QUASI-EXPERIMENTAL DESIGNS FOR MEASURING IMPACTS OF DEVELOPMENTAL HIGHWAYS IN RURAL AREAS

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Abstract

Quasi-experimental techniques were developed to provide decision-making tools for documenting the impacts of developmental highways in rural areas. Regression discontinuity analysis (RDA) with limited observations was used to compare economic changes in highway counties to those in adjacent and non-adjacent control counties. The RDA models found statistically significant changes in population, per capita income, and taxable sales related to highway development. The study found that some counties benefitted from developmental highways, some were unchanged, while some experienced economic decline. RDA models with adjacent controls had better explanatory powers while those with non-adjacent controls were more sensitive to highway-related changes in economic activity. When significant non-highway activities were present, adjacent control models may have understated highway-related impacts, while non-adjacent control models may have overstated these impacts. Arguments for using adjacent and non-adjacent experimental designs are discussed.

Key words: highways, impact assessment, quasi-experimental design, rural development, transportation, infrastructure investments

The construction of developmental highways to encourage economic growth is an innovative idea when compared to the practice of building highways where growth has already occurred. Proponents of developmental highway construction in rural areas expect these highways to (1) stimulate economic activity in rural areas, (2) improve the quality of life of farm and rural families by improving access to schools, hospitals, and shopping areas, and (3) decrease the transportation costs of farm and non-farm products. While highway construction has been shown to have positive impacts on local economies (Kau; Yeats; Jordan; Henry; Smith, Deaton, and Kelch; Miller; Isserman and Merrifield; Johnson), a consensus on the significance of these benefits and the appropriate techniques for measuring these benefits has not emerged (Henry et al.).

This research was motivated by the need to provide rural areas with decision-making tools for documenting the impacts of developmental highways. State-of-the-art techniques for measuring the impact of developmental highways (input-output analysis, regional growth models, and auto-regressive models) tend to be data and computer intensive and beyond the human capital skills and monetary resources of local planners and research staffs. Also, estimates of highway-related impacts derived from aggregate models may not be applicable to specific highways or communities. As potential beneficiaries of future highway investments, rural decision makers need practical, alternative ways to document the impacts of existing developmental highways. To this end, this paper offers a practical technique for assessing impacts of developmental highways at the site-specific or case-study level.

OBJECTIVES

This study examined relationships between selected developmental highways and economic changes in rural areas. Economic development indicators were identified and used to compare counties with developmental highways to control counties with alternate specifications. Specifically, the objectives of this paper were to (1) develop a with-and-without framework for measuring changes in local economies associated with highway development, (2) estimate changes in economic activity associated with highway development using quasi-experimental designs with alternate control specifications, and (3) discuss policy implications for future highway development and offer suggestions for future research.

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This paper presents conceptual and empirical problems associated with the selection of quasi-experimental controls. Empirical estimates using alternate quasi-experimental controls are presented and discussed.

Local decision-makers can use these techniques to document the impacts of developmental highways in their communities. Quasi-experimental techniques are well suited for activities in which economic linkages are not well established or where decisions are not based solely on economic criteria. While developmental highways impact local economies, the rationale for construction is often based on non-economic criteria. This should not suggest that the economic linkages are unimportant in the development process, but that knowledge of linkages is not a necessary condition for using quasi-experimental techniques.

METHODS

Highway-related changes in local economic activity were examined over a 17-year period in a quasi-experimental design framework to determine whether significant changes were associated with highway development. A quasi-experimental framework was developed to meet the following design criteria (Isserman and Merrifield, p.15). First, the research design should establish plausible causality to support the claim that the given economic impacts are caused by the developmental highways. Second, the research design should control for tractable causality or non-highway related factors that might influence economic development. Third, the research design should achieve spatial independence such that the highway-related impacts in experimental counties are independent of the economic conditions in the control counties. Fourth, the researcher should identify appropriate controls.Because the researcher's ability to meet these design criteria largely depends on the availability of data, a fifth criterion suggests that the research design should be adapted to the availability of data.

The quasi-experimental design used in this study is the interrupted time-series analysis with non-equivalent no-treatment control groups, more commonly referred to as regression discontinuity analysis (Cook and Campbell, p. 214). Regression discontinuity analysis (RDA) was used to compare economic trends in counties *with* developmental highways to those that would have occurred in these counties *without* developmental highways (Campbell and Stanley; see Figure 1). Because developmental highways are not constructed under "experimental conditions" (for political and economic reasons), their impacts were measured under quasi-experimental conditions. Counties with developmental highways in this study were defined as experimental or highway counties. Counties without developmental highways were defined as control counties.

For time-series with more than 50 to 100 observations, the preferred modeling technique for inter-

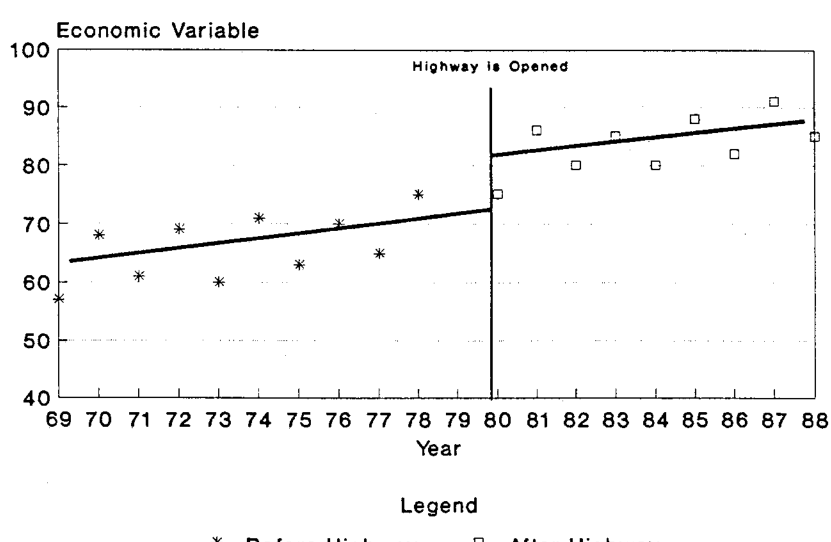

Figure 1. Regression Discontinuity Model

rupted time-series analysis is the auto-regressive integrated moving average (ARIMA; McCain and McCleary). Because the time-series for the current study was limited to seventeen observations, multiple regression was used instead of ARIMA to measure highway-related impacts on the local economy. Specifically, regression discontinuity models were estimated using binary or dummy variables to test for significant intercept shifts or discontinuities associated with the opening of developmental highways as follows (Kmenta):

(1) $Y_i = B_0 + B_1C_i + B_2E_i + e_i$,

where Y_i = the i^{th} economic variable in the county with the highway, C_i=the i^{th} economic variable in the control counties without the highway, E_i=the intercept binary set at 0 before the highway was opened and 1 after the highway was opened for traffic, and e_i =error term.

In the absence of serial correlation, multiple regression was judged to be an appropriate statistical technique for measuring highway related impacts on local economies.

Cook and Campbell assert that effects measured by RDA are either instantaneous or delayed in their initial manifestation following the treatment. Instantaneous effects are matched exactly to the time of intervention. Delayed effects are more difficult to interpret, especially if there is no theoretical specification of how long a delay should elapse before an effect is expected. Lacking specifications on the lagged development effects of highway construction, this analysis accepted only abrupt changes or intercept shifts as valid evidence of plausible causality (that economic development was associated with highway construction). Gradual changes in the economic variables (slope changes) were rejected because of the probability that such changes might be due to tractable causality (where economic change is due to both highway and non-highway factors). Thus, while this analysis does not preclude the temporal effects of highway development, the timing of these effects is not readily captured by RDA.

THE CONTROL PROBLEM

This study was primarily concerned with controlling for non-highway related factors in the development process. Economic trends in counties with developmental highways were assumed to approximate economic trends in the counties with similar socioeconomic characteristics. Highway-related impacts on local economic activity were initially estimated using adjacent counties with similar socioeconomic attributes. When more than one control county could be identified for a particular experimental county, a multi-county average was computed for the analysis. To control for the potential influence of urban centers, the study was limited to developmental highways constructed in rural areas. Non-highway events that occurred during the study period were assumed to have had similar effects on the experimental and control counties. Given these assumptions, changes in economic trends associated with highway development were attributed to highway development.

Growth pole theorists argue that, over time, economic development in one area "spreads" or "trickles down" to surrounding areas. While the use of adjacent control counties minimizes tractable causality (the influence of non-highway factors on the control county), the presence of these factors may threaten spatial independence (when highway-related impacts affect not only the experimental county but also the adjacent control counties). Although the time required for this phenomena to develop is unclear, potential threats to spatial independence must be considered. That is, in cases where highway construction affects both experimental and control counties, RDA may overstate or understate the magnitude of highway-related impacts. If post-construction growth in the experimental county is at the expense of growth in the adjacent control counties, the use of adjacent controls will overstate the highway's impact on the region. If the highway has a similar impact on both experimental and control counties, highway-related impacts may be understated.

In response to these concerns, the RDA models were re-estimated using non-adjacent control counties. Once the proximity criterion was removed, the number of potential control counties increased dramatically, as did the selection problem. Cluster analysis was chosen as the appropriate statistical tool for grouping counties with similar socioeconomic characteristics. Cluster analysis places observations into groups such that observations within county groups tend to be similar, while observations across county groups tend to be dissimilar.

The FASTCLUS program in SAS was used to do the clustering procedure (SAS Institute). Socioeconomic characteristics used in the cluster analysis were taken from data compiled by the Southern Growth Policies Board. These data include: county population, per capita income, manufacturing employment, service employment, relationship to interstate highways, and proximity to MSA (metropolitan statistical areas).

While the cluster procedure narrows the list of counties from which experimental controls can be selected, the number of counties in the individual clusters were too large to serve as a control group. Therefore, five control counties were selected from each cluster according to the following criteria: (1) non-proximity to the experimental county, (2) absence of other developmental highways, and (3) geographical dispersion throughout the state. The criteria were used to minimize highway-related impacts in the control counties. In addition, a five-county average was computed to minimize the impacts of non-highway related impacts on the experiment.

SITE SELECTION

Developmental highways examined in this study were selected from highways constructed in rural Georgia during the period 1975 through 1981. Table 1 shows developmental highways, the counties in which the highways were constructed (highway counties), adjacent and non-adjacent control counties along with their year of development, and approximate length.

Six economic development variables were examined in the analysis. The variables selected for study were intended to be representative and not exhaustive of variables in the rural development process. Variables examined in the study include:population, number of manufacturing firms, manufacturing employment, service industry employment, per capita annual gross income, and taxable sales.

RDA RESULTS

Local economic activity in the control and experimental counties were examined for the period 1969-1985 in a quasi-experimental framework. This use of a 17-year period enabled RDA to identify trends in economic activity before and after highway development and to measure highway-related shifts in these trends. Regression discontinuity results for population, per capita income, and taxable sales for the six developmental highways are reported in Tables 2 through 4. Included in the tables are regression coefficients and standard errors for economic variables in the control county, highway binary, and R^2 value. Model results were evaluated on (1) how

Table 1. Selected Developmental Highways in Georgia with Experimental and Control Counties, 1975-1981

Name	Experimental Counties[a]	Control Counties: Adjacent	Control Counties: Non-adjacent	Year Developed	Approximate Length[b]
I-16	Candler	Evans	Calhoun Heard Pike Taylor Warren	1978	15
GA-38	Early	Baker Decatur Miller Mitchell	Appling Brooks Dodge Jones Macon	1975	8
GA-400	Lumpkin	Rabun Towns Union White	Bacon Dade Pierce Putnam Randolph	1980	11
GA-38	Seminole	Baker Decatur Miller Mitchell	Calhoun Heard Jasper Pike Warren	1975	10
I-16	Treutlen	Johnson	Atkinson Lanier Lincoln Marion Towns	1977	24
GA-300	Worth	Colquitt	Appling Brooks Dodge Jones Macon	1981	13

[a]Counties in which developmental highways were constructed.
[b]Length in miles.

Table 2. Impacts of Developmental Highways on Population in Selected Georgia Counties (Ordinary Least Squares)

Highway County	Adjacent Control Counties			Non-adjacent Control Counties		
	Population	Highway	R^2	Population	Highway	R^2
	-regression coefficients[a]					
Candler	0.53* (0.28)	711.55*** (213.97)	0.84	1.01 (0.71)	759.88*** (236.69)	0.82
Early	0.16** (0.07)	113.91 (111.41)	0.64	0.07 (0.06)	215.35* (115.64)	0.53
Lumpkin	1.26*** (0.13)	-324.00 (255.38)	0.99	0.87*** (0.20)	917.11*** (306.12)	0.95
Seminole	0.65*** (0.11)	294.87 (183.04)	0.90	1.95*** (0.30)	327.99* (163.53)	0.91
Treutlen	-0.03 (0.12)	307.86** (117.52)	0.58	-0.09 (0.23)	331.68** (143.94)	0.58
Worth	1.00*** (0.14)	-510.98 (372.19)	0.93	1.34*** (0.28)	-375.20** (552.92)	0.85

[a]Dependent variable = population county. Models estimated for the period 1969-85. Data taken from U.S. Department of Commerce "Population Estimates and Projections." Standard errors are shown in parentheses.

*significant at alpha level = 0.10.
**significant at alpha level = 0.05.
***significant at alpha level =0.01.

accurately economic activities in control counties were associated with economic activities in the experimental county and (2) whether significant intercept shifts were associated with the opening of the developmental highway. Regression results for manufacturing employment, manufacturing firms, and service employment were not statistically significant and are not reported. The lack of significance among these variables was attributed to the low number and high variation in manufacturing and service activities in these counties.[1]

Regression results for population with adjacent and non-adjacent controls are shown in Table 2. Population in counties with developmental highways was significantly related to the population in five of six adjacent control models and three of six non-adjacent control models. The findings suggest that adjacent controls may be better predictors of population than non-adjacent controls. Except for Early and Worth Counties, the proportion of variation explained by the explanatory variables (R^2) in the adjacent control models and that in the non-adjacent control models were comparable. In models with significant control coefficients, the highway binary was significant more often in the non-adjacent models than in the adjacent models. These findings suggest that RDA models with adjacent controls may fail to detect highway-related impacts in experimental counties when such impacts also affect control counties.

Regression results for per capita income with adjacent and non-adjacent controls are shown in Table 3. Per capita income in counties with developmental highways was significantly related to per capita income in all adjacent and non-adjacent control models. The proportion of variation explained (R^2) in the adjacent control models and that in the non-adjacent control models were comparable. While the highway binary was significant in only one adjacent control model, that same variable was significant in two of six of the non-adjacent control models. Non-adjacent control models for per capita income displayed greater sensitivity, despite some apparent loss in explanatory powers.

Regression results for taxable sales for adjacent and non-adjacent controls are shown in Table 4. Taxable sales in counties with developmental highways were significantly related to taxable sales in all adjacent and non-adjacent control models. No significant differences were found in the explanatory power of either of the model groups. However, significance levels for the highway binary were higher in the non-adjacent models. Highway-related declines in taxable sales were consistently significant only in Worth County.

[1] Studies that document the weak link between highway development, manufacturing, and employment are summarized by Henry et al.

Table 3. Impacts of Developmental Highways on Per Capita Gross Income in Selected Georgia Counties (Ordinary Least Squares)

Highway County	Adjacent Control Counties			Non-adjacent Control Counties		
	Population	Highway	R^2	Population	Highway	R^2
	-regression coefficients[a]					
Candler	0.84*** (0.11)	-194.95 (274.92)	0.95	0.83*** (0.11)	-12.00 (253.68)	0.96
Early	1.04*** (0.04)	92.98 (92.34)	0.99	0.94*** (0.05)	246.66** (112.68)	0.99
Lumpkin	1.08*** (0.06)	61.73 (153.45)	0.99	1.27*** (0.14)	171.18 (290.22)	0.97
Seminole	0.87*** (0.07)	431.37*** (140.55)	0.98	0.69*** (0.07)	539.74** (179.26)	0.97
Treutlen	0.84*** (0.07)	146.27 (135.70)	0.98	0.94*** (0.04)	87.23 (84.19)	0.99
Worth	1.09*** (1.10)	-402.69 (263.13)	0.96	1.23*** (0.16)	-447.38 (369.14)	0.94

[a]Dependent variable = per capita gross income in highway county. Models estimated for the period 1969-85. Data taken from Georgia Department of Revenue "Annual Stastical Reports." Standard errors are shown in parentheses.

***significant at alpha level = 0.01.
**significant at alpha level = 0.05.

Table 4. Impacts of Developmental Highways on Taxable Sales in Selected Georgia Counties, (Ordinary Least Squares)

Highway County	Adjacent Control Counties			Non-adjacent Control Counties		
	Sales	Highway	R^2	Sales	Highway	R^2
	-regression coefficients[a]					
Candler	0.83*** (0.03)	-2,413.48* (1,049.87)	0.99	1.95*** (0.74)	-3,732.79 (2,278.21)	0.98
Early	0.72*** (0.04)	2,586.61* (1,430.65)	0.99	0.64*** (0.05)	7,620.48*** (1,677.16)	0.98
Lumpkin	1.12*** (0.11)	-2,880.87 (3,063.93)	0.96	0.87*** (0.16)	3,439.11 (4,466.79)	0.90
Seminole	0.75*** (0.03)	2,386.93** (999.63)	0.99	3.01*** (0.16)	4,777.04*** (1,312.77)	0.99
Treutlen	0.35*** (0.07)	3,216.54*** (835.90)	0.94	0.47*** (0.06)	2,191.31*** (669.01)	0.97
Worth	0.31*** (0.02)	-7,318.94 (1,957.81)	0.99	1.16*** (0.06)	-8,027.95 (2,013.85)	0.99

[a]Dependent variable =taxable sales x $1000. Models estimated for the period 1969-85. Data taken from Georgia Department of Revenue "Annual Stastical Reports." Standard errors shown in parentheses.

*significant at alpha level = 0.10.
**significant at alpha level = 0.05.
***significant at alpha level = 0.01.

IMPACT ESTIMATES

Regression coefficients in Tables 2-4 were used to estimate impacts of developmental highways. Initial and percentage changes in population, per capita income, and taxable sales are shown in Table 5. Initial or pre-highway data were those in existence just before the opening of the highway. Percentage changes were computed by dividing highway binary coefficients in Tables 2-4 by initial values. These data were computed for regression coefficients obtained from adjacent control and non-adjacent control designs. For example, Candler County had a population of 7,518 residents in 1977, the year before the highway was opened. Highway binary estimates for Candler County were 711.55 and 759.88 for adjacent and non-adjacent designs, respectively

(Table 2). Dividing these values by the initial population of 7,518 yields percentage increases of 9.5 and 10.1, respectively.

Comparisons of percentage changes in economic activity under alternate research designs lends support to the hypothesis that adjacent control designs may understate the impacts of highway development while non-adjacent controls may overestimate these impacts. If such were the case, one would expect non-adjacent estimates of highway-related changes to be larger than those of adjacent estimates. As expected, non-adjacent estimates of highway-related changes were larger (in absolute values) than adjacent estimates in five of six population estimates, four of six estimates of income, and five of six estimates of taxable sales.

Economic impacts of highway development were attributed to highway-related changes in travel or commuting time, access to consumer and labor markets, and tourism. Of concern to local residents is how developmental highways will affect their communities. That is, will highways promote or attract economic activity to the county or will the highways better enable residents to shop, work, or vacation elsewhere?

Comparisons of changes across economic activities, shown in Table 5, provide some insights into the inter and intra-county effects of highway development. For example, Candler County experienced an increase in population with decreases in per capita income and taxable sales. These data suggest that some economic activity that would have accompanied population growth may have been lost to other counties. The highway may have made this county a better place to live, but not to shop and visit. In contrast, Early County experienced increases in per capita income and taxable sales with virtually no increase in population. These data suggest that the highway may have attracted economic activity from outside the county. While RDA estimates do not always indicate the inter and intra-county impacts of highway development, these data provide some evidence of the distributive effects of highway development.

LIMITATIONS

Although RDA models control for the influence of non-highway factors, such factors were not explicitly identified in the analysis. Non-highway factors that have been shown to influence economic development include urbanization, industrial base, human capital, government activities, and environmental amenities (Briggs). Potential threats of non-highway factors on the validity of the RDA models depend, in part, on the time frame in which non-highway activities occur. Marginal changes in non-highway activities or those that occur gradually do not threaten the validity of RDA results. Non-marginal changes in non-highway activities or those that occur abruptly do, however, pose problems for the analysis, especially if such changes occur simultaneously with the highway. For example, model estimates of highway-related impacts would be misstated if a military base or large manufacturing firm were

Table 5. Estimated Changes in Economic Activity Associated with Highway Development in Selected Georgia Counties

Highway County	Population		Per Capita Income		Taxable Sales[a]	
	Initial	% Change	Initial	% Change	Initial	% Change
			adjacent control estimates			
Candler	7,518	9.5	3,271	-6.0	36,761	-6.6
Early	13,200	0.8	2,637	3.5	39,579	6.5
Lumpkin	11,100	-2.9	4,237	1.5	26,690	-10.8
Seminole	8,100	3.6	2,884	14.9	33,596	7.1
Treutlen	6,200	5.0	2,797	5.2	13,392	24.0
Worth	18,100	-2.8	3,812	-10.5	54,090	-13.5
			non-adjacent control estimates			
Candler	7,518	10.1	3,271	-0.3	36,761	-10.1
Early	13,200	1.6	2,637	9.4	39,579	19.3
Lumpkin	11,100	8.3	4,237	4.0	26,690	12.9
Seminole	8,100	4.0	2,884	18.7	33,596	14.2
Treutlen	6,200	5.4	2,797	3.1	13,392	16.4
Worth	18,100	-2.1	3,812	-11.7	54,090	-14.8

[a]Taxable sales x $1,000

closed that same year. While beyond the scope of this paper, knowledge of non-highway activities can be used to judge the appropriateness of the RDA model, the selection of controls, or the interpretation of its results.

From an experimental design standpoint, the question is, which control specification is the more appropriate? The findings discussed here suggest that RDA models with non-adjacent controls offered less explanatory power, found more instances of highway-related changes in economic activity, and were more likely to overstate such impacts. Non-adjacent control designs are also limited by the techniques for identifying and selecting non-adjacent controls. Given that the category of non-adjacent counties has a large membership, the reliability of the selection process is crucial to the validity of the statistical results. While the cluster procedure offered some systematic guidance for narrowing the number of counties that serve as controls, the choice of socioeconomic variables around which clusters were developed, and the criteria used for subsequent selection of control counties are subjective.

RDA models with adjacent controls appeared to have better explanatory powers but lacked sensitivity in detecting highway-related changes in economic activity. Also, adjacent control estimates of highway-related changes tended to be more conservative than those from non-adjacent controls and were less likely to overstate such impacts. Adjacent controls can be readily identified and may prove to be superior in controlling for non-highway related factors that impact either the experimental or the control counties coincidental with the highway. For local research staffs, the use of adjacent control greatly simplifies the data and modeling requirements of RDA. Finally, highway-related impacts are apt to be intuitively more appealing to state and local decision-makers when evidence of these impacts are obtained from adjacent control settings.

Because of theoretical limitations, RDA did not identify or rule out lagged and intra-county effects of highway development. Such effects are thought to be important and should be treated explicitly in future research.

CLOSING REMARKS

This study examined selected changes in local economies associated with developmental highways and found that some counties benefitted from highway development, some were unaffected, while others experienced economic decline. These findings suggest that highway construction alone may not be sufficient for economic growth and development.

While highway construction may generate some short-term economic activity, sustained economic growth is a complex process that depends upon many socioeconomic factors (Nijkamp; Henry et al.). First, the impacts of developmental highways are likely to depend on geography and location, factors the community can do little about. Geographic proximity to urban areas or environmental amenities may affect the community's ability to use the highway to attract tourists, shoppers, new residents, or new business firms. Second, the impacts of developmental highways also may depend on current business activities and the industrial organization of the community. Highways that increase access to raw materials and markets or reduce the transportation or transactions costs of business activities are likely to attract new economic activity to the community. Employment levels and prevailing wage rates are likely to affect consumer spending power and their ability to participate in more-accessible consumer markets.

Third, the degree of success or failure of developmental highways also may depend on human capital, infrastructure, and institutional characteristics of the community. Sustained economic growth requires public and private initiatives in education and other human capital investments. For example, the highway's potential to attract new industry may not be realized with a poor quality labor pool. And, the cost advantages of new highways may be contingent on the availability of other infrastructures, including public utilities, secondary roads, and local services. Finally, developmental highways should be viewed as but one component in the developmental process. Strategies that complement highway development with growth oriented land-use planning, taxation, and other public initiatives are likely to be more successful.

Communities wanting to attract developmental highways may discover that having the economic prerequisites may not be enough. In many states, highway funds are allocated on the basis of political criteria. More research is needed to determine the political-economic process by which developmental highways are allocated and used by competing counties. Since highway construction involves questions of income distribution, interest groups compete for developmental highways and their associated benefits. Future research should examine the political economy of highway development with emphasis on the political incentives and rewards of highway development at the state and local levels.

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