

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 (TVA). 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 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. We develop a novel approach to assessing the aggregate consequences of place based policies. Our findings suggest that the TVA boosted national manufacturing productivity by roughly 0.3% and that the dollar value of these productivity gains exceeded the program's costs.

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1 Introduction

Like most countries, the United States exhibits vast differences in income across cities and regions. After adjusting for differences in skill composition, average wages in the highest and lowest paying U.S. metropolitan areas differ by nearly a factor of 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 roughly \$95 billion per year on such programs, significantly more than Unemployment Insurance in a typical year.¹ In many cases, these policies seek to retain or attract manufacturing plants to a specific jurisdiction. Such programs have arguably become the de-facto industrial policy in the United States, and are also prevalent in Canada, Europe, and Asia (Albouy, 2012; Criscuolo et al., 2012; Wang, 2011; Wren and Taylor, 1999).

A fundamental concern often raised by economists is that spatially targeted policies may simply shift economic activity from one locality to another, with little impact on the aggregate level of output. In such a case, the benefits enjoyed by the target locality may come at the expense of other (possibly quite distant) areas. Echoing this concern, Glaeser and Gottlieb (2008) conclude in a recent review that “any government spatial policy is as likely to reduce as to increase welfare.” Likewise, a recent analysis by the New York Times describes such policies as a “zero sum game” among American communities (Story, 2013).

In this paper, we evaluate the local and aggregate effects of one of the most ambitious place based economic development policies in the history of the United States: the Tennessee Valley Authority (TVA). Charged by President Roosevelt with “touching and giving life to all forms of human concerns” the program was intended to modernize the economy of the Tennessee Valley region via a series of large scale infrastructure investments including electricity generating dams and an extensive network of new roads, canals, and flood control systems.

The TVA makes for a particularly interesting case study for at least two reasons. First, because of its large size and ambitious goals, the TVA program is perhaps the best example of a “big push” development strategy in the history of the United States. Such strategies are predicated on the notion that economic development exhibits threshold effects, so that large enough public investments in a severely underdeveloped region may generate huge increases in productivity and welfare (Rosenstein-Rodan, 1943; Murphy, Shleifer, and Vishny, 1989; Azariadis and Stachurski, 2005). An important channel through which this process is sometimes thought to occur involves agglomeration forces, particularly productive spillovers between workers and firms, which have received a growing amount of theoretical and empir-

¹Story (2013) estimates that state and local governments spend at least \$80 billion annually. The federal government spends about \$15 billion annually (GAO, 2012). 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. Annual federal outlays for Unemployment Insurance averaged \$33 billion from 2004 to 2007 (Carrington, 2013).

ical attention in the literature (Ellison and Glaeser, 1999; Ellison, Glaeser, and Kerr, 2010; Rosenthal and Strange, 2004; Greenstone, Hornbeck and Moretti, 2010). At the time of the TVA’s inception in 1933, its service region was among the poorest, least developed, areas in the nation. If the program’s large localized investments in public infrastructure failed to yield a sustained boost in local productivity, it is hard to imagine what programs might have succeeded.

Second, the timing of the program’s investments provides an opportunity to examine whether a lapsed development policy may have persistent effects. At the program’s peak in the period 1950-1955, the annual federal subsidy to the region amounted to \$750 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. Big push models of development typically suggest the positive effects of an initial subsidy on the local economy may be long lasting provided the initial investment is large enough. The TVA provides us with an opportunity to scrutinize this prediction empirically. In doing so, we contribute to a growing literature on the persistence and uniqueness of spatial equilibria (Davis and Weinstein, 2002, 2008; Miguel and Roland, 2011; Redding, Sturm, and Wolf, 2011).

Our analysis proceeds in two steps. In the first part of the paper, we use a rich panel data set of counties to conduct an evaluation of the dynamic effects of the TVA on the regional economy in the seventy year period following the program’s inception. The manufacturing and agricultural sectors are analyzed separately, as there is a long standing presumption in the literature that manufacturing exhibits agglomeration economies but little reason to expect such effects in agriculture (Hornbeck and Naidu, 2012). A first research design compares the TVA area to observationally similar controls, both in the South and the rest of the country. 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 began. An alternative research design uses the fact that in the years following the program’s inception, Congress considered creating six additional regional authorities modeled upon the TVA. Due to political infighting, these additional authorities were never approved. Hence, our second design compares TVA counties to counties covered by 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. However, between 1960 and 2000 – during which time federal transfers were scaled down – the gains in agriculture were completely reversed, while the gains in manufacturing employment continued to intensify. Thus, 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. Because the manufacturing sector paid higher wages than agriculture, this shift raised aggregate income in the TVA region for an extended period of time.

A key question for policy purposes is whether the local gains associated with the TVA came at the expense of other parts of the country. In the second part of the paper, we seek to quantify the impact of the TVA on national welfare. This exercise is complicated

by the difficulty of constructing a credible counterfactual for the entire nation. Put simply, we don't observe the entire U.S. economy in the absence of the TVA. Like many researchers seeking to identify general equilibrium impacts (Donaldson, 2012; Donaldson and Hornbeck, 2012; Ahlfeldt et al., 2012), we address this problem by developing an equilibrium model to structure our empirical analysis. Methodologically, our approach has the advantage of being extremely tractable and is easily adapted to the evaluation of other place based policies.

Our model incorporates the spatial mobility of workers and capital and allows for dynamic adjustment to shocks, including the TVA's investments. The TVA affects the national economy in two ways. First, the TVA may have *directly* raised labor productivity due to the improvement in public infrastructure. With mobile workers, these localized productivity gains will yield national labor market impacts. Second, the program may have had an *indirect* effect through agglomeration economies, if they exist. This second channel allows for the possibility – highlighted by the literature on big push – that the effects of a one-time localized public investment might become self sustaining due to agglomeration economies.

We develop a dynamic panel approach to identifying the model parameters governing the direct productivity effects of the TVA, as well as the shape of any agglomeration economies. Notably, although many of the structural parameters are identified using model based instruments rather than policy variation, our estimates imply dynamic responses to the TVA very similar with those found in our reduced form program evaluation. In addition, our estimates of the strength of agglomeration economies are in line with the latest estimates in the literature.

Having estimated the model parameters, we then conduct a cost-benefit analysis of TVA's long run aggregate effects using approximations to the model's steady state. This exercise allows a quantitative assessment of whether the TVA was welfare enhancing for the U.S. as a whole or simply for the TVA region.

Our quantitative exercise yields three primary conclusions. First, the direct productivity effects of the program appear to have been substantial. The TVA's investments in productive infrastructure resulted in a large increase in local manufacturing productivity, which in turn led to a significant increase in national productivity. We find that the TVA raised national manufacturing productivity by roughly 0.3%.

Second, the indirect welfare impacts of the TVA operating through reallocation of manufacturing activity to less developed areas were limited. While we do find strong evidence of localized agglomeration effects in the manufacturing sector, these effects exhibit a roughly constant elasticity with respect to the density of manufacturing activity.² Building on the arguments in Glaeser and Gottlieb (2008), we show that a constant agglomeration elasticity implies that the welfare gains from agglomeration in subsidized areas are offset by losses elsewhere. Thus, spillovers in manufacturing appear to be the rare example of a localized market failure that “cancels out” in the aggregate. Notably, this finding casts doubt on the traditional big push rationale for spatially progressive subsidies.

Ultimately, when we compare costs to benefits, we find that the aggregate return on the TVA program was substantially positive. In our most pessimistic scenario, the net present

²To our knowledge, this is the first clear evidence of nonlinearities in manufacturing agglomeration.

value of the aggregate productivity gains are estimated to exceed program costs by about 30%. These gains are entirely explained by the direct productivity effects of the program's infrastructure investments. We caution, however, that our calculation of net benefits depends upon several untestable assumptions on aggregate labor demand and supply, and that our findings are likely specific to the local conditions that prevailed at the inception of the TVA program. We also caution that our calculations do not include the standard deadweight costs of taxation, which are likely to lower the program's rate of return.

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. Section 4 develops our spatial equilibrium model. In section 5 we estimate the model's parameters. Section 6 provides a cost benefit analysis of TVA's effects on the national economy. Section 7 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.³ The federal effort to modernize the TVA region's economy entailed one of the largest place based development programs in U.S. history. Large investments were made in public infrastructure projects including a series of hydroelectric dams, a 650-mile navigation canal, and an extensive road network, with additional money flowing to the construction of new schools and flood control systems. Funds were also spent on a hodgepodge of smaller programs including malaria prevention, soil erosion mitigation programs, educational programs, health clinics, the distribution of cheap fertilizers to farmers, reforestation and forest fire control, and provision of federal expertise for local economic development.

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

Between 1934 and 2000, federal appropriations for the TVA totaled approximately \$20 billion (2000 dollars). The size of these transfers varied significantly across decades. As a federal regulatory agency, the Authority initially relied on government subsidies to conduct

³A 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.

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. 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 drop-off in federal appropriations is even more pronounced when per-capita figures are considered. The second axis of Figure 2 shows yearly per-capita federal transfers to the TVA. Peak transfers occurred over the period 1950-1955, during which time the federal government was transferring approximately \$150 to each resident in each year in the form of subsidies to TVA. Since, at the time, the typical household in TVA counties had 5 members, the per household transfer was roughly \$750 per year, or about 10% of average household income.

2.2 Selection into the 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;⁴
- 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.⁵

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 Fishback, Haines, and Kantor (2011). Details on data construction are provided in the Appendix.⁶

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

⁴In the case of North Carolina, counties were excluded from the jurisdiction of the Authority as the state did not have enabling legislation.

⁵The Authority eliminated some counties from its jurisdiction to which supplying electricity would be too costly.

⁶We drop the state of Virginia where county splits and merges are common. We also drop counties in Hawaii and Alaska.

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 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 The Effects of the TVA on the Local Economy

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.⁷

⁷In 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.

Establishing that subsidies which target an area raise contemporaneous employment is a useful first step. However, 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 benefiting 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 the 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.⁸

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 geographic characteristics, including: a quadratic in 1920 and 1930 log population and interactions; 1920 and 1930 urban share; 1920 and 1930 log employment; a quadratic in 1920 and 1930 agricultural employment share; a quadratic in 1920 and 1930 manufacturing employment share; 1920 and 1930 log wages in manufacturing; 1920 and 1930 log wages in trade (retail + wholesale); dummies for 1920 and 1930 wages in manufacturing or trade being missing; 1920 and 1930 farm values, owner occupied housing values and rental rates; a quadratic in 1920 and 1930 white share; the share of the population age 5+ that are illiterate in 1920 and 1930; the 1920 and 1930 share of whites who are foreign born; the 1930 share of households with a radio; the 1930 unemployment rate, maximum elevation, and elevation range (to capture mountainous terrain). Our vector of covariates controls not only for some of the key differences in levels between TVA and non-TVA counties in 1930, but also for some differences in trends.

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 sub-

⁸As 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.

stantially different from TVA counties (see Angrist and Pischke, 2008 for a similar exercise). 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.⁹ 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:

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

where $y_{it} - y_{it-1}$ is the change in the relevant dependent variable between year $t - 1$ and t for county i and X_i is the vector of preprogram characteristics listed above. We then use the vector $\hat{\beta}$ of estimated coefficients to predict the counterfactual mean for the treated counties. The Oaxaca-Blinder regression has the advantage over standard regression methods of identifying the average treatment effect on treated counties in the presence of treatment effect heterogeneity.¹⁰

Another appealing characteristic of the Oaxaca-Blinder estimator is its dual interpretation as a propensity score reweighting estimator (see Kline, 2011 for discussion).¹¹ 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 be spatially correlated. We deal with this possibility by

⁹In 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.

¹⁰In practice, standard regression models yield generally similar results and are available upon request.

¹¹Relative 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.

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, 2013) 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 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 the 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 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.¹² (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 1940.¹³ 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

¹²As we argued before, the vast majority of the program took place after 1940.

¹³For 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.

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 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.¹⁴

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

¹⁴The 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.¹⁵

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 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.¹⁶ We end up using the six Authorities listed by Leuchtenburg, and their geographical borders as specified in HR 1824: an Atlantic Seaboard Authority, a

¹⁵Specifically, 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.

¹⁶Among the 10 bills in front of Congress in 1945, HR 1824 appears to be the most detailed.

Great Lakes-Ohio Valley Authority, Missouri Valley Authority, Arkansas Valley Authority, Columbia Authority, and a Western authority.¹⁷ We assume that within each region, the exact boundaries of each authority would 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.¹⁸ 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 7.5% and 7.7% 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 authorities and in the TVA is respectively -.010% and -.018%, vs. a nationwide change of -.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).¹⁹ 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

¹⁷HR 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.

¹⁸Because we do not drop counties with low propensity scores, columns 4 and 8 are identical.

¹⁹Compared 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.

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 Local Effects of the TVA

(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 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.

It is interesting to know what happened to the counties outside, but near, the TVA region. On one hand, it is possible that the TVA led to some displacement of economic activity from geographically proximate regions. On the other hand, it is possible that economic growth within TVA spilled over into neighboring counties. In reported results, we tried estimating the effects of TVA on adjacent counties using the same models as in Table 3. This exercise failed to detect any significant spillover effects, however precision was low (estimates available on request).

(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 - 11.9 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.²⁰ The value of farm production increases significantly.

²⁰For example, the point estimates for population are 0.037, 0.042, 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

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

The two research designs use different sources of variation but yield a picture that is qualitatively and quantitatively very similar. 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,²¹ this suggests a large population of potential workers capable of moving to the region or switching out of local agriculture and into manufacturing.²² 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 – 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.²³ Manufacturing employment, by contrast, continued to grow even after the

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

²¹See, for example, recent work by Hornbeck (2012b and 2011c) and Hornbeck and Naidu (2012) on labor reallocation following historical localized shocks to Southern counties.

²²It is also possible that the labor supply of local residents increased. 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.

²³The period after 1960 was a time of rapid capital deepening in agriculture in the South as the cost of capital went down and the opportunity cost of labor went up. Given that TVA had particularly high initial employment rates in agriculture, it is certainly possible that technical change influenced TVA counties

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 growth collapses after 1960 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.²⁴ In practice, of course, the TVA infrastructure was not allowed to fully depreciate. But from 1959 onwards 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 suggests that firms in the region enjoyed a competitive advantage even after the subsidies lapsed. This is suggestive of agglomeration effects in manufacturing of the type documented by Greenstone, Hornbeck and Moretti (2010).²⁵ By contrast, the retrenchment of the agricultural sector after 1960 suggests agglomeration effects in agriculture are limited, a view consistent with recent evidence by Hornbeck and Naidu (2012) who conclude that “agricultural production does not appear to generate local economic spillovers.” (In the next Section, we make these statements more precise and provide more direct empirical evidence.) Because the manufacturing sector paid higher wages than agriculture, these sectoral shifts raised aggregate income in the TVA region for an extended period of time.

4 A Framework for Interpreting the TVA’s Effects

Up to now, our analysis has focused on the benefits of the TVA for the region’s economy. But a key concern with place based policies is that they may simply reallocate economic activity across space without raising national income. The research designs of Section 3 are not easily adapted to identifying the TVA’s effects on the entire U.S. economy. The reason is clear: we cannot find a suitable control group to serve as an estimate of the counterfactual for the entire U.S. economy in the absence of the TVA.

In this and the following two sections, we lay the foundations for a structured cost-benefit analysis of the TVA’s national labor market impacts that addresses these difficulties. While our immediate interest is in the effect of the TVA program on the nation’s economy, our approach provides a general framework that can be adapted to estimate the aggregate impact of other place based policies.

differently than other counties.

²⁴The exact implied depreciation rate depends on the 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 estimated by engineers and 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).

²⁵Of course other interpretations of the dynamic effect of the program on the manufacturing sector – including for example credit constraints or slow adjustment of capital stocks – can’t be ruled out at this stage.

Road Map We start in this section by developing a spatial equilibrium model that can rationalize the reduced form impacts of the TVA uncovered thus far. Our model allows the TVA to affect labor productivity in two ways. First, the TVA may directly raise labor productivity via public infrastructure investments. Second, it may indirectly raise labor productivity due to agglomeration economies. The magnitude of this second effect hinges on the exact form of the agglomeration economies. Building on the arguments of Glaeser and Gottlieb (2008), we discuss the conditions under which endogenous reallocation of manufacturing activity can raise aggregate output through agglomeration effects. We then discuss the potential impact of sharp non-linearities in agglomeration on the qualitative dynamics of the local manufacturing sector.

In Section 5 we take the model to the data and estimate its key structural parameters, including the direct productivity effects of the TVA, the strength of any agglomeration economies and their shape. We also compare our structural estimates with the reduced form estimates from the previous Section.

Finally, in Section 6 we use our structural estimates to compute the aggregate benefits of the TVA, which are compared to its costs.

4.1 Model

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 model of Roback (1982).²⁶ 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:

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

where the reservation utility level \bar{u}_t varies only across years. As detailed in section 6, \bar{u}_t is an equilibrium object, determined by aggregate supply and demand in the national labor market.

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

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

²⁶The 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. As in Roback, we additionally assume that the amount of labor supplied by each worker is fixed.

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 nonreproducible 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 price r_t . Normalizing the price of manufacturing output (which is assumed to be sold on global markets) to 1, price taking behavior on the part of firms implies the usual first order conditions and the following inverse labor demand curve:

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

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

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:

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

where D_i is a dummy for whether a county is exposed to TVA and δ_t is a measure of the direct effect of TVA investments on local productivity in year t . TVA raised local productivity both by reducing the cost of electricity and providing investments in local infrastructure. The fixed effect η_i captures the time invariant suitability of the county for manufacturing due to, for example, proximity to a body of water. Heterogeneity in this factor leads manufacturing steady states to differ across counties based upon locational fundamentals. The 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 Blanchard and Katz (1992), who study the persistence of local employment changes, we assume ε_{it} contains a unit root, so that:

$$\varepsilon_{it} = \varepsilon_{it-1} + \xi_{it} \quad (5)$$

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 $g\left(\frac{L_{it-1}}{R_i}\right)$ captures the local agglomeration effects of manufacturing activity. Different mechanisms have been proposed in the urban economics literature that may generate such agglomeration economies.²⁷ This specification is consistent with many of the models

²⁷See for example Henderson (1995, 1997, 2003) and Ahlfeldt et al. (2012). Duranton and Puga (2004) and Henderson (2005) provide reviews.

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.²⁸ This determinism is desirable as it rules out implausible situations where a county could take on, in any given period, wildly different levels of manufacturing activity by chance (see Krugman, 1991; Matsuyama, 1991 for further discussion).²⁹ 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 et al., 1992) or through thick market effects (Moretti, 2011).

4.2 Comparative Statics

Our model allows for both direct and indirect effects of TVA on productivity. The direct effects operate through the impact of TVA's public infrastructure on local 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.

To study these effects in more detail it is useful to consider the properties of the model's deterministic steady state. We write steady state productivity as:

$$\ln A_i = g \left(\frac{L_i}{R_i} \right) + \eta_i + \delta D_i. \quad (6)$$

Likewise, steady state output can be written:

$$\ln Y_i = \frac{\alpha}{1-\alpha} \ln \alpha + \frac{1-\alpha-\beta}{1-\alpha} \ln L_i + \frac{\beta}{1-\alpha} \ln F_i - \frac{\alpha}{1-\alpha} \ln r + \frac{1}{1-\alpha} \ln A_i.$$

The impact of a marginal increase in the productivity of TVA's investments on the output of county i is:

$$\frac{dY_i}{d\delta} = \frac{1}{1-\alpha} Y_i \left(D_i + \frac{1-\alpha-\beta+\sigma_i}{L_i} \frac{dL_i}{d\delta} \right),$$

where $\sigma_i \equiv \frac{d \ln A_i}{d \ln \left(\frac{L_i}{R_i} \right)} = g' \left(\frac{L_i}{R_i} \right) \frac{L_i}{R_i}$ is the local agglomeration elasticity (i.e. the elasticity of county productivity with respect to manufacturing density). Note that σ_i , may vary across

²⁸Duranton (2007) makes use of a similar timing assumption in his model of urban growth.

²⁹While 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.

counties depending on the shape of the agglomeration function $g\left(\frac{L_i}{R_i}\right)$ and the density of local manufacturing employment.

Thus, a scaling up of TVA has two effects. First, a direct effect, which is to raise output in affected areas by $\frac{1}{1-\alpha}$ percent.³⁰ Second, an indirect effect that operates through endogenous labor adjustment. This indirect effect has two components. Adding manufacturing workers mechanically raises output by an amount proportional to labor’s share and average labor productivity in the county $\left(\frac{Y_i}{L_i}\right)$. It also raises output through agglomeration, as represented by the agglomeration elasticity σ_i .

This result is useful because it allows us to better understand the aggregate impact of place based policies, and TVA in particular. Summing across all counties, it is straightforward to see that the direct effect of TVA on nation-wide manufacturing output is unambiguously positive. Intuitively, an exogenous increase in productive infrastructure paid for by the federal government can only raise total output in the sector.³¹ By contrast, the indirect effect due to labor reallocation is ambiguous and depends on whether the agglomeration benefits in the counties that gains workers outweigh the costs in counties that lose workers. More precisely, endogenous reallocation of a worker from county i to county j raises aggregate output if and only if:

$$\frac{Y_i}{L_i} (1 - \alpha - \beta + \sigma_i) < \frac{Y_j}{L_j} (1 - \alpha - \beta + \sigma_j),$$

which depends upon the average labor productivity and agglomeration elasticity in each county.

Consider first the special case when amenities are equal across the two communities, in which case wages must also be equal. In our setting, equal wages imply equal average labor productivity. Hence, reallocation from county i to j raises output only when the agglomeration elasticity is greater in community j . When the agglomeration elasticities are everywhere equal ($\sigma_i = \sigma$), spatially reallocating labor has no aggregate effects. Intuitively, a constant elasticity implies that the benefits in the counties that gain workers are identical to the costs in the counties that lose workers.

When the agglomeration elasticity is constant but amenity levels differ across communities, aggregate output can be raised by moving workers to lower amenity areas where wages (and hence average labor productivity) are higher. However, this comes at a utility cost to workers who must make do with worse amenities. One can show that this utility cost perfectly offsets the value of any increases in aggregate output.³² Thus, although agglomeration economies generate market failures at the local level, these inefficiencies may “cancel out” in the aggregate if agglomeration elasticities are constant.

³⁰The productivity-output elasticity is greater than one because capital adjustment augments a productivity change. When capital’s share is zero, the elasticity becomes 1.

³¹Of course, we have ignored the issue of how the federal funds were raised, a concern to which we will return below.

³²More precisely, it is possible to show that when $\sigma_i = \sigma$, the decentralized allocation of workers across communities maximizes aggregate utility, defined as $\sum_i L_i (\ln w_i + M_i)$. We provide a local version of this result in section 6. See also Glaeser and Gottlieb (2008).

To preview our results, our empirical analysis in section 5 will point to a constant agglomeration elasticity. Because we care about national welfare rather than output per se, this finding casts doubt on the efficiency rationale for government policies aimed at shifting the spatial distribution of economic activity.

4.3 Comparative Dynamics

We turn now to examining the transitional dynamics of our model. Figure 5 contrasts a hypothetical county’s dynamic behavior when the agglomeration elasticity is constant with its behavior when the elasticity is not constant. Specifically, Figure 5a, depicts the case where $g(\cdot)$ is log-linear – so that σ_i is the same in all counties – while Figure 5b depicts its behavior when $g(\cdot)$ is substantially nonlinear in logs – so that σ_i varies significantly across counties depending upon the local manufacturing density.

Consider first the panels of Figure 5a. 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 $-\frac{\beta}{1-\alpha}$ equal to the inverse of the short run elasticity of labor demand. 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.³³ The second panel shows what happens with the introduction of TVA. Because the new infrastructure makes firms in TVA more productive, the new LR curve is to the right of the initial LR curve. Specifically, the Authority shifts both the SR and LR curves up by an amount δ_t , which motivates a series of employment increases as manufacturing employment converges towards its new steady state. The one period lag in agglomeration yields geometric adjustment to the steady state, depicted in the final panel of Figure 5a. Hence, the model exhibits conditional convergence of the sort found in traditional growth models (Barro and Sala-i-Martin, 2004), albeit due to agglomeration forces rather than capital adjustment.³⁴

In this setting, a constant agglomeration elasticity has two implications. First, without amenity differences, there can be no aggregate effect of TVA on manufacturing productivity other than through the direct effects of the TVA infrastructure. As argued above, the productivity gains to this region associated with the additional workers must equal the losses in the counties from which those workers came.

³³Note 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 non-stationary.

³⁴Convergence 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} .

Second, 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.

Contrast this setting with Figure 5b. Here $g(\cdot)$ exhibits strong threshold effects so that productivity increases rapidly once the sector reaches some critical level of density but begins to decrease afterward due to the presence of the fixed factor.

Two key differences emerge here relative to the log-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.

An important goal of our empirical analysis in the next section is to determine whether Figure 5a or 5b (or some intermediate case) provides a better approximation to the dynamics of county growth.³⁵ Uncovering the shape of the function $g(\cdot)$ 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 log-linear case is that now the program has long lasting effects, even after the end of the federal investment. In Figure 5b, multiple steady state equilibria are present, two of which are stable and one of which is an unstable tipping point.³⁶ 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.

Recall that our estimates in Table 4 in the previous section pointed to a long lasting effect of TVA on manufacturing employment growth. We note that either form of agglomeration may yield long lasting effects qualitatively consistent with the evidence uncovered in Table 4, since even the log-linear model exhibits momentum due to the convergence process. Structural estimates are necessary to determine whether truly permanent effects underlie the qualitative patterns of the previous section or whether simple slow adjustment is at work.

5 Structural Estimates

In this and the next section, we seek to estimate the direct and indirect effects of TVA on the U.S. economy and compare them to the program’s costs. Specifically, in this section we develop an instrumental variables approach to estimating the magnitude of the direct productivity effects of the TVA program and the parameters governing the shape of the local agglomeration forces, which are important for quantifying the indirect benefits of the

³⁵Though not depicted here, it is clearly possible to have nonlinearity but a single steady state equilibrium.

³⁶That is, the system exhibits locally, but not globally, convergent dynamics.

program. In the next section, these parameters are used to conduct a quantitative cost-benefit analysis of the TVA program.

To introduce our identification strategy, 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. In addition, detecting nonlinearities in the agglomeration forces requires inferring 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.

To address these shortcomings, we will 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.

Consistent with the reduced form evidence in Section 3, we find that changes in manufacturing density in a county lead to subsequent changes in employment. We also find that agglomeration exhibits a near constant density elasticity which suggests it is difficult to raise worker welfare by reallocating employment. Although our identification strategy uses sources of variation unrelated to the TVA, the model’s predictions turn out to be remarkably consistent with the reduced form impacts of TVA on manufacturing employment.

5.1 Estimating Equation

We begin by introducing covariates into the model by assuming the productivity shocks ξ_{it} in (5) may be written:

$$\xi_{it} = X_i' \lambda + \nu_{it},$$

where X_i contains the vector of covariates used in our earlier reduced form analysis of TVA. Rewriting (3) in terms of the direct demand relationship and removing county fixed effects by taking decade level differences yields:

$$\begin{aligned} \ln(L_{it}) - \ln(L_{it-1}) &= -\frac{1-\alpha}{\beta} (\ln w_{it} - \ln w_{it-1}) + \frac{\delta_t - \delta_{t-1}}{\beta} D_i \\ &\quad + \frac{1}{\beta} \left[g\left(\frac{L_{it-1}}{R_i}\right) - g\left(\frac{L_{it-2}}{R_i}\right) \right] \\ &\quad + \tilde{\gamma}_t - \tilde{\gamma}_{t-1} + X_i' \tilde{\lambda} + \tilde{v}_{it}, \end{aligned} \quad (7)$$

where tilde's over variables indicate they have been renormalized by $\frac{1}{\beta}$.^{37,38}

A key object of interest in our model is the agglomeration function $g(\cdot)$. The shape of this function is unknown with, to our knowledge, no compelling prior evidence on functional form. As such, we approximate it with a three piece linear spline in manufacturing density:

$$g\left(\frac{L_{it}}{R_i}; \theta\right) = \sum_{i=1}^3 \theta_i g_i\left(\frac{L_{it}}{R_i}\right) \quad (8)$$

where the $g_i(\cdot)$ are the spline basis functions. We consider two choices for these functions:

$$g_i^{levels}(x) \equiv \begin{cases} x & \text{if } i = 1 \\ \min\{x - q_{i-1}, q_i - q_{i-1}\} 1[x > q_{i-1}] & \text{if } i > 1 \end{cases}$$

$$g_i^{logs}(x) \equiv \begin{cases} \ln x & \text{if } i = 1 \\ \min\{\ln x - \ln q_{i-1}, \ln q_i - \ln q_{i-1}\} 1[x > q_{i-1}] & \text{if } i > 1 \end{cases}$$

where the q_i 's are the spline knots.³⁹ In the “levels” specification $g_i^{levels}(\cdot)$, the θ_i give the proportional effect on manufacturing productivity of increasing manufacturing density by one worker per square mile over the relevant range. While in the “logs” specification $g_i^{logs}(\cdot)$, the θ_i give the elasticity of manufacturing productivity with respect to manufacturing density over the relevant density range – that is, they give the local agglomeration elasticity. Note

³⁷We omit the cost of capital r_t from this expression since it is absorbed into the year fixed effect $\tilde{\gamma}_t$.

³⁸Note that $\frac{1-\alpha}{\beta} > 1$, so the model places a lower bound of one on the slope of the contemporaneous derived demand relationship. This restriction is an artifact of the Cobb-Douglas functional form which imposes a unitary elasticity of substitution between capital and labor.

³⁹We choose $q_1 = 5.26$, $q_2 = 15.28$, $q_3 = \infty$. The points q_1 and q_2 are knots corresponding to the 60th and 85th percentiles of the 1980 distribution of county manufacturing density measured in workers per square mile. These percentiles were chosen in order to yield approximately equal variation in the first difference of each spline component over our sample period. For reference, the median county in our estimation sample has a 1980 manufacturing density of approximately 3.8 (the corresponding figure for TVA counties is 7.1). As we show in an Appendix, placing knots at the 33rd and 66th percentiles of the 1980 density distribution yields qualitatively similar (though imprecise) results.

that a constant agglomeration elasticity requires that $g(\cdot)$ be concave in density levels and linear in logs.

With this addition, (7) evaluates to:

$$\begin{aligned} \ln(L_{it}) - \ln(L_{it-1}) = & -\frac{1-\alpha}{\beta} (\ln w_{it} - \ln w_{it-1}) + \frac{\delta_t - \delta_{t-1}}{\beta} D_i \\ & + \frac{\theta_1}{\beta} \left[g_1 \left(\frac{L_{it-1}}{R_i} \right) - g_1 \left(\frac{L_{it-2}}{R_i} \right) \right] \\ & + \frac{\theta_2}{\beta} \left[g_2 \left(\frac{L_{it-1}}{R_i} \right) - g_2 \left(\frac{L_{it-2}}{R_i} \right) \right] \\ & + \frac{\theta_3}{\beta} \left[g_3 \left(\frac{L_{it-1}}{R_i} \right) - g_3 \left(\frac{L_{it-2}}{R_i} \right) \right] \\ & + X_i' \tilde{\lambda} + \tilde{\gamma}_t - \tilde{\gamma}_{t-1} + \tilde{\nu}_{it}. \end{aligned} \quad (9)$$

Equation (9) is our key estimating equation. The primary objects of interest are :

- The coefficients $\frac{\delta_t - \delta_{t-1}}{\beta}$ which give the change in the direct effects of TVA between decades;
- The spline coefficients $\frac{\theta_i}{\beta}$ which determine the indirect effects of the program since they give the labor demand effects of increasing manufacturing density within the relevant density range. We refer to $\frac{\theta_1}{\beta}$ as the agglomeration effect at “low” density, $\frac{\theta_2}{\beta}$ the effect at “medium” density, and $\frac{\theta_3}{\beta}$ the effect at “high” density.

We begin by focusing on the indirect effects and return to the direct effects in section 5.4.

5.2 Identification

To identify the parameters of interest, we examine the dynamic responses of counties to shocks to their manufacturing base. There are two key impediments to direct OLS estimation of (9). First, and most importantly, 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, agglomeration effects will be understated.⁴⁰ 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

⁴⁰Negative correlation could result, for example, if instead of (5) the idiosyncratic component of productivity ε followed a stationary autoregressive process.

correlated. To address this problem, we employ an instrumental variables strategy relying on lagged manufacturing changes. Our instruments are of the form:

$$Z_{it}^{(k)} \equiv g_k \left(\frac{L_{it-2}}{R_i} \right) - g_k \left(\frac{L_{it-3}}{R_i} \right) \quad (10)$$

for $k \in \{1, 2, 3\}$. That is, the instruments are changes in the spline components of manufacturing density lagged by two decades. This functional form mirrors that of the endogenous variables in (9).⁴¹

In the context of our model, these instruments induce exogenous variation in employment changes through the process of agglomeration. That is, regardless of why the manufacturing base changes in a period, that change should affect manufacturing growth in subsequent periods through its effects on local productivity. For the instruments to be valid we need that:⁴²

$$E[\nu_{it} Z_{it}^{(k)}] \forall k. \quad (11)$$

A sufficient condition for this restriction to hold is that the shocks to productivity be independent over a horizon of 20 years:

$$\nu_{it} \perp \nu_{it-2} \quad (12)$$

where \perp denotes independence. Note that this condition prohibits counties from possessing long lasting heterogeneous trends in productivity growth. (It does not prohibit counties from possessing heterogeneous productivity levels or short lived trends in productivity growth.)

One important reason why trends might be present and our assumption might be invalid is if counties exhibit conditional convergence in manufacturing activity for reasons having little to do with agglomeration (e.g., as in the capital mobility arguments of Barro and Sala-i-Martin (1991, 1992a, 1992b)). Several points are worth highlighting in this respect.

First, as mentioned, we condition on the vector X_i of 38 baseline controls, which include 1920 and 1930 population and quadratics in 1920 and 1930 agricultural and manufacturing shares. These variables ought to absorb a significant fraction of the heterogeneity in initial conditions that could give rise to convergence. Second, in some specifications, we also condition on 1940 manufacturing density. If conditional convergence were still present after controlling for the vector X_i of covariates, counties with lower 1940 manufacturing density would have faster growth in the following decades. In this case, controlling for 1940 manufacturing density would absorb additional heterogeneity in initial conditions, which should

⁴¹To 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 endogenous variables are measured using employment data from the Decennial Census.

⁴²Identification also requires that the instruments have sufficient predictive power. Our tables report first stage partial F-statistics which indicate a strong relationship between the instruments and each of the spline components. We note in passing however that, if treated as a truly nonparametric problem, identification of $g(\cdot)$ is inherently untestable without further assumptions (Canay, Santos, and Shaikh, 2013). Identification would follow however if we were to assume the innovations in our model are normally distributed, see Newey (2013) for discussion.

significantly change our estimates. We find instead that our results are insensitive to this control. Third, we also examine the robustness of our results to the inclusion of fixed regional trends, and find that our estimates are not very sensitive. Finally, we have also estimated models where the instruments are changes in the spline components of manufacturing density lagged by three decades instead of two. The first stage in these models was not statistically significant, lending further credibility to the assumption that our instrument is not picking up long run trends.

While these robustness exercises do not guarantee that all trend heterogeneity has been removed, we believe they suggest our results are not spurious. Moreover, we note that many of our conclusions rest on the *relative* magnitude of the three $\frac{\theta_k}{\beta}$ parameters. Even if assumption 11 were violated, we see little reason for omitted trends to induce (or suppress) any nonlinearities in the agglomeration process. As we shall see in section 6, our cost-benefit analysis hinges more on the shape of the agglomeration function than the estimated strength of any agglomeration effects.

A second impediment to the estimation of (9) 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 our baseline model we calibrate $-\frac{1-\alpha}{\beta}$, which represents the (short-run) elasticity of labor demand. Based on Hamermesh (1993)'s influential review, we use 1.5 as the most plausible estimate of the relevant labor demand elasticity.⁴³ We use this as our starting point, and then assess the sensitivity of our estimates to different values of the elasticity.

5.3 Estimates of Agglomeration Economies.

Table 5 provides OLS and two stage least squares estimates of (9) based on four decades of changes in log manufacturing density as measured in the Decennial Census.⁴⁴ This table sets $g_i(\cdot) = g_i^{levels}(\cdot)$. At the bottom of the table we report p-values for the hypothesis that the three spline components have equal coefficients, so that the $g(\cdot)$ function is linear in levels; and for the hypothesis that all three coefficients equal zero.

The first column provides baseline OLS estimates which display evidence of modest agglomeration effects in manufacturing. These effects exhibit a concave relationship with density – raising manufacturing density by one worker per square mile in a low density county is associated with a 3.0% increase in labor demand while a corresponding increase in a high density county is associated with virtually no increase in demand. The null hypothesis of linearity is rejected. Adding controls for regional trends and 1940 manufacturing density has

⁴³In his review of empirical literature, Hamermesh (1993) documents a variety of estimates of national labor demand elasticities, centered in the range 1 to 1.5. Since we are interested in regional demand, we pick a parameter on the high end of the spectrum for our baseline specification. As we show below, our estimates are robust to using elasticities in the 1-2 range.

⁴⁴Specifically, 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.

very minor effects on the point estimates, suggesting our results are unlikely to be driven by spurious trends.

The fourth column instruments for density changes using twice lagged density changes. This raises the magnitude of the estimated agglomeration effects within each density range and induces a strikingly nonlinear pattern of marginal effects. Raising manufacturing density by one worker per square mile in a low density county is associated with an 8.7% increase in labor demand while a corresponding increase in a medium density county is associated with a 3.0% increase in demand. As before, raising density in a high density county has essentially no effect. These coefficients are estimated quite precisely – we easily reject the null that the agglomeration effects are equal across density levels, with a p-value of 0.0004. The results are also robust to changes in specification, with only very minor effects on the point estimates of controlling for 1940 population density and/or regional trends (columns 5 and 6).

In the Appendix we show that our results are robust to a number of different variations on our approach. Estimating the short run elasticity of labor demand instead of calibrating it has minor effects on the spline coefficients (see Appendix Table 1).⁴⁵ As a check on the sensitivity of our calibration we also report IV estimates that assume the elasticity of demand takes alternative values (see Appendix Table 2). Again, the spline coefficients exhibit very limited sensitivity to these changes, in all cases exhibiting a significantly concave pattern with respect to density. Finally, in Appendix Table 3 we report estimates changing the knots used to define our spline categories in terms of 1980 manufacturing terciles.⁴⁶

Overall, these findings point to significant non-linearities in the agglomeration function. The pattern that emerges is that of marked concavity in $g(\cdot)$, whereby increases in manufacturing density are estimated to have significantly stronger effects in counties with a weak manufacturing presence than in counties with a more established presence. One might be tempted to infer that place based policies should reallocate manufacturing employment from high density areas to low density areas. However, as discussed in section 4.2, this intuition is incorrect. Reallocating workers to low density areas only raise aggregate worker welfare if lower density counties have a greater agglomeration *elasticity*.

We turn now to a direct assessment of agglomeration elasticities. Table 6 repeats our analysis using a three piece spline in the log of manufacturing density (i.e. setting $g_i(\cdot) = g_i^{logs}(\cdot)$). This specification provides estimates of elasticities for counties with low, medium, and high levels of density respectively and it enables us to directly test for constant elasticities. As before, OLS estimation yields small and only marginally significant coefficients. Instrumenting raises these figures substantially, with a 10% increase in density estimated to yield a 3%-3.5% increase in labor demand depending upon the spline segment. As with the levels specification, the estimates are robust to controlling for baseline density and regional trends. Notably, we cannot reject a constant elasticity relationship in any of the IV specifications. The p-values for the test of equal elasticity are all above .89, and

⁴⁵The estimate of the coefficient on wages has the wrong sign. As noted, this is unsurprising given the many measurement and endogeneity issues involved.

⁴⁶These estimates are again concave but substantially noisier because less variation is present in the low density groups under this definition.

the point estimates are tightly clustered around values in the range .3-.32. Thus, we conclude that manufacturing productivity exhibits a nearly constant elasticity relationship with manufacturing density.

Discussion

Three points are worth noting regarding the estimates of Tables 5 and 6. First, our estimates strongly suggest agglomeration economies are concave in manufacturing density and that this concavity is well-approximated by a stable logarithmic function, though our confidence intervals are wide enough to allow for some elasticity variation across density levels. This finding has important policy implications. As discussed in section (4.2), a near constant elasticity severely proscribes the ability of governments to raise welfare via pure reallocations of manufacturing activity. Though agglomeration economies have external effects not captured by the price system, our finding of constant elasticity indicates that these effects cancel out in the aggregate. Thus, this is an interesting case where the existence of a market failure does not generate efficiency losses in the aggregate.

Second, the magnitude of the implied agglomeration economies is in line with existing estimates in the literature. Recall from (9) that the agglomeration elasticity in each range is β (the fixed factor share) times the coefficients reported in Table 6. If we assume capital's share in manufacturing α is in this period approximately 0.3 (Griliches, 1967), and that the elasticity of demand $\frac{1-\alpha}{\beta}$ is 1.5, then we expect $\beta \approx 0.47$. Hence, the agglomeration elasticities θ_i implied by Table 6 are in the neighborhood of 0.14. A recent meta-analysis of 34 different studies of agglomeration economies finds that 90% of the estimates of the elasticity of productivity with respect to city size range between -0.090 and 0.292, depending on the sector and the details of the estimation procedure (Melo et al., 2009). Our estimates are squarely in the middle of this range and well within the range of elasticities reported in several of the most prominent recent studies.⁴⁷

Finally, the estimates in Table 6 make clear that the dynamics of the system are stable. A 10% increase in county employment yields roughly 3% extra employment next decade due to agglomeration effects. Figure 6 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 worker productivity. The estimated shape of the curve implies the system admits a unique steady state equilibrium, which suggests the effects of TVA will eventually die out.

⁴⁷For example, Henderson (2003) obtains an elasticity of productivity with respect to density of same industry plants of .01-.08. Estimates for France in Combes et al. (2010) and Combes et al. (2012) imply elasticities of 0.029 and .032, respectively. At the other extreme, Greenstone, Hornbeck and Moretti (2010)'s estimates imply an elasticity in the range 1.25-3.1. Of course, part of the variation in these estimates is due to the fact that models, data, time periods and industries used in the studies are vastly different. See Rosenthal and Strange (2004) for a survey of the literature.

⁴⁸These estimates are from column 4 of Table 5.

5.4 Estimates of the Direct Productivity Effects of the TVA

Recall that our model allows for both direct and indirect effects of the TVA. The direct effects capture the gains to the region’s productivity due to federally financed public investments (the δ_t). In the specifications reported in Table 5, the estimated coefficient on the TVA dummy is positive but statistically indistinguishable from zero. Because the model is in differences, this suggests the direct productivity effects of TVA were roughly constant over the sample period 1960-2000.

Table 7 examines this finding more closely by recomputing the direct effects over three distinct horizons, the first of which lies outside the sample period used in Table 5.⁴⁹ The estimates in the Table were computed via a regression of residuals of the form $Q_{it} \equiv \ln L_{it} - \ln L_{it-2} - \frac{\hat{\theta}_1}{\beta} \left[g_1 \left(\frac{L_{it-1}}{R_i} \right) - g_1 \left(\frac{L_{it-3}}{R_i} \right) \right] - \frac{\hat{\theta}_2}{\beta} \left[g_2 \left(\frac{L_{it-1}}{R_i} \right) - g_2 \left(\frac{L_{it-3}}{R_i} \right) \right] - \frac{\hat{\theta}_3}{\beta} \left[g_3 \left(\frac{L_{it-1}}{R_i} \right) - g_3 \left(\frac{L_{it-3}}{R_i} \right) \right] - 1.5 (\ln w_{it} - \ln w_{it-2})$ on baseline covariates and a TVA dummy. For completeness, we consider both the specification of Table 5 where $g(\cdot)$ is piecewise linear in the level of manufacturing density and that of Table 6 where it is a spline in the log of manufacturing density. Hats denote estimated coefficient values, which come from column (4) of Table 5 in the “Spline in levels” specification and column (4) of Table 6 in the “Spline in logs” specification. The resulting coefficients on the TVA dummy provide estimates of $\frac{\delta_t - \delta_{t-2}}{\beta}$ for the relevant time horizon.

Reassuringly, the two specifications of the $g(\cdot)$ function yield very similar results. Consistent with our reduced form findings in Section 3, the TVA is estimated to have substantially boosted productivity over the period 1940-1960. Taking $\beta = 0.47$ (as before), we have that TVA raised local productivity by approximately 8.4% over the 1940-1960 period. This was followed by insignificant negative direct effects in later periods, which is in keeping with the earlier evidence that TVA transfers scaled down over this horizon and that local infrastructure began to depreciate.

5.5 Comparison with reduced form estimates

A rough comparison of the structural estimates with the reduced form impacts of Table 4 is possible using the logarithmic autoregressive specification of Table 6 and the direct productivity impacts of Table 7. The direct effect of TVA on local labor demand over the 1940-1960 period is roughly 9% per decade. Given an autoregressive coefficient of 0.3, this implies a composite change between 1940 and 1960 in direct demand of $.09 \times 1.3 + .09 = .207$ which is somewhat below the reduced form 22.8% impact in Table 4 but well within sampling error. The implied impact on growth over the subsequent 1960-2000 period, assuming no further direct impacts of TVA, is $(0.3 + (0.3)^2 + (0.3)^3 + (0.3)^4) \times .207 = .087$ which is below the 13.2% growth impact implied by column 2 of Table 4 but, again, well within sampling error. For comparison, if we use an autoregressive coefficient of 0.4, we get an impact over the 1940-1960 period of 21.6% and an impact over the 1960-2000 period of 14.0%.

⁴⁹Changes over the period 1940-1960 weren’t included in the estimation sample for Table 5 because we lacked instrument data for those years.

This finding is reassuring and lends additional credibility to our structural estimates. Despite using completely different sources of variation for identification, our structural estimates are in line with the reduced form impacts of section 3.

6 A Cost Benefit Analysis

In this section, we use our structural parameter estimates to conduct a quantitative cost-benefit analysis of the TVA’s long run effects. Our goal is to assess whether the program was welfare enhancing from the point of view of the United States as a whole. Computing the program’s costs is straightforward: we use the 1940 present value of the year by year stream of federal appropriations to the TVA listed in Figure 1. Computing program benefits is more challenging and relies upon the structure of our model. To quantify the nationwide benefits of the productivity gains associated with the TVA, we compute the steady state elasticity of worker utility with respect to the TVA’s productivity effects. This elasticity is combined with our estimates of the direct productivity effects of the TVA to compute an impact on worker welfare which is then converted to dollars terms.

We begin in subsection 6.1 by deriving the formula for the elasticity of worker utility with respect to TVA’s local investments under the assumption of fixed sectoral labor supply. In subsection 6.2 we compare costs and benefits of the program under this assumption. In subsection 6.3 we generalize our analysis to the more plausible case of elastic supply. In subsection 6.4 we highlight some key limitations.

6.1 TVA and Worker Utility

We begin by developing the additional general equilibrium assumptions necessary to conduct our analysis. In particular, we add to our model the following sectoral market clearing condition:

$$L_t^S(\bar{u}_t) = L_t^D(\bar{u}_t) \tag{13}$$

where L_t^S denotes the aggregate supply of manufacturing workers in period t which is increasing in the utility level \bar{u}_t . $L_t^D \equiv \sum_i L_{it}$ denotes aggregate labor demand which is decreasing in manufacturing wages and hence, from (2), also in \bar{u}_t .

A useful baseline assumption for our analysis is to assume that the supply of manufacturing workers is fixed at each moment in time ($L_t^S(\bar{u}_t) = \bar{L}_t$). We will relax this assumption below. With fixed supply, gains in the TVA region must be offset by losses elsewhere and increases in aggregate demand must be offset by changes in wages.

Though our model is dynamic, our structural estimates indicate the rate of adjustment to the steady state is relatively rapid, which suggests that a steady state analysis should provide a good approximation to a full dynamic solution.⁵⁰ The steady state of our model

⁵⁰In addition to its simplicity, a steady state analysis has the advantage of formalizing our intuition from section 4.2 that a constant agglomeration elasticity renders the magnitude of agglomeration economies irrelevant for welfare purposes.

is given by (6) and the following equations:

$$\sum_i L_i = \bar{L} \quad (14)$$

$$\ln w_i + M_i = \bar{u}$$

$$\ln w_i = C - \frac{\beta}{1-\alpha} \ln L_i + \frac{\beta}{1-\alpha} \ln F_i - \frac{\alpha}{1-\alpha} \ln r + \frac{1}{1-\alpha} \ln A_i$$

We are interested in the elasticity of worker utility with respect to TVA's local investments, which can be written:

$$\frac{d\bar{u}}{d\delta} = \frac{d \ln w_i}{d\delta} = -\frac{1}{1-\alpha} \frac{1}{L_i} (\beta - \sigma_i) \frac{dL_i}{d\delta} + \frac{1}{1-\alpha} D_i$$

Solving for $\frac{dL_i}{d\delta}$ yields:

$$\frac{dL_i}{d\delta} = \frac{D_i - (1-\alpha) \frac{d\bar{u}}{d\delta}}{\frac{1}{L_i} (\beta - \sigma_i)}$$

But (14) implies:

$$\sum_i \frac{dL_i}{d\delta} = \sum_i \frac{D_i - (1-\alpha) \frac{d\bar{u}}{d\delta}}{\frac{1}{L_i} (\beta - \sigma_i)} = 0$$

Hence, the elasticity of interest can be written:

$$\frac{d\bar{u}}{d\delta} = \frac{1}{1-\alpha} \frac{\sum_i \frac{D_i L_i}{\beta - \sigma_i}}{\sum_i \frac{L_i}{\beta - \sigma_i}}.$$

With a constant agglomeration elasticity ($\sigma_i = \sigma$), this expression simplifies to:

$$\frac{d\bar{u}}{d\delta} = \frac{1}{1-\alpha} \frac{\sum_i D_i L_i}{\sum_i L_i}. \quad (15)$$

Note that this formula doesn't depend upon the strength of agglomeration forces σ . This is because, with a constant elasticity, the agglomeration effects of worker reallocation cancel out. Hence, worker utility simply increases in proportion to the TVA region's share of the manufacturing workforce. In essence, this expression tells us that TVA should be thought of as only nominally place based in nature. Rather, it is a national investment that raises welfare through its direct effects on the productivity of a fraction of the manufacturing workforce.

While it is certainly possible that agglomeration elasticities do vary across communities, our point estimates of $g(\cdot)$ are so close to log-linear that we expect the effects of small nonlinearities to be trivial. Hence, we turn now to using the simple expression in (15) to assess TVA's benefits.

6.2 Comparing Aggregate Costs and Benefits

We now have all the pieces that are needed to compare the TVA's costs to its benefits. TVA's share of national manufacturing employment in 1940 was approximately 3.3% which we use as our estimate of $\frac{\sum_i D_i L_i}{\sum_i L_i}$. This number, along with our estimates from Table 7, allow us to quantify TVA's impact on national productivity. Specifically, we find that the program raised national productivity by $.084 \times .033 \times 100 = .3\%$ between 1940 and 1960. This is a plausible magnitude that will be shown to imply important effects on worker utility.

Given that $\frac{1}{1-\alpha} \approx 1.43$, our estimate of the utility elasticity of TVA productivity is $\frac{d\bar{u}}{d\delta} \approx 1.43 \times .033 = .047$. From Table 7, we know that δ increased by roughly .084 between 1940 and 1960 and may have declined slowly in subsequent years. Interpolating linearly, we assume δ grew by .0042 per year between 1940 and 1960 and then fell by .0002 per year afterward due to depreciation. Table 8 details this calculation. Multiplying $\frac{d\bar{u}}{d\delta}$ by each year's level of δ yields the proportional utility gain in the manufacturing sector in that year. We then multiply this figure by the manufacturing wage bill in that year in order to value the utility gain measured in 2000 dollars. This yields the flow of program benefits in column 4 of Table 8. The net present value of this stream of benefits using a real annual discount rate of 3% is roughly \$32.3B.⁵¹ This is to be compared with the present value of federal transfers which amount to \$17.3B. Hence, we find a substantial rate of return to the TVA's public investments, with benefits nearly double program costs.

6.3 Relaxing Fixed Supply

The fixed supply assumption upon which the above estimates are predicated is a strong one. If sectoral labor supply is not fixed, manufacturing gains in the TVA region need not crowd out the manufacturing bases of other geographic areas. Rather, workers will be diverted, in part, from other sectors (e.g. agriculture or home production). Suppose we replace (14) with the assumption that

$$\sum_i L_i = \bar{L}(\bar{u})$$

This implies that

$$\sum_i \frac{dL_i}{d\delta} = \sum_i \frac{D_i - (1-\alpha) \frac{d\bar{u}}{d\delta}}{\frac{1}{L_i}(\beta - \sigma)} = \bar{L}'(\bar{u}) \frac{d\bar{u}}{d\delta}$$

Some algebra yields a new expression for the utility elasticity of the TVA's productivity effects:

$$\frac{d\bar{u}}{d\delta} = \frac{1}{1 - \alpha + (\beta - \sigma) \psi} \frac{\sum_i D_i L_i}{\sum_i L_i},$$

⁵¹This figure assumes the benefits end discretely in the year 2000, when our data end. If one assumes a permanent effect after 2000, our estimate rises slightly to \$34.7B

where $\psi \equiv \bar{L}'(\bar{u})/\bar{L}$ is the elasticity of labor supply to the manufacturing sector. Note that now the level of the agglomeration elasticity is relevant for our calculation. This is because increases in market size lead to additional agglomeration everywhere and hence additional productivity. This force is offset by the fixed factor which yields declining marginal products as market size increases. Given the basic regularity condition that $\beta > \sigma$, this expression has the intuitive property that the utility consequences of TVA on manufacturing workers dissipate as the elasticity of labor supply to the sector increases.⁵² Moreover, if the elasticity is zero, we return to the expression for the fixed supply case.

To assess the impact of a reasonable degree of elasticity to the manufacturing sector we set $\psi = 1$. And following our earlier calibrations, we take $\beta - \sigma = .33$. This gives us $\frac{1}{1-\alpha+(\beta-\sigma)\psi} \approx 1$ and hence $\frac{d\bar{u}}{d\delta} \approx .033$. The stream of benefits associated with this choice of parameters is reported in columns (5) and (6) of Table 8. Under this calibration, the net present value of benefits in the manufacturing sector falls to approximately \$22.7B – still above program costs but significantly lower than before.

6.4 Caveats

Several caveats are worth keeping in mind when interpreting our results. First, with variable supply, the outflow of workers from other sectors may yield wage increases in those sectors which are not captured in our accounting of benefits. However, if the sectors from which workers are diverted exhibit roughly constant returns to scale, then wages may remain stable in the face of outflows, provided workers are not too heterogeneous in their tastes for sectors. Hornbeck and Keskin (2012), for example, argue that agriculture has constant returns in this period.

Second, for a variety of reasons, labor market impacts probably capture only a fraction of the true general equilibrium impact of TVA. For example, with transport costs or trading frictions, it is possible that the productivity enhancements associated with TVA would depress the national price of manufactured goods. This would result in increased consumer surplus ignored in our calculation.

In the other direction, we have ignored the social costs associated with raising the federal funds transferred to TVA via taxation. Feldstein (1999), for example, estimates the marginal cost of funds at thirty cents on the federal dollar. We are not aware of econometric estimates of the marginal cost of funds for the 1940-1960 period during which TVA received the bulk of its transfers but can imagine that the costs were substantial. This dead weight loss is likely to increase substantially the ultimate social costs of the program.

Finally, our analysis relies on steady state approximations to the time path of welfare impacts on manufacturing workers. These approximations simplify our analysis dramatically, but a more sophisticated analysis taking into account out of steady state dynamics would be interesting, if tedious. In particular, such an analysis would have the advantage of capturing interactions (which we ignore) between national shocks to manufacturing and TVA's dynamic

⁵²If $\beta < \sigma$ the model would become unstable as the steady state demand curve for labor would slope up globally. This would lead to an equilibrium where all labor locates at a single point.

productivity effects.

7 Conclusions

This paper makes two primary contributions. Our substantive contribution is to estimate the local and aggregate effects of one of the largest place based policies in U.S. history. To our knowledge, we are the first to empirically quantify the long run social costs and benefits of a place based policy. A second contribution is methodological: we have developed a tractable empirical framework for evaluating the aggregate welfare effects of place based policies, with the potential to be applied to many other settings.

Our empirical findings are policy relevant. The evaluation designs of Section 3 provide 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 agglomeration forces, retracted dramatically once subsidies terminated.

Our analysis in Section 6 suggests the TVA substantially raised the productivity of the U.S. manufacturing sector by roughly 0.3% between 1940 and 1960. We estimate that the stream of benefits associated with this increase exceeded the program's costs, though this conclusion rests on several unverifiable assumptions regarding the functioning of labor markets.

Most of the national impact of the TVA on worker welfare is accounted for by the direct effects of the program's vast investments in public infrastructure. Our finding of a roughly constant agglomeration elasticity suggests the program's indirect effects were minimal. A noteworthy implication is that although agglomeration economies represents an important market failure at the local level, this failure does not provide a rationale for federal intervention in the spatial distribution of manufacturing activity.

We caution, however, that our findings do not necessarily apply to all contexts, as the strength and shape of agglomeration economies may well vary across industries, periods and levels of aggregation. Our results are specific to the manufacturing sector and a period of U.S. history when manufacturing employment was expanding and earnings were relatively high. An important task for future work is to assess whether similar qualitative results hold for modern development efforts, such as those centered on building high tech clusters.

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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 of 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.
- M-wage: 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.
- Pcm-wage: per capita county level manufacturing wage. Defined as m-wage 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.⁵³
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 build 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.⁵⁴ 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.)
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);

⁵³More 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>

⁵⁴We 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 area 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.

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.

Figure 1: The TVA Service Area

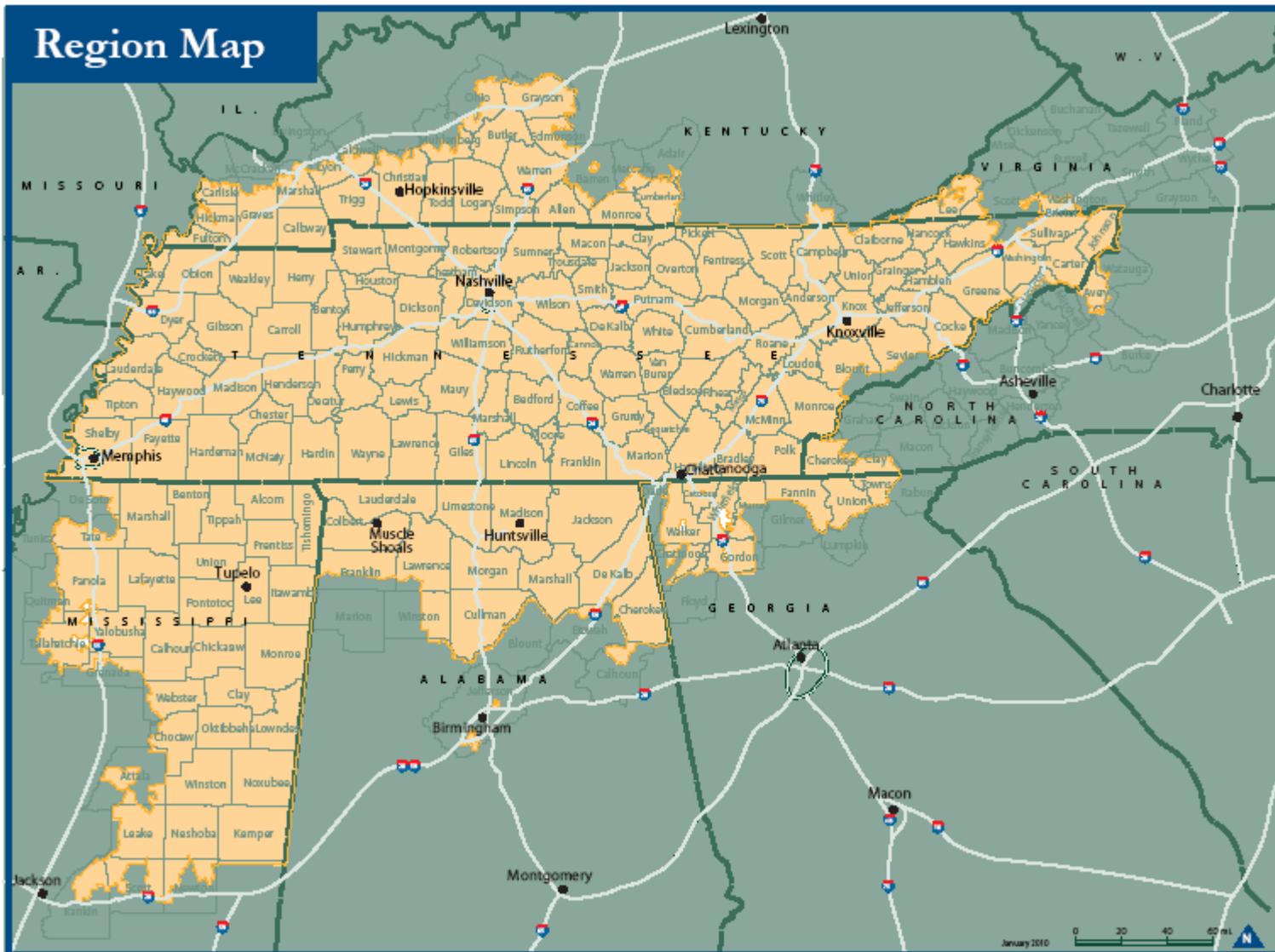
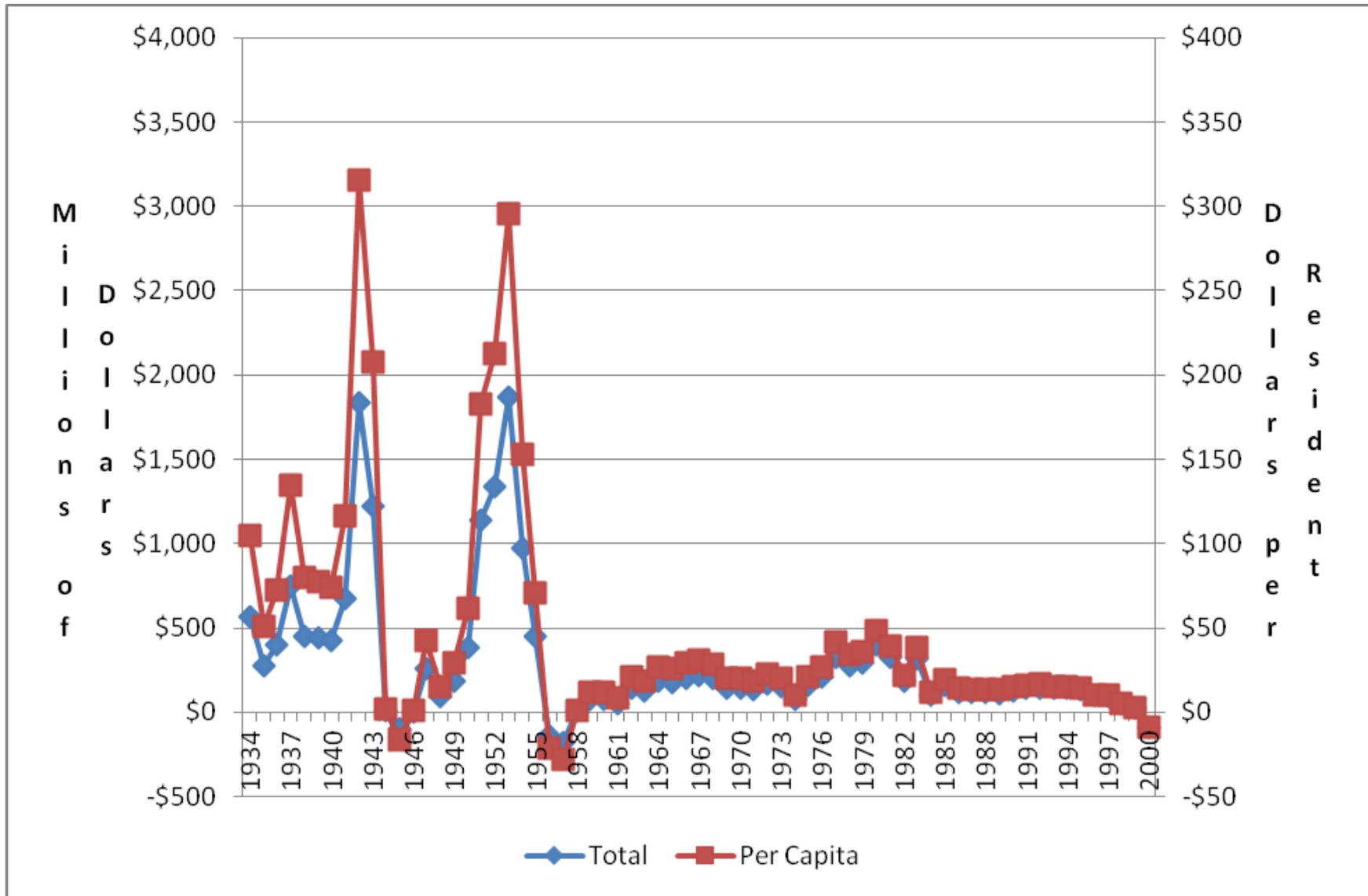


Figure 2: Federal Transfers to TVA by Year (2000 Dollars)



Note: Federal transfers defined as net federal outlays plus property transfers minus repayments (see Data Appendix for sources).

Figure 3a – Estimation Sample

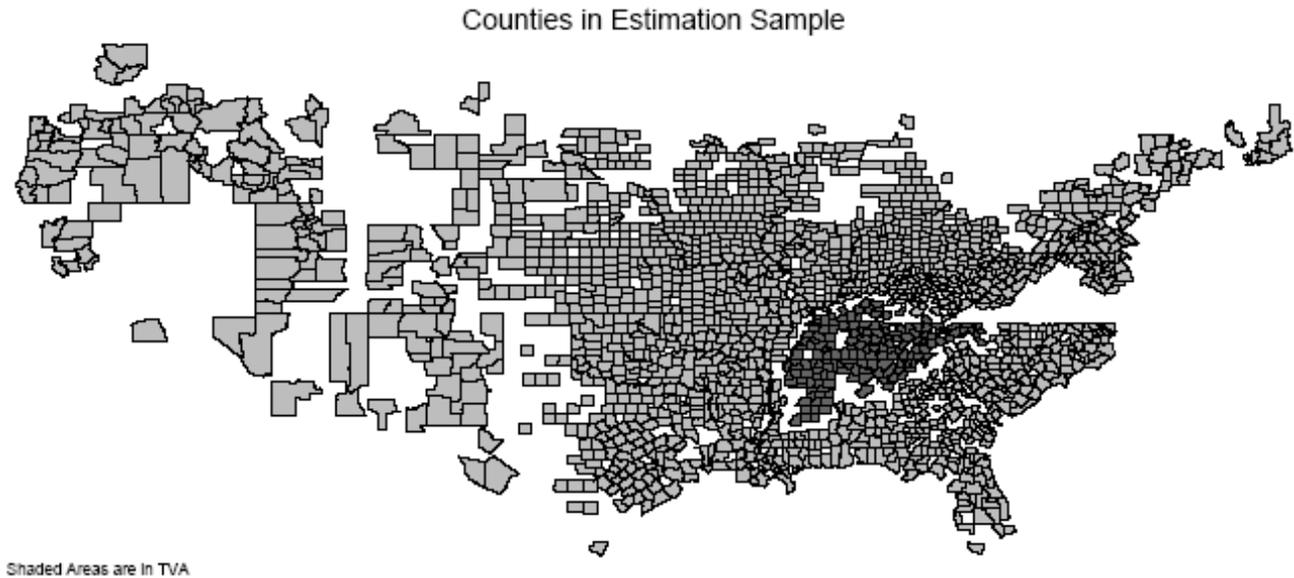
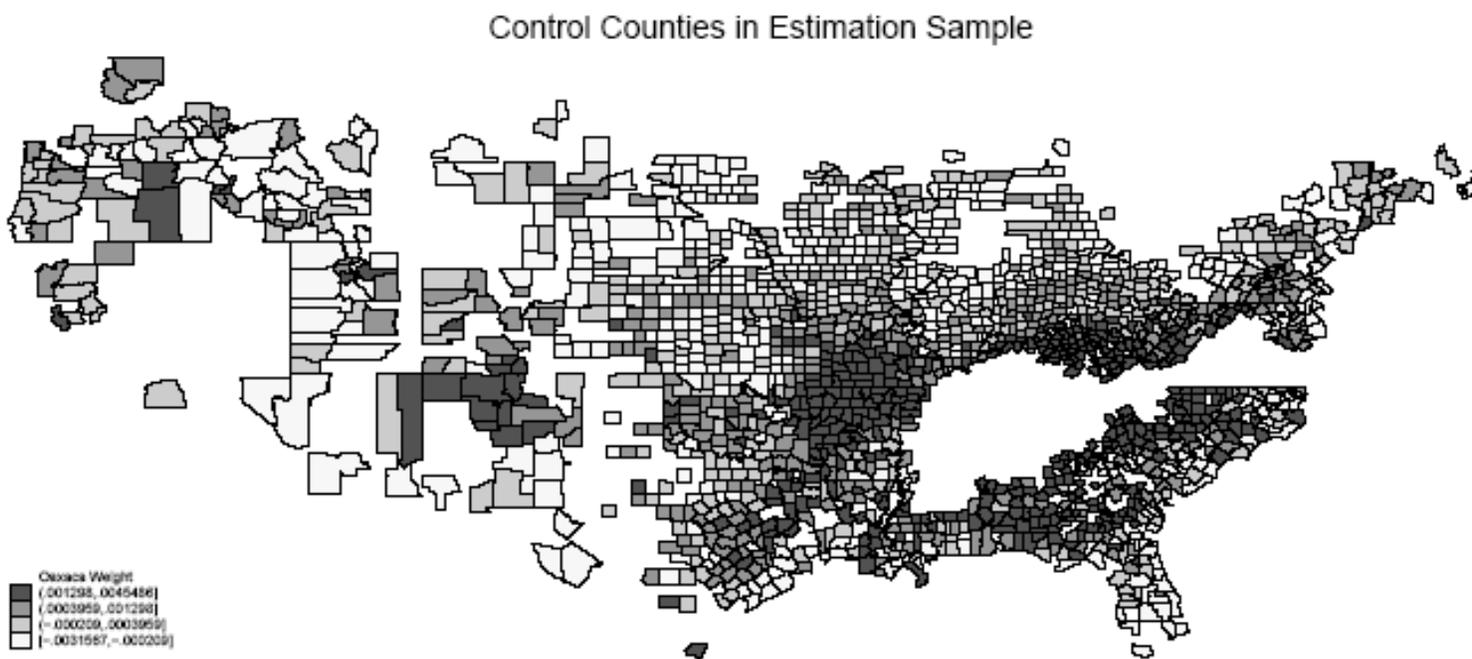
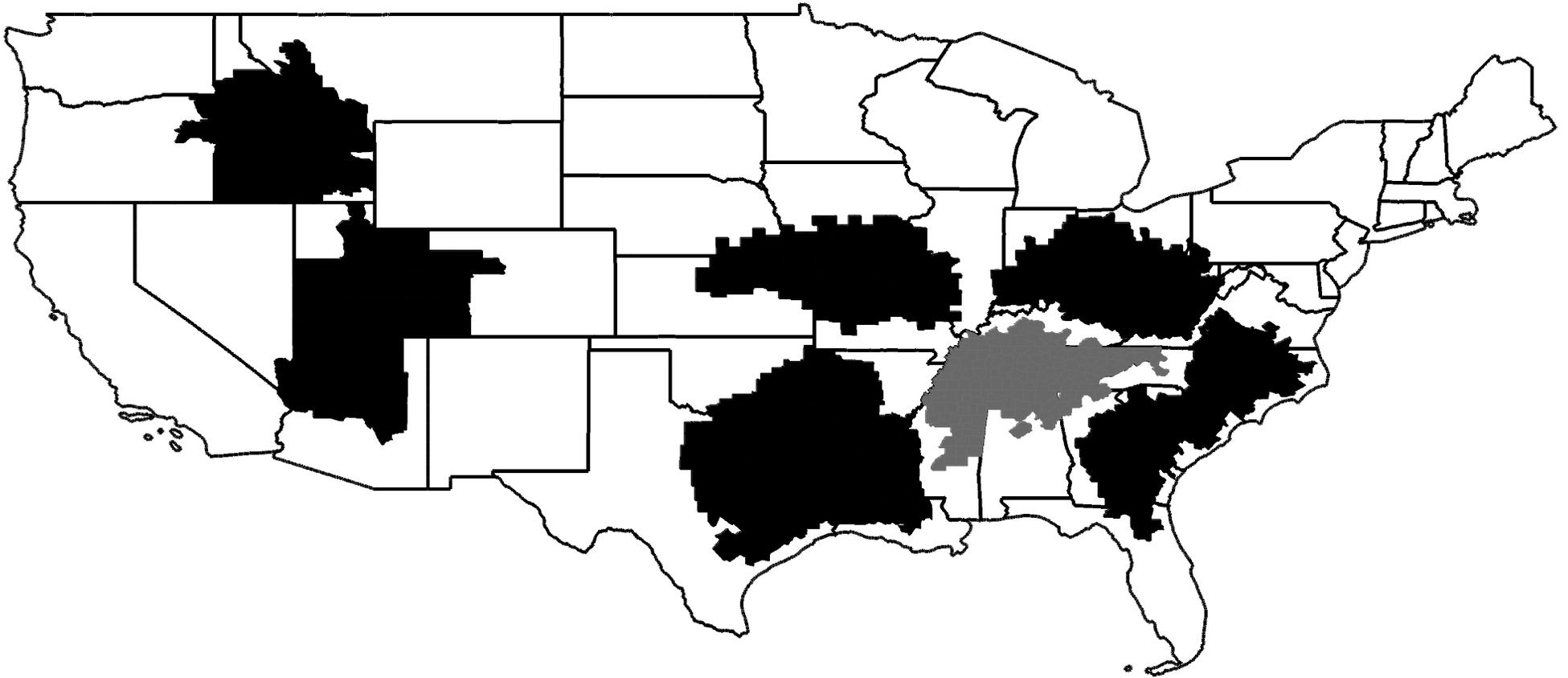


Figure 3b – Weight on Untreated Counties



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

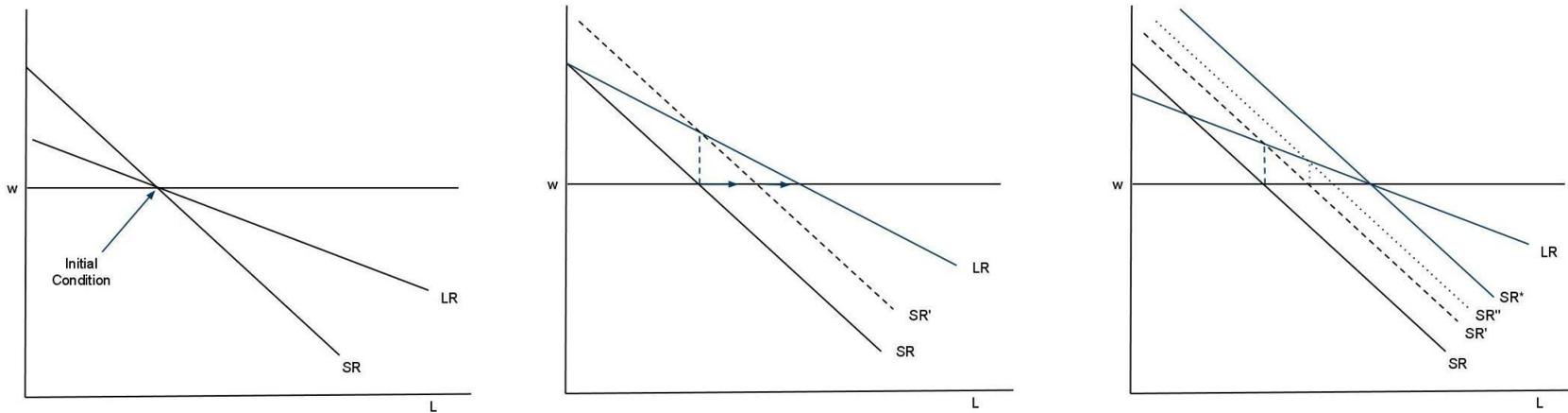
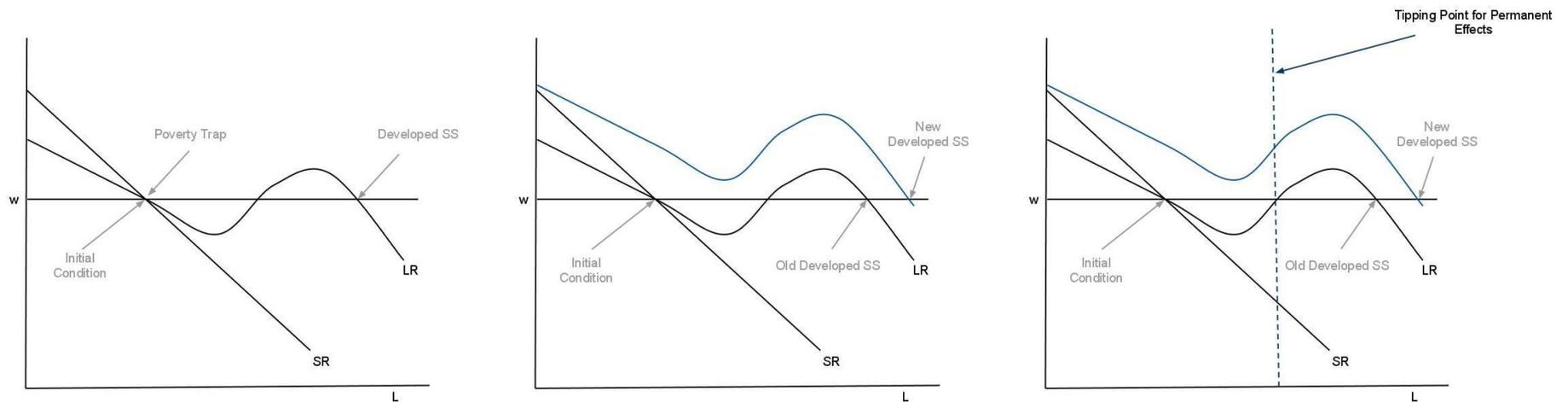
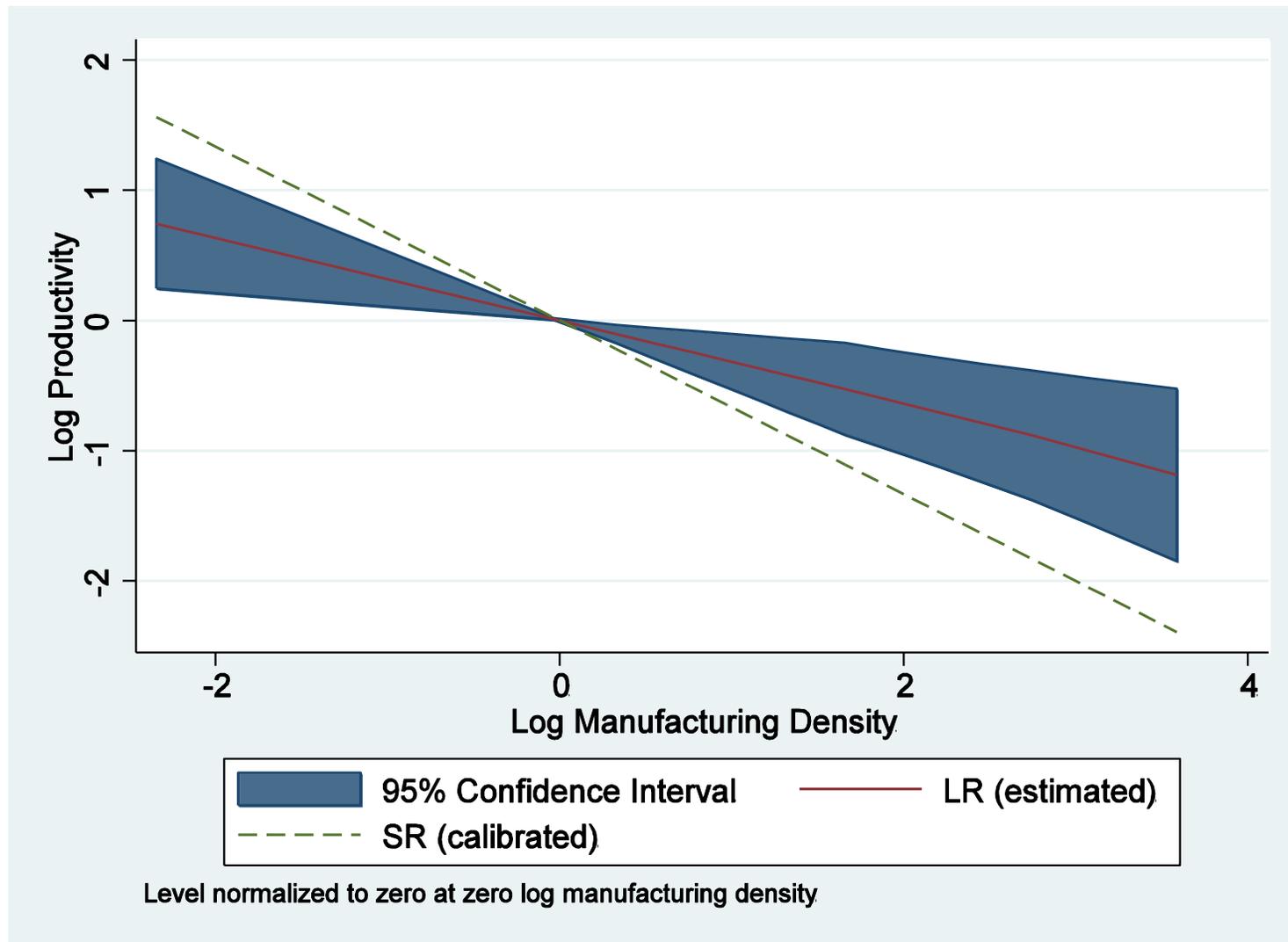


Figure 5b: Nonlinear Agglomeration



Notes: In each figure, the horizontal axis is log manufacturing density and the vertical axis is the log manufacturing wage. SR and LR refer to short run and long run inverse demand curves respectively (see section 4.3 of text). Figure 5a depicts convergence from initial condition to the new unique steady state under linear agglomeration after a permanent productivity shift. Figure 5b depicts effects of transitory productivity shift on steady state in the presence of nonlinear agglomeration effects.

Figure 6: Short and Long Run Inverse Labor Demand Functions



Note: This figure depicts the short and long run inverse labor demand functions implied by our estimates from column (4) 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 of -1.5 based on Hamermesh (1993).

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)
<u>1930 Characteristics</u>								
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
<u>Changes 1920-1930</u>								
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

		Point Estimate (Unadjusted)	Clustered S.E.	Point Estimate (Controls)	Clustered S.E.	Spatial HAC	N
	Outcome	(1)	(2)	(3)	(4)	(5)	(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: Column (1) gives the unconditional difference between TVA and non-TVA counties in the 1900-1940 change in the log of the relevant outcome divided by four (shares not converted to logs). Column (3) adjusts for pre-program differences between TVA counties and controls via a Oaxaca-Blinder regression as in Kline (2011). Covariates include time invariant geographic characteristics and levels and trends in pre-program industrial mix, population, and demographic characteristics (see Section 3.1 for full list of covariates). Clustered S.E. columns provide 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

		Point Estimate (Unadjusted)	Spatial HAC	Point Estimate (Controls)	Spatial HAC	N
	Outcome	(1)	(2)	(3)	(4)	(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: Column (1) gives the unconditional difference between TVA and other southern counties in the 1900-1940 change in the log of the relevant outcome divided by four (shares not converted to logs). Column (3) adjusts for pre-program differences between TVA counties and controls via a Oaxaca-Blinder regression as in Kline (2011). Covariates include time invariant geographic characteristics and levels and trends in pre-program industrial mix, population, and demographic characteristics (see Section 3.1 for full list of covariates). Spatial HAC columns provide 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 2c : Decadalized Growth Rates in TVA Region vs. Proposed Authorities 1900-1940

		Point Estimate (Unadjusted)	Spatial HAC	Point Estimate (Controls)	Spatial HAC	N
	Outcome	(1)	(2)	(3)	(4)	(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: Column (1) gives the unconditional difference between TVA and counties in proposed authorities in the 1900-1940 change in the log of the relevant outcome divided by four (shares not converted to logs). Column (3) adjusts for pre-program differences between TVA counties and controls via a Oaxaca-Blinder regression as in Kline (2011). Covariates include time invariant geographic characteristics and levels and trends in pre-program industrial mix, population, and demographic characteristics (see Section 3.1 for full list of covariates). Spatial HAC columns provide 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)

		Point Estimate (Unadjusted)	Clustered S.E.	Point Estimate (Controls)	Clustered S.E.	Spatial HAC	N
	Outcome	(1)	(2)	(3)	(4)	(5)	(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)	Agricultural Employment	-0.130***	(0.026)	-0.056**	(0.024)	(0.027)	1907
(4)	Manufacturing Employment	0.076***	(0.013)	0.059***	(0.015)	(0.023)	1907
(5)	Value of Farm Production	-0.028	(0.028)	0.002	(0.032)	(0.026)	1903
(6)	Median Family Income (1950-2000 only)	0.072***	(0.014)	0.021	(0.013)	(0.011)	1905
(7)	Average Agricultural Land Value	0.066***	(0.013)	-0.002	(0.012)	(0.016)	1906
(8)	Median Housing Value	0.040**	(0.017)	0.005	(0.015)	(0.015)	1906

Note: Column (1) gives the unconditional difference between TVA and non-TVA counties in the 1940-2000 change in the log of the relevant outcome divided by six. Column (3) adjusts for pre-program differences between TVA counties and controls via a Oaxaca-Blinder regression as in Kline (2011). Covariates include time invariant geographic characteristics and levels and trends in pre-program industrial mix, population, and demographic characteristics (see Section 3.1 for full list of covariates). Clustered S.E. columns provide 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

		Point Estimate (Unadjusted)	Spatial HAC	Point Estimate (Controls)	Spatial HAC	N
	Outcome	(1)	(2)	(3)	(4)	(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)	Agricultural Employment	-0.097***	(0.030)	-0.051*	(0.027)	942
(4)	Manufacturing Employment	0.079***	(0.023)	0.063***	(0.024)	942
(5)	Value of Farm Production	-0.005	(0.025)	-0.006	(0.026)	939
(6)	Median Family Income (1950-2000 only)	0.041***	(0.012)	0.024**	(0.011)	942
(7)	Average Agricultural Land Value	0.031*	(0.018)	-0.003	(0.017)	942
(8)	Median Housing Value	0.019	(0.017)	0.007	(0.016)	942

Note: Column (1) gives the unconditional difference between TVA and southern counties in the 1940-2000 change in the log of the relevant outcome divided by six. Column (3) adjusts for pre-program differences between TVA counties and controls via a Oaxaca-Blinder regression as in Kline (2011). Covariates include time invariant geographic characteristics and levels and trends in pre-program industrial mix, population, and demographic characteristics (see Section 3.1 for full list of covariates). Spatial HAC columns provide 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 3c: Decadalized Impact of TVA on Growth Rate of Outcomes (1940-2000) - Relative to Proposed Authorities

		Point Estimate (Unadjusted)	Spatial HAC	Point Estimate (Controls)	Spatial HAC	N
	Outcome	(1)	(2)	(3)	(4)	(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)	Agricultural Employment	-0.101***	(0.029)	-0.071***	(0.027)	991
(4)	Manufacturing Employment	0.066***	(0.024)	0.053**	(0.024)	991
(5)	Value of Farm Production	0.002	(0.026)	0.011	(0.035)	989
(6)	Median Family Income (1950-2000 only)	0.060***	(0.012)	0.025**	(0.011)	991
(7)	Average Agricultural Land Value	0.060***	(0.019)	-0.003	(0.016)	991
(8)	Median Housing Value	0.033**	(0.016)	0.009	(0.016)	991

Note: Column (1) gives the unconditional difference between TVA and counties in proposed authorities in the 1940-2000 change in the log of the relevant outcome divided by six. Column (3) adjusts for pre-program differences between TVA counties and controls via a Oaxaca-Blinder regression as in Kline (2011). Covariates include time invariant geographic characteristics and levels and trends in pre-program industrial mix, population, and demographic characteristics (see Section 3.1 for full list of covariates). Spatial HAC columns 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

	Outcome	Entire U.S.		South		Proposed Authorities	
		1940-1960	1960-2000	1940-1960	1960-2000	1940-1960	1960-2000
		(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)	Agricultural Employment	0.106***	-0.134***	0.106***	-0.130***	0.119***	-0.166***
(4)	Manufacturing Employment	0.114***	0.033**	0.116***	0.035*	0.097**	0.032**
(5)	Value of Farm Production	0.076*	-0.030	0.081**	-0.044	0.118**	-0.033
(6)	Median Family Income	N/A	0.017	N/A	0.016	N/A	0.019*
(7)	Average Agricultural Land Value	0.027	-0.017	0.018	-0.015	0.029	-0.021
(8)	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 log outcomes divided by two or four respectively on TVA dummy and interacted controls as in Kline (2011). 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 basis)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	2SLS	2SLS	2SLS
<i>Change in Manufacturing Density Spline Components:</i>						
Low	0.030 (0.010)	0.025 (0.010)	0.024 (0.010)	0.087 (0.030) [124.66]	0.078 (0.031) [115.79]	0.078 (0.030) [114.53]
Medium	0.006 (0.004)	0.007 (0.005)	0.006 (0.005)	0.030 (0.010) [100.33]	0.030 (0.010) [99.71]	0.029 (0.010) [100.36]
High	-0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.001 (0.001) [31.91]	0.001 (0.001) [31.37]	0.001 (0.001) [25.98]
Log Manufacturing Wages	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
TVA	0.022 (0.013)	0.025 (0.013)	0.026 (0.014)	0.006 (0.012)	0.010 (0.012)	0.010 (0.013)
Regional Trends	no	no	yes	no	no	yes
1940 Manufacturing Density	no	yes	yes	no	yes	yes
Decade Effects	yes	yes	yes	yes	yes	yes
Controls for 1920 and 1930 characteristics	yes	yes	yes	yes	yes	yes
P-value equal slopes	0.013	0.048	0.058	0.000	0.001	0.002
P-value slopes equal zero	0.027	0.082	0.099	0.001	0.003	0.005
N	5462	5462	5462	5328	5328	5328

Notes: Dependent variable is change in log county manufacturing employment. 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. "Low" refers to spline component corresponding to density below 60th percentile of 1980 distribution, "Medium" to density between 60th and 85th percentile of 1980 distribution, and "High" to density above 85th percentile of 1980 distribution. Spline coefficients give the proportional effect on labor demand of an increase in lagged manufacturing density of one worker per square mile over the relevant range.

Table 6: Structural Estimates of Agglomeration Function (log basis)

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	2SLS	2SLS	2SLS
<i>Change in Log Manufacturing Density Spline Components:</i>						
Low	0.078 (0.030)	0.053 (0.031)	0.052 (0.030)	0.349 (0.109) [182.83]	0.323 (0.122) [149.61]	0.325 (0.123) [148.34]
Medium	0.072 (0.049)	0.075 (0.050)	0.069 (0.050)	0.339 (0.097) [92.69]	0.327 (0.101) [96.61]	0.319 (0.103) [97.01]
High	0.084 (0.059)	0.090 (0.059)	0.086 (0.059)	0.306 (0.134) [206.26]	0.304 (0.135) [204.81]	0.307 (0.136) [202.69]
Log Manufacturing Wages	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
TVA	0.024 (0.013)	0.027 (0.013)	0.029 (0.014)	0.008 (0.011)	0.011 (0.011)	0.012 (0.012)
Regional Trends	no	no	yes	no	no	yes
1940 Manufacturing Density	no	yes	yes	no	yes	yes
Decade Effects	yes	yes	yes	yes	yes	yes
Controls for 1920 and 1930 characteristics	yes	yes	yes	yes	yes	yes
P-value equal slopes	0.981	0.799	0.837	0.891	0.980	0.982
P-value slopes equal zero	0.039	0.141	0.173	0.002	0.007	0.012
N	5462	5462	5462	5318	5318	5318

Notes: Dependent variable is change in log county manufacturing employment. 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. "Low" refers to spline component corresponding to log density below 60th percentile of 1980 distribution, "Medium" to log density between 60th and 85th percentile of 1980 distribution, and "High" to log density above 85th percentile of 1980 distribution. Spline coefficients give the elasticity of labor demand with respect to lagged manufacturing density over the relevant range.

Table 7: Direct Effects of TVA on Labor Demand, by Period

	(1)	(2)	(3)
	1940-1960	1960-1980	1980-2000
Spline in Levels	0.179** (0.069)	0.002 (0.029)	-0.016 (0.042)
Spline in Logs	0.179** (0.091)	-0.029 (0.023)	-0.002 (0.039)
Controls for 1920 and 1930 characteristics	yes	yes	yes
N	1364	1357	1168

Note: Dependent variable is residualized change in log county employment over specified horizon (see text for details). Coefficients obtained from regression of residual on TVA dummy and baseline controls. 'Spline in levels' specification forms residual assuming agglomeration function is three piece spline in levels with coefficients from column (4) of Table 5. 'Spline in Logs' specification assumes agglomeration function is three piece spline in log of manufacturing density with coefficients from column (4) of Table 6. Standard errors clustered by state.

Table 8: Estimated Benefits of TVA

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Year	Log Manufacturing Wage Bill (2000 \$)	Direct Productivity Effect	Utility Gain in Manufacturing Sector (Fixed Supply)	Dollar Value (Fixed Supply)	Utility Gain in Manufacturing Sector (Variable Supply)	Dollar Value (Variable Supply)
1940	25.558	0.000	0.00%	\$0	0.00%	\$0
1941	25.614	0.004	0.02%	\$26,258,336	0.01%	\$18,436,704
1942	25.670	0.008	0.04%	\$55,540,180	0.03%	\$38,996,297
1943	25.726	0.013	0.06%	\$88,106,638	0.04%	\$61,862,108
1944	25.782	0.017	0.08%	\$124,238,859	0.06%	\$87,231,540
1945	25.838	0.021	0.10%	\$164,239,478	0.07%	\$115,317,080
1946	25.894	0.025	0.12%	\$208,434,157	0.08%	\$146,347,387
1947	25.950	0.029	0.14%	\$257,173,235	0.10%	\$180,568,441
1948	26.006	0.034	0.16%	\$310,833,488	0.11%	\$218,244,790
1949	26.062	0.038	0.18%	\$369,820,015	0.12%	\$259,660,862
1950	26.118	0.042	0.20%	\$434,568,247	0.14%	\$305,122,386
1951	26.174	0.046	0.22%	\$505,546,099	0.15%	\$354,957,899
1952	26.230	0.050	0.24%	\$583,256,264	0.17%	\$409,520,356
1953	26.285	0.055	0.26%	\$668,238,673	0.18%	\$469,188,855
1954	26.341	0.059	0.28%	\$761,073,108	0.19%	\$534,370,480
1955	26.397	0.063	0.30%	\$862,382,009	0.21%	\$605,502,262
1956	26.453	0.067	0.32%	\$972,833,459	0.22%	\$683,053,280
1957	26.509	0.071	0.34%	\$1,093,144,378	0.24%	\$767,526,903
1958	26.565	0.076	0.36%	\$1,224,083,931	0.25%	\$859,463,186
1959	26.621	0.080	0.38%	\$1,366,477,170	0.26%	\$959,441,417
1960	26.677	0.084	0.39%	\$1,521,208,918	0.28%	\$1,068,082,857
1961	26.706	0.084	0.39%	\$1,561,158,208	0.28%	\$1,096,132,359
1962	26.734	0.084	0.39%	\$1,602,147,503	0.28%	\$1,124,912,076
1963	26.762	0.083	0.39%	\$1,644,203,589	0.28%	\$1,154,440,818
1964	26.791	0.083	0.39%	\$1,687,353,937	0.27%	\$1,184,737,871
1965	26.819	0.083	0.39%	\$1,731,626,713	0.27%	\$1,215,823,011
1966	26.847	0.083	0.39%	\$1,777,050,799	0.27%	\$1,247,716,518
1967	26.875	0.083	0.39%	\$1,823,655,811	0.27%	\$1,280,439,187
1968	26.904	0.082	0.39%	\$1,871,472,116	0.27%	\$1,314,012,337
1969	26.932	0.082	0.39%	\$1,920,530,852	0.27%	\$1,348,457,832
1970	26.960	0.082	0.39%	\$1,970,863,945	0.27%	\$1,383,798,089
1971	26.989	0.082	0.38%	\$2,022,504,132	0.27%	\$1,420,056,092
1972	27.017	0.082	0.38%	\$2,075,484,977	0.27%	\$1,457,255,409
1973	27.045	0.081	0.38%	\$2,129,840,896	0.27%	\$1,495,420,203
1974	27.074	0.081	0.38%	\$2,185,607,175	0.27%	\$1,534,575,251
1975	27.102	0.081	0.38%	\$2,242,819,993	0.27%	\$1,574,745,953
1976	27.130	0.081	0.38%	\$2,301,516,445	0.27%	\$1,615,958,355
1977	27.159	0.081	0.38%	\$2,361,734,561	0.27%	\$1,658,239,160
1978	27.187	0.080	0.38%	\$2,423,513,334	0.27%	\$1,701,615,745
1979	27.215	0.080	0.38%	\$2,486,892,741	0.26%	\$1,746,116,180
1980	27.243	0.080	0.38%	\$2,551,913,767	0.26%	\$1,791,769,241
1981	27.224	0.080	0.38%	\$2,495,368,890	0.26%	\$1,752,067,518
1982	27.204	0.080	0.37%	\$2,440,061,597	0.26%	\$1,713,234,738
1983	27.184	0.079	0.37%	\$2,385,965,071	0.26%	\$1,675,252,071
1984	27.164	0.079	0.37%	\$2,333,053,070	0.26%	\$1,638,101,092
1985	27.144	0.079	0.37%	\$2,281,299,917	0.26%	\$1,601,763,771
1986	27.124	0.079	0.37%	\$2,230,680,485	0.26%	\$1,566,222,468
1987	27.104	0.079	0.37%	\$2,181,170,190	0.26%	\$1,531,459,921
1988	27.084	0.078	0.37%	\$2,132,744,975	0.26%	\$1,497,459,238
1989	27.064	0.078	0.37%	\$2,085,381,300	0.26%	\$1,464,203,891
1990	27.044	0.078	0.37%	\$2,039,056,133	0.26%	\$1,431,677,710
1991	27.025	0.078	0.37%	\$1,993,746,936	0.26%	\$1,399,864,870
1992	27.005	0.078	0.36%	\$1,949,431,657	0.26%	\$1,368,749,887
1993	26.985	0.077	0.36%	\$1,906,088,718	0.26%	\$1,338,317,611
1994	26.965	0.077	0.36%	\$1,863,697,006	0.25%	\$1,308,553,217
1995	26.945	0.077	0.36%	\$1,822,235,862	0.25%	\$1,279,442,201
1996	26.925	0.077	0.36%	\$1,781,685,073	0.25%	\$1,250,970,370
1997	26.905	0.077	0.36%	\$1,742,024,859	0.25%	\$1,223,123,837
1998	26.885	0.076	0.36%	\$1,703,235,868	0.25%	\$1,195,889,014
1999	26.865	0.076	0.36%	\$1,665,299,164	0.25%	\$1,169,252,605
2000	26.845	0.076	0.36%	\$1,628,196,220	0.25%	\$1,143,201,601

Notes: Column (1) reports the natural logarithm of totals from the Decennial Census and linearly interpolates inter-censal years. Column (2) provides interpolated estimates of the direct productivity effects of the TVA as described in the text. Column (3) multiplies column (2) by 0.047, which is the utility elasticity under fixed labor supply, in order to arrive at the proportional impact on worker wages. Column (4) multiplies column (3) by the manufacturing wage bill in order to arrive at a dollar value. Column (5) multiplies column (2) by .033, which is the utility elasticity when labor supply to the manufacturing sector exhibits a unit elasticity. Column (6) multiplies column (5) by the wage bill in order to arrive at a dollar value.

**Appendix Table 1: Structural Estimates of Agglomeration Function
(Estimated Wage Coefficient)**

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	2SLS	2SLS	2SLS
<i>Change in Manufacturing Density Spline Components:</i>						
Low	0.028 (0.009)	0.022 (0.009)	0.022 (0.009)	0.065 (0.022) [124.71]	0.054 (0.022) [115.85]	0.053 (0.022) [114.58]
Medium	0.010 (0.004)	0.010 (0.004)	0.010 (0.004)	0.023 (0.006) [102.18]	0.023 (0.006) [101.58]	0.022 (0.007) [102.31]
High	-0.000 (0.001)	-0.000 (0.001)	-0.000 (0.001)	0.000 (0.001) [31.83]	0.000 (0.001) [31.30]	0.000 (0.001) [25.89]
Log Manufacturing Wages	0.072 (0.037)	0.070 (0.037)	0.070 (0.037)	0.074 (0.039)	0.072 (0.039)	0.072 (0.038)
TVA	0.012 (0.013)	0.016 (0.013)	0.014 (0.014)	0.003 (0.012)	0.007 (0.012)	0.006 (0.013)
Regional Trends	no	no	yes	no	no	yes
1940 Manufacturing Density	no	yes	yes	no	yes	yes
Decade Effects	yes	yes	yes	yes	yes	yes
Controls for 1920 and 1930 characteristics	yes	yes	yes	yes	yes	yes
P-value equal slopes	0.000	0.002	0.002	0.000	0.001	0.002
P-value slopes equal zero	0.001	0.005	0.006	0.000	0.002	0.005
N	5462	5462	5462	5328	5328	5328

Notes: Dependent variable is change in log county manufacturing employment. 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. "Low" refers to spline component corresponding to density below 60th percentile of 1980 distribution, "Medium" to density between 60th and 85th percentile of 1980 distribution, and "High" to density above 85th percentile of 1980 distribution. Spline coefficients give the proportional effect on labor demand of an increase in lagged manufacturing density of one worker per square mile over the relevant range.

**Appendix Table 2: Structural Estimates of Agglomeration Function
(Alternate Values for Short Run Elasticity of Demand)**

	(1)	(2)	(3)	(4)	(5)	(6)
	2SLS	2SLS	2SLS	2SLS	2SLS	2SLS
<i>Change in Manufacturing Density Spline Components:</i>						
	0.079	0.070	0.069	0.095	0.087	0.087
Low	(0.026)	(0.026)	(0.026)	(0.035)	(0.036)	(0.036)
	[124.66]	[115.79]	[114.53]	[124.66]	[115.79]	[114.53]
	0.028	0.028	0.027	0.033	0.033	0.032
Medium	(0.008)	(0.008)	(0.008)	(0.012)	(0.012)	(0.012)
	[100.33]	[99.71]	[100.36]	[100.33]	[99.71]	[100.36]
	0.001	0.001	0.001	0.001	0.001	0.001
High	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	[31.91]	[31.37]	[25.98]	[31.91]	[31.37]	[25.98]
Log Manufacturing Wages	-1	-1	-1	-2	-2	-2
TVA	0.005	0.009	0.008	0.007	0.011	0.011
	(0.012)	(0.012)	(0.013)	(0.013)	(0.013)	(0.014)
Regional Trends	no	no	yes	no	no	yes
1940 Manufacturing Density	no	yes	yes	no	yes	yes
Decade Effects	yes	yes	yes	yes	yes	yes
Controls for 1920 and 1930 characteristics	yes	yes	yes	yes	yes	yes
P-value equal slopes	0.000	0.000	0.001	0.001	0.002	0.004
P-value slopes equal zero	0.000	0.001	0.003	0.003	0.006	0.010
N	5462	5462	5462	5328	5328	5328

Notes: Dependent variable is change in log county manufacturing employment. 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. "Low" refers to spline component corresponding to density below 60th percentile of 1980 distribution, "Medium" to density between 60th and 85th percentile of 1980 distribution, and "High" to density above 85th percentile of 1980 distribution. Spline coefficients give the proportional effect on labor demand of an increase in lagged manufacturing density of one worker per square mile over the relevant range.

**Appendix Table 3: Structural Estimates of Agglomeration Function
(Tercile Knots)**

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	OLS	2SLS	2SLS	2SLS
<i>Change in Manufacturing Density Spline Components:</i>						
Bottom Tercile	0.058 (0.034)	0.029 (0.036)	0.029 (0.036)	0.170 (0.097) [120.81]	0.133 (0.110) [91.87]	0.138 (0.110) [90.72]
Middle Tercile	0.020 (0.008)	0.018 (0.008)	0.017 (0.008)	0.092 (0.025) [78.89]	0.086 (0.025) [77.36]	0.085 (0.026) [76.20]
Top Tercile	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.001 (0.001) [32.64]	0.001 (0.001) [32.32]	0.001 (0.001) [26.75]
Log Manufacturing Wages	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5
TVA	0.023 (0.014)	0.026 (0.014)	0.028 (0.015)	0.007 (0.013)	0.010 (0.013)	0.011 (0.014)
Regional Trends	no	no	yes	no	no	yes
1940 Manufacturing Density	no	yes	yes	no	yes	yes
Decade Effects	yes	yes	yes	yes	yes	yes
Controls for 1920 and 1930 characteristics	yes	yes	yes	yes	yes	yes
P-value equal slopes	0.046	0.090	0.118	0.001	0.003	0.004
P-value slopes equal zero	0.101	0.181	0.228	0.002	0.008	0.011
N	5462	5462	5462	5328	5328	5328

Notes: Dependent variable is change in log county manufacturing employment. 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. "Bottom Tercile" refers to spline component corresponding to density below 33rd percentile of 1980 distribution, "Middle Tercile" to density between 33rd and 66th percentile of 1980 distribution, and "Top Tercile" to density above 66th percentile of 1980 distribution. Spline coefficients give the proportional effect on labor demand of an increase in lagged manufacturing density of one worker per square mile over the relevant range.