve for labor slopes up. As discussed above, this is not unexpected, and likely reflects a combination of measurement error and correlation between amenity and productivity shocks. To address this problem, Table 6 provides estimates calibrating the short run labor demand elasticity $-\frac{1-\alpha}{\beta}$ at various plausible values taken from the literature.[45] Based on Hamermesh's (1993) review, we use 1.5 as the most likely value for the elasticity, also reporting estimates setting the elasticity equal to 1 and 2.[46] Table 6 indicates that the results are not sensitive to the specific value chosen.

Calibrating the short run elasticity has two general effects on the results. First, we find somewhat larger agglomeration effects in our 2SLS specifications. For example, in our moderate elasticity scenario, the marginal effect of an increase in manufacturing density for a median density county rises by about 60% relative to the uncalibrated case.

Second, and most importantly, the apparent convexity of the structural agglomeration function disappears with calibration. The estimated marginal effects in the 2SLS specification of Table 6 are approximately equal at different points in the distribution of manufacturing density and we lose the ability to reject the null hypothesis that the quadratic and cubic terms are insignificant.

Figure 7 depicts the estimated agglomeration function from column 7 of Table 6 along with its corresponding 95% confidence interval. The estimated function is very close to linear in log manufacturing density. Alternative specifications yield similar conclusions. Thus, our estimates, particularly those with the intermediate short run demand elasticity of 1.5, cast doubt on the notion that the agglomeration function is nonlinear.

4.5 Discussion

The estimates in Tables 5 and 6 yield three main conclusions:

(1) We find evidence of substantial agglomeration economies. Using, for instance, the 2SLS estimates in column 8 of Table 6, a 10% increase in the density of manufacturing employment is estimated to yield somewhere between a β% and 6β% increase in TFP over the coarse of a decade. If one takes the major fixed factor to be land, then we can calibrate

[45] This is accomplished by subtracting the assumed coefficient times the wage change from the dependent variable and running an OLS or 2SLS regression with this residual as the dependent variable.

[46] We note that most estimates in Hamermesh's review are for the national market, while our model focuses on a local market. Since labor demand is likely to be more elastic at the local level than at the national level, Hamermesh's estimates should arguably be considered a lower bound for our purposes.

β using the Census of Manufacturers, which yields land cost shares of about .07, implying medium run productivity-density elasticities in the range $[.07, .42]$.

The magnitude of these productivity effect is sizable, but not unreasonable. Indeed, the magnitude of our estimates is significantly smaller than the corresponding estimates in Greenstone, Hornbeck and Moretti (2010), who find productivity elasticities in the interval $[2, 6]$.[47] 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 implausibly large compared with previous estimates.

(2) Our estimates suggest little potential for pure reallocations of manufacturing activity to raise aggregate productivity. Indeed, our uncalibrated estimates actually yield a convex agglomeration function (Figure 6), which implies that counties with a high density of manufacturing activity would benefit more from subsidies to manufacturing than counties with low density of manufacturing activity. In other words, progressive place based policies like TVA that redistribute manufacturing activity from more to less developed counties might end up lowering aggregate productivity and income, while regressive policies that shift activity from less to more developed counties might raise aggregate productivity and income.

However our calibrated estimates, which we find more plausible, suggest nearly linear agglomeration economies of modest strength (Figure 7). This implies that policies that redistribute manufacturing activity from less developed counties to areas with denser manufacturing bases have no aggregate productivity effect, since the gains in the former group are exactly offset by the losses in the latter group.

Figure 8 depicts our calibrated short run inverse labor demand function along with the estimated long run inverse labor demand function and its 95% confidence interval.[48] This Figure is the empirical equivalent of Figure 5. As expected, the estimated long run curve is less steep than the short run curve because the presence of agglomeration economies reduces the limiting effect of the fixed factor on workers productivity. Importantly, the long run demand curve is linear (this reflects the linearity of the agglomeration function). Going back to the discussion of subsection 4.2, we conclude that Figure 5a is a better description of this

[47] 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.

[48] These estimates are from column 7 of Table 6.

economy than Figure 5b.

(3) The estimated dynamics of our model are roughly consistent with our reduced form findings from Section 3. At decadal frequencies, the estimates from Column 3 of Table 4 suggest we can think of TVA as providing two decades of productivity impulses of size 12%. The estimates in column 8 of Table 6 imply that, in the absence of depreciation, the impact of those initial impulses between 1960 and 2000 would be approximately:

$$\left(.34 + (.34)^2 + (.34)^3 + (.34)^4\right) \times (.12 + .34 \times .12) \times 100 = 8.2\% \tag{12}$$

The decadalized impact then is 2.05% which is well within the confidence interval for the annualized impact of TVA on manufacturing employment growth over the period 1960-2000 reported in Table 4. The fact that the employment changes predicted using the structural estimates are roughly consistent with the employment changes estimated in the specific case of TVA is reassuring and suggests the partial equilibrium approach taken in this section captures a substantial fraction of the total TVA impact.

5 Conclusions

Our analysis in Section 3 provides strong evidence that the TVA sped the industrialization of the Tennessee Valley and provided lasting benefits to the region in the form of high paying manufacturing jobs. Notably, the impact on manufacturing employment persisted well beyond the lapsing of the regional subsidies, suggesting the presence of powerful agglomeration economies. By contrast, the agricultural sector, which is unlikely to exhibit substantial forces agglomeration, retracted once subsidies terminated.

Less clear is the impact of the TVA program on the country as a whole. Our finding of a linear agglomeration function in Section 4 suggests that if the manufacturing gains in the region were accomplished at the expense of equal sized manufacturing losses elsewhere, national income would likely be unchanged. Indeed, if one also takes into account the traditional dead weight losses from taxation, one might reasonably expect a net loss in national income.

We note, however, that some of the regional gains in manufacturing employment induced by TVA may have come from agriculture or from the home production sector (i.e. through increases in national labor force participation). Since neither of these sectors is likely to exhibit agglomeration, diverting employment from them would entail fewer offsetting costs. If these channels are important, TVA may well have raised national income.

Ultimately, our findings indicate that the economic rationale for investing in distressed regions like the TVA may not hinge on the level of distress per se, but rather the potential to raise local productivity without crowding out alternative opportunities involving positive externalities. At the time of the New Deal, heavily agricultural areas may have had fewer productive opportunities to crowd out than denser areas. We conclude that a priority for future research on place based policies is determining the nature and strength of any employment diversion effects within and between industries.

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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 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. 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.

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.

3. Proposed Authorities

Here we describe the process used to identify the most likely geographical scope of the proposed authorities. We started with the definition of the broad regional authorities enumerated in bill HR 1824.

1. Atlantic Seaboard: Drainage basins of rivers flowing into the Atlantic Ocean and the Gulf of Mexico from the east
2. Great Lakes-Ohio Valley: Drainage basins of rivers flowing into or from the Great Lakes, the Niagara River, the St. Lawrence River and the Ohio River (except drainage basins of Tennessee and Cumberland Rivers) and of the rivers flowing into the Mississippi River above Cairo, Illinois, from the east
3. Missouri Valley: Drainage basins of the Missouri River and Red River of the North and rivers flowing into the Mississippi River above Cairo, Illinois, from the west
4. Arkansas Valley: Drainage basins of the Arkansas River, Red River, White River, Rio Grande River and rivers flowing into the Mississippi River below Cairo, Illinois, from the west and rivers flowing into the Gulf of Mexico west of the Mississippi River
5. Columbia Valley: Drainage basins of the Columbia River and rivers flowing into the Pacific Ocean north of the California-Oregon line
6. Great Basin: Drainage basins of rivers flowing into the Great Basin (have no outlet to the sea)
7. California: Drainage basins of rivers flowing into the Pacific Ocean below the California-Oregon line
8. Colorado: Drainage basin of the Colorado River

Leuchtenburg (1952 and 1997), presents as more likely to be approved the scenario where the Great Basin, California and colorado Colorado authorities are merged into one. Following Leuchtenburg, we merge the last three into one authority, called Western authority. For each authority, we merged the relevant hydrology polygons (HUC-2, hydrologic unit code 2) on ArcGIS and obtained the relevant area. We then merged the data with the Administrative Counties Boundaries with the area. HUC-2 polygons were obtained from the U.S. Geological Survey. The polygons are aggregations of Basins and Sub-Basins in this USGS map http://viewer.nationalmap.gov/viewer/nhd.html?p=nhd.

As explained in the main text, the proposed legislation broadly identified the regions that each authority was supposed to belong to, but did not identify precisely which set of counties within each region would have belonged to each authority. This is consistent with the process that was adopted for TVA. Recall that when Congress passed legislation to create TVA, it defined its regional scope only broadly. The precise list of counties that ended up belonging to the TVA service area was identified by geographers at the Division of Land Planning and

Housing only later. The geographers defined the borders of service area based a number of criteria provided by Congress. In Section 2.2 we list the main criteria. The map of TVA drafted by geographers was ultimately approved by the TVA Board of Directors.

In order to come up with a concrete definition of the geographic scope of each proposed authority, we had to select subregions within each authority area, just like the TVA geographers did. To make our selection the least arbitrary as possible, we sought to replicate the criteria originally used by the geographers at the Division of Land Planning and Housing to define the TVA borders. For each of the six regions, we defined each authority as encompassing the subregion with land mass equal to a third of the region that matches most closely the TVA geographers' criteria.

Specifically, we used the following algorithm:

1. For each of the 6 proposed authorities, we used a Python script to generate all possible sets of spatially adjacent counties within the region.[49]

2. For the Western authority, we removed all sets that included counties within the Bonneville Power Administration (BPA) service area. The BPA is a federal nonprofit agency created by Congress in 1937. Its area includes parts of Oregon and Washington states. Similarly to TVA, BPA was charged by Congress to built dams and roads, with most of the federal investment taking place between the 1940's and the 1960's. The BPA region is clearly not a good counterfactual, since it did receive treatment similar to that of TVA. Additionally, we removed all sets that contained counties that touch the boundary of a region. This was done in order to prevent the authority subregions from touching each other. For authorities 1 to 4, we also removed all the counties touching counties belonging to TVA, and all the counties touching counties that touch counties belonging to TVA. This was done in order to assure that there are at least two "rings" of counties between the authority subregions and TVA.

3. We kept all subregions that had an area equal to a third of the total area in the region.[50] The resulting number of counties is 227 for region 1; 233 for region 2; 179 for region 3; 250 for region 4; and 43 for region 5 and 6. (Counties in the West are much larger than counties in the rest of the country.)

[49] More specifically, starting from the list of all counties, the Python script generated all combinations of "seed clusters" within that list. The seed clusters consisted of 4 adjacent counties.The information on adjacent counties is obtained from the Contiguous County File, 1991 [United States], available from the ICPSR archive at http://dx.doi.org/10.3886/ICPSR09835.v1

[50] We expanded the seed clusters by attaching the set of all contiguous counties until the final cluster size is such that the resulting authority subregion has an area that is equal to a third of the total area in the region. More specifically, in order to determine the final cluster size, we started from the county that contains the centroid of a region. We attached the set of counties contiguous to that county, then the set of counties contiguous to those counties and so on up to the point when the total area of the sub-region reaches a third of the are of the region. To achieve the exact final cluster size, the python script grows the cluster until it exceeds that size, then randomly chooses counties to remove from the last layer added.

4. We used the following vector of (standardized) variables measured in 1920 and 1930 to proxy for the criteria used by the TVA geographers:

   - urban share and share of agriculture over total employment (To identify areas that are particularly rural);

   - percent illiterate (to identify areas that lack schools and libraries);

   - manufacturing wage, manufacturing share, population, employment, average farm value, median housing value and median rent (to identify areas that are economically underdeveloped);

   An important limitation is that we have no way of measuring other criteria used by TVA geographer, such as willingness to receive technical and advisory assistance from the Authority; existence of planning agencies and enabling legislation; willingness to experiment with new fertilizers.

5. Of all subregions within each region, we selected the subregion that minimized the Euclidean distance between each subregion's vector and TVA's vector.

The resulting six authorities are shown in Figure 4.

Table 1: Summary Statistics

	Overall				Estimation Sample			
	TVA	Non-TVA	Non-TVA South	Non-TVA Proposed Authorities	TVA	Non-TVA	Non-TVA South	Non-TVA Proposed Authorities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1930 Characteristics								
Log Population	9.991	9.977	9.989	9.940	9.991	9.905	9.979	9.940
Log Employment	8.942	8.967	8.959	8.908	8.942	8.881	8.947	8.908
Log # of Houses	8.445	8.508	8.455	8.466	8.445	8.442	8.445	8.466
Log Average Manufacturing Wage	1.406	1.802	1.545	1.685	1.406	1.728	1.538	1.685
Manufacturing Employment Share	0.075	0.090	0.080	0.077	0.075	0.080	0.078	0.077
Agricultural Employment Share	0.617	0.455	0.541	0.510	0.617	0.487	0.547	0.510
% White	0.813	0.885	0.722	0.830	0.813	0.863	0.724	0.830
% Urbanized	0.153	0.280	0.233	0.216	0.153	0.242	0.215	0.216
% Illiterate	0.088	0.045	0.092	0.060	0.088	0.051	0.092	0.060
% of Whites Foreign Born	0.002	0.059	0.013	0.020	0.002	0.030	0.011	0.020
Log Average Farm Value	5.252	5.646	5.386	5.552	5.252	5.579	5.370	5.552
Log Median Housing Value	9.271	9.581	9.360	9.452	9.271	9.516	9.358	9.452
Log Median Contract Rent	8.574	9.030	8.679	8.834	8.574	8.934	8.672	8.834
% Own Radio	0.079	0.296	0.114	0.210	0.079	0.256	0.112	0.210
Max Elevation (meters)	1576.190	2364.531	1068.943	1758.893	1576.190	2044.656	1070.334	1758.893
Elevation Range (Max-Min)	1127.761	1521.322	712.336	1083.293	1127.761	1251.074	715.253	1083.293
% Counties in South	1.000	0.342	1.000	0.554	1.000	0.447	1.000	0.554
Changes 1920-1930								
Log Population	0.051	0.049	0.067	0.004	0.051	0.037	0.060	0.004
Log Employment	0.082	0.096	0.111	0.045	0.082	0.083	0.103	0.045
Log # of Houses	0.078	0.092	0.108	0.046	0.078	0.078	0.100	0.046
Log Average Manufacturing Wage	0.117	0.217	0.108	0.172	0.117	0.197	0.103	0.172
Manufacturing Employment Share	-0.010	-0.035	-0.018	-0.018	-0.010	-0.026	-0.018	-0.018
Agricultural Employment Share	-0.047	-0.036	-0.047	-0.046	-0.047	-0.042	-0.047	-0.046
% White	0.012	-0.011	-0.010	0.000	0.012	-0.006	-0.004	0.000
% Urbanized	0.047	0.064	0.080	0.042	0.047	0.054	0.069	0.042
% Illiterate	-0.030	-0.014	-0.029	-0.019	-0.030	-0.015	-0.028	-0.019
% of Whites Foreign Born	-0.001	-0.023	-0.016	-0.012	-0.001	-0.015	-0.012	-0.012
Log Average Farm Value	-0.013	-0.076	0.025	-0.182	-0.013	-0.102	0.013	-0.182
# of Observations	163	2326	795	828	163	1744	779	828
# of States	6	46	14	25	6	43	14	25

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

	Outcome	Point Estimate (Unadjusted) (1)	Clustered S.E. (2)	Point Estimate (Controls) (3)	Clustered S.E. (4)	Spatial HAC (5)	N (6)
(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

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

	Outcome	Point Estimate (Unadjusted) (1)	Spatial HAC (2)	Point Estimate (Controls) (3)	Spatial HAC (4)	N (5)
(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). Spatial HAC column provides standard error estimates based upon technique of Conley (1999) using bandwidth of 200 miles. Because this Table is based on only one region of the country, we do not report standard errors clustered by state, as they are likely to be incorrect. Stars based upon clustered standard errors. Legend: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 2c : Decadalized Growth Rates in TVA Region vs. Proposed Authrorities 1900-1940

	Outcome	Point Estimate (Unadjusted) (1)	Spatial HAC (2)	Point Estimate (Controls) (3)	Spatial HAC (4)	N (5)
(1)	Population	0.026	(0.019)	0.011	(0.016)	926
(2)	Total Employment	-0.012	(0.017)	0.006	(0.015)	926
(3)	Housing Units	-0.014	(0.016)	0.006	(0.013)	926
(4)	Average Manufacturing Wage	0.012	(0.015)	0.008	(0.017)	734
(5)	Manufacturing Share	0.007	(0.006)	0.005	(0.006)	926
(6)	Agricultural Share	-0.005	(0.006)	0.004	(0.006)	926
(7)	Average Agricultural Land Value	0.080***	(0.026)	0.017	(0.018)	908

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). 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) (1)	Clustered S.E. (2)	Point Estimate (Controls) (3)	Clustered S.E. (4)	Spatial HAC (5)	N (6)
(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)	Value of Farm Production	-0.028	(0.028)	0.002	(0.032)	(0.026)	1903
(7)	Median Family Income (1950-2000 only)	0.072***	(0.014)	0.021	(0.013)	(0.011)	1905
(8)	Average Agricultural Land Value	0.066***	(0.013)	-0.002	(0.012)	(0.016)	1906
(9)	Median Housing Value	0.040**	(0.017)	0.005	(0.015)	(0.015)	1906
(10)	Median Rent	0.063***	(0.014)	0.004	(0.009)	(0.006)	1905

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

	Outcome	Point Estimate (Unadjusted) (1)	Spatial HAC (2)	Point Estimate (Controls) (3)	Spatial HAC (4)	N (5)
(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)	Value of Farm Production	-0.005	(0.025)	-0.006	(0.026)	939
(7)	Median Family Income (1950-2000 only)	0.041***	(0.012)	0.024**	(0.011)	942
(8)	Average Agricultural Land Value	0.031*	(0.018)	-0.003	(0.017)	942
(9)	Median Housing Value	0.019	(0.017)	0.007	(0.016)	942
(10)	Median Rent	0.016	(0.010)	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. Because this Table is based on only one region of the country, we do not report standard errors clustered by state, as they are likely to be misleading. Stars: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Table 3c: Decadalized Impact of TVA on Growth Rate of Outcomes (1940-2000) -- Relative to Proposed Authorities

	Outcome	Point Estimate (Unadjusted) (1)	Spatial HAC (2)	Point Estimate (Controls) (3)	Spatial HAC (4)	N (5)
(1)	Population	0.011	(0.018)	0.001	(0.017)	991
(2)	Average Manufacturing Wage	0.018***	(0.007)	0.005	(0.006)	618
(3)	Average Retail/Wholesale Wage	0.005	(0.019)	0.036	(0.025)	924
(4)	Agricultural Employment	-0.101***	(0.029)	-0.071***	(0.027)	991
(5)	Manufacturing Employment	0.066***	(0.024)	0.053**	(0.024)	991
(6)	Value of Farm Production	0.002	(0.026)	0.011	(0.035)	989
(7)	Median Family Income (1950-2000 only)	0.060***	(0.012)	0.025**	(0.011)	991
(8)	Average Agricultural Land Value	0.060***	(0.019)	-0.003	(0.016)	991
(9)	Median Housing Value	0.033**	(0.016)	0.009	(0.016)	991
(10)	Median Rent	0.048***	(0.011)	0.008	(0.006)	990

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 based upon clustered standard errors. Legend: * 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

		Entire U.S.		South		Proposed Authorities	
		1940-1960	1960-2000	1940-1960	1960-2000	1940-1960	1960-2000
	Outcome	(1)	(2)	(3)	(4)	(5)	(6)
(1)	Population	0.037	-0.008	0.042	-0.000	0.028	-0.013
(2)	Average Manufacturing Wage	-0.005	0.014*	-0.003	0.010	0.007	0.012
(3)	Average Retail/Wholesale Wage	-0.011	0.039	-0.006	0.065**	0.001	0.058**
(4)	Agricultural Employment	0.106***	-0.134***	0.106***	-0.130***	0.119***	-0.166***
(5)	Manufacturing Employment	0.114***	0.033**	0.116***	0.035*	0.097**	0.032**
(6)	Value of Farm Production	0.076*	-0.030	0.081**	-0.044	0.118**	-0.033
(7)	Median Family Income	N/A	0.017	N/A	0.016	N/A	0.019*
(8)	Average Agricultural Land Value	0.027	-0.017	0.018	-0.015	0.029	-0.021
(9)	Median Housing Value	0.019	-0.003	0.010	0.005	0.020	0.003

Note: Full set of controls included in all specifications. 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 and Proposed Authorities) 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: Structural Estimates of Agglomeration Function

	Linear						Cubic					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	OLS	2SLS	2SLS	2SLS	OLS	OLS	OLS	2SLS	2SLS	2SLS
Log Manuf.	0.082	0.069	0.066	0.223	0.196	0.191	0.076	0.047	0.045	0.155	0.058	0.058
Density	(0.025)	(0.025)	(0.025)	(0.072)	(0.074)	(0.075)	(0.026)	(0.027)	(0.027)	(0.068)	(0.081)	(0.082)
				[212.10]	[199.23]	[196.83]				[162.93]	[116.43]	[115.40]
Log Manuf.							0.024	0.030	0.029	0.054	0.070	0.067
Density^2							(0.007)	(0.006)	(0.007)	(0.020)	(0.023)	(0.023)
										[17.55]	[16.44]	[13.89]
Log Manuf.							-0.004	-0.004	-0.004	-0.008	-0.009	-0.008
Density^3							(0.001)	(0.002)	(0.001)	(0.004)	(0.004)	(0.004)
										[10.11]	[9.84]	[7.99]
Log Manuf. Wages	0.073	0.071	0.072	0.075	0.074	0.074	0.070	0.068	0.067	0.070	0.067	0.067
	(0.037)	(0.037)	(0.037)	(0.040)	(0.040)	(0.040)	(0.037)	(0.037)	(0.037)	(0.039)	(0.039)	(0.039)
TVA	0.014	0.018	0.017	0.007	0.010	0.009	0.012	0.015	0.014	0.003	0.009	0.007
	(0.012)	(0.012)	(0.013)	(0.010)	(0.011)	(0.011)	(0.012)	(0.012)	(0.013)	(0.010)	(0.010)	(0.011)
Regional Trends	no	no	yes	no	no	yes	no	no	yes	no	no	yes
1940 Manuf. Density	no	yes	yes	no	yes	yes	no	yes	yes	no	yes	yes
Decade Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
1920 and 1930 X's	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
P-value squared and cubic terms = 0							0.001	0.000	0.000	0.031	0.009	0.011
N	5462	5462	5462	5318	5318	5318	5462	5462	5462	5318	5318	5318
Marginal effect of density increase at:												
20th percentile	0.082	0.069	0.066	0.223	0.196	0.191	0.075	0.045	0.043	0.151	0.053	0.053
	(0.025)	(0.025)	(0.025)	(0.072)	(0.074)	(0.075)	0.026	0.027	0.026	0.069	0.082	0.083
50th percentile	0.082	0.069	0.066	0.223	0.196	0.191	0.117	0.102	0.100	0.254	0.197	0.192
	(0.025)	(0.025)	(0.025)	(0.072)	(0.074)	(0.075)	0.028	0.029	0.029	0.054	0.060	0.060
80th percentile	0.082	0.069	0.066	0.223	0.196	0.191	0.116	0.112	0.109	0.271	0.242	0.236
	(0.025)	(0.025)	(0.025)	(0.072)	(0.074)	(0.075)	0.032	0.032	0.032	0.066	0.066	0.067

Notes: Manufacturing density is manufacturing employment per square mile. Standard errors clustered by state in parentheses. Angrist-Pischke cluster robust first stage F-stat in brackets. All estimates weighted by 1950 county population. Marginal effects computed at quantiles of the 1980 distribution of manufacturing density.

Table 6: Sensitivity Analysis

	Low Elasticity				Medium Elasticity				High Elasticity			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	OLS	2SLS	2SLS	OLS	OLS	2SLS	2SLS	OLS	OLS	2SLS	2SLS
Log Manuf.	0.048	0.046	0.241	0.244	0.049	0.047	0.340	0.344	0.049	0.047	0.438	0.444
Density	(0.030)	(0.030)	(0.101)	(0.101)	(0.034)	(0.034)	(0.127)	(0.127)	(0.040)	(0.040)	(0.157)	(0.158)
			[121.28]	[120.11]			[121.28]	[120.11]			[121.28]	[120.11]
Log Manuf.	0.023	0.023	0.019	0.015	0.019	0.019	-0.009	-0.013	0.016	0.015	-0.036	-0.041
Density^2	(0.008)	(0.008)	(0.025)	(0.025)	(0.009)	(0.009)	(0.034)	(0.033)	(0.010)	(0.010)	(0.044)	(0.044)
			[16.70]	[14.18]			[16.70]	[14.18]			[16.70]	[14.18]
Log Manuf.	-0.003	-0.003	-0.003	-0.002	-0.003	-0.003	0.001	0.002	-0.002	-0.002	0.004	0.005
Density^3	(0.002)	(0.002)	(0.005)	(0.005)	(0.002)	(0.002)	(0.006)	(0.006)	(0.002)	(0.002)	(0.007)	(0.008)
			[9.96]	[8.11]			[9.96]	[8.11]			[9.96]	[8.11]
Log Manuf. Wage	**-1**	**-1**	**-1**	**-1**	**-1.5**	**-1.5**	**-1.5**	**-1.5**	**-2**	**-2**	**-2**	**-2**
TVA	0.022	0.022	0.010	0.011	0.025	0.026	0.011	0.013	0.028	0.030	0.012	0.015
	(0.012)	(0.013)	(0.010)	(0.010)	(0.013)	(0.014)	(0.011)	(0.012)	(0.014)	(0.015)	(0.014)	(0.014)
Region Trends	no	yes	no	yes	no	yes	no	yes	no	yes	no	yes
1940 Manuf. Dens.	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Decade Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
1920 and 1930 X's	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
P-value squared and cubic terms = 0	0.010	0.015	0.744	0.805	0.083	0.106	0.937	0.898	0.285	0.332	0.600	0.537
N	5462	5462	5318	5318	5462	5462	5318	5318	5462	5462	5318	5318
Marginal effect at:												
20th percentile	0.047	0.045	0.240	0.243	0.047	0.045	0.340	0.345	0.048	0.046	0.440	0.446
	0.030	0.030	0.102	0.102	0.034	0.034	0.128	0.128	0.040	0.040	0.159	0.159
50th percentile	0.092	0.089	0.278	0.274	0.086	0.083	0.321	0.318	0.081	0.077	0.364	0.362
	0.032	0.032	0.084	0.085	0.035	0.035	0.104	0.105	0.039	0.039	0.126	0.127
80th percentile	0.102	0.098	0.287	0.283	0.096	0.092	0.312	0.308	0.090	0.086	0.336	0.333
	0.033	0.034	0.085	0.086	0.035	0.036	0.100	0.102	0.038	0.038	0.117	0.120

Notes: Manufacturing density is manufacturing employment per square mile. Standard errors clustered by state in parentheses. Angrist-Pischke cluster robust first stage F-stat in brackets. All estimates weighted by 1950 county population. Marginal effects computed at quantiles of the 1980 distribution of manufacturing density. "Low elasticity" columns impose short run elasticity of -1. "Medium elasticity" columns impose short run elasticity of -1.5. "High elasticity" columns impose short run elasticity of -2.

Figure 1: The TVA Service Area

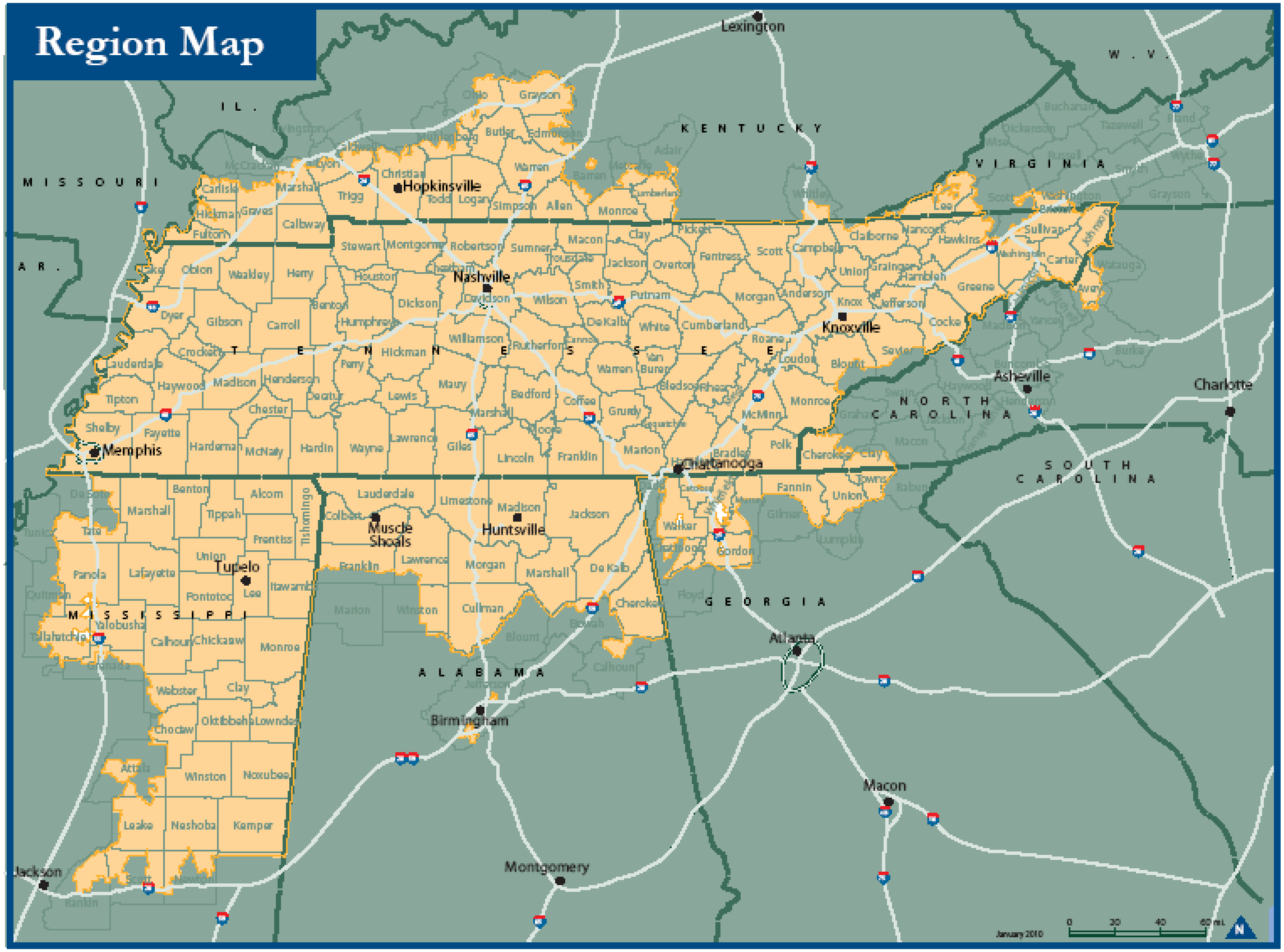
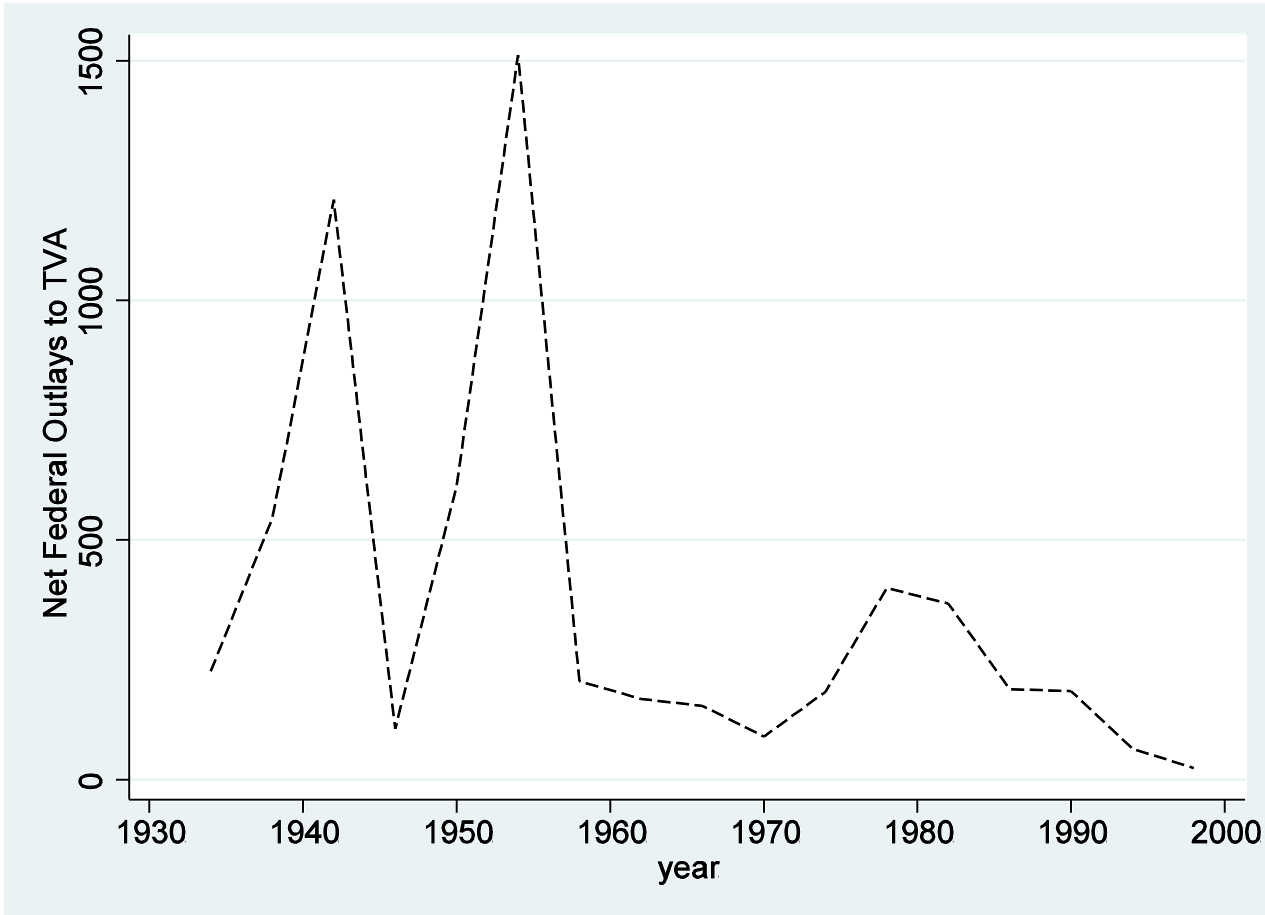


Figure 2: Net Federal Outlays to TVA by Year



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

Figure 3a – Estimation Sample

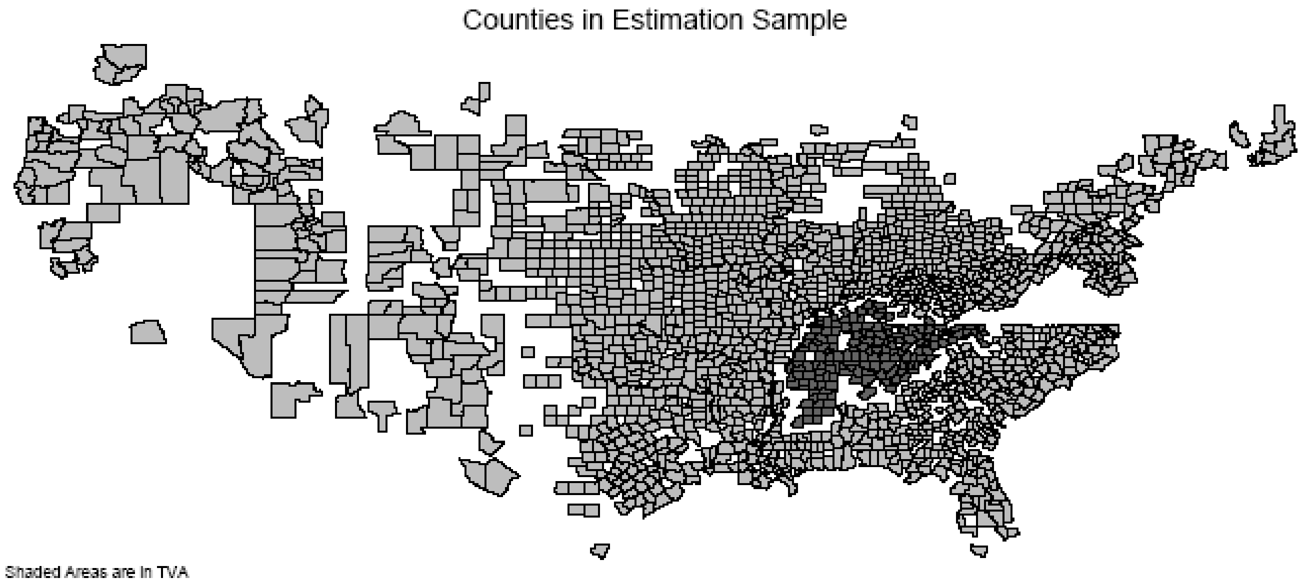
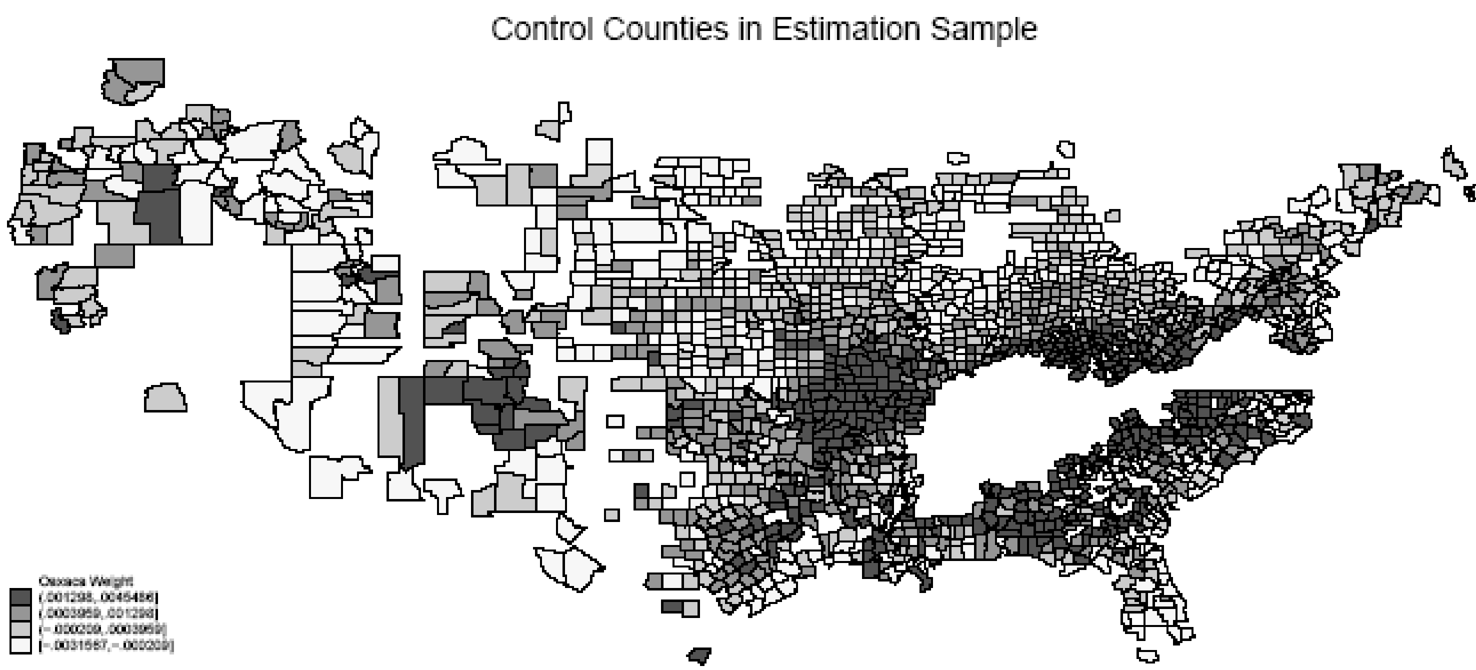
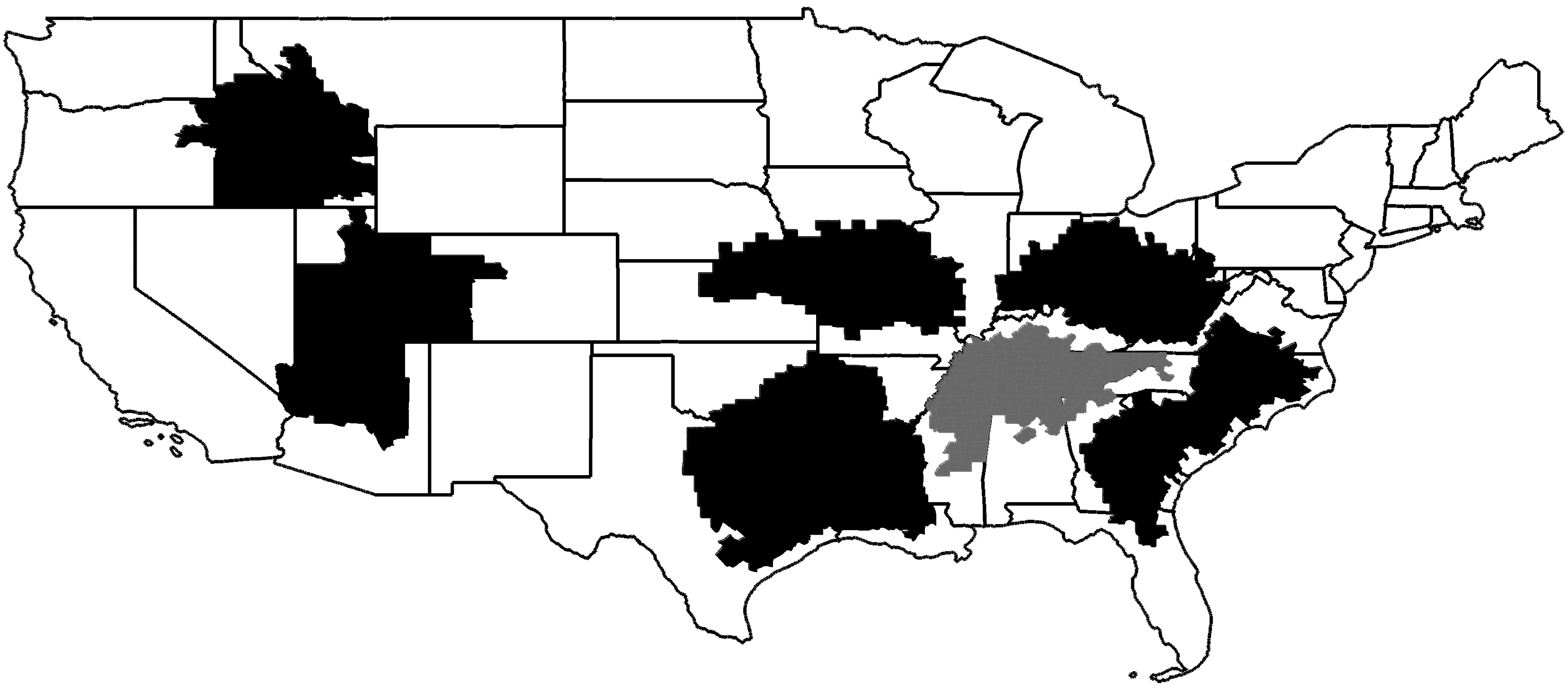


Figure 3b – Weight on Untreated Counties



Note: In a Oaxaca-Blinder regression, each control county is implicitly assigned a weight: counties that look more similar to TVA counties in the years before TVA receive more weight. The weight is proportional to an estimate of the odds of treatment.

Figure 4: Map of Proposed Authorities



Note: The map displays in black the six proposed authorities: the Atlantic Seaboard Authority, the Great Lakes-Ohio Valley Authority, the Missouri Valley Authority, the Arkansas Valley Authority, the Columbia Authority, and the Western Authority. The TVA region is displayed in gray.

Figure 5a: Linear Agglomeration

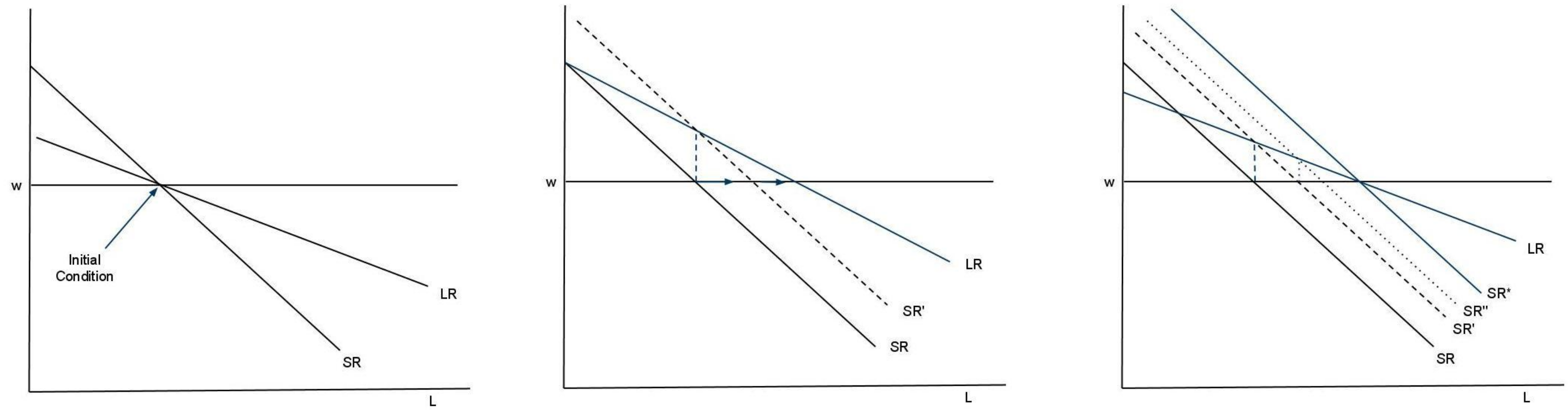
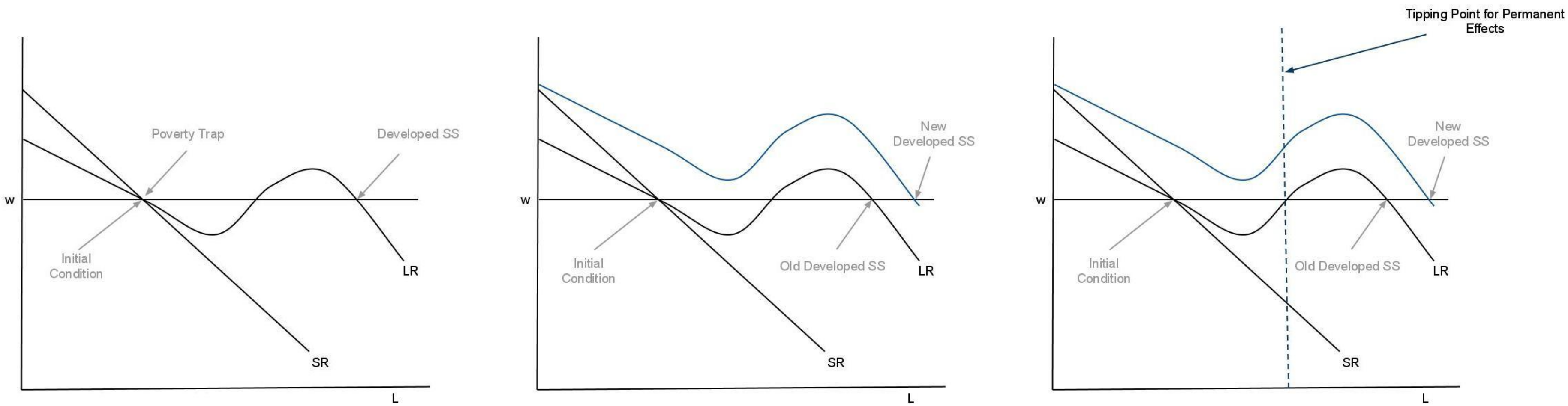
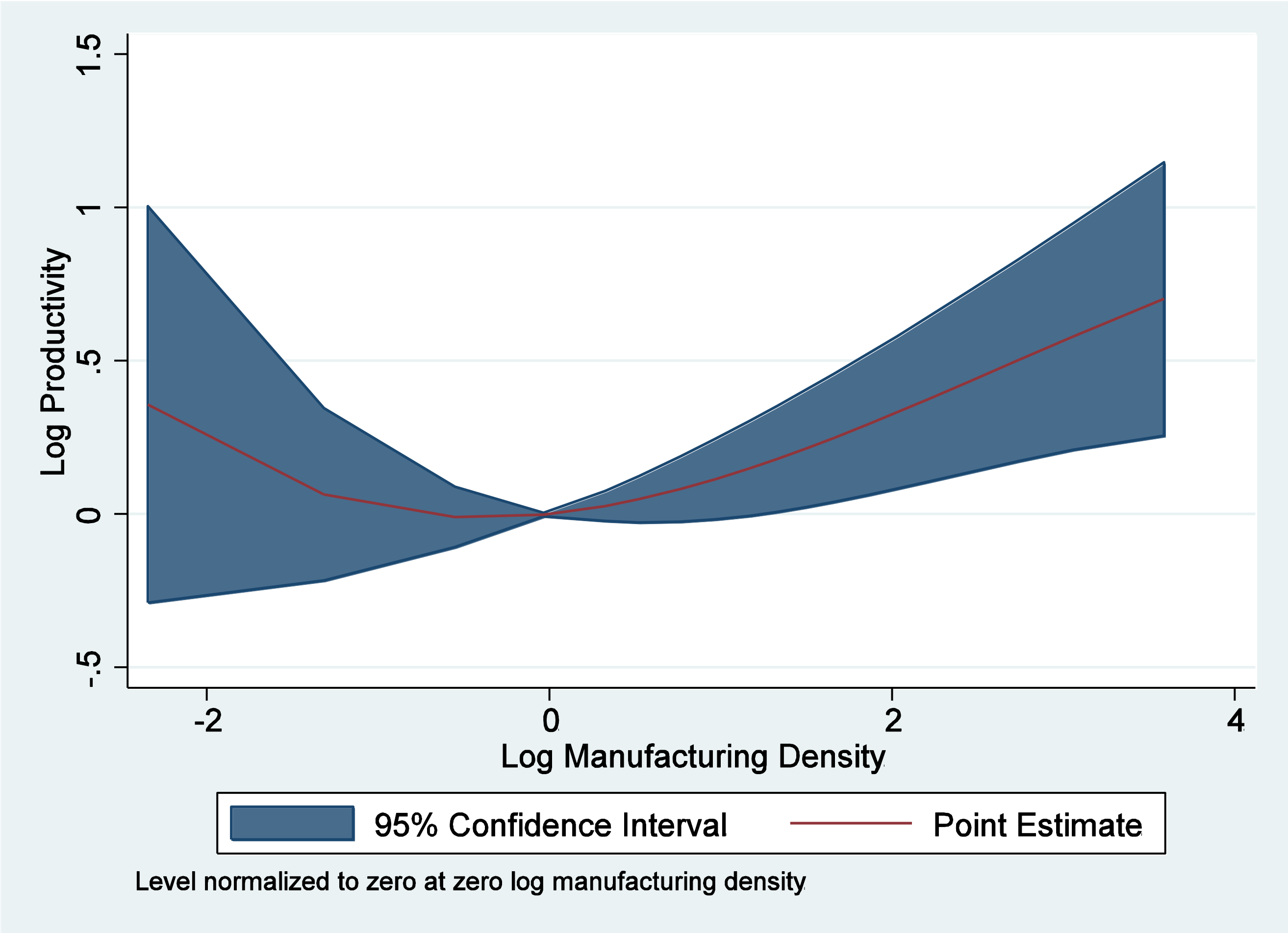


Figure 5b: Nonlinear Agglomeration



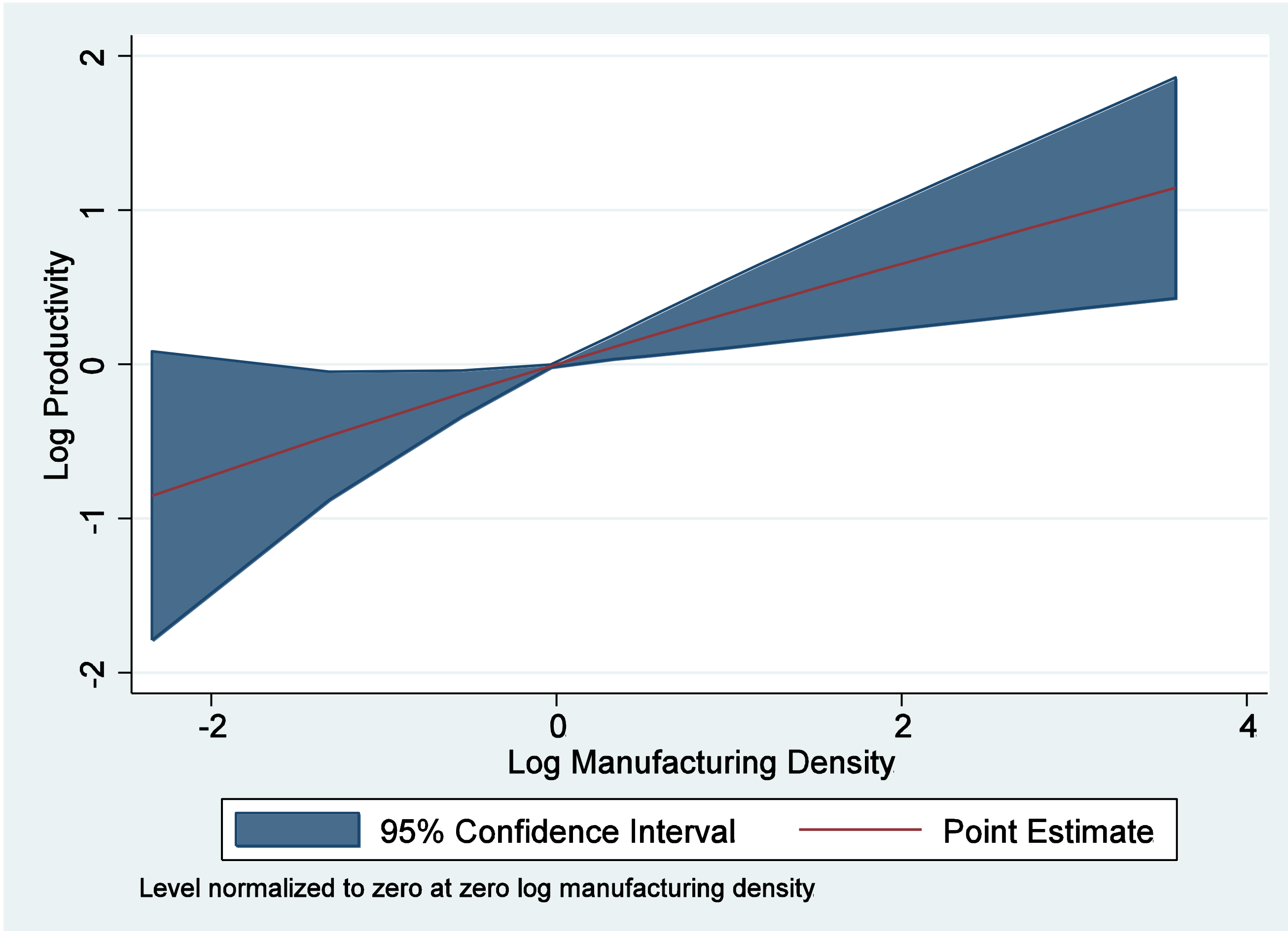
Notes: The x-axis is log manufacturing density and the y-axis is the log manufacturing wage. SR and LR refer to short run and long run inverse demand curves respectively (see section 4.2 of text). Figure 4a depicts convergence from initial condition to the new unique steady state under linear agglomeration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

Figure 6: Estimated Agglomeration Function



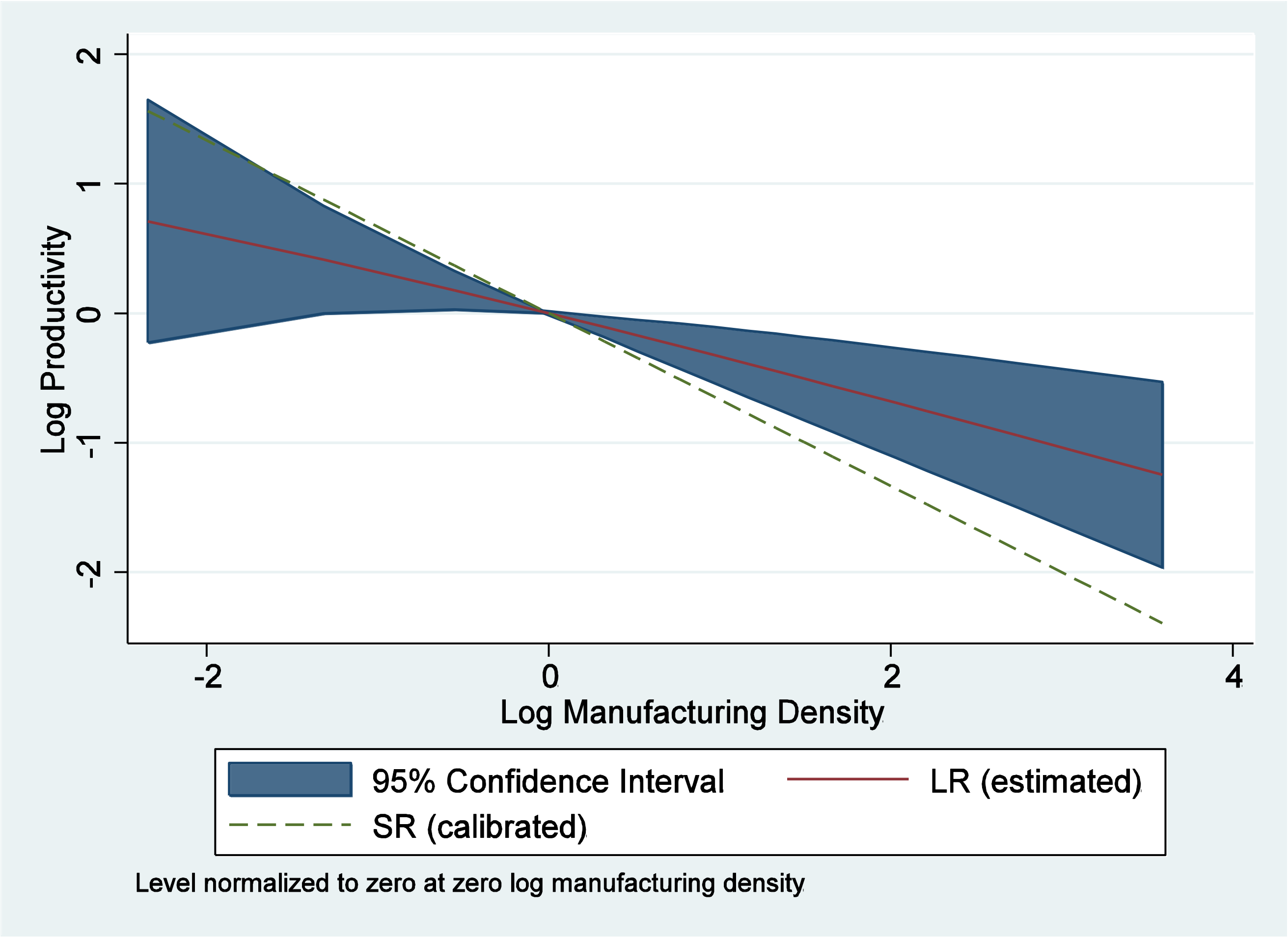
Note: The Figure shows the estimated agglomeration function and its 95% confidence interval based on the specification in column 11 of Table 5.

Figure 7 Estimated Agglomeration Function (Calibrated SR Elasticity)



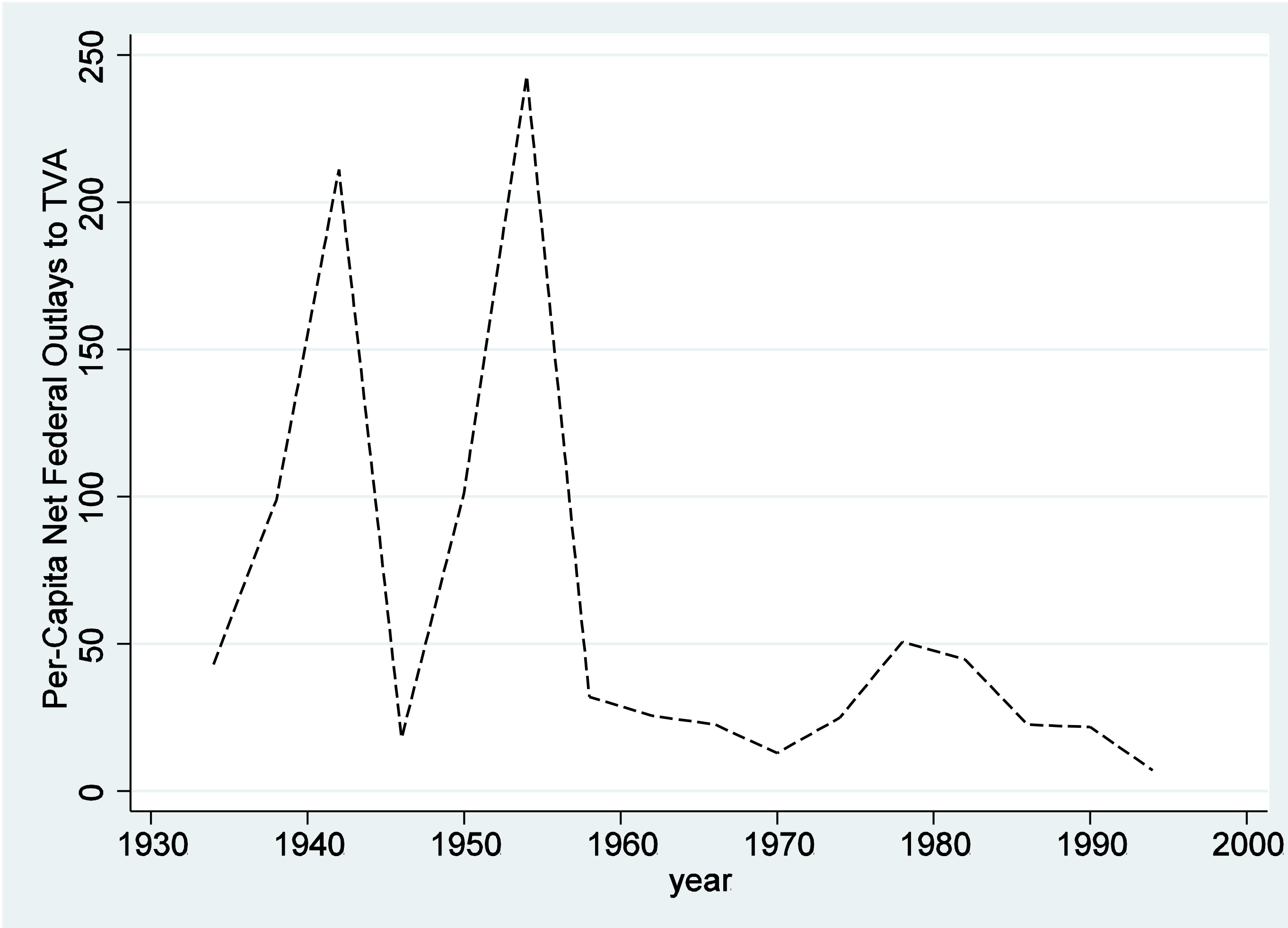
Note: The Figure shows the estimated agglomeration function and its 95% confidence interval based on the specification in column 7 of Table 6.

Figure 8: Short and Long Run Inverse Labor Demand Functions



Note: The Figure shows the short and long run inverse labor demand functions implied by our estimates from column 7 of Table 6, together with a 95% confidence interval for the long run inverse demand function. The short run inverse demand function is calibrated with slope = -1.5 based on Hamermesh (1993).

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



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