LOCAL ECONOMIC DEVELOPMENT, AGGLOMERATION ECONOMIES, AND THE BIG PUSH: 100 YEARS OF EVIDENCE FROM THE TENNESSEE VALLEY AUTHORITY*

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We study the long-run effects of one of the most ambitious regional development programs in U.S. history: the Tennessee Valley Authority (TVA). Using as controls authorities that were proposed but never approved by Congress, we find that the TVA led to large gains in agricultural employment that were eventually reversed when the program's subsidies ended. Gains in manufacturing employment, by contrast, continued to intensify well after federal transfers had lapsed—a pattern consistent with the presence of agglomeration economies in manufacturing. Because manufacturing paid higher wages than agriculture, this shift raised aggregate income in the TVA region for an extended period of time. Economists have long cautioned that the local gains created by place-based policies may be offset by losses elsewhere. We develop a structured approach to assessing the TVA's aggregate consequences that is applicable to other place-based policies. In our model, the TVA affects the national economy both directly through infrastructure improvements and indirectly through agglomeration economies. The model's estimates suggest that the TVA's direct investments yielded a significant increase in national manufacturing productivity, with benefits exceeding the program's costs. However, the program's indirect effects appear to have been limited: agglomeration gains in the TVA region were offset by losses in the rest of the country. Spillovers in manufacturing appear to be the rare example of a localized market failure that cancels out in the aggregate. *JEL* Codes: R11, J20, N92, O40.

I. Introduction

Like most countries, the United States exhibits vast differences in income across cities and regions. After adjusting for skill composition, average wages in the highest and lowest paying U.S. metropolitan areas differ by nearly a factor of three (Moretti

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2011). Such disparities have prompted governments to create a variety of place-based economic development policies aimed at reducing regional inequality. These programs, which target public resources toward disadvantaged geographic areas rather than toward disadvantaged individuals, are widespread. In the United States, it is estimated that federal and local governments spend roughly \$95 billion a year on such programs, significantly more than unemployment insurance in a typical year.[1]

In many cases, place-based policies seek to attract manufacturing plants to a specific jurisdiction. Such programs have arguably become the de facto industrial policy in the United States and are also widespread in Europe and Asia. 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 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 article, we evaluate 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 Franklin D. 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 U.S. history. Such strategies are predicated on the notion that economic development exhibits

1. The federal government spends about \$15 billion annually (Government Accountability Office 2012). Story (2012) estimates that state and local governments spend at least \$80 billion annually. In addition to the direct provision of subsidies, states often compete on income and corporate taxes and labor and environmental regulations. Bartik (1991) provides a comprehensive taxonomy of place-based policies.

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 might occur when output is traded on national markets involves agglomeration forces, particularly productive spillovers between workers and firms, which have received a growing amount of theoretical and empirical attention in the literature (Ellison and Glaeser 1997; 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 federal investments in the TVA provide 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; Redding, Sturm, and Wolf 2011).

Our analysis proceeds in two steps: we first conduct a reduced-form evaluation of the TVA's local impacts. We then use a more structured approach to assess the program's national effects.

The first part of the article uses a rich panel data set of counties to conduct an evaluation of the dynamic effects of the TVA on the regional economy in the 70-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). To identify regional counterfactuals, we exploit the fact that in the years following the program's inception, Congress considered creating six additional regional authorities modeled on the TVA. Due to political infighting, these additional authorities were never approved. We use the counties covered by authorities that were proposed but never implemented as controls for TVA counties with similar observable characteristics. Two other controls groups with similar characteristics are also considered. Placebo tests indicate that our covariates are successful at balancing economic trends in TVA and control counties in the two decades before the program began.

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, 40 years after TVA became financially self-sufficient, manufacturing employment in the region was still growing at a significantly faster pace than in 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 article, 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 do not observe the entire U.S. economy in the absence of the TVA. 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.

In the model, the TVA affects the national economy in two ways. First, the TVA *directly* raises labor productivity due to the improvement in public infrastructure. With mobile workers, these localized productivity gains will yield national labor market effects. Second, the program may have an *indirect* effect through agglomeration economies, if they exist. This second channel allows for the possibility—highlighted by the big push literature—that the effects of a one-time localized public investment might become self-sustaining due to agglomeration economies. In our setting, agglomeration economies are technological externalities that arise through social interactions and learning (Moretti 2004a, 2004b) or thick market effects (Marshall 1890).[2] Building on Glaeser and Gottleib (2008), the model clarifies the conditions under which place-based policies can affect aggregate output. Reallocating economic activity from one region of the country to another results in a long-run increase in total output only when the elasticity of agglomeration with respect to economic density is greater in the receiving region.

We develop a dynamic panel approach to estimating both the direct and indirect productivity effects of the TVA. The model parameters governing agglomeration are identified using restrictions on the timing and serial dependence of unobserved productivity shocks. Corroborating these restrictions, the estimated model yields predictions quantitatively consistent with the results of our reduced-form program evaluation of the TVA's dynamic effects.

We find that the TVA's direct productivity effects were substantial. The investments in productive infrastructure resulted in a large increase in local manufacturing productivity, which in turn led to a 0.3% increase in national manufacturing productivity. By contrast, the indirect effects of the TVA on manufacturing productivity were limited. Although we do find strong evidence of localized agglomeration economies in the manufacturing sector, our empirical analysis clearly points to a constant agglomeration elasticity. When the elasticity of agglomeration is the same everywhere in the country, spatially reallocating economic activity has no aggregate effects, as the benefits in the areas that gain activity are identical to the costs in areas that lose it. Thus, we estimate that the spillovers in the TVA region were fully offset by the losses in the rest of the country. 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.

Using our model estimates to conduct a cost-benefit analysis, we find the net present value of the TVA program's long-run

2. The big push literature has traditionally focused on models with demand externalities, whereby income growth in an area causes increases in the demand for local goods and services and stimulates entry of firms with better technologies, ultimately resulting in higher aggregate productivity (Rosenstein-Rodan 1943; Murphy, Shleifer, and Vishny 1989).

benefits and costs to be $23.8 billion and $17.3 billion, respectively. This positive rate of return to the TVA's federal investments is entirely explained by the direct productivity effects of the program's infrastructure investments. We caution, however, that our calculation of net benefits depends on conditions that are probably specific to the inception of the TVA program.

The remainder of the article is organized as follows. Section II describes the program. Section III provides estimates of the impact of the TVA on the region's economy. Section IV develops our spatial equilibrium model. Section V estimate the model's parameters and the program effects on the national economy. Section VI concludes.

II. The TVA Program

II.A. 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 TVA's primary objective was to invest in and rapidly modernize the Tennessee Valley's economy. The TVA service area, pictured in Figure I, includes 163 counties spanning several states, including virtually all of Tennessee, and substantial portions of Kentucky, Alabama, and Mississippi. 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.[3]

Probably the most salient changes prompted by the TVA came from the electricity generated by dams. Electricity was intended to attract manufacturing industries to what was a heavily agricultural region. In principle, electricity could have been exported outside the region, but the Authority primarily sold to

3. 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.

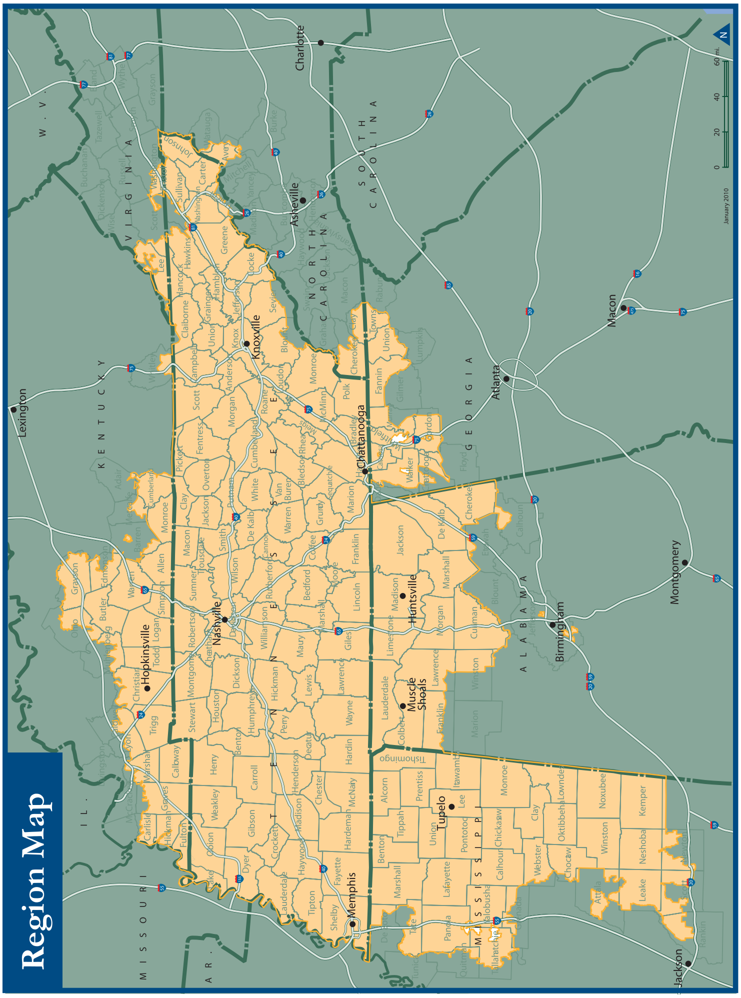

FIGURE I

The TVA Service Area (as of 2010)

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 (in 2000 dollars). The size of these transfers varied significantly across decades. A time series of federal transfers to the Authority is shown in Figure II. Only a small fraction of total federal appropriations were actually used in the program's first seven years. 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, and 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. 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. At the time, the typical household in TVA counties had five members, so the per household transfer was roughly $750 a year, or about 10% of average household income.

In 1959, Congress passed legislation making the TVA power generation system self-financing. From that year on, federal subsidies declined sharply. Figure II shows that the magnitude of the overall federal transfer dropped significantly in the late 1950s—in both absolute and per capita terms—and remained low in the following four decades. Currently, TVA no longer receives a substantial net federal transfer.

II.B. Selection into the TVA and Summary Statistics

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 (Kimble 1933; Morgan 1934; Barbour 1937; Satterfield 1947; Menhinick and Durisch 1953; Boyce, 2004). These criteria prioritized counties which (i) were heavily rural and required

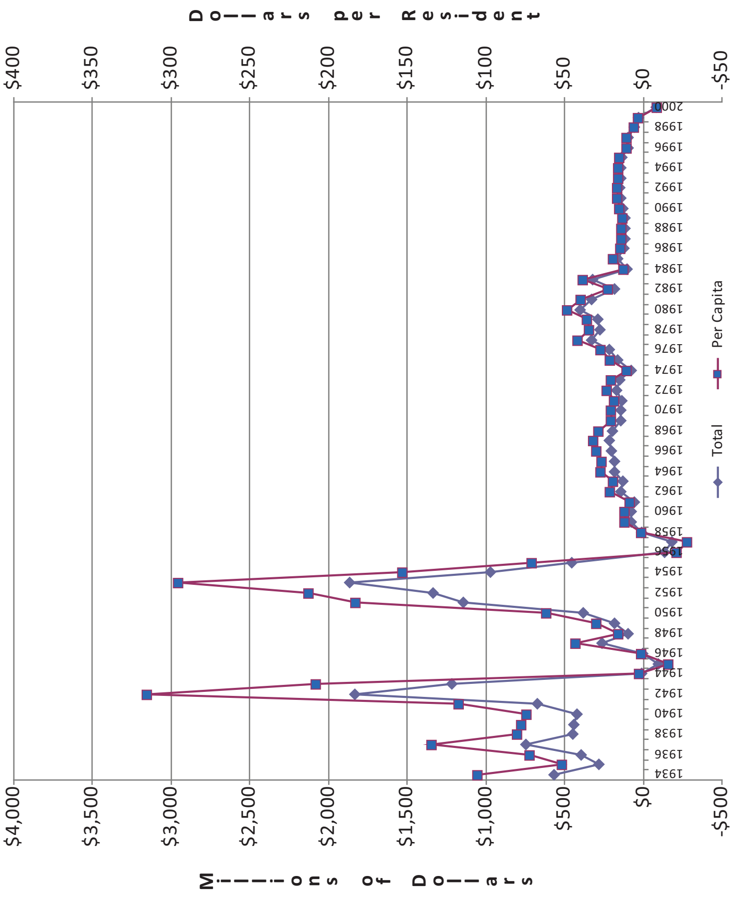

FIGURE II

Federal Transfers to TVA by Year (2000 Dollars)

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

additional electric power; (ii) experienced severe flooding and/or had misguided land use; (iii) experienced heavy deficits; (iv) lacked public facilities such as libraries, health services, and schools; (v) were willing to receive technical and advisory assistance from the TVA; (vi) had planning agencies and enabling legislation and agreed to experiment with new fertilizers; and (vii) were within reasonable transmission distance of power plants.[4]

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 (2007). The quality of some of the key variables is not ideal. Details on data construction and quality issues are provided in the Online Appendix.

In Table I 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)). Based on 1930 levels, TVA counties appear to have had worse economic outcomes than other U.S. counties and other Southern counties. In particular, in 1930 the economies of TVA counties were significantly more dependent on agriculture and had a significantly smaller manufacturing base, as measured by the share of workers in the two sectors. Manufacturing wages, housing values, and agricultural land values were all lower, pointing to lower local productivity. TVA counties also tended to be less urbanized, had lower literacy rates, and, in contrast with the rest of the country, had virtually no foreign immigrants. The lower fraction of households with a radio likely reflects both the lower local income level and the lack of electricity. TVA counties had a higher fraction of white residents than did the rest of the South. The lower panel of Table I reports the average 10-year percentage changes between 1920 and 1930 for our covariates and suggests that the TVA region also exhibited somewhat different trends over the 1920s than the rest of the country.

4. 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 foregoing criteria and later approved by the TVA Board of Directors.

TABLE I

SUMMARY STATISTICS

	(1)	(2)	(3)	(4)	(5)	(6)
	Overall				Trimmed sample	
	TVA	Non-TVA	Non-TVA South	Non-TVA proposed authorities	Non-TVA	Non-TVA South
1930 characteristics						
Log population	9.991	9.977	9.989	9.940	9.905	9.979
Log employment	8.942	8.967	8.959	8.908	8.881	8.947
Log # of houses	8.445	8.508	8.455	8.466	8.442	8.445
Log average manufacturing wage	1.406	1.802	1.545	1.685	1.728	1.538
Manufacturing employment share	0.075	0.090	0.080	0.077	0.080	0.078
Agricultural employment share	0.617	0.455	0.541	0.510	0.487	0.547
% White	0.813	0.885	0.722	0.830	0.863	0.724
% Urbanized	0.153	0.280	0.233	0.216	0.242	0.215
% Illiterate	0.088	0.045	0.092	0.060	0.051	0.092
% of Whites foreign born	0.002	0.059	0.013	0.020	0.030	0.011
Log average farm value	5.252	5.646	5.386	5.552	5.579	5.370
Log median housing value	9.271	9.581	9.360	9.452	9.516	9.358
Log median contract rent	8.574	9.030	8.679	8.834	8.934	8.672
% Own radio	0.079	0.296	0.114	0.210	0.256	0.112
Max elevation (meters)	1,576.190	2,364.531	1,068.943	1,758.893	2,044.656	1,070.334
Elevation range (max–min)	1,127.761	1,521.322	712.336	1,083.293	1,251.074	715.253
% Counties in South	1.000	0.342	1.000	0.554	0.447	1.000

TABLE I
(CONTINUED)

	(1)	(2)	(3)	(4)	(5)	(6)
	Overall				Trimmed sample	
	TVA	Non-TVA	Non-TVA South	Non-TVA proposed authorities	Non-TVA	Non-TVA South
Changes 1920–1930						
Log population	0.051	0.049	0.067	0.004	0.037	0.060
Log employment	0.082	0.096	0.111	0.045	0.083	0.103
Log # of houses	0.078	0.092	0.108	0.046	0.078	0.100
Log average manufacturing wage	0.117	0.217	0.108	0.172	0.197	0.103
Manufacturing employment share	−0.010	−0.035	−0.018	−0.018	−0.026	−0.018
Agricultural employment share	−0.047	−0.036	−0.047	−0.046	−0.042	−0.047
% White	0.012	−0.011	−0.010	0.000	−0.006	−0.004
% Urbanized	0.047	0.064	0.080	0.042	0.054	0.069
% Illiterate	−0.030	−0.014	−0.029	−0.019	−0.015	−0.028
% of Whites foreign born	−0.001	−0.023	−0.016	−0.012	−0.015	−0.012
Log average farm value	−0.013	−0.076	0.025	−0.182	−0.102	0.013
# of Observations	163	2,326	795	828	1744	779
# of States	6	46	14	25	43	14

Notes. The unit of observation is a county. The trimmed sample is obtained by dropping control counties which, based on their preprogram characteristics, have a predicted probability of treatment in the bottom 25%. All monetary values are in constant 2000 dollars. Data are from the 1920 and 1930 Census of Population and Housing, with the exception of farm value data, which are from the 1920 and 1930 Agricultural Census, and elevation data, which were collected by Fishback, Haines, and Kantor (2007). Manufacturing wage is obtained by dividing the total annual wage bill in manufacturing by the estimated number of workers in the industry. Details on data construction and limitations are provided in the Online Appendix.

Overall, Table I confirms that at the time of the Authority's inception, the Tennessee Valley was an economically lagging region, relative to both 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 that we are careful to address in the next section's empirical evaluation of TVA's long-run effects.

II.C. Proposed Authorities

From the beginning, the 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: "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.[5] But a split within the Roosevelt administration on the exact nature of the power to be granted to the authorities led to delays, postponements, and the ultimate failure of the bill.[6] The push for new

5. 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 supportive.

6. Specifically, Leuchtenburg (1952) reports that Agriculture Secretary Henry Wallace and War Secretary Harry Woodring objected to the plan. Wallace and Woodring told Roosevelt that they would approve of regional planning authorities only if they were limited to a planning role. 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.

authorities, suspended by the onset of World War II, gathered new momentum toward the end of the war. In 1945, 10 bills proposing the establishment of "valley authorities" comparable to the TVA were before Congress. Contemporary accounts suggest that approval was again considered likely.[7] But none of the bills mustered enough support for final approval, and they were ultimately dropped.

In our empirical analysis, we use these failed attempts to create additional Authorities to construct a set of counterfactual regions. These authorities offer a credible counterfactual because they were modeled on the TVA and were therefore likely to be economically similar by design. The proposed authorities had a reasonable ex ante chance of being 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.

A limitation is that although 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 requires us to make some assumptions on their exact geographical definition. We end up using six authorities: an Atlantic Seaboard Authority, a Great Lakes–Ohio Valley Authority, Missouri Valley Authority, Arkansas Valley Authority, Columbia Authority, and a Western Authority. They include 828 counties in 25 states. In the Online Appendix, we provide details on the algorithm used to impute their borders and a map of the regions.

Column (4) in Table I presents summary statistics for counties belonging to the proposed authorities. Since the proposed authorities were chosen with criteria similar to TVA, they have preprogram characteristics generally closer to the TVA counties than to the average U.S. county. Among the key variables of interest, a comparison of columns (1) and (4) reveals that 7.5%

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.

7. 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."

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 important, the change over time in the manufacturing share between 1920 and 1930 in the proposed authorities and in the TVA is, respectively, −0.010% and −0.018% versus a nationwide change of −0.035%. However, trends in population, employment, and housing units in the counterfactual authorities differ somewhat from trends in the TVA.

III. 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. Establishing that subsidies targeting 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. 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 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 TVA—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.

III.A. Econometric Model

To identify the long-run effect of TVA on local economies, we compare the economic performance of TVA counties with the performance of counties with similar preprogram characteristics located (i) in the rest of the country, (ii) in the rest of the South, and (iii) in the proposed authorities. We control for preprogram differences between TVA counties and controls using Oaxaca-Blinder regressions. That is, we first fit regression models to the non-TVA counties of the form:

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

where $y_{it} - y_{it-1}$ is the change in the relevant dependent variable between year $t-1$ and t for county i and X_i is a vector of preprogram characteristics. We then use the vector $\hat{\beta}$ of estimated coefficients to predict the counterfactual mean for the treated counties. Our vector of covariates includes a rich set of 38 economic, social, demographic, and geographical variables measured in 1930 and in 1920.[8] These covariates control for differences not only in levels between TVA and non-TVA counties before the program but also in trends. Because it is possible that counties outside but near TVA are directly affected by the program, we drop from the sample all non-TVA counties that border the TVA region.[9]

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 is its dual interpretation as a propensity score reweighting estimator (Kline 2011). 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

8. In particular, controls incude 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).

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

10. In practice, standard regression models yield similar results.

TVA receive more weight. This weight is proportional to an estimate of the odds of treatment. The weights generated by a Oaxaca regression in the set of all non-TVA counties satisfying our selection criteria are depicted in Figure III. 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 preintervention characteristics.

When comparing the TVA to the rest of the country and the South, we further increase comparability of TVA and control counties by dropping from our models control counties which, based on their preprogram characteristics, appear to be substantially different from TVA counties (see Angrist and Pischke 2010 for a similar exercise). In practice, 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%. 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). Online Appendix Figure A1 provides a map of counties in our trimmed estimation sample.[11] Columns (5) and (6) in Table I show the unconditional averages in the trimmed estimation sample. Although the exclusion of counties with low probability of treatment reduces some of the differences with TVA counties, other important differences remain, in both levels and trends. When comparing the TVA to the failed authorities, we do not drop counties with low propensity scores because we want this identification strategy to be based only on the historical accident of the failed authorities.

An important concern in estimating equation (1) is that the residual is likely to spatially correlated. We deal with this possibility by presenting two sets of standard errors. First, we compute standard errors clustered by state. These variance estimates allow for unrestricted spatial correlation across counties within each state, but assume no correlation across states. Second, we use a spatial heteroskedasticity and autocorrelation consistent (HAC) variance estimator based on the method of Conley (1999), which allows for correlation between counties that are geographically close but belong to different states.

11. All appendix figures and tables can be found in the Online Appendix.

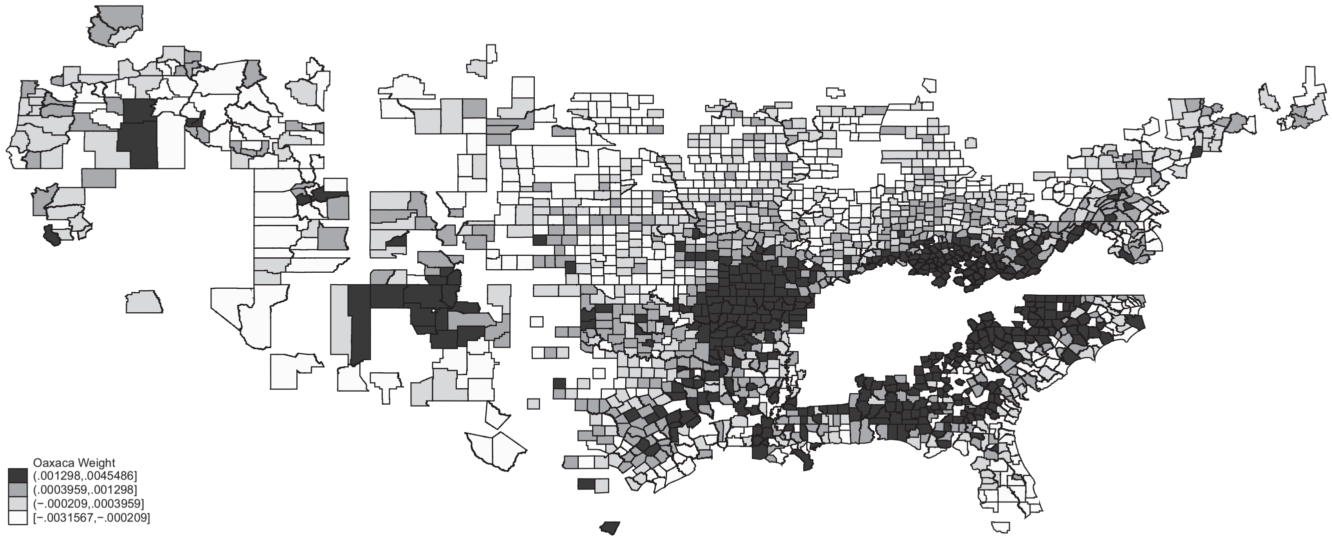

FIGURE III

Weight on Untreated Counties

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, which may be negative, is proportional to an estimate of the odds of treatment. See Kline (2011) for discussion.

Of course, the TVA was not the only spatially biased intervention occurring over our sample period. Since the 1930s, 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 effects, 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 effect 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.

III.B. Placebo Test

To evaluate the effectiveness of our controls in matching the pretreatment growth patterns of the TVA region, Table II 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 just prior to the TVA treatment, the finding of significant differences between TVA counties and controls would be evidence of selection bias.[12]

Column (1) shows the unconditional difference between TVA counties and non-TVA counties, while 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 HAC variance estimator (Conley 1999), where we use a bandwidth of 200 miles.

12. All our controls are measured in 1920 and 1930. We focus on the 1900–1940 change to avoid the possibility of a spurious mechanical correlation between the regressors and outcomes due to measurement error. As we argued before, the vast majority of the federal investment took place after 1940.

TABLE II

DECADALIZED GROWTH RATES IN TVA REGION VERSUS CONTERFACTUAL REGIONS, 1900–1940

Outcome	(1) Point estimate (unadjusted)	(2) Clustered std. err.	(3) Point estimate (controls)	(4) Clustered std. err.	(5) Spatial HAC	(6) N
Panel A: TVA region versus rest of U.S.						
Population	0.007	(0.016)	0.010	(0.012)	(0.016)	1,776
Total employment	−0.009	(0.016)	0.005	(0.013)	(0.016)	1,776
Housing units	−0.006	(0.015)	0.007	(0.011)	(0.013)	1,776
Average manufacturing wage	0.009	(0.018)	0.010	(0.021)	(0.016)	1,428
Manufacturing share	0.007*	(0.004)	0.005	(0.004)	(0.005)	1,776
Agricultural share	−0.007*	(0.004)	−0.001	(0.005)	(0.005)	1,776
Average agricultural land value	0.078***	(0.021)	0.025	(0.018)	(0.018)	1,746
Panel B: TVA region versus U.S. South						
Population	−0.018	(0.018)	0.003		(0.016)	850
Total employment	−0.028	(0.018)	0.001		(0.016)	850
Housing units	−0.025	(0.016)	0.005		(0.013)	850
Average manufacturing wage	0.001	(0.015)	0.001		(0.016)	687
Manufacturing share	0.005	(0.005)	0.005		(0.005)	850
Agricultural share	0.003	(0.004)	−0.002		(0.005)	850
Average agricultural land value	−0.009	(0.020)	−0.007		(0.017)	839

TABLE II
(CONTINUED)

Outcome	(1) Point estimate (unadjusted)	(2) Clustered std. err.	(3) Point estimate (controls)	(4) Clustered std. err.	(5) Spatial HAC	(6) *N*
Panel C: TVA region versus proposed authorities						
Population	0.026	(0.019)	0.011		(0.016)	926
Total employment	−0.012	(0.017)	0.006		(0.015)	926
Housing units	−0.014	(0.016)	0.006		(0.013)	926
Average manufacturing wage	0.012	(0.015)	0.008		(0.017)	734
Manufacturing share	0.007	(0.006)	0.005		(0.006)	926
Agricultural share	−0.005	(0.006)	0.004		(0.006)	926
Average agricultural land value	0.080***	(0.026)	0.017		(0.018)	908

Notes. 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 4 (shares not converted to logs). Column (3) adjusts for preprogram 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 preprogram industrial mix, population, and demographic characteristics (see Section III.A for full list of covariates). Clustered std. err. columns provide standard errors estimates clustered by state. Spatial HAC column provides standard error estimates based on technique of Conley (1999) using bandwidth of 200 miles. Asterisks based on clustered standard errors: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

Throughout the article, we report decadalized growth rates to aid comparability across tables. In Table II, for example, the 1900–1940 changes are divided by 4. 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.

A comparison of columns (1) and (3) in Panel A 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 0. Notably, this is due to the point estimates shrinking substantially rather than an increase in the standard errors.

Panel B reports analogous figures for the sample of Southern counties. In this panel, 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 0. Thus, 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.

Panel C 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)). Like for Panel A, 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)).

Overall, we interpret the evidence in Table II as broadly supportive of the notion that our controls capture the bulk of the selectivity biases associated with a comparison of TVA to non-

TVA counties. In the case of the South, TVA counties seems comparable even before conditioning on our controls.

Of course, the tests in Tables II 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 cannot 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 United States, 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 controls.

III.C. Estimates of the Local Effects of the TVA

1. Long-Run Estimates. Panel A in Table III 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 II, the substantial differences between our unconditional and conditional estimates illustrate the importance of controlling for pretreatment 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 Panel A 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 effects on growth rates are economically large, amounting to −5.6% and 5.9% a 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

TABLE III
Decadalized Impact of TVA on Growth Rate of Outcomes (1940–2000)

Outcome	(1) Point estimate (unadjusted)	(2) Clustered std. err.	(3) Point estimate (controls)	(4) Clustered std. err.	(5) Spatial HAC	(6) N
Panel A: TVA region versus rest of U.S.						
Population	0.004	(0.021)	0.007	(0.020)	(0.018)	1,907
Average manufacturing wage	0.027***	(0.006)	0.005	(0.004)	(0.005)	1,172
Agricultural employment	−0.130***	(0.026)	−0.056**	(0.024)	(0.027)	1,907
Manufacturing employment	0.076***	(0.013)	0.059***	(0.015)	(0.023)	1,907
Value of farm production	−0.028	(0.028)	0.002	(0.032)	(0.026)	1,903
Median family income (1950–2000 only)	0.072***	(0.014)	0.021	(0.013)	(0.011)	1,905
Average agricultural land value	0.066***	(0.013)	−0.002	(0.012)	(0.016)	1,906
Median housing value	0.040**	(0.017)	0.005	(0.015)	(0.015)	1,906
Panel B: TVA region versus U.S. South						
Population	−0.007	(0.018)	0.014		(0.019)	942
Average manufacturing wage	0.003	(0.006)	0.001		(0.005)	610
Agricultural employment	−0.097***	(0.030)	−0.051*		(0.027)	942
Manufacturing employment	0.079***	(0.023)	0.063***		(0.024)	942
Value of farm production	−0.005	(0.025)	−0.006		(0.026)	939
Median family income (1950–2000 only)	0.041***	(0.012)	0.024**		(0.011)	942
Average agricultural land value	0.031*	(0.018)	−0.003		(0.017)	942
Median housing value	0.019	(0.017)	0.007		(0.016)	942

TABLE III

(CONTINUED)

Outcome	(1) Point estimate (unadjusted)	(2) Clustered std. err.	(3) Point estimate (controls)	(4) Clustered std. err.	(5) Spatial HAC	(6) *N*
Panel C: TVA region versus proposed authorities						
Population	0.011	(0.018)	0.001		(0.017)	991
Average manufacturing wage	0.018***	(0.007)	0.005		(0.006)	618
Agricultural employment	–0.101***	(0.029)	–0.071***		(0.027)	991
Manufacturing employment	0.066***	(0.024)	0.053**		(0.024)	991
Value of farm production	0.002	(0.026)	0.011		(0.035)	989
Median family income (1950–2000 only)	0.060***	(0.012)	0.025**		(0.011)	991
Average agricultural land value	0.060***	(0.019)	–0.003		(0.016)	991
Median housing value	0.033**	(0.016)	0.009		(0.016)	991

Notes. Point estimates obtained from regression of 1940–2000 change in outcomes divided by 6 on TVA dummy. All outcomes besides share variables are transformed to logarithms before taking difference. In specification titled controls, counterfactual change in TVA sample computed via Oaxaca-Blinder regression as in Kline (2011). Covariates include time-invariant geographic characteristics and levels and trends in preprogram industrial mix, population, and demographic characteristics (see Section III.A for full list of covariates). Clustered std. err. column provides standard errors estimates clustered by state. Spatial HAC column provides standard error estimates based on technique of Conley (1999) using bandwidth of 200 miles. Asterisks based on clustered standard errors: * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

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.

Panel B 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 Panel B in Table II, 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 effects in column (3) are similar to those in the corresponding column of Panel A in Table III. The estimated effect on agricultural employment and manufacturing employment are −0.51 and 0.063, respectively. Unlike Panel A in Table III, 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.

Panel C provides estimates of the effect of TVA on long-run growth rates using proposed authorities as a comparison group.[13] The conditional estimates in column (3) appear to be similar to the ones in Panel A and, especially, the ones in Panel B. The estimated effect on agricultural employment is −0.071, whereas the estimated impact on manufacturing employment is 0.053. Like in Panel B, 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 United States, 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.

Data limitations prevent us from separately identifying the impact of each feature of the TVA program. Kitchens (2011) provides some preliminary evidence on this question. Using archival

13. 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.

data on contracted electricity rates, he finds that residents of counties with a TVA electricity contract faced electricity prices comparable to those elsewhere, although large manufacturing firms faced lower rates. He also finds a limited effect of TVA electricity contracts on manufacturing value added. These findings suggest that changes in the local electricity market may not solely account for the program's effects that we uncover.[14]

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. To explore these possibilities, we tried estimating the effects of TVA on adjacent counties using the same models as in Table III. This exercise failed to detect any significant spillover effects (see Table A1 in the Online Appendix).

2. Estimates by Period. In Table IV, we present separate estimates for the periods 1940–1960 and 1960–2000. Specifically, we estimate Oaxaca-Blinder models analogous to those in column (3) of Table III. 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 made TVA financially self-sustaining in 1959 are characterized by limited federal transfers to TVA.

14. Our article and Kitchens's paper seek to answer different questions. Kitchens's models include state-by-year dummies and use an instrumental variable based on distance to TVA dams to identify program effects. Identification comes from the comparison of counties near TVA dams with other counties *within the same state and year* that are further away from the dam. Therefore, Kitchens's approach aims to estimate the heterogeneity in the TVA treatment effect resulting from the supply of electricity. By contrast, our approach compares the entire TVA region with other areas and seeks to estimate the overall effect of the TVA program on the regional economy, abstracting from the heterogeneity of the effect within the region and irrespective of the specific channel.

TABLE IV

DECADALIZED IMPACT OF TVA ON GROWTH RATE OF OUTCOMES OVER TWO SUBPERIODS

	(1)	(2)	(3)	(4)	(5)	(6)
	Entire U.S.		South		Proposed authorities	
Outcome	1940–1960	1960–2000	1940–1960	1960–2000	1940–1960	1960–2000
Population	0.037	−0.008	0.042	−0.000	0.028	−0.013
Average manufacturing wage	−0.005	0.014*	−0.003	0.010	0.007	0.012
Agricultural employment	0.106***	−0.134***	0.106***	−0.130***	0.119***	−0.166***
Manufacturing employment	0.114***	0.033**	0.116***	0.035*	0.097**	0.032**
Value of farm production	0.076*	−0.030	0.081**	−0.044	0.118**	−0.033
Median family income	N/A	0.017	N/A	0.016	N/A	0.019*
Average agricultural land value	0.027	−0.017	0.018	−0.015	0.029	−0.021
Median housing value	0.019	−0.003	0.010	0.005	0.020	0.003

Notes. 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 2 or 4, respectively, on TVA dummy and interacted controls as in Kline (2011). Covariates include time-invariant geographic characteristics and levels and trends in preprogram industrial mix, population, and demographic characteristics (see Section III.A for full list of covariates). Asterisks 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. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.

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 United States 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 effects on growth rates of population and farm land values also appear substantial; however, the estimates are very imprecise and preclude definitive conclusions. The value of farm production increases significantly.

In the later period the estimated effects 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 end 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 United States, 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.

III.D. Discussion

Comparisons of TVA counties against our three control groups 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 was accomplished with limited long-run effect on local wage rates. Lack of significant wage effects points to a large supply of potential workers capable of moving to the local manufacturing sector from outside the TVA region, the local agricultural sector, or the local home sector. 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 traditionally 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 the TVA enjoyed large federal transfers—we find a sharp increase in both manufacturing and agricultural employment. Over the period 1960–2000 (when the TVA subsidies were scaled back), we find a retrenchment in agriculture. Manufacturing employment, by contrast, continued to grow even after the end of federal investment.

Of course, the TVA dams and public infrastructure did not disappear when transfers to the region stopped. Rather, the value of these investments gradually depreciated. Our finding that agricultural employment 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.[15] In practice, of course, the TVA infrastructure was not allowed to fully depreciate. But from 1959 onward maintenance of the TVA capital stock was paid for by local taxpayers and local users of electricity.

The resilience of manufacturing employment in the face of this depreciation of the initial capital infusion indicates that firms in the region enjoyed a competitive advantage even after the subsidies lapsed. This is suggestive of agglomeration effects in manufacturing of the type documented by Greenstone, Hornbeck, and Moretti (2010). 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."

15. We find this degree of depreciation reasonable. In fact, it is not inconsistent with 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 around 5%. See for example, Mississippi State Auditor (2002).

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.

IV. A Framework to Evaluate the Effect of TVA on the National Economy

While the evidence provided in the previous section indicates that the TVA program generated benefits for its service region, its aggregate effect is unclear. A key concern with place-based policies is that they may simply reallocate economic activity across space without raising national income. Lack of knowledge of their aggregate impact precludes any assessment of whether these policies are efficient from the point of view of the nation.

We now turn to estimates of the effect of the TVA program on the entire U.S. national economy. Doing so requires adopting a different methodology than the previous section, as 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. Like other researchers seeking to identify general equilibrium impacts (Donaldson 2012; Donaldson and Hornbeck 2012; Ahlfeldt et al. 2012), we need to impose some structure on the data. In the following two sections, we lay the groundwork for a structured cost-benefit analysis of the TVA's national labor market effects. Our framework is sufficiently general that it can easily be adapted to other place-based policies.

In this section, we develop a simple 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 (Glaeser and Gottlieb 2008). Using the model, we derive the conditions under which endogenous reallocation of manufacturing activity can raise aggregate output through agglomeration effects. In the next section, we take the model to the data, estimate its key structural parameters, and use them to compute the economic rate of return on the TVA federal investment.

IV.A. 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 homogeneous tastes as in the classic model of Roback (1982).[16] The mobility and homogeneity assumptions imply that utility, which we model as a Cobb-Douglas function of wages w_{it} and amenity levels M_{it}, is equalized across counties in each year. Hence we have that:

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

where the reservation utility level $\bar{u}_t$ varies only across years. As detailed in Section V.E, $\bar{u}_t$ 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,

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

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.

Normalizing the price of manufacturing output (which is assumed to be sold on global markets) to 1, price taking behavior

16. The homogeneity assumption is a strong one and, in many cases, would not be appropriate for modeling place-based policies as argued by Kline (2010) and Moretti (2011). We employ it here because our focus is on long-run changes—so that the process of regional adjustment may in fact span generations—and, especially, because we found little empirical evidence of wage impacts in our evaluation despite large effects on manufacturing employment. As in Roback (1982), we additionally assume that the amount of labor supplied by each worker is fixed.

on the part of firms implies the usual first-order conditions and the following inverse labor demand curve:

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

where r_t is the (nationwide) price of capital and $C \equiv \ln(1-\alpha-\beta) + \frac{\alpha}{1-\alpha} \ln \alpha$.

Consistent with much of the growth and urban economics literature on agglomeration economies, we assume that the productivity of firms in a county depends on 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:

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

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. This specification offers a deliberately simplified representation of how TVA investment in local infrastructure—new roads, canals, and electricity—increase productive in manufacturing. (An alternative would be a model where transportation infrastructure and electricity explicitly enter the production function and TVA investment increases their supply. This model would be notationally more complicated but yield identical results.) 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 on 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:

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

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

The term $g\left(\frac{L_{it-1}}{R_i}\right)$ captures the local agglomeration effects of manufacturing activity. 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. This determinism is desirable because 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).

In our model, agglomeration forces drive the persistent local effects of the TVA on productivity and manufacturing employment. This is in contrast to much of the big push literature, which has traditionally focused on models with demand externalities, whereby income growth in an area causes increases in the demand for local goods and services and stimulates entry of firms with better technologies, ultimately resulting in higher aggregate productivity (Rosenstein-Rodan 1943; Murphy, Shleifer, and Vishny 1989). Such models are better suited to explaining productivity growth in the local nontraded sector than the manufacturing sector, whose demand is arguably national in scope. Explanations for agglomeration economies that are relevant to our context are technological externalities that may arise through social interactions and learning (Glaeser et al. 1992) or through thick market effects in either the labor market or the intermediate input market (Moretti 2011).[17] Our choice to allow agglomeration to operate through the density of manufacturing employment per square mile is consistent with both types of technological externalities. Distinguishing between these two type of externalities is behind the scope of this article.

17. In principle, input-output linkages may further increase the effect of technological externalities, but in the absence of agglomeration economies of some type they would not generate persistent effects.

IV.B. The Effect of TVA on Aggregate Output

Our model allows for both direct and indirect effects of TVA on national output. The direct effects operate through the effect of TVA's public infrastructure on local productivity as captured by the δ_t coefficients. The indirect effects of TVA 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:

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

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 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 $\frac{1}{1-\alpha}$%.[18] 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.

18. The productivity-output elasticity is greater than 1 because capital adjustment augments a productivity change. When capital's share is 0, the elasticity becomes 1.

This result is useful because it allows us to better understand the aggregate effect of place-based policies, and TVA in particular. Summing across all counties, we obtain the nationwide impact of TVA on U.S. output. It is straightforward to see that the direct effect of TVA on nationwide 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.[19] 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:

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

which depends on 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.[20] Thus, although agglomeration economies generate market failures at the local

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

20. More 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 V.E.

level, these inefficiencies may "cancel out" in the aggregate if agglomeration elasticities are constant. A similar point was made by Glaeser and Gottleib (2008) in a static model of spatial equilibrium with agglomeration.

To preview our results, our empirical analysis in Section V points 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.

IV.C. Dynamic Behavior

Figure IV contrasts a hypothetical county's dynamic behavior when the agglomeration elasticity is constant with its behavior when the elasticity is not constant. Specifically, Figure IV, Panel A depicts the case where $g(.)$ is log-linear—so that σ_i is the same in all counties—while Figure IV, Panel B depicts the case where $g(.)$ is substantially nonlinear in logs—so that σ_i varies significantly across counties depending on the local manufacturing density.

Consider first Figure IV, Panel A. 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 equation (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 equation (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.[21] 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

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

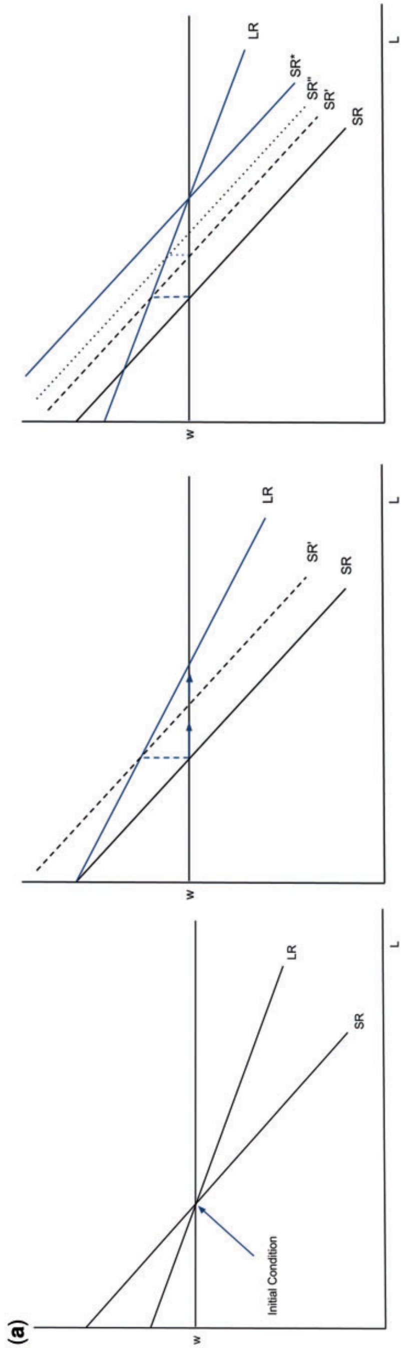

FIGURE IV

Panel A. Dynamics under Linear Agglomeration

In each panel, 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 IV.C of text). Panel A depicts convergence from initial condition to the new unique steady state under linear agglomeration after a permanent productivity shift. Panel B depicts effects of transitory productivity shift on steady state in the presence of nonlinear agglomeration effects.

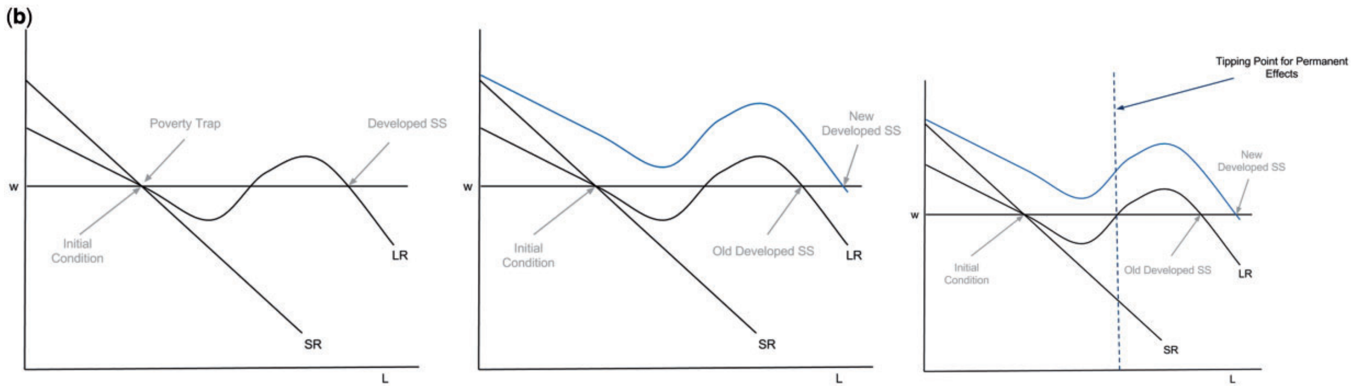

FIGURE IV

Panel B. Dynamics under Nonlinear Agglomeration employment increases as manufacturing employment converges toward its new steady state. The one-period lag in agglomeration yields geometric adjustment to the steady state, depicted in the final panel of Figure IV, Panel A. 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.[22]

In this setting, a constant agglomeration elasticity has two implications. First, there can be no aggregate effect of TVA on manufacturing productivity other than through the direct effects of the TVA infrastructure. As argued before, the productivity gains to this region associated with the additional workers must equal the losses in the counties from which those workers came.

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 IVb. Here $g(.)$ 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 important 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 out-migration alleviates crowding of the fixed factor.

An important goal of our empirical analysis in the next section is to determine whether Figure IV, Panel A or Figure IV, Panel B provides a better approximation to the dynamics of county growth. Uncovering the shape of the function $g(.)$ is critical to understanding whether place-based policies like TVA can be welfare improving for the United States as a whole.

22. Convergence is conditional because each county may possess a different intercept for its LR demand curve based on locational fundamentals (η_i in our setting) and the current state of the idiosyncratic component ε_{it}.

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 IV, Panel B, multiple steady-state equilibria are present, two of which are stable and one of which is an unstable tipping point. Consider the prospects of a county stuck in the low employment "poverty trap." If the direct productivity effects of the TVA are sufficiently large for the tipping point depicted in the final panel of Figure IV, Panel B to be crossed, manufacturing employment will fall within the basin of attraction of the developed equilibrium.

Recall that our estimates in Table IV 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 IV, because 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.

V. Structural Estimates and Cost Benefit Analysis

We now use the model outlined in Section IV to estimate the effects of TVA on the U.S. economy and compare them to the program's costs. Specifically, we develop an instrumental variables (IV) 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 program. These estimates are then used to conduct a quantitative cost-benefit analysis of the TVA program.

V.A. *Estimating Equation*

A key object of interest in our model is the agglomeration function $g(.)$. 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:

$$g\left(\frac{L_{it}}{R_i};\theta\right)=\sum_{k=1}^{3}\theta_k g_k\left(\frac{L_{it}}{R_i}\right), \tag{7}$$

where the $g_k(.)$ are the spline basis functions. We consider two choices for these functions: In the "levels" specification, $g(.)$ is piecewise linear in the level of manufacturing density and the θ_k give the proportional effect on manufacturing productivity of increasing manufacturing density by one worker per square mile. In the "logs" specification, $g(.)$ is piecewise log linear and the θ_k give the elasticity of manufacturing productivity with respect to manufacturing density—that is, they give the local agglomeration elasticity.[23] Note that a constant agglomeration elasticity requires that $g(.)$ be concave in density levels and linear in logs.

We introduce covariates into the model by assuming the productivity shocks ξ_{it} in equation (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.

With these additions, we can rewrite equation (3) in terms of the direct demand relationship to obtain our key estimating equation:

$$\begin{aligned}\ln(L_{it}) - \ln(L_{it-1}) = &-\frac{1-\alpha}{\beta}(\ln w_{it} - \ln w_{it-1}) + \frac{\delta_t - \delta_{t-1}}{\beta}D_i \\ &+ \sum_{k=1}^{3}\frac{\theta_k}{\beta}\left[g_k\left(\frac{L_{it-1}}{R_i}\right) - g_k\left(\frac{L_{it-2}}{R_i}\right)\right] \\ &+ X_i'\tilde{\lambda} + \tilde{\gamma}_t - \tilde{\gamma}_{t-1} + \tilde{\nu}_{it}. \end{aligned} \tag{8}$$

where we have removed county fixed effects by differencing over time and we use tildes over variables to indicate they have been renormalized by $\frac{1}{\beta}$. The primary objects of interest are:

23. More formally:

$$g_k^{levels}(x) \equiv \begin{cases} \min\{x, q_1\} & \text{if } k = 1 \\ \min\{x - q_{k-1}, q_k - q_{k-1}\}1[x > q_{k-1}] & \text{if } k > 1 \end{cases}$$

$$g_k^{logs}(x) \equiv \begin{cases} \min\{\ln x, \ln q_1\} & \text{if } k = 1 \\ \min\{\ln x - \ln q_{k-1}, \ln q_k - \ln q_{k-1}\}1[x > q_{k-1}] & \text{if } k > 1 \end{cases}$$

where the q_k's are the spline knots. We 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 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).

- The coefficients $\frac{\delta_t - \delta_{t-1}}{\beta}$, which give the change in the direct effects of TVA between decades;
- The spline coefficients $\frac{\theta_k}{\beta}$, 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.

V.B. *Identification*

Estimation of equation (8) is challenging for several reasons. To see why, 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 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.

More precisely, ordinary least squares (OLS) estimation of equation (8) is problematic because 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. Although 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 seriously consider the possibility that shocks are correlated. To address this problem, we employ an IV strategy relying on lagged manufacturing changes. Our instruments are of the form:

$$Z_{it}^{(k)} \equiv g_k\left(\frac{L_{it-2}}{R_i}\right) - g_k\left(\frac{L_{it-3}}{R_i}\right), \tag{9}$$

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 equation (8).[24]

24. To avoid any mechanical correlation with the elements of $g\left(\frac{L_{it-1}}{R_i};\theta\right) - g\left(\frac{L_{it-2}}{R_i};\theta\right)$ that might result from measurement errors in L_{it-2}, we construct these instruments using manufacturing employment data from the Economic Census while the endogenous variables are measured using employment data from the Decennial Census.

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:[25]

$$E[\nu_{it} Z_{it}^{(k)}]\ \forall k. \tag{10}$$

A sufficient condition for this restriction to hold is that the shocks to productivity ν_{it} be independent over a horizon of 20 years. Note that this prohibits counties from possessing long-lasting heterogeneous trends in productivity growth.

One important reason trends might be present 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 was 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 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

25. Identification 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 however that, if treated as a truly nonparametric problem, identification of $g(.)$ is inherently untestable without further assumptions (Canay, Santos, and Shaikh 2013). Testability would follow however if we were to assume the innovations in our model are normally distributed, see Newey (2013) for discussion.

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.

Although 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 (10) 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 V.E, our cost-benefit analysis hinges more on the shape of the agglomeration function than the estimated strength of any agglomeration effects.

A separate impediment to the estimation of equation (8) 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.[26] Based on Hamermesh's (1993) influential review, we use 1.5 as the most plausible estimate of the relevant labor demand elasticity.[27] We use this as our starting point and then assess the sensitivity of our estimates to different values of the elasticity.

V.C. Structural Estimates

Table V provides estimates of equation (8) based on four decades of changes in log manufacturing density.[28] This table assumes that $g(.)$ is piecewise linear in density. The first three columns provides baseline OLS estimates which exhibit evidence of modest agglomeration effects and a concave relationship with

26. We also use a five-year lagged wage measure to break any mechanical correlation between the wage and the quantity measures in equation (8).

27. Hamermesh (1993) documents a variety of estimates of national labor demand elasticities, centered in the range 1 to 1.5. Because we are interested in regional demand, we pick a parameter on the high end of the spectrum for our baseline specification.

28. Specifically, the data consist of changes over the intervals 1960–1970, 1970–1980, 1980–1990, and 1990–2000.

TABLE V

Structural Estimates of Agglomeration Function (Linear Basis)

	(1) OLS	(2) OLS	(3) OLS	(4) 2SLS	(5) 2SLS	(6) 2SLS
Change in manufacturing density spline components:						
Low	0.066	0.060	0.060	0.097	0.084	0.082
	(0.010)	(0.010)	(0.010)	(0.037)	(0.037)	(0.037)
				[129.06]	[122.25]	[121.07]
Medium	0.021	0.022	0.022	0.042	0.043	0.042
	(0.0045)	(0.0044)	(0.0044)	(0.011)	(0.011)	(0.011)
				[116.87]	[114.87]	[116.66]
High	−0.000075	0.000031	0.00011	0.0019	0.0021	0.0018
	(0.00074)	(0.00075)	(0.00071)	(0.0020)	(0.0020)	(0.0020)
				[41.82]	[40.96]	[32.04]
Log manufacturing wages	−1.5	−1.5	−1.5	−1.5	−1.5	−1.5
TVA	0.0033	0.0081	0.0026	−0.0052	0.0012	−0.0043
	(0.015)	(0.015)	(0.015)	(0.017)	(0.016)	(0.016)
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	0.0000	0.0000	0.0000	0.0007	0.0006	0.0006
p-value slopes equal 0	0.0000	0.0000	0.0000	0.0022	0.0015	0.0019
N	6,057	6,057	6,057	5,952	5,952	5,952

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-statistic 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. The instruments are changes in the spline components of manufacturing density lagged by two decades.

density. Columns (4)–(6) instrument for density changes using twice lagged density changes. Instrumenting raises the magnitude of the estimated agglomeration effects and induces a strikingly concave pattern of marginal effects. For example, column (4) indicates that raising manufacturing density by one worker per square mile in a low-density county is associated with a 9.7% increase in labor demand, whereas a corresponding increase in a medium-density county is associated with a 4.2% increase in demand. 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 .0022 (see bottom of the table). 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 Online Appendix Tables A2 through A4, we show that our results are also robust to different assumptions on the short-run elasticity of labor demand and the spline knots.

Overall, these findings point to significant nonlinearities in the agglomeration function. The pattern that emerges is one of marked concavity in $g(.)$, 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 IV.B, this intuition is incorrect. Reallocating workers to low-density areas only raise aggregate worker welfare if lower density counties have a greater agglomeration *elasticity*.

Thus, we turn now to direct estimates of agglomeration *elasticities*. Table VI repeats our analysis using a three-piece spline in the log of manufacturing density. 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. We find similar estimates across the three density groups, with a 10% increase in density estimated to yield a 4–4.7% increase in labor demand. 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 reported at the bottom of the table for the null hypothesis of equal elasticity are all above .66, and the point estimates are tightly clustered in the range 0.40–0.45. We conclude that manufacturing productivity exhibits a nearly constant elasticity relationship with manufacturing density.

We turn now to the direct productivity effects of the TVA, which result from the program's federally financed public investments. Because the model is in differences, the coefficient on the TVA dummy in equation (8) reflects the change over time in the direct effects. In the specifications reported in Tables V and VI, the estimated coefficient on the TVA dummy is statistically indistinguishable from 0, suggesting the direct productivity effects

TABLE VI

STRUCTURAL ESTIMATES OF AGGLOMERATION FUNCTION (LOG BASIS)

	(1) OLS	(2) OLS	(3) OLS	(4) 2SLS	(5) 2SLS	(6) 2SLS
Change in log manufacturing density spline components:						
Low	0.173	0.147	0.146	0.443	0.400	0.396
	(0.037)	(0.037)	(0.037)	(0.102)	(0.108)	(0.107)
				[177.17]	[159.14]	[157.20]
Medium	0.221	0.227	0.226	0.456	0.440	0.438
	(0.045)	(0.044)	(0.045)	(0.124)	(0.123)	(0.124)
				[106.74]	[109.55]	[110.13]
High	0.143	0.012	0.141	0.466	0.467	0.453
	(0.051)	(0.050)	(0.050)	(0.150)	(0.150)	(0.151)
				[206.66]	[204.69]	[200.36]
Log manufacturing wages	−1.5	−1.5	−1.5	−1.5	−1.5	−1.5
TVA	0.007	0.012	0.008	−0.003	0.002	−0.002
	(0.014)	(0.014)	(0.014)	(0.012)	(0.013)	(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	0.2483	0.1298	0.1038	0.9545	0.6695	0.7171
p-value slopes equal 0	0.0000	0.0000	0.0000	0.0002	0.0007	0.0016
N	6,057	6,057	6,057	5,935	5,935	5,935

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-statistic 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. The instruments are changes in the spline components of log manufacturing density lagged by two decades.

of TVA were roughly constant over the sample interval (1960–2000).

Table VII examines this finding more closely by recomputing the direct effects over three distinct horizons.[29] We consider both the specification where $g(.)$ is piecewise linear and where it is

29. The estimates in the table were computed via a regression of residuals of the form $Q_{it} \equiv \ln L_{it} - \ln L_{it-2} - \frac{\widehat{\theta_1}}{\beta}\left[g_1\left(\frac{L_{it-1}}{R_i}\right) - g_1\left(\frac{L_{it-3}}{R_i}\right)\right] - \frac{\widehat{\theta_2}}{\beta}\left[g_2\left(\frac{L_{it-1}}{R_i}\right) - g_2\left(\frac{L_{it-3}}{R_i}\right)\right] - \frac{\widehat{\theta_3}}{\beta}\left[g_3\left(\frac{L_{it-1}}{R_i}\right) - g_3\left(\frac{L_{it-3}}{R_i}\right)\right] + 1.5(\ln w_{it} - \ln w_{it-2})$ on baseline covariates and a TVA dummy. Hats denote estimated coefficient values, which come from column (4) of Table V in the "Spline in levels" specification and column (4) of Table VI in the "Spline in logs" specification.

TABLE VII

Direct Effects of TVA on Labor Demand, by Period

	(1) 1940–1960	(2) 1960–1980	(3) 1980–2000
Spline in levels	0.225	−0.011	−0.004
	(0.070)	(0.041)	(0.039)
Spline in logs	0.185	−0.036	−0.033
	(0.081)	(0.033)	(0.035)
Controls for 1920 and 1930 characteristics	yes	yes	yes
N	1,587	1,498	1,533

Notes. 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 V. "Spline in logs" specification assumes agglomeration function is three-piece spline in log of manufacturing density with coefficients from coulmn (4) of Table VI. Standard errors clustered by state.

piecewise log linear. Reassuringly, the two specifications yield very similar results. Consistent with our reduced-form findings in Section III, the TVA is estimated to have substantially boosted productivity over the period 1940–1960. 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 $\beta \approx 0.47$. Taking $\beta = 0.47$, we have that the TVA raised local productivity by approximately 8.7% 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.

V.D. Discussion

Four points are worth noting regarding our structural estimates. First, the estimates can be used to predict the dynamic effects of the TVA on manufacturing activity. In the Online Appendix, we show that these predictions are closely in line with the reduced-form estimates of Table IV. Specifically, we show that the estimated sequence of direct effects and the agglomeration function yield predicted changes in manufacturing employment over the 1940–1960 and 1960–2000 intervals close to the reduced-form effects reported in Table IV. This finding is important: using a substantially different source of variation, it corroborates our modeling strategy and the exclusion restrictions necessary for our instruments to be valid.

Second, the magnitude of the implied agglomeration economies is in line with existing estimates in the literature. With $\beta = 0.47$, the agglomeration elasticities θ_k implied by Table VI are in the neighborhood of 0.2. A recent meta-analysis of 34 different studies of agglomeration economies (Melo, Graham, and Noland 2009) indicates that our estimates are squarely in the middle of the distribution of existing estimates, and well within the range of elasticities reported in several of the most prominent recent studies.[30]

Third, our estimates strongly suggest that agglomeration economies are concave in manufacturing density and that this concavity is well approximated by a logarithmic function. This finding has important policy implications. As discussed in Section IV.B, a nearly 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, our estimates suggest manufacturing agglomeration is an interesting case where the existence of a market failure does not generate efficiency losses in the aggregate.

Fourth, according to our estimates, the effects of TVA will eventually die out. Figure V depicts our calibrated short-run inverse labor demand function along with the estimated long-run inverse labor demand function and its 95% confidence interval. This figure is the empirical equivalent of Figure IV.[31] Based on the discussion in Section IV.C, it is clear that the estimated shape of the curve implies the system admits a unique steady-state

30. For example, Henderson (2003) obtains an elasticity of productivity with respect to density of same industry plants of 0.01–0.08. Estimates for France in Combes et al. (2010) and Combes et al. (2012) imply elasticities of 0.029 and 0.032, 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.

31. 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.

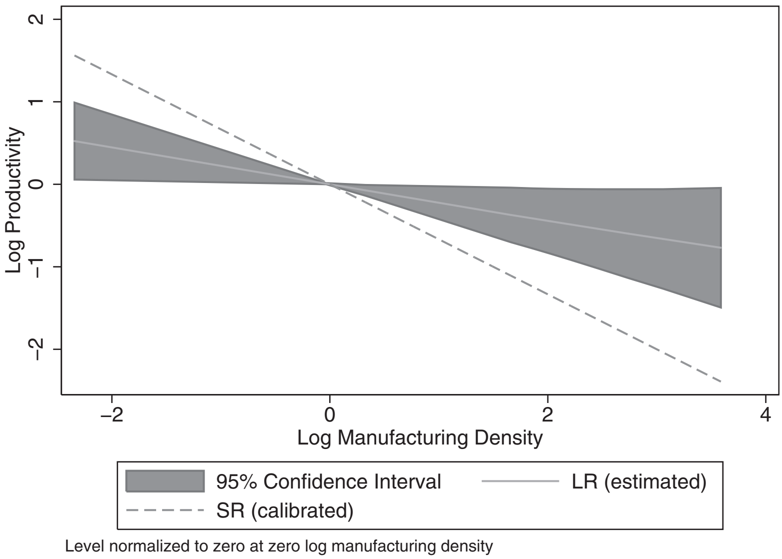

FIGURE V

Short- and Long-Run Inverse Labor Demand Functions

This figure depicts the short- and long-run inverse labor demand functions implied by our estimates from column (4) of Table VI, 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).

equilibrium so that the TVA region will ultimately revert back to its preprogram equilibrium.

V.E. *Cost Benefit Analysis*

We now 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 I. Computing program benefits is more challenging and relies on 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. In the Online Appendix we show that the aggregate elasticity of worker utility with respect to TVA's local investments can be written as:

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

Our finding of a roughly constant agglomeration elasticity ($\sigma_i = \sigma$) implies this expression simplifies to:

$$\frac{d\bar{u}}{d\delta} = \frac{1}{1-\alpha} \frac{\sum_i D_i L_i}{\sum_i L_i}. \tag{11}$$

Note that this formula doesn't depend on 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.

Using this formula, we find that the net present value of this stream of benefits using a real annual discount rate of 3% is \$23.8–36.5 billion, depending on what assumptions are made on the elasticity of labor supply (see the Online Appendix for a detailed explanation of the methodology and the results). This is to be compared with the present value of federal transfers, which amount to \$17.3 billion. Hence, we find a positive rate of return to the TVA's public investments.

VI. Conclusions

This article 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 such a 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 design of Section III provides strong evidence that the TVA sped the industrialization of the Tennessee Valley and provided lasting benefits to the region in the form of high-paying manufacturing jobs. Notably, the effect 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 V.E suggests the TVA 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 that the program's indirect effects were minimal. A noteworthy implication is that although agglomeration economies represent 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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Supplementary Material

An Online Appendix for this article can be found at QJE online (qje.oxfordjournals.org).

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