NEW HIGHWAYS AS ECONOMIC DEVELOPMENT TOOLS:

AN EVALUATION USING QUASI-EXPERIMENTAL MATCHING METHODS

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Abstract: Stimulating economic growth and development in rural and economically lagging regions is the goal of several federal and state highway programs. This paper examines the effectiveness of highway investment as an economic development tool. A quasi-experimental matching method is used to examine the effects of interstate highways on counties which obtained links during the period 1963-75 or are in close proximity to these newly linked counties. The results show that the beneficiaries of the interstate links in terms of economic growth are interstate counties in close proximity to large cities or having some degree of prior urbanization, such as a city with more than 25,000 residents. Rural interstate and off-interstate counties exhibit few positive effects.

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1. Introduction

Approximately three decades ago the U.S. Congress and President embarked on a plan to develop one of America's most persistently lagging regions. The Appalachian Redevelopment Act, signed in 1965 by President Lyndon Johnson, created the Appalachian Regional Commission (ARC). It was assigned the task of improving Appalachia's basic economic and social infrastructure and developing its human and natural resources. The Commission had broad-based goals and a comprehensive regional development philosophy, but 65% of the program's initial expenditures were assigned to highway construction. This highways emphasis was justified by language contained in an earlier recommendation forwarded to the President. According to the President's Appalachian Commission (1964), "penetration by an adequate transportation network" was the biggest obstacle to the region's future economic development.

Although regional economic development has been the cornerstone of few federal highway initiatives since then (Rephann 1993a), the late 1980s and early 1990s witnessed increased interest in infrastructure-based development strategies. Investment in state road infrastructure figured prominently among these, and several states embarked on sizable highway construction and rehabilitation programs, including provisions for assisting the development of lagging and rural intra-state regions (Johnson 1989; Forkenbrock et al. 1990). In response to both this revival of state interest and publicity surrounding numerous bridge collapses, traffic gridlock, and the San Francisco earthquake disaster, new comprehensive federal legislation passed in 1991. The Intermodal Surface Transportation Efficiency Act designated a 155,000 mile national highway system composed of interstate highways and primary arterial roads. As in debates past and present, regional and rural economic development were invoked during Congressional hearings as reasons for adopting the legislation.

The continuing appeal of highways as regional economic development tools might give the impression that there is substantial agreement about their likely regional economic effects, but three contentious groups exist. The first consists primarily of citizens of declining rural communities, government officials, and producers of highway related goods and services. They argue that new highways create broad economic growth and development along the highway routes (see ARC 1982 for an example). The second group argues that "highways are necessary but not sufficient for economic growth and development" (Huddleston and Pangotra 1990; Sears et al. 1990). This group includes growth center proponents who argue that new highway construction may help to reinforce urban areas along a route and may eventually spread growth to peripheral lagging regions (Hansen 1966; Newman 1972). The third group consists of critics who charge that developmental highway construction has little merit because such investment is economically inefficient, theoretically unjustified, and empirically unsubstantiated (Caudill 1969; Munro 1969; Manuel 1971; Wright and Blase 1971; Lord 1972; Hale and Walters 1974; Waters 1980).

Much speculation has been offered about the likely effect of new highway construction on rural economic growth (e.g., Hansen 1966; Caudill 1969; Munro 1969; Gauthier 1970; Manuel 1971; Newman 1972; Straszheim 1972; ARC 1982; Hale and Walters 1974; Siccardi 1986; Gillis 1989; Huddleston and Pangotra 1990; Sears et al. 1990), but few comprehensive empirical studies exist. The objective of this paper is to begin to fill the empirical gaps. To this end, the spatial and economic consequences of new interstate highways in rural areas during construction and after construction are examined. Counties that received interstate highways built during the 1960s and early 1970s and counties off the interstate system are studied for clues about the spatial and industrial pattern of effects. Of particular interest are the economic effects of these new highways during the post-construction period on nonmetropolitan cities, the urban fringe, more spatially isolated rural areas, and nearby off-interstate counties. This information will be used to understand the spatial contexts in which interstate highways stimulate economic growth and the characteristics of the resulting growth. It will also provide some insight into development patterns within rural areas, particularly the relationship between rural cities and their hinterlands.

This study also has a methodological orientation. It uses a quasi-experimental matching method to measure economic effects. By "quasi-experimental" is meant a research design that has all the hallmarks of an experiment--a treatment, an outcome measure, and a control group whose experience forms the baseline against which to infer the effects of the treatment. Missing from the true experimental design is the random assignment of places to a treated group and an untreated control group. Therefore, the control group must be selected in such a way so as to compensate for the lack of initial randomness in deciding where highways are to be built.

The research method presented here entails matching counties with a policy treatment to twin counties without the treatment. The treatment is the construction of an interstate highway either within or near a county, and the treatment outcome is measured as the deviation between treated counties and their untreated twins in terms of income growth by sector. The treatment is considered a success from an economic development standpoint if earnings increase faster on average in the treated places than in the untreated control places.

The paper is divided into several parts. Section 2 discusses previous theoretical and empirical literature concerned with the economic effects of highways and presents the conceptual framework for this study. Section 3 explains the quasi-experimental matching method. Section 4 describes the county classifications used for subsequent analysis. Section 5 discusses the empirical results for pre-construction, construction, and post-construction periods. Section 6 provides a conclusion and considers some of the policy ramifications of the results.

2. Highways and economic growth

The relationship between highway investment and regional economic growth is a complex one, not easily summarized by appealing to one regional economic theory or another. A reason for the complexity is that transportation infrastructure has both spatial and economic properties. On the one hand, transportation infrastructure has "network properties" (Rietveld 1989), meaning it has the extraordinary ability to shift market areas and affect communication channels. On the other hand, it is an input into the production of private and public sector goods. Therefore, it affects the socioeconomic landscape in ways that no single location model (e.g., von Thünen, Weber, Hoover) can fully anticipate. In order to be tractable, these models assume industrial linkages and transportation structures pertinent to particular types of industries and, therefore, their results cannot be generalized to all industries (Paelinck and Nijkamp 1975). Highway investment also affects household location decisions. Residential choices are affected by the costs of commuting, which are lowered by new highways. These residential choices may, in turn, influence the location decisions of firms and industries.

Because of the multifaceted nature of highway investment and its disparate causal links with economic growth, its influence is frequently broken down into components which are easier to analyze. Previous empirical studies tend to focus on three dimensions: (1) differences in highway effects occurring over time, (2) differences in highway effects by industry, and (3) differences in highway effects by region. The following sections examine each of these more closely.

2.1. Temporal effects

Researchers normally divide the study period into construction and post-construction stages when investigating the temporal effects of highway investment. Construction expenditures made locally stimulate the region during the highway construction phase. Construction and engineering firms employ local labor and purchase local building supplies, which have multiplicative effects on the regional economy. The magnitude of these multiplier effects depend on the extent of interindustry linkages, interregional leakages, the size of construction expenditures, and the size of highway displacement effects.

The duration and timing of post-construction economic effects are more difficult to assess. Most studies have confined their evaluation periods to two decades or less. One view is that the effects are immediate "and continue to influence the level and distribution of economic activity over a long period of time" (Gaegler et al. 1979). Another view is that the economic effects of highways are realized after a lag of several years (Munro 1966). Lags between four and seven years have been estimated empirically (Wilson et al. 1986; Burress et al. 1989).

The timing of highway effects may also be tied to national and extra-regional fortunes. Several studies suggest that regions traversed by interstate highways perform no better than non-interstate regions during recessionary time periods (Miller 1979; Cromley and Leinbach 1981; Isserman et al. 1989). Keeble (1980, 946) argues that temporal variation occurs because government policies are weakened during recessionary periods when there is "a dearth of mobile investment for policy to steer." Isserman et al. (1989, 3) liken highways to riverbeds because "the amount of water flowing past a particular point varies over time and depends largely on conditions elsewhere." Extra-regional conditions may include the vitality of nearby urban areas (Ayers and Freiberg 1976) or the addition or completion of other highway links (Wilson et al. 1986).

2.2. Industrial effects

The industrial distribution of highway effects varies from the construction to post-construction stages. During the construction stage, a region experiences an exogenous boost in construction expenditures, which is sustained over a few years until the project is completed. These effects can be highlighted by considering two input-output models: that of the United States and West Virginia, a predominantly rural state.[1] These models can illustrate the effect of each dollar change in demand for new highway and street construction (SIC code 1611) on output by industry.

As figure 1 shows, the primary sectors such as construction (CON) and manufacturing (MFG) are stimulated most. Tertiary sectors such as services (SVC), trade (TRD), finance, insurance, and real estate (FIR), and transportation and public utilities (TPU) follow. Government (GVT), farming (FAR), and agricultural services (AGS) are least affected. The large disparity in the mining (MIN) effects is probably caused by the availability of construction material, including stone, gravel, sand, and asphalt. Inputs provided to West Virginia by out-of-state suppliers explain the large divergence in import purchases between the United States (0.01) and West Virginia (0.51). Thus, the degree of openness of a particular region and its industrial structure can result in substantial differences in highway construction impacts.

During the post-construction period, the construction stimulus is largely removed, although there may be small multiplier effects associated with continued state expenditures on maintenance and highway services (e.g., highway snow removal, surface repair, and policing). The primary economic effect is through residential and industrial location decisions. Most industry research focuses on three sectors: manufacturing, retail trade, and services. Primary industries such as farming and mining are generally unaffected, possibly because these industries rely more heavily on long-haul modes of output and input transportation (Harris 1974).

Interstate highways seem to have their greatest effect on market-oriented industries and interstate traffic related industries (Lichter and Fuguitt 1980; Briggs 1980; Isserman et al. 1989). The short-haul transportation cost reductions associated with improved highway service tend to re-draw trade and service boundaries in favor of highway counties (Kuehn and West 1971; Briggs 1980; Blum 1982). Furthermore, increased through traffic can create additional demand for non-local travel and tourism services (Lichter and Fuguitt 1980). Some studies found negligible manufacturing effects (Kuehn and West 1971; Lichter and Fuguitt 1980; Briggs 1980), but others focusing on urban areas found manufacturing is stimulated (Wheat 1969; Stephanedes and Eagle 1986; Eagle and Stephanedes 1988; Isserman et al. 1989).

2.3. Spatial effects

Highways have effects on two spatial scales, the local and the regional. Interchange development related to traffic services may accrue at heavily traveled interchanges. Some interchanges may also develop higher order central place functions (Moon 1988). Interchange development depends on several geographical, economic, and traffic factors, including (1) topography, (2) distance from cities, (3) distances from adjacent interchanges, (4) age of interchange, (5) volume of traffic on highway, (6) population density, and (7) existing development near the highway (Mason 1973; Corsi 1974; Epps and Stafford 1974; Twark et al. 1980; Moon 1988).

Interstate highways also reorganize region-wide central place functions. Although highway traversed regions may gain a competitive advantage over non-highway regions, the primary effect along highway routes appears to reinforce the major urban areas of a region (Humphrey and Sell 1975; Kau 1977; Botham 1980; Briggs 1980; Hilewick et al. 1980; Lichter and Fuguitt 1980; Stephanedes and Eagle 1986; Eagle and Stephanedes 1988; Isserman et al. 1989). Hence, an isolated rural interstate county may gain a competitive advantage over its immediate non-highway supplied neighbors only to see this advantage usurped by an interstate served neighbor able to offer even greater market economies. Humphrey and Sell (1975), Lichter and Fuguitt (1980), and Briggs (1980) find that the effects of highways on rural or non-metropolitan areas atrophy with increasing distance from core or metropolitan areas, with little development beyond a twenty-five mile radius of those areas.

These patterns may be integrated into a more comprehensive regional development theory to provide some insight into development patterns within rural areas, particularly the relationship between rural cities and their hinterlands. Rephann (1993b) distinguishes a regional taxonomy that emphasizes spatial characteristics but is similar to the regional development taxonomies proposed by Hansen (1966), Chinitz (1969), and others (Rephann 1993a). This taxonomy consists of competitive regions, urban spillover regions, and uncompetitive regions. Competitive regions have cities that gain competitive advantages from a highway link and experience positive economic effects on tertiary industries. Urban spillover regions are located in close proximity to large metropolitan regions and are stimulated by residential and employment decentralization. Uncompetitive regions are primarily isolated rural regions that gain few economic advantages from being linked with a highway.

2.4. Synthesis and hypotheses

The diffuse empirical studies of the temporal, industrial, and spatial effects of highways suggest a rich tapestry of testable hypotheses that have never been completely tested. Contrary to most proponents and opponents of regional highway development, the question of whether a highway stimulates the regional economy cannot be reduced to a binary choice: do or do not highways have positive economic effects? The effect is likely to be more subtle. It will depend on the magnitude of the highway treatment, where it is, what it connects, what is near it, what is there, and the overall economic climate.

The construction stage effects are related to the magnitude of construction expenditures, the intraregional and interregional linkages of the region, and the extent to which the construction labor is local. Construction affects primarily the construction, manufacturing, and tertiary sectors. During the post-construction period, trade and service industries are likely to be more sensitive, possibly because of the re-assignment of market-areas in favor of more urbanized regions along the highway. However, residential decentralization from urban cores may counteract this tendency to some degree. The result is three distinctive regional types. Urban regions and regions in close proximity to large cities may be stimulated, while more isolated rural regions may experience little effect.

The objective of the balance of this article is to subject these plausible empirical hypotheses to more rigorous testing using a consistent empirical framework which disentangles the contribution of highways from other proximate factors. The quasi-experimental matching method will account for all three dimensions of regional change identified above (i.e., temporal, industrial, and spatial). Both construction-stage and post-construction effects will be examined for how the industrial linkages between highways and growth evolve over time and space. Several additional advantages of the method over conventional regression analysis are discussed in the following section.

3. Quasi-experimental matching method

The method introduced here is a combination of non-equivalent control group and interrupted time series methods (Campbell and Stanley 1963). It is applied to multidimensional data in a way that allows the behavior of several variables to be examined at the same time. It improves upon previous methods (Isserman and Merrifield 1982, 1987; Isserman and Beaumont 1989) by choosing a control group from both theoretical and statistical standpoints, evaluating the characteristics and appropriateness of the control group, and introducing statistical tests for making inferences about policy effects. It responds to the call for "better methods for choosing control groups" (Bartik 1991, 19). The essence of the method is to match policy treated counties with untreated ones which have similar economic and spatial characteristics. The untreated twins subsequently form the baseline from which to measure economic effects and to conduct statistical tests.

As is explained elsewhere (Bohm and Lind 1993; Beaumont and Rinderle 1991), quasi-experimental matching methods may offer certain advantages over alternative methods in regional policy measurement. These methods economize on the amount of structure that is imposed on the measurement problem. Detailed behavioral models are not required, and parametric assumptions are weak. Since regional policy studies have shown considerable sensitivity to the structural qualities of the method and model used (Nicol 1982), matching methods have a proper place in regional research. Under certain conditions, they may result in more robust measurement and inference than are obtained from regression methods.

The quasi-experimental procedure is divided into several stages. Treated and untreated counties are matched on the basis of similar economic and spatial characteristics (section 3.1) during the selection period. The resulting group of untreated counties is tested for comparability with the treated counties on the basis of growth rates before the treatment. If the counties are not well-matched, as indicated by this pre-test, several methods may be used to remedy the situation. After a successful pre-test, post-tests are performed to assess the effects of the highway on regional growth and development. The pre- and post-tests are described more fully in section 3.2.

3.1. County matching

County matching entails three steps, application of sequential calipers, calculation of a similarity measure, and optimal matching. The calipers are global constraints which ensure both that similar policy treatments were not administered to the control group and that other conditions are met. Calipers are tolerance levels $\varepsilon(1),...,\varepsilon(p)$ determined by the researcher for certain control variables $X(1),...,X(p)$. For instance, when studying highways, the researcher will want to exclude from the control group all counties that have received interstate highways. This action removes the possibility of interstate treated counties being matched with other counties receiving interstates later, which would confound the policy measurement. Variables used as calipers in this study are listed in table 1.

The sequential calipers produce a list of potential twins for each treated county. To obtain the best twin, it is necessary to use a measure of similarity to rank the potential twins. A metric frequently used in statistical analysis, the Mahalanobis distance, is used to measure similarity here.[2] It implicitly scales and weights the variables by the variances and covariances in the data, and it permits trade-offs among competing selection variables. In this way, dissimilarity on one variable is exchanged for tighter fit on another variable. Theory enters into the analysis in specifying the variables to be used. The variables used here (see table 1) reflect industrial structure, market demand, urbanization, spatial context, policy, and prior growth, all factors identified by previous studies as important determinants of regional growth (Richardson 1973, 1974; von Böventer 1975; Martin 1979; Wheat 1986).

After the potential twins for each treated county have been ranked by the Mahalanobis metric, it is necessary to assign one untreated county to each treated county. Optimal matching is used for this purpose.[3] The optimal matching technique relies on an iterating optimization algorithm. It searches for the set of twins which minimizes the total distance of the untreated counties taken as a group from the treated counties. More specifically, optimal matching minimizes the sum of the Mahalanobis distances over all matched pairs. The algorithm is computationally equivalent to a network flow problem and entails finding the minimum cost flow through a network. This procedure is explained more fully in Rosenbaum (1989) and Beaumont and Rinderle (1991).

3.2. Statistical testing

Two tests are needed to evaluate policy treatment effects. The pre-test determines whether the growth paths of the treated and untreated counties correspond during a trial period before the construction of highways. All of the variables in table 2 are considered. If the test is passed, it reinforces the argument that the twins are well chosen. If it is not passed, it may be necessary to make new matches. Next, post-tests are conducted on cumulative growth rates, beginning at the onset of the treatment and ending with the final year of analysis, to determine if there are statistically significant differences in the growth rates. Statistically significant differences are attributed to the policy effect.

Two types of statistical significance are distinguished for the pre-test and post-tests. Univariate significance refers to statistically significant differences between the highway treated counties and their twins on growth rates of individual variables. The test is a t-test of the mean growth rate difference of the matched pairs[4], where the growth rate difference is:

$$_{TC}D_{jt} = {}_{T}r_{jt} - {}_{C}r_{jt}$$ [5]

where:

D is the growth rate difference
T is treated county T (T = 1,...,f)
C is untreated county C (C = 1,...,f)
r_j is growth rate j measured from base year b
j is one of the 20 variables listed in table 2
t is the test year.

Univariate statistical tests provide information that can be used to make inferences about particular sectors. When univariate significance occurs during the pre-test, the researcher may not want to attribute post-test differences for the particular behavioral variable to the policy effect unless there is a marked change in trend. For example, when the pre-test shows statistically significant negative effects and the post-test period effects are positive, a conservative estimate of the effect will be obtained for policies expected to have positive impacts.

The second type of significance, called global significance, refers to growth differences for the vector of growth rates taken as a whole. The statistic used in testing here is the Hotelling T^2 test statistic, a multivariate extension of the univariate t-test (Press 1972). It is an overall test of growth rate similarity for assessing the fitness of the twins during the pre-test. Global pre-tests can be failed for several reasons. Depending on the reason, any one of the following responses might be appropriate: (1) changing the composition of the treated group by removing counties that were difficult to match, (2) choosing another pre-treatment selection period and making new matches, (3) changing the calipers and/or covariates used in matching (the matching method analog to regression respecification), or (4) accepting the poor pre-tests as a second best alternative to aborting the study.

4. County selection and classification

4.1. County selection

The treated counties to be studied were selected from among 1,360 counties which contained interstate highway mileage as of 1987 or were located close to an interstate. Interstates are built to higher engineering standards and accommodate higher traffic volumes than non-interstate routes. Holding all other factors constant, interstates should have larger economic effects than qualitatively poorer highway classes because of their greater capacities and traffic volumes.

The treated counties had to meet additional criteria to be studied further. Construction characteristics and data availability were the most important factors. The interstate highway program began in 1956, and most of the mileage was open to traffic during the 1960s (see figure 2). However, annual income data for counties from the Bureau of Economic Analysis (BEA) are spotty during the early years of the program and do not become continuous until 1965. Also, the series that includes 1965 ends in 1984 because the BEA subsequently changed its accounting conventions and chose not to revise its personal income and earnings figures any further back than 1969. Balancing the multiple goals of maximizing the number of study counties, avoiding data gaps, and obtaining a sufficient number of years for impact analysis led to selecting 1962 as the base impact year. This choice means that the period 1950-59 is used for matching counties, the 1959-62 period is used for the pre-test, and 1962-84 is the treatment period. In order to have enough treatment period years to make inferences about post-construction effects, all treated counties had to have both the beginning and end of construction during the period 1963-75.

Three additional restrictions were imposed in selecting treated counties. First, they had to contain at least nine miles of interstate, thus screening out counties that were less likely to have interchange access and avoiding situations in which an interstate highway merely nipped the corner of a county. Second, all the counties had to have the same suppressed variables in the BEA data for the Mahalanobis metric to be computed. Thus, counties with suppressed data for variables other than three frequently suppressed sectors, agricultural services, forestry, and fishing, mining, and finance, insurance, and real estate, were ineligible as either treated or untreated counties. Finally, all off-interstate counties had to be within 30 miles from the population centroid of a selected county with interstate mileage. These screening rules resulted in a group of 142 interstate treated counties and 192 off-interstate counties.

4.2. County classification

Five groups of counties help examine the economic effects of highways. The first serves to investigate the linkages between construction activity and county economic growth, and the remaining four serve to examine the post-construction effects. Beginning with the latter, competitive counties contain substantial urban areas and are expected to experience positive stimulus to tertiary and manufacturing industries. Urban spillover counties are close enough to urban areas to experience substantial spread effects, usually through residential decentralization from a nearby city. Uncompetitive counties are predominantly rural and relatively far from cities, so highway improvements might not create locational advantages for residential settlement or industrial location there. Adjacent counties are relatively close to the treated counties but located off the interstate. They might experience few positive economic impacts and possibly lose locational advantages for locally provided goods and services to counties located along the interstate highway.

The effects of highway construction must be studied using a group of counties with highway construction schedules that are brief and overlapping. The short construction interval maximizes the likelihood of capturing heavy construction activity instead of a drawn out period of surveying, land acquisition, and other work. The coinciding schedules avoid mixing post-construction effects in some counties with construction in others. Counties were selected for this group if their highways required four years to complete, start to finish. In order to maximize the number of study counties, time is measured with respect to the initial year of construction instead of chronological year. Therefore, counties with construction occurring during the time period 1965-68 are joined by counties where construction occurred 1966-69, 1967-70, and so on through 1971-74. Twenty-four counties representing a diverse cross-section of the 142 interstate highway treated counties met this criterion.

Counties were assigned to the four spatial categories based on central place characteristics, as approximated by the counties' distances to cities of various sizes and proximity to counties containing interstates. Because of data availability, only cities with more than 25,000 residents in 1960 could be identified. Competitive counties contain cities with 25,000 or more residents. Because most larger cities already had some freeway construction which was converted to interstate status in 1956 and were therefore not feasible for study, the cities in these counties are generally small (the largest, Fresno, CA had only 133,929 residents in 1960). Thus, this category consists primarily of small cities. Urban spillover counties are near large cities. The urban fields of large cities will diffuse much greater distances than smaller cities, so the potential for any given county to experience urban spillover depends on the size of the nearby city and distance to the city (Fox and Kumar 1965; Berry and Gillard 1977). Three assumptions are made in identifying spillover counties:[6] (1) counties within sixty miles of counties with large cities (i.e., cities with at least 250,000 residents) are urban spillover because sixty miles approximates the urban field for larger cities (Berry and Gillard 1977), (2) counties within forty miles of counties with mid-sized cities (i.e., cities with at least 100,000 residents but less than 250,000) are urban spillover counties, and (3) counties with small cities (i.e., cities with at least 25,000 residents but less than 100,000) are too small to generate spillover effects. All remaining interstate counties are in the uncompetitive group. Although they may be adjacent to counties with small cities, they are beyond the reach of urban spillover and have no cities with 25,000 or more residents. Finally, adjacent off-interstate counties are located within 30 miles of the 142 interstate counties studied here. Altogether, there are 13 competitive, 48 urban spillover, 81 uncompetitive, and 192 adjacent counties. More observations would have been preferable for some of these categories but were not possible because of data suppression and the limited number of counties getting interstate highways in any given period.

5. Analysis of results

5.1. Pre-test results

The pre-test provides a means for assessing the suitability of the matched twins. Its null hypothesis is that there is no difference between the growth rates of the treated counties and their untreated twins before the highways were constructed. Table 3 shows the pre-test results for each of the five categories. In each instance, the number of significant differences in 1959-62 mean growth rates is four or less. Among the highway sensitive sectors, significant differences are relatively rare. Exceptions are population for the competitive counties, state and local government for the uncompetitive counties, and transfers and retail trade for the adjacent counties. These variables are important for post-test hypothesis testing, and, if they are not random occurrences, the differences are troublesome for inferring impacts. On the other hand, the fact that a Hotelling T^2 test calculated using a vector of nine highway sensitive sectors where data suppression is unproblematic (total, earnings, population, residential adjustment, transfer payments, construction, manufacturing, retail trade, services, and state and local government) revealed no statistically significant differences suggests that the matches are good. Therefore, the pre-tests are passed, and the twins are deemed adequate for use in the treatment period.

5.2. Construction stage effects on rural economies

Figure 3 shows pre and post-test results for industries that are expected to have strong construction linkages (based on the input-output simulations reported in section 2.2) using the twenty-four county highway construction group. During the construction period, each of the sectors exhibits positive effects.[7] Residential adjustment has a negative mean growth residual, suggesting that incommuting, possibly of construction workers, leads to an earnings leakage during the period. However, only the effects on construction and total earnings are statistically significant, and then, only for one and two years respectively. The performances of the other sectors do not appear to be linked strongly to the construction stimulus, even when statistical significance is ignored. Retail trade and manufacturing growth achieve their maxima in years three and four rather than the second year when construction peaks. These results suggest that highway construction can affect overall county growth, but it does not induce a local boom period characterized by broader sectoral effects. Leakages may be so substantial or the direct effects so small that other construction sensitive sectors are not affected.

5.3. Post construction effects

5.3.1. Competitive

The effects of interstate highways on competitive counties (the counties with cities of more than 25,000) are positive. Mean growth rate differentials for selected sectors are illustrated in figure 4. These results suggest that the mechanisms for this stimulation are tertiary industry and government. Retail trade and state and local government are important sources of treatment period gains. These sectors begin to show statistically significant positive growth divergences early in the treatment period and continue until the last data point, 1984. Services does not show statistically significant differences, although it exhibits relatively large growth differences starting in 1974. Contrary to the findings of other empirical studies, manufacturing is negative by the end of the treatment period, but this difference is never statistically significant. Unpictured sectors (tables available from the authors) have few statistically significant results and often negative effects.

Three factors may be responsible for the lack of even more broad-based industrial effects. First, the competitive counties do not have sufficient urbanization to result in significant agglomeration economies. The cities are relatively small and fairly isolated from larger metropolitan areas. They are competitive only in the provision of local public and private services and offer little possibility for financial or manufacturing center development. Second, some of the new employment opportunities opened up in competitive counties may be filled by commuters. Statistically significant negative residential adjustment differences occur upon the completion of interstate routes, indicating that net commuter inflow is stimulated. Third, many of the sectors that exhibit negative mean growth differences for competitive counties are positively affected in the urban spillover counties. Therefore, some of the negative effects (for manufacturing and such unpictured sectors as finance, insurance, and real estate and transportation and public utilities) may be related to changes in locational preferences which favor other counties.

5.3.2. Urban spillover

Urban spillover counties show the most profound, sustained, and propitious aggregate income effects. Total income (unpictured) exhibits positive and significant effects throughout most of the period following the completion of all treated county highway segments. It is accompanied by positive, significant population differences throughout much of the period and statistically significant total earnings differences during the final three years. However, the total earnings effect is not as large as the total income effect, indicating that part of the income effect is the consequence of residential decentralization and income sources tied to new inmigrants (transfer payments and dividends, interest, and rent). Residence adjustment turns positive in 1974 and achieves a statistically significant result for five of the last six last years. This effect is accompanied by positive and statistically significant transfer payment income differences. This latter result suggests that interstate highways may attract older inmigrants to outlying areas of urban areas, which become more appealing as residences when served by interstate highways.

Much of the industry stimulation appears to be connected to the positive population impacts. Service activity in interstate counties outpaces non-interstate counties for much of the treatment period, and the difference is statistically significant for two intermediate years and the final year. Retail trade differences are positive and statistically significant beginning in 1971. In addition, several industry effects appear to follow the population effect. Manufacturing and (unpictured) transportation and public utilities show large positive and statistically significant divergences in the final four years of the treatment period. This result supports the hypothesis that "jobs follow people." Other unpictured categories such as mining, agricultural services, wholesale trade, and finance, insurance, and real estate showed positive effects, but they are never statistically significant in later years.

In summary, urban spillover counties appear to undergo a metamorphosis after the construction of the interstate highways. Although residential decentralization may be the primary mechanism early on, later these counties appear to develop viable economic bases of their own based on primary and secondary industries. Moreover, in contrast to competitive centers, whose impact trajectories level off in the later years, urban spillover counties have considerable upward momentum.

5.3.3. Uncompetitive

The uncompetitive counties, those without a city or near a metropolitan area, exhibit little effect on total income or earnings. What little growth occurs stems from three sources. First, income categories such as transfer payments and (unpictured) dividends, interest, and rent exhibit positive and often statistically significant effects. These results suggest that uncompetitive counties become more attractive for retirees, vacationers, and, perhaps, commuters. This speculation is qualified because, although population and residential adjustment are positively affected during the treatment period, the effects are almost never statistically significant.

Second, retail trade grows faster for uncompetitive counties than their twins. Statistically significant mean differences begin in 1971 and carry through to the end of the analysis period. These magnitudes are smaller than was the case for the competitive and spillover counties, and they tend to level off toward the end of the treatment period. This pattern and the absence of similar positive impacts in services and state and local government suggest that, instead of the dynamic competitive advantages which resulted in sustained tertiary sector improvement for competitive and spillover counties, the effect for uncompetitive counties may be limited to highway related retail outlets like gas stations and grocery stores.

Third, the performance of some sectors appears to bear a slight resemblance to urban spillover counties. For instance, manufacturing has about the same timing and follows the same trajectories. It begins when impacts peak for the competitive group, suggesting that the same locational forces that result in diffusion from the competitive core may later push these industries into the more remote periphery. However, these differences never become statistically significant, even in later years.

Taken all together then, the positive forces affecting uncompetitive counties are of smaller magnitude than the ones affecting the previous two categories. While new interstates give these counties residential and industrial location advantages compared to rural hinterland counties off the interstate system and may allow them to attract some activities that decentralize from competitive counties, these advantages are more anemic than elsewhere. Apparently, the advantages that come from improved interstate access are offset to some extent by competition from more centralized locations along the route.

5.3.4. Adjacent

Counties located in close proximity to interstate counties show many negative effects. Included are population, services, and state and local government, sectors which never had negative effects at the conclusion of the analysis period for on-interstate counties. Retail trade exhibits statistically significant negative effects during four intermediate years, but no inferences can be made because it was also growing significantly slower during the pre-test. Of the pictured industries, only manufacturing improves as a result of new highway construction, but it is statistically significant for just 1968. These results provide weak support for the hypothesis that new interstate highways make adjacent counties vulnerable to competition in local goods and services from locations along the route, particularly competition from more urbanized locations there.

6. Conclusion and policy implications

This study has employed a quasi-experimental matching method to examine the regional economic effects of interstate highways. It has focused on such highways because they have often been advocated for the purpose of stimulating economic growth and development. Federal and state highway programs, including current legislation, have been justified, in part, by the claim that additional freeway mileage will enhance the economic competitiveness of predominantly rural regions. The new empirical work presented in this study, as well as careful assessment of the theoretical and empirical literatures, calls into question some of these claims. The main beneficiaries of the interstate system in terms of economic growth have not been isolated rural regions or regions in close proximity to the system. Instead, the areas that have benefited most are those in close proximity to large cities or with some degree of prior urbanization, such as counties having cities with more than 25,000 residents.

These results have implications for public policy that are worth pondering. New freeways can be a useful part of a growth center strategy to reinforce the competitive characteristics of small cities. Counties with cities of 25,000 (or even less perhaps) can be stimulated. Yet, the largest economic changes will be on the urban fringe of larger cities. This conclusion dovetails with conventional wisdom and contradicts the predictions of early interstate highway planners, who argued that new highways would aid urban revitalization and curtail decentralization (Rose 1990). On the other hand, the current perception that interstate highways merely foster decentralization is equally inaccurate. When combined with other policies that take advantage of the increased accessibility to smaller cities and the stimulation of public and private services, interstate highways can lead to planned small city growth centers that exhibit even greater dynamism than those found in the empirical results.

This research provides support for both proponents and critics of the Appalachian Development Highway System. Among other things, critics asserted that new multi-lane highways would contribute to the exodus of residents from the region, that any regional growth and development would not spread evenly, and that the region's cities were too small and exhibited too little economic potential to be stimulated by highway investment. The critics are correct in observing that freeways do not result in spatially balanced effects. Isolated rural counties and off-freeway counties, such as make up a significant portion of Appalachia, do not experience substantial growth within the initial two decades following interstate highway construction. The rims of large cities on the periphery and outside of Appalachia are probably the biggest beneficiaries of the new highway system. The critics, however, are incorrect when they question the relevance of new freeways for stimulating urban growth within the region. The results here show that new interstate highways do help small cities.

These policy conclusions for interstate highways do not necessarily hold for other physical or social infrastructure. Its distinctive spatial elements make interstate highway investment different from most other public investment. First of all, by its very nature highway investment affects many types of regions. It cannot be concentrated at a single point to improve economic welfare. Highways must necessarily cross low density regions with limited economic development potential. Second, and more importantly, new highways affect market boundaries, commuter sheds, and residential choices. Their principle effects are to foster changes in residential location and the location and viability of private and public services. These qualities are not as pronounced for other types of public infrastructure. Hence, it does not follow that roads built for local transportation, water, sewerage, education, health, and other types of public infrastructure will have the centralizing and dispersing effects that interstate highways do.

Endnotes

[1] The U.S. model is a 537 sector commodity-by-industry model constructed by the Bureau of Economic Analysis based on 1977 Bureau of Census data (U.S. Department of Commerce 1977). The West Virginia model is a 435 sector commodity-by industry model which is a non-survey revision of the BEA 1977 model based on 1982 data from a variety of governmental sources (Greenstreet 1987). Because these models yield only type I multipliers, induced consumption effects of highway expenditures are not captured.

[2] The Mahalanobis distance is defined as follows:

$$d(\mathbf{X}_T, \mathbf{X}_i) = (\mathbf{X}_T - \mathbf{X}_i)^T \mathbf{R}^{-1} (\mathbf{X}_T - \mathbf{X}_i)$$

where:

$d(\mathbf{X}_T, \mathbf{X}_i)$ is the distance between the vector of selection variables for treated county and county i and

R is the variance-covariance matrix of the variables for the potential twins.

[3] Basically, two methods for assigning a unique twin to each treated county are available: (1) heuristic matching techniques and (2) optimal matching techniques (Beaumont et al. 1990; Beaumont and Rinderle 1991). Heuristic matching techniques are relatively simple rules of thumb that are comparatively inexpensive to compute, but they are sensitive to the ordering of the treatment observations. Moreover, they are not optimal in the sense of choosing the best twins for the treatment regions taken as a whole.

[4] Statistical tests on groups of counties can be performed in basically two ways. The mean growth rates for groups of treated counties and their twins can be compared without recognizing the pairwise matching and conducting a standard difference of means test. This test, however, is less efficient than testing on paired growth differences when meaningful matched pairs can be formed because it throws away information about pairwise association.

[5] Residential adjustment is treated differently than the other categories because it can assume negative values for counties that have a net outflow of commuters' income. This property creates a problem when making growth rate calculations because the growth rate of a negative number does not make intuitive sense. The procedure used to correct this problem is explained in Rephann (1993b).

[6] Several other distance assumptions were explored to classify urban spillover and uncompetitive counties. For instance, the urban spillover category was expanded to include all counties within sixty miles of a city of 100,000-249,999. These different classifications did not appreciably change the empirical results.

[7] Like most regional data, the BEA personal income figures need to be interpreted with some caution. The basic data used to estimate industry earnings are derived from payroll statements (ES-202) submitted by firms

to provide information for state and federal unemployment insurance administration. These statements may not reflect the geographical location of a firm's activities. Under certain circumstances, firms may allocate worker disbursements to national or regional headquarters rather than the place of employment. BEA attempts to re-assign the disbursements so that it reflects the correct location of the work itself. This problem may be more serious for the construction sector where firm activity is often transient.

References

Appalachian Regional Commission, 1982, Appalachian highways are catalysts of change, Appalachia 15, 8-17.

Ayers, T. F., and L. Freiberg, 1976, Alternative transportation expenditures in development strategy: Arterial highways versus local roads, Review of Regional Studies 6, 37-43.

Bartik, T. J., 1991, Who benefits from state and local economic development policies? (W. E. Upjohn Institute for Employment Research, Kalamazoo, MI).

Beaumont, P., and A. Rinderle, 1991, A Monte Carlo investigation of optimal and heuristic matching methods for treatment-effects tests, Paper presented at the 38th Annual North American Regional Science Association Meetings, New Orleans.

Beaumont, P., D. Sorenson, and A. Isserman, 1990, Opting for optimal matching? Control group selection for rural development, Paper presented at the 37th Annual North American Regional Science Association Meetings, Boston.

Berry, B. J., and Q. Gillard, 1977, The changing shape of metropolitan America (Ballinger, Cambridge, MA).

Blum, U., 1982, Effects of transportation investments on regional growth: A theoretical and empirical investigation, Papers of the Regional Science Association 49, 169-84.

Bohm, P., and H. Lind, 1993, Policy evaluation quality: A quasi-experimental study of regional employment subsidies in Sweden, Regional Science and Urban Economics 23, 51-65.

Botham, R. W., 1980, The regional development effects of road investment, Transportation Planning and Technology 6, 97-108.

Briggs, R., 1980, The impact of Interstate Highway System on non-metropolitan growth (Office of University Research, U.S. Department of Transportation, Washington, DC).

Burress, D., N. Clifford, and A. Redwood, 1989, Some effects of government on the growth of Kansas counties, Presented at the 28th Annual Southern Regional Science Association Meetings, Chapel Hill, NC.

Campbell, D. T., and J. C. Stanley, 1963, Experimental and quasi-experimental designs for research, (Rand McNally, Chicago).

Caudill, H., 1969, Appalachia: The dismal land, in: J. Larner and I. Howe, eds., Poverty: View from the left (William Morrow and Co., New York).

Chinitz, B., 1969, The regional problem in the U.S.A., In E. A. G. Robinson, ed., Backward areas in advanced countries (St. Martin's, New York).

Corsi, T. M., 1974, A multivariate analysis of land use change: Ohio Turnpike interchanges, Land Economics 50, 232-41.

Cromley, R. G., and T. R. Leinbach, 1981, The pattern and impact of the filter down process in nonmetropolitan Kentucky, Economic Geography 57, 208-24.

Eagle, D., and Y. J. Stephanedes, 1988, Dynamic highway impacts on economic development, Transportation Research Record 1116, 56-62.

Epps, J. W. and D. B. Stafford, 1974, Interchange development patterns on interstate highways in South Carolina, Paper presented at the 53rd Annual Meeting of Highway Research Board, Washington, DC.

Forkenbrock, D. J., T. F. Pogue, N. S. J. Foster, and D. J. Finnegan, 1990, Road investment to foster local economic development (Midwest Transportation Center, Iowa City).

Fox, K. A., and T. K. Kumar, 1965, The functional economic area: Delineation and implications for economic analysis and policy, Papers of the Regional Science Association 15, 57-85.

Gaegler, A. J., J. W. March, and P. Weiner, 1979, Dynamic social and economic effects of the Connecticut Turnpike, Transportation Research Record 716, 28-32.

Gauthier, H. L., 1970, Geography, transportation, and regional development, Economic Geography 46, 612-19.

Gillis, W. R., 1989, Introduction: The relevance in rural transportation, in W. R. Gillis, ed., Profitability and mobility in rural America (Pennsylvania State University Press, University Park).

Greenstreet, D. L., 1987, A users guide to the 1982 West Virginia input-output model, (Center for Economic Research, Morgantown, West Virginia).

Hale, C. W., and J. Walters, 1974, Appalachian regional development and the distribution of highway benefits, Growth and Change 5, 3-11.

Hansen, N. M., 1966, Some neglected factors in American regional development policy: The case of Appalachia, Land Economics 42, 1-9.

Harris, C. C., 1974, Regional economic effects of alternative highway systems (Ballinger, Cambridge, MA).

Hilewick, C. L., E. Deak, and E. Heinze, 1980, A simulation of communications and transportation investments, Growth and Change 11, 26-38.

Huddleston, J. R., and P. P. Pangotra, 1990, Regional and local economic impacts of transportation investments, Transportation Quarterly 44, 579-94.

Humphrey, C. R., and R. R. Sell, 1975, The impact of controlled access highways on population growth in Pennsylvania nonmetropolitan communities, 1940-1970, Rural Sociology 40, 332-43.

Isserman, A. M., and P. M. Beaumont, 1989, Quasi-experimental control group methods for the evaluation of regional economic development policy, Socio-Economic Planning Sciences 23, 39-53.

Isserman, A. M., and J. Merrifield, 1982, The use of control groups in evaluating regional economic policy, Regional Science and Urban Economics 12, 43-58.

Isserman, A. M., and J. Merrifield, 1987, Quasi-experimental control group methods for regional analysis: An application to an energy boomtown and growth pole theory, Economic Geography 63, 3-19.

Isserman, A. M., T. J. Rephann, and D. J. Sorenson, 1989, Highways and rural economic development: Results from quasi-experimental approaches, Working Paper 8907, Regional Research Institute, Regional Research Institute.

Johnson, T. G., 1989, State rural transportation programs in an era of contraction (National Governors Association, Washington, DC).

Kau, J., 1977, A transportation land use model for rural areas, Annals of Regional Science 11, 41-54.

Keeble, D., 1980, Industrial decline, regional policy, and the urban-rural manufacturing shift in the United Kingdom, Environment and Planning A 12, 945-62.

Kuehn, J. A., and J. G. West, 1971, Highways and regional development, Growth and Change 2, 23-28.

Lichter, D. T., and G. V. Fuguitt, 1980, Demographic response to transportation innovation: The case of the interstate highway, Social Forces 59, 492-511.

Lord, J. H., 1972, Pecuniary external economies of public highway investment in Appalachia: Simulating regional economic development with input-output data, Ph.D. dissertation, Indiana University.

Manuel, E. H., 1971, The Appalachian Development Highway program in perspective, Study Paper 3, Division of Regional Program Planning and Evaluation, Appalachian Regional Commission, Washington, DC.

Martin, R. C., 1979, Federal regional development programs and U.S. problem areas, Journal of Regional Science 19, 157-70.

Mason, J. B., 1973, Highway interchange land use development, Growth and Change 4, 38-43.

Miller, J. P., 1979, Interstate highways and job growth in nonmetropolitan areas: A reassessment, Transportation Journal 19, 78-81.

Moon, H. E., 1988, Interstate highway interchanges as instigators of nonmetropolitan development, Transportation Research Record 1125, 8-14.

Munro, J. M., 1966, Transportation investment and depressed regions, Ph.D. dissertation, Indiana University.

Munro, J. M., 1969, Planning the Appalachian Development Highway System: Some critical questions, Land Economics 45, 149-61.

Newman, M., 1972, The political economy of Appalachia (Lexington Books, Lexington, MA).

Nicol, W., 1982, Estimating the effects of regional policy: A critique of the European experience, Regional Studies 16, 199-210.

Paelinck, J. H. and P. Nijkamp, 1975, Operational theory and method in regional economics (Lexington Books, Lexington, MA).

President's Appalachian Regional Commission, 1964, Appalachia (US GPO, Washington, DC).

Press, S. J., 1972, Applied multivariate analysis (Holt, Rinehart and Winston, New York).

Rephann, T. J., 1993a, Highway investment and regional economic development: Decision methods and empirical foundations, Urban Studies 30, 437-450.

Rephann, T. J., 1993b, A study of the relationship between highways and regional economic growth and development using quasi-experimental control group methods, Ph.D dissertation, West Virginia University.

Richardson, H., 1973, Regional growth theory (John Wiley, New York).

Richardson, H., 1974, Empirical aspects of regional growth in the United States, Annals of Regional Science 8, 8-23.

Rietveld, P., 1989, Infrastructure and regional development: A survey of multiregional economic models, Annals of Regional Science 23, 255-74.

Rose, M. H., 1990, Interstate: Express highway politics, 1939-1989, Knoxville, University of Tennessee Press.

Rosenbaum, P. R., 1989, Optimal matching for observational studies, Journal of the American Statistical Association 84, 1024-32.

Siccardi, A. J., 1986, Economic effects of transit and highway construction and rehabilitation, Journal of Transportation Engineering 112, 63-76.

Sears, D. W., T. D. Rowley, and J. N. Reid, 1990, Infrastructure investment and economic development: An overview, in Infrastructure investment and economic development: Rural strategies for the 1990s, Staff Report No. AGES 9069, Agriculture and Rural Economy Division, U.S. Department of Agriculture, Washington, DC.

Stephanedes, Y., and D. M. Eagle, 1986, Highway expenditures and non-metropolitan employment, Journal of Advanced Transportation 20, 43-61.

Straszheim, M. R., 1972, Researching the role of transportation in regional development, Land Economics 48, 212-19.

Twark, R. D., R. Eyerly, and T. Nassi, 1980, Quantitative technique for estimating economic growth at non-urban limited access highway interchanges, Transportation Research Record 747, 12-19.

U.S. Department of Commerce, Bureau of the Census, 1979, County and city data book consolidated file, county and city data, 1947-1977, Prepared by the Data User Services Division, Washington, DC.

U.S. Department of Commerce, Bureau of the Census, 1980, Census of population and housing, 1980: Master area reference file (MARF) 2, Prepared by the Data User Services Division, Washington, DC.

U.S. Department of Commerce, Bureau of Economic Analysis, 1977, The detailed input-output structure of the U.S. economy, 1977 (US GPO, Washington, DC).

U.S. Department of Commerce, Bureau of Economic Analysis, 1986, Regional Economic Information System, Washington, DC.

U.S. Department of Transportation, 1990, PR-511 Master File, Prepared by the Data Systems Division of the Federal Highway Administration, Washington, DC.

von Böventer, E., 1975, Regional growth theory, Urban Studies 12, 1-29.

Waters, W. G., 1980, Transportation and regional development: The persistent myth, The Logistics and Transportation Review 15, 527-43.

Wheat, L. F., 1969, The effect of modern highways on urban manufacturing growth, Highway Research Board 277, 9-24.

Wheat, L. F., 1986, The determinants of 1963-77 regional manufacturing growth: Why the South and West grow, Journal of Regional Science 26, 635-59.

Wilson, F. R., G. M. Graham, and M. Aboul-Ela, 1986, Highway investment as a regional development policy tool, Transportation Research Record 1046, 10-14.

Wright, A. L., and M. G. Blase, 1971, A depressed region and three myths, Growth and Change 2, 14-22.

Table 1. Selection Variables used in Empirical Analysis

Name	Variable Description	Years
<u>Calipers</u>		
HWY[a]	Interstate highway presence or proximity[c]	1987
MISSING	Missing data	1959
SPAIND[b,c]	Spatial independence	
<u>Covariates</u>		
PRES	Residential adjustment share[d]	1959
PDIR	Dividends, interest, and rent income share[d]	1959
PTRF	Transfer income share[d]	1959
PFAR	Farm earnings share[d]	1959
PCON	Construction earnings share[d]	1959
PMFG	Manufacturing earnings share[d]	1959
PTPU	Transportation and public utilities earnings share[d]	1959
PWHL	Wholesale trade earnings share[d]	1959
PRTL	Retail trade earnings share[d]	1959
PSVC	Services earnings share[d]	1959
PFED	Federal, civilian earnings share[d]	1959
PMIL	Federal, military earnings share[d]	1959
PSTL	State and local earnings share[d]	1959
POTH	Suppressed earnings data share[d]	1959
LPOP	Log of population (base ten)	1959
LPTPP[c]	Logarithm of population potential ($r \leq 60$)	1959
LPTPPP[c]	Logarithm of population potential ($60 < r \leq 500$)	1959
PDN	Population per square mile	1959
PCI	Per capita earnings	1959
CITY25[c]	Distance to city of population 25,000 or greater	1960
CITY100[c]	Distance to city of population 100,000 or greater	1960
CITY250[c]	Distance to city of population 250,000 or greater	1960
CITY500[c]	Distance to city of population 500,000 or greater	1960
CITY1000[c]	Distance to city of population 1,000,0000 or greater	1960
RTOT	Total income growth rate	1950-59
RPOP	Population growth rate	1950-59
SPC	State and local earnings per capita	1959

[a] Highway existence is used as a caliper for treated counties that received a new interstate highway. Highway proximity is used as a caliper for those treated counties located close to an interstate but not along the route. This caliper removes counties that are located within 30 miles of the county centroid of a county that is traversed by an interstate highway in addition to those counties containing interstate mileage.
[b] This caliper removes counties within 60 miles of a treated county.
[c] This variable is calculated using 1980 population centroids.
[d] Share of total personal income.

Data sources: U.S. Department of Commerce, Bureau of Economic Analysis (1986); U.S. Department of Transportation, Federal Highway Administration (1990); U.S. Department of Commerce, Bureau of Census (1979); and U.S. Department of Commerce, Bureau of Census (1980).

Table 2. Growth Rates used in Empirical Analysis

Abbreviation	Variable
TOT	Total personal income
POP	Population
PCI	Per capita personal income
EAR	Total earnings by place of work
RES	Residence adjustment (earnings from outcommuters residing in the county less incommuter earnings)
DIR	Dividends, interest, and rent
TRF	Transfer payments
FAR	Farm earnings
AGS	Agricultural services, forestry, fishing, and other earnings
MIN	Mining earnings (includes coal, oil and gas, metals, nonmetallic minerals)
CON	Construction earnings (includes general building, heavy construction, special trade)
MFG	Manufacturing earnings (includes nondurable and durable goods)
TPU	Transportation and public utilities (includes railroad, trucking, water, transportation services, communication, electric, gas and sanitary services)
WHL	Wholesale trade earnings
RTL	Retail trade (includes building materials, general merchandise, food, automotive dealers and service stations, apparel and accessory stores, eating and drinking places)
FIR	Finance, insurance, and real estate earnings
SVC	Service earnings (includes hotels, personal services, private households, business services, auto repair, amusement and recreation, health, legal, educations, social, museums)
FED	Federal, civilian government earnings
MIL	Federal, military government earnings
STL	State and local government earnings

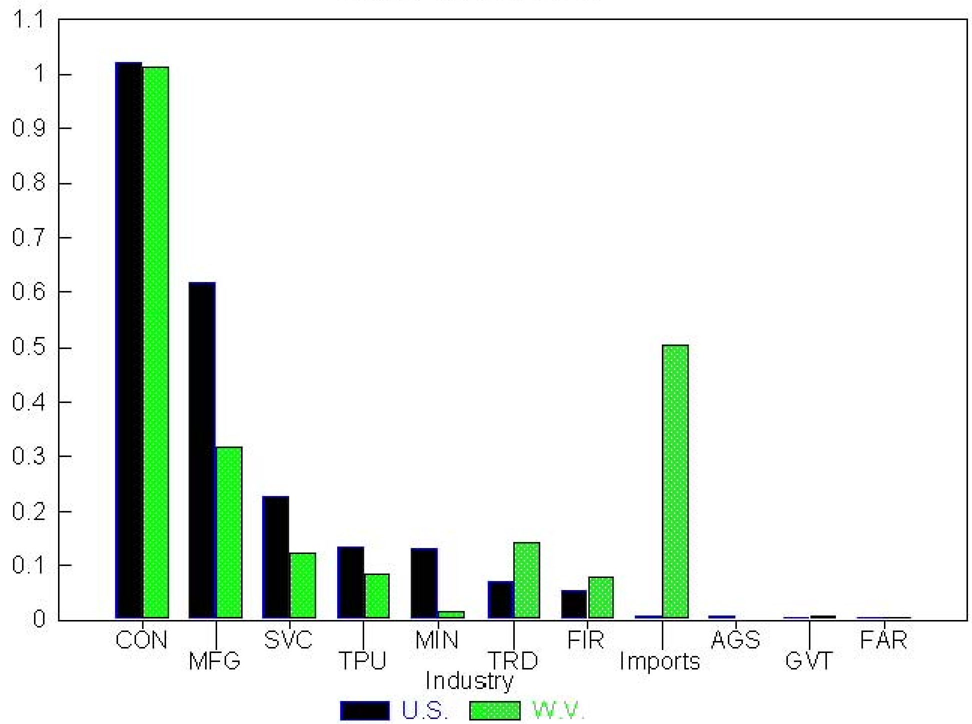
Source: U.S. Department of Commerce, Bureau of Economic Analysis (1986).

Table 3. Pre-test Results by Category, 1959-62
(Mean Growth Rate Differences and Statistical Significance, * α =.10)

	Highway Construction	Competitive	Urban Spillover	Uncompetitive	Adjacent
TOTAL INCOME	-0.3	-1.1	0.8	2.2	0.3
POPULATION	0.8	2.3*	1.2	0.5	-0.2
PER CAPITA INCOME	-1.1	-3.8	-0.6	1.6	0.7
EARNINGS	0.1	-0.9	1.6	2.7	-0.1
RESIDENTIAL ADJUSTMENT	-1.3	-0.4	-0.1	-0.2	0.2
DIVIDENDS, INTEREST, RENT	0.0	-0.3	3.5	3.1	2.0*
TRANSFER PAYMENTS	-1.2	0.7	-1.5	0.0	1.0*
FARM	-4.5	0.1	1.0	4.5	0.6
AG. SERVICES AND OTHER	5.1	0.6	4.2	6.3	-0.3
MINING	5.7	0.7	0.3	1.3	-3.0
CONSTRUCTION	3.6	-2.9	1.0	5.7*	1.4
MANUFACTURING	2.2	1.3	3.6	0.3	-0.4
TPU	-1.9	-0.1	-3.0*	-1.5	1.5*
WHOLESALE TRADE	0.5	1.3	0.1	1.1*	-0.1
RETAIL TRADE	0.0	0.7	0.9	0.2	-0.9*
FIR	-1.4	1.0	0.4	-0.4	0.5
SERVICES	-1.6	-3.6	1.6	0.3	-2.2
FEDERAL, CIVILIAN	6.7	10.6	12.9	2.8	-1.5
MILITARY	7.1*	46.8	41.0	0.9	4.8
STATE AND LOCAL	-0.9	2.2	0.1	-3.1*	-0.3
Counties	24	13	48	81	192
Hotelling T^2	13.6	19.2	13.5	8.1	14.3
F Test Statistic	0.841	0.711	1.228	0.775	1.515

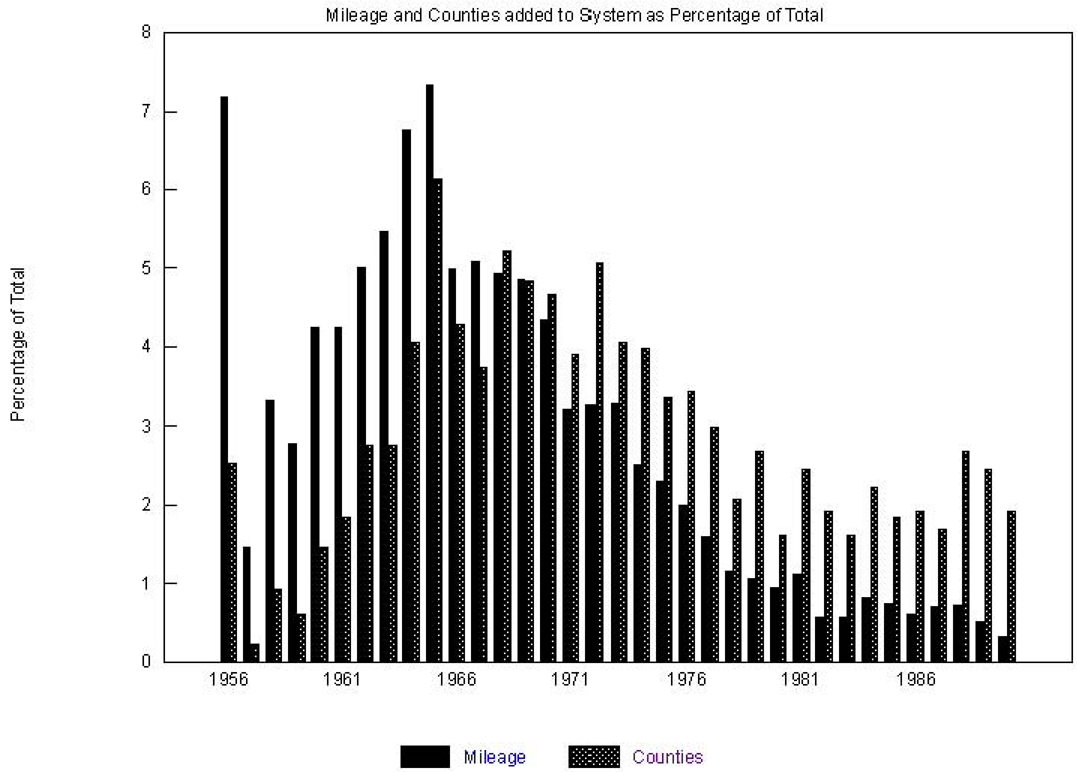
Figure 1. Highway Construction Effects by Industry

(Output per $ Final Demand)



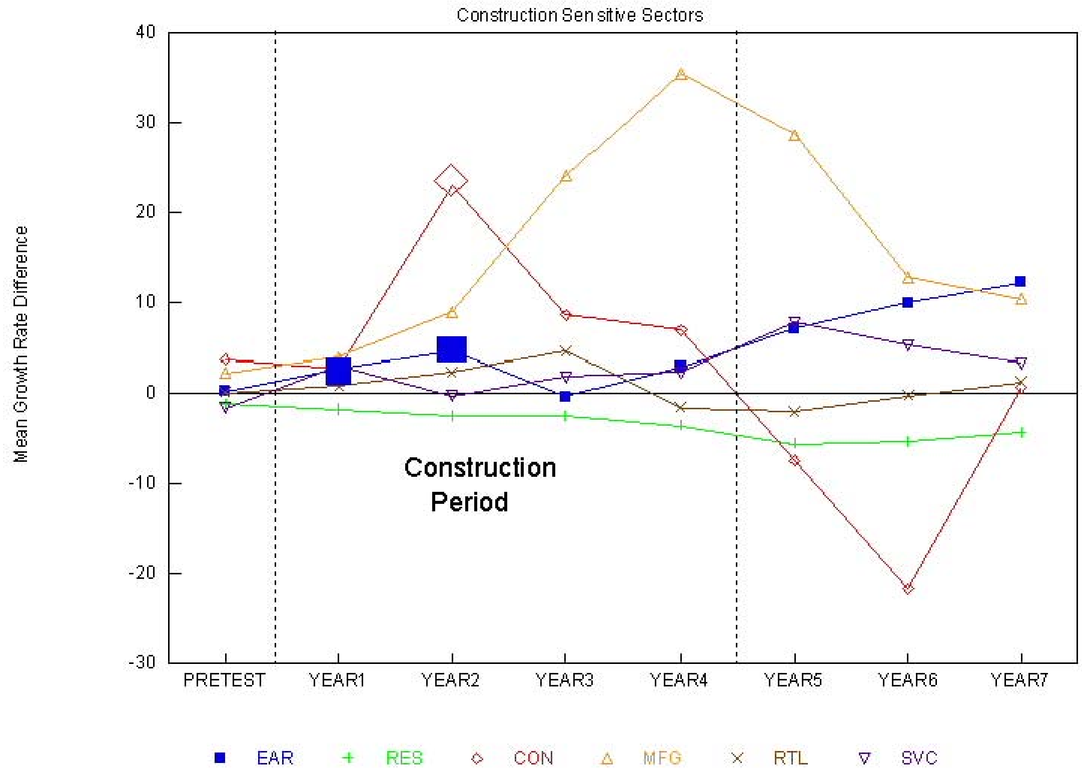
Sources: U.S. Department Commerce (1977) and Greenstreet (1987)

Figure 2. Interstate Completion



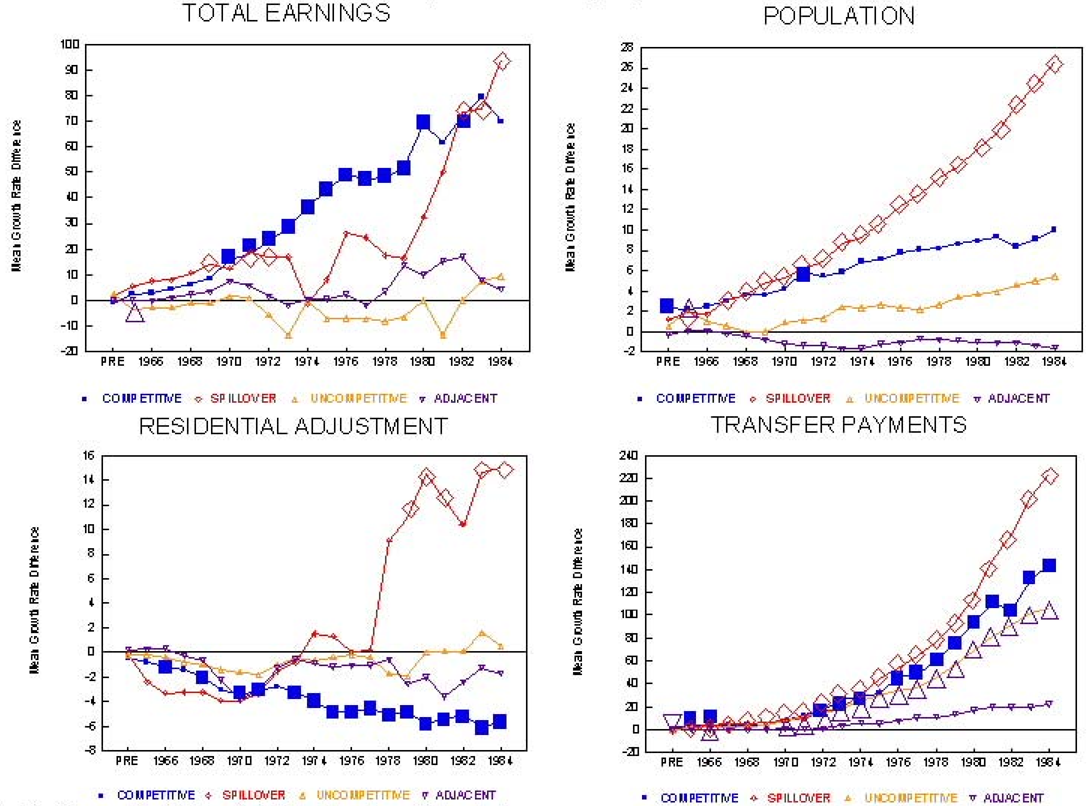
Source: U.S. Department of Transportation (1990)

Figure 3. Highway Construction Effects



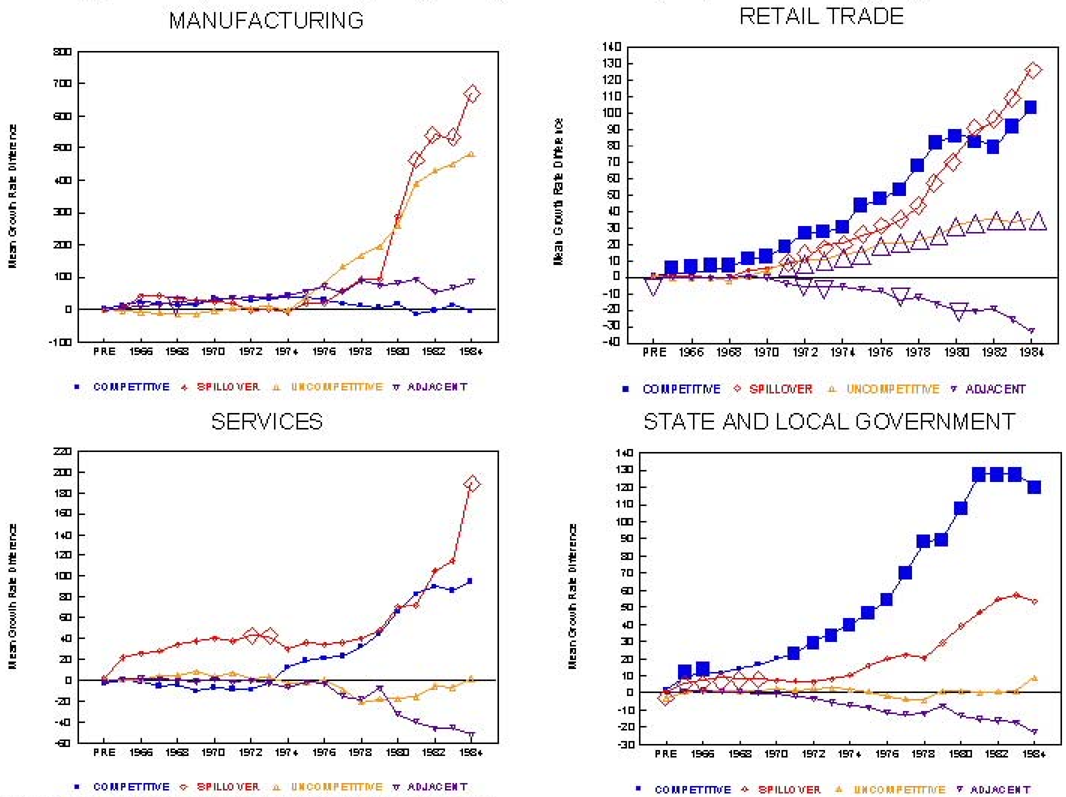
Statistical significance at the 10% level is indicated by enlarged tick symbols.

Figure 4. Highway Effects by Spatial Category



Statistical significance at the 10% level is indicated by enlarged tick symbols.

Figure 4. (continued) Highway Effects by Spatial Category



Statistical significance at the 10% level is indicated by enlarged tick symbols.