

**PRIVATE DEMAND FOR PUBLICLY PROVIDED GOODS:
A CASE STUDY OF RURAL ROADS IN TEXAS**

Laurence M. Crane, Nat Pinnoi
Stephen W. Fuller*

*U.S.-Mexico Free Trade Issues for Agriculture Series
TAMRC International Market
Research Report No. IM-7-92
August 1992*

- * Crane is Farm Financial Specialist, North Dakota State University and formerly Research Associate, Texas Transportation Institute, Texas A&M University, Pinnoi is Research Associate, Texas Transportation Institute and Fuller is Professor, Department of Agricultural Economics, both are at Texas A&M University.

**PRIVATE DEMAND FOR PUBLICLY PROVIDED GOODS:
A CASE STUDY OF RURAL ROADS IN TEXAS**

Texas Agricultural Market Research Center (TAMRC) U.S.-Mexico Free Trade Issues for Agriculture Series, TAMRC International Market Research Report No. IM-6-92, by Laurence M. Crane, Nat Pinnoi and Stephen Fuller, Texas Agricultural Market Research Center, Department of Agricultural Economics, Texas A&M University, College Station, Texas, June 1992. The authors express appreciation to Dr. Gary W. Williams for editing this paper and for comments and suggestions.

ABSTRACT

Following Bergstrom and Goodman, private demand functions for publicly provided rural roads in Texas are estimated at the county level. Results show the effect of income and tax rate (price) to have the expected effect and the demand for rural roads to have changed over time. In particular, demand has become more inelastic and the influence of income on demand has moderated.

The Texas Agricultural Market Research Center (TAMRC) has been providing timely, unique, and professional research on a wide range of issues relating to agricultural markets and commodities of importance to Texas and the nation for more than two decades. TAMRC is a market research service of the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service. The main TAMRC objective is to conduct research leading to expanded and more efficient markets for Texas and U.S. agricultural products. Major TAMRC research divisions include International Market Research, Consumer and Product Market Research, Commodity Market Research, and Contemporary Market Issues Research.

PRIVATE DEMAND FOR PUBLICLY PROVIDED GOODS: A CASE STUDY OF RURAL ROADS IN TEXAS

INTRODUCTION

Many rural economies have undergone a major restructuring that results from an accelerated exodus from farming, increased unemployment, and the subsequent declines in tax base and population. The economic down-turn has been further compounded in oil producing states where there has been a decline in the value of oil production. There is concern about the ability of rural governments to provide roads and bridges, as well as other essential public services and infrastructure (U.S. Department of Agriculture, 1991; Johnson, Deaton, and Segarra, 1988; Chicoine and Walzer, 1986).

Rural transportation arteries are an important link between farmers, markets and rural employment centers. Agriculture depends on the timely marketing of commodities and products and on purchased inputs, both of which move over the rural road system. Yet the condition of this transportation infrastructure is cause for concern (Chicoine, Walzer, and Deller, 1989; U.S. Department of Transportation, 1985). Recent studies have analyzed disinvestment in rural low-volume roads and bridges (Nyamaah and Hitzhusen, 1985; Hartwig, 1979; Baumel, Schornhorst, and Smith, 1989). The costs of improving and upgrading major parts of the system exceed resources available to rural local governments (Baumel and Schornhorst, 1983; Chicoine, 1987). Expenditures for public highways support the third largest function of state and local governments; expenditures for education and welfare are first and second, respectively (Anderson, Murray, and Farley, 1984).

In recognition of the transportation problems in rural America, the recent Secretary of Transportation Skinner designated "Rural America Transportation Systems and Services" as one of the critical problem areas in U.S. transportation. And, as such, has recently authorized the development of a national transportation policy to establish guidelines for meeting the nation's transportation needs over the next decade and into the 21st century (Federal Register, 1989). In view of this impetus it

seems important to learn more about the economic forces which have shaped the demand for rural transportation infrastructure so that rational policies might be developed and forwarded.

The deteriorated physical and financial condition of the public rural road system has been exacerbated by the increasing numbers of rail line abandonments by private railroads (Casavant and Lenzi, 1989). Furthermore, structural shifts in rural America have dramatically changed the types of traffic on the rural road system. Increased farm size has resulted in a dramatic reduction in the number of farms and people living on farms. This has been accompanied by an increase in the size and weight of vehicles and equipment on the rural road system. These heavy and often over-weight vehicles break-up road surfaces, while the frequent lack of paved surfaces creates dust, roadability, and safety problems.

Narrow lanes and other design characteristics on many of these roads are inadequate for today's large trucks thus creating safety hazards. Similarly, deficient rural bridges pose serious safety and traffic constraints. Some states that have not been able to generate sufficient revenues have downgraded the size of their rural system through road abandonment and private provision (Hamlett and Baumel, 1990; Baumel, Schornhorst, and Smith, 1989; Hartwig, 1979).

Earlier studies have investigated means of reducing the supply of rural road infrastructure (ex. road abandonment). This study in contrast, examines factors that effect the demand for publicly provided rural roads. The objective of this paper is to examine appropriate methodology to determine the demand for rural road infrastructure and to subsequently estimate the demand for rural roads in Texas. The results will provide policy makers with valuable information on economic forces (income, price) influencing the demand for rural roads thus enabling them to develop better policies to address the problem of supplying privately-demanded, but publicly-supplied rural roads.

In Texas there are approximately 134,000 miles of rural roadway and 17,000 rural bridges, the largest rural road network in the U.S. (Texas Almanac, 1988); U.S. Department of Transportation, 1985). Maintaining these roads, many of which are very low-volume, is a major expense of local highway budgets (U.S. Department of Commerce, 1982). State government in Texas, supplies about

17 percent of the funds for rural roads through motor fuel taxes (U.S. Department of Transportation, 1985).

METHODOLOGY

Traditional demand theory is oriented to an individual consumer's behavior. The market demand relation is simply a gross aggregation of the demands of all individual consumers. In this framework, the individual's utility function is assumed to be strictly increasing in all arguments, smooth, quasi-concave, and twice-continuously differentiable. This utility function is maximized subject to a linear budget constraint. The ratio of the partial derivatives from the first order conditions are the marginal rates of substitution between the goods in an individual's utility function. The solution to this problem yields the Marshallian demand function that relate quantities demanded to given levels of prices and income.

Goods and services which are publicly supplied generally share two characteristics that distinguish them from private goods. First, consumption by any one person need not diminish the quantity consumed by anyone else, and second, it is impossible to confine the benefits of the good to selected persons (Buchanan, 1968); Browning and Browning, 1983). Because of these characteristics, aggregate consumption patterns are consistent with utility maximization only when restrictions are placed on the shapes of individual preferences. However, the results from public sector studies based on the utility maximization paradigm have verified that most of the classical conditions hold.

Rather than viewing expenditures as responses to collectively exercised demands, Deacon (1978) incorporates the possibility of substitution among public services in response to changes in relative costs by directly modeling and estimating the substitution effects in collective consumption. Deacon carries out the analysis using the classical consumer choice model which assumes a separable maximization of a utility function subject to a linear budget constraint. Deacon found the negativity

and homogeneity properties of utility maximization held, thus suggesting classical demand theory is appropriate for analyzing public sector expenditures. That is, public budgets are allocated among public goods and services in the same theoretical manner individuals allocate income to private sector goods.

Since a public good simultaneously benefits all members of the community, each of these individual's marginal valuations must be accounted for when the resource allocation decision is made. Samuelson (1954, 1955) has shown the Pareto optimal condition for a public good requires the following first order condition be satisfied:

$$\sum_{i=1}^n MRS_{xy}^i = MRT_{xy} ,$$

where, n is the number of community members, y is a private sector good, and x is the public good. This condition, referred to as the Samuelsonian condition, is derived by maximizing the utility of any individual, while the utility levels of the remaining community are held constant (Cornes and Sandler, 1986; Starrett, 1988; Boadway and Wildasin, 1984).

As the cost of publicly provided goods and services increase, demand theory suggests private goods and services will substitute for public sector goods and services. To test this notion, Ehrenberg (1973) estimates wage elasticities of demand for different categories of state and local government employees and finds that an increase in the relative price of a public service leads to a substitution against that service. The substitution of capital for labor is easier to measure than the substitution between transportation modes. This is because there are no viable alternatives to the public rural road system. Currently the only alternative to the rural road system is the railroad. And, as Casavant and Lenzi (1989) have documented, users of these systems are forced to substitute the rural road system for abandoned rural rail lines.

Variations in per capita expenditures on public services such as highways, health and education, are often explained by population densities, urban-rural distinctions, average income

levels, and age distributions, Ohls and Wales (1972) noted that theory is not clear on whether these demographic variables enter on the demand or supply side of the market.

Borcherding and Deacon (1972) used the theory of collective decision-making to posit a model of public spending and to test the significance of the variables assumed by collective decision theory to be important determinants of state and local government expenditures. The effects of income, price, city size, and other social variables on the demand for municipal services were estimated by Bergstrom and Goodman (1973).

In principle it is possible to directly observe the choices that individuals of particular demographic groups make, under alternative price and income situations, for privately produced commodities. For obvious reasons this is generally not the case with publicly supplied commodities. Bergstrom and Goodman made inferences about the effect of price, income, and other relevant variables on individual demands for municipal services by making strong assumptions about the political process of municipalities.

Rubinfeld (1987) pointed out that aggregation of preferences, measurement of output, and determination of price are conceptual problems in estimating public demands. Assumptions of the Bergstrom and Goodman model overcome the major conceptual problem of preference aggregation outlined by Rubinfeld.

Estimation Technique

In this paper, a variation of the Bergstrom and Goodman (1973) model is estimated using the sample of 254 counties in the state of Texas, for 1972 and 1986. The usefulness of the publicly provided goods (rural roads in our case) to an individual, is a function of the total number of users and the quantity of such goods. Mathematically this can be stated as:

$$Q^* = n^{-\nu} Q , \tag{1}$$

where,

Q^* is the usefulness of rural roads to a user,

n is the total number of road users,

Q is the total quantity of rural roads,

ν is a crowding parameter (i.e. if Q is a pure public good then $\nu = 0$ and if $\nu = 1$ then every user shares the same amount of the facility).

The individual is assumed to maximize their utility function, consisting of both private and public goods, subject to their budget constraint. Mathematically this maximization problem is formulated as:

$$\text{Max}_{X_i, Q^*} U_i (X_i, Q^*) , \quad (2)$$

$$\text{Subject to, } X_i + \tau_i q Q \leq Y_i , \quad (3)$$

or equivalently by substituting in (1), the budget constraint becomes

$$X_i + \tau_i q n^\nu Q^* \leq Y_i , \quad (4)$$

where q is a unit cost of the rural roads (assuming that the unit cost of private goods is unity), τ_i is a tax share, X_i is private goods, and Y_i is the budget of individual i . If we assume further that income and price elasticities, η_Y and η_P , for Q^* are constant, then the derived demand for Q^* can be written as a Cobb-Douglas function:

$$A \left(\tau_i q n^\nu \right)^{\eta_P} Y_i^{\eta_Y} . \quad (5)$$

Therefore, the demand function (after taking a natural logarithm) for rural roads is:

$$a + \alpha \ln n + \eta_P \ln \tau + \eta_Y \ln Y , \text{ where } \alpha = \nu(1 + \eta_P).$$

Under the assumption that τ_i and q_i are constant, the county's expenditure on rural roads and streets can be considered as the quantity of rural roads demanded. Finally, the estimated demand for rural roads is described below as:

$$\ln \text{REXP} = a + \alpha \ln n + \eta_P \ln \tau + \eta_Y \ln Y + \sum_{j=1}^G \theta_j Z_j , \quad (6)$$

where,

Z_j 's are variables representing specific characteristics for Texas counties,

a, θ_j are parameters to be estimated,

REXP is the total annual expenditure on roads and streets by a county.

Let X be a matrix of all the independent variables with its corresponding vector of parameters $\underline{\beta}$, and $rexp$ a column vector of $\ln(REXP)$, then in matrix form:

$$rexp = X\underline{\beta} + u, \text{ where } u \sim (0, \sigma^2).$$

Demands are estimated by ordinary least squares (OLS) for 1972 and 1986 samples and the pooled sample.

Empirical Model and Data

The empirical model (6) can be rewritten with the selected auxiliary variables for the rural road system in Texas, including the county characteristics as:

$$\ln REXP = a + \alpha \ln n + \eta_P \ln \tau + \eta_Y \ln Y + \sum_{j=1}^5 \theta_j Z_j, \quad (6a)$$

where n is the average annual daily traffic (AADT) on the rural farm to market (FM) system in the county, Y is nonfarm per capita income in the county¹, and τ is per capita tax value upon which the tax rate is levied in each county. The five auxiliary variables are total county road mileage, county area, population density, and dummy variables for agricultural and metropolitan counties. Inclusion of the dummy variable controls for county-specific variables. It is conjectured that the demand for publicly provided roads would be greater for metropolitan counties than agricultural counties. It is thought that economic and social activities in the metropolitan counties would require more frequent use of the roads than in the non-metropolitan counties.

Similar to any consumer demand analysis, we expect price (represented by τ) to have a negative effect on quantity demanded. Whereas, the demand for roadways is expected to increase as income and county population increase (except in the case of a rare Giffen good). Likewise, we would expect population density, county area, and road mileage to have a positive impact on road demand.

¹ Per capita farm income as well as total per capita income were also used as a measure of average county income. However when these variables were included the results were not satisfactory (e.g., explanation declined and the expected signs on several of the key variables were not obtained).

The data set consists of annual observations for the 254 counties of Texas for the years 1972 and 1986. The 1972 sample was selected because it was the last year before the oil crises. The 1986 sample was selected because it was the most current year for which complete data were available on all of the variables at the county level. Following Bergstrom and Goodman (1973), the county expenditures on road maintenance and construction (*REXP*) were used to represent the demand for rural roads. These highway maintenance and construction expenditures are reported by the Texas Department of Transportation (TxDOT) in their biennial reports. Data on personal income and population were taken from a U.S. Department of Commerce document, and the per capita tax (τ) was calculated using county data from the Texas State Property Tax Board. Data on miles of rural roads and the average annual daily traffic are available from the TxDOT, and data on county size was taken from the Texas Almanac. The topology of counties used in this study are the classifications used by the U.S. Department of Agriculture, Economic Research Service (USDA, ERS).

To exclude the effects of inflation, the nominal dollar values were deflated into real dollars using the GNP implicit price deflators (1982=100) in the Economic Report of The President. The descriptive statistics for these variables for 1972 and 1986, as well as the pooled data are shown in Table 1. Because cross-sectional data were used, a series of misspecification tests were conducted to test and correct for heteroskedasticity and structural changes over time. Specifically, White's general test for heteroskedasticity, and a Wald test were performed to test and correct for the stabilization of the estimated coefficients over time. The details of these tests are outlined in the Appendix.

RESULTS

White's general test for heteroskedasticity shows the empirical model suffers from unequal error variances (Table 2). In the absence of a priori information on the known structure of the heteroskedasticity, a Feasible Generalized Least Squares is precluded. A Chow test for structural change is invalid when heteroskedasticity occurs. Alternatively, we rely on a Wald statistic which is unaffected by the inequality of the variances, given a large sample. The null hypothesis of equality

between the two sets of regressions (1972 and 1986 samples), is rejected at 1% level as a Type I error (Table 2). Therefore, the results of the two cross-section sub-samples should be more precise than the pooled regression. As such, attention is focused on the separate models rather than the pooled model.

Approximately 60% of the variation in demand for county roads in Texas was explained by the selected set of regressors (Table 2). The explanatory power of the equations estimated by Bergstrom and Goodman (1973) ranged from 35 to 96 percent. Based on White's general test for heteroskedasticity consistent estimates of the covariances, most coefficients are statistically significant at the 5% level or higher except for the coefficients on income (significant at 15%) from the 1986 sample. Furthermore, the point estimates of all parameters possess the expected sign (except for the coefficient on the per capita tax variable in the pooled sample but it is statistically insignificant).

As expected, as nonfarm per capita income increases by 1 percent, the demand or expenditure for rural roads is estimated to increase by 0.48 and 0.21 percent, based upon the 1972 and 1986 data, respectively. The estimated income elasticities suggest rural road demand was less sensitive to the changes in income in 1986 than in 1972. Real per capita income was increasing in 93 percent of the counties in 1972, but was increasing in only 51 percent of the counties in 1986. Further, as the "price" of rural roads increase by 1 percent, the expenditure or demand for rural roads decrease by 0.25 percent based on the 1972 sample and decrease by 0.19 percent based on the 1986 data. This suggests tax payers were slightly more responsive to price changes in 1972 than 1986. This may be due to an increase in the level of traffic congestion experienced by road users in some rural counties, as well as a deterioration in the quality of the rural system.

The above finding seems consistent with those by Peterson who reports approximately 25 percent of infrastructure proposals (the majority of which is for highways and streets) were approved by households in a 1990 study. During the 1970's approval rates for proposed public expenditures were as low as 30 percent. However, during the late 1980's taxpayers approved 80 percent of all state and local infrastructure bond proposals. Furthermore the average margin of approval exceeded 66 percent, significantly higher than any other type of expenditure referendum. Evidently, taxpayers

were willing to buy more infrastructure than was actually furnished by the state and local governments.

Consumption of public goods by one person diminishes the quantity consumed by another. Consequently a crowding parameter was estimated to measure this effect. A zero crowding parameter would indicate a pure public good, whereas a parameter value of one would indicate a pure private good. A crowding parameter of less than one, but greater than zero, suggests the public investment is not a pure public commodity. In this study the crowding parameter is estimated to be 0.37 in 1986 and 0.2 in 1972 indicating that the rural road system in Texas is more crowded in 1986. Thus an additional road user would decrease the availability of the roads to others, but would not completely prevent other motorists from using the roads. Bergstrom and Goodman (1973) found the estimates of crowding parameters for municipal, police, and parks and recreation expenditures were generally equal to one or greater. Their results imply that "*... as the size of municipalities increase, the advantages of sharing the cost of public services among more person are countervailed by the cost of sharing the services among more persons.*" In summary, income elasticity is decreasing over time, while, the price elasticity and the crowding parameter are increasing over time (Figure 1).

A series of dummy variables were used to determine if the social and economic characteristics of the county affected the demand for rural roads. Counties were classified as either metropolitan or as non-metropolitan. The non-metropolitan counties were then sorted according to a sub-classification, depending upon the dominant characteristic of that county. The possible sub-classifications for the non-metropolitan counties were agricultural, manufacturing, mining, federal lands, government, poverty, or retirement. The demand for rural roads in metropolitan counties and in agricultural counties were found to be the only statistically significant dummy variables. The negative parameter estimates for the agricultural county dummy variable and the positive value for the metropolitan county indicate that, on average, the demand for rural roads in agricultural counties is less than that of users in metropolitan counties.

SUMMARY AND CONCLUSIONS

The demand for rural roads in Texas, using county data from 1972 and 1986, is estimated following the procedure developed by Bergstrom and Goodman. The estimated demand relationships are consistent with consumer theory and generally comparable with earlier results. The sign and magnitude of the coefficients are reasonable. The effect of income on rural road demand was found to vary from 0.48 in 1972 to 0.21 in 1986, while the influence of tax rate on demand varied from -0.25 in 1972 to -0.19 in 1986. This outcome suggests some change in the effect of income and tax rate (price) on the demand for rural roads over time. In particular, demand has become more inelastic and the influence of income on demand has moderated. A less favorable economic climate in 1986 relative to 1972 may offer some explanation. Further, the fact that rural roads in Texas are increasingly more crowded may partially explain the observed changes.

Finally, there have been few efforts to measure the demand for rural road infrastructure in the United States. This study shows the feasibility of estimating these demands and suggests this type of information is necessary input to development of a meaningful and comprehensive rural transportation policy.

REFERENCES

- Anderson, James E., Richard W. Murray, and Edward L. Farley. *Texas Politics*. Harper and Row, New York (1984).
- Baumel, C. Phillip, and Eldo Schornhorst. "Local Rural Roads and Bridges: Current and Future Problems and Alternatives." *Transportation Research Record* 898 (1983):374-378.
- Baumel, C. Phillip, Eldo Schornhorst, and Wesley D. Smith. "Alternatives for Solving the Local Rural Road and Bridge Problem." in *Profitability and Mobility in Rural America*, edited by W.R. Gillis. The Pennsylvania State University Press, University Park, PA, 1989.
- Bergstrom, Theodore C., and Robert P. Goodman. "Private Demand for Public Goods." *The American Economic Review* 63(1973):280-296.
- Boadway, Robin W., and David E. Wildasin. *Public Sector Economics*, Second Edition. Boston: Little, Brown, 1984.
- Borcherding, Thomas E., and Robert T. Deacon. "The Demand for the Services of Non-Federal Governments." *The American Economic Review* 62(1972):891-901.
- Browning, Edgar K., and Jacqueline M. Browning. *Public Finance and the Price System*, Second Edition. New York: Macmillian Publishing Co., Inc., 1983.
- Buchanan, James M. *The Demand and Supply of Public Goods*. Chicago:Rand McNally and Company, 1968.
- Casavant, Kenneth L. and J.C. Lenzi. "Predicting Financial Impacts on Rural Roads of Potential Rail Line Abandonments." *Transportation Research Record* 1229 (1989):62-70.
- Chicoine, David L. "Issues and Implications of the Financial Crisis in Agriculture: The State/Local Government Finance Dimension." *Agricultural Finance Review*, 47 (Special Issue 1987):62-71.
- Chicoine, David L., and Norman Walzer, eds. *Financing Local Infrastructure in Nonmetropolitan Areas*. New York: Praeger press, 1986.
- Chicoine, David L., Norman Walzer and Steven C. Deller. "Financing Rural Roads and Bridges: Issues and Trends." in *Profitability and Mobility in Rural America*, edited by W.R. Gillis. The Pennsylvania State University Press, University Park, PA, 1989.
- Cornes, Richard, and Todd Sandler. *The Theory of Externalities, Public Goods, and Club Goods*. New York: Cambridge University Press, 1986.
- Deacon, Robert T. "A Demand Model for the Local Public Sector." *The Review of Economics and Statistics* 60(1978):184-192.
- District and County Statistics*. Finance Division, Texas State Department of Highways and Public Transportation, Austin, Texas, October 1988.

- Ehrenberg, Ronald G. "The Demand for State and Local Government Employees." *The American Economic Review* 63(1973):366-379.
- Federal Register*. Vol 54, No. 126, Monday, July 3, 1989.
- Hamlett, Cathy A., and C. Phillip Baumel. "Rural Road Abandonment: Policy Criteria and Empirical Analysis." *American Journal of Agricultural Economics* 72(1990):114-120.
- Hartwig, William. "Rural Road-Closure Program to Preserve Agricultural Land." *Transportation Research Record* 716 (1979).
- Johnson, Thomas G., Brady J. Deaton, and Eduardo Segarra, eds. *Local Infrastructure Investment in Rural America*, Boulder, Colorado: Westview Press, 1988.
- Nyamaah, Kofi, and Fred Hitzhusen. "A Circuitry Model for Rehabilitation/Closure of Rural Bridges." *North Central Journal of Agricultural Economics* 7(1985):41-50.
- Ohls, James C., and Terence J. Wales. "Supply and Demand for State and Local Services." *The Review of Economics and Statistics* 54(1972):424-438.
- Peterson, George E. "Is Public Infrastructure Undersupplied?" in *Is There a Shortfall in Public Capital Investment?*, Proceedings of a Conference Held at Harwick Port, Massachusetts, edited by Alicia H. Munnell, Sponsored by: Federal Reserve Bank of Boston, June 1990.
- Rubinfeld, Daniel L. "The Economics of the Local Public Sectors." in *Handbook of Public Economics, Vol. II*, edited by A.J. Auerbach and M. Feldstein, Elsevier Science Publishers B.V (North Holland), 1987.
- Samuelson, Paul A. "The Pure Theory of Public Expenditure." *The Review of Economics and Statistics* 36(1954):387-389.
- Samuelson, Paul A. "Diagrammatic Exposition of a Theory of Public Expenditures." *The Review of Economics and Statistics* 37(1955):350-356.
- Starrett, David A. *Foundations of Public Economics*. New York: Cambridge University Press, 1988.
- 1988-1989 Texas Almanac and State Industrial Guide*. A.H. Bello Corp., Communications Center, Dallas, Texas, 1988.
- U.S. Department of Agriculture. *Transportation in Rural America: A Policy Backgrounder*. Transportation and Marketing Division, Agricultural Marketing Service, USDA, Washington D.C., April, 1991.
- U.S. Department of Commerce. 1982 Census of Government, *Governmental Organization*, Washington D.C.
- U.S. Department of Transportation. *Highway Statistics - 1985*. Federal Highway Administration, Washington D.C.
- White, H. "A Heteroscedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroscedasticity." *Econometrica*, 48(1980):817-838.

Table 1. Descriptive Statistics for the Variables in 1972, 1986, and Pooled.

Pooled Data (N=508)	Minimum	Maximum	Mean	Std. Dev.
Log (Nonfarm per Capita Income)	5.2086650	8.0698050	6.1500372	0.3809354
Log (Tax per Capita)	1.7799460	12.5320600	7.4843978	1.3983444
Log (AADT)	19.7521800	26.2450200	23.4614415	0.9934561
Rural Road Mileage	8.5300000	388.7900000	154.4636126	66.9824937
County Area	128.0000000	6169.0000000	1029.2200000	647.2357216
Population Density	1.4903130	20830.6800000	588.3328262	1761.3200000
Log (County Expenditures on Roads)	10.5907000	19.4160400	14.7923283	1.1747187
1972 Data (N=254)				
Log (Nonfarm per Capita Income)	19.7521800	7.0562110	6.0568728	0.3579479
Log (Tax per Capita)	8.5300000	9.9018400	6.4009775	0.7707535
Log (AADT)	128.0000000	26.2450200	23.6590609	1.0126441
Rural Road Mileage	1.4903130	381.8400000	150.0346630	647.8749669
County Area	10.5907000	6169.0000000	1029.2200000	647.2357216
Population Density	1.4903130	15378.4100000	488.0587626	1432.8400000
Log (County Expenditures on Roads)	10.5907000	18.6075200	14.5953315	1.1408493
1986 Data (N=254)				
Log (Nonfarm per Capita Income)	5.2086650	8.0698050	6.2432016	0.3811071
Log (Tax per Capita)	1.7799460	12.5320600	8.5678180	0.9836281
Log (AADT)	19.7521800	26.05250000	23.26382112	0.9348558
Rural Road Mileage	8.5300000	388.7900000	158.892622	68.8265154
County Area	128.0000000	6169.0000000	1029.2200000	647.8749669
Population Density	1.4903130	20830.6800000	688.6068897	2035.5700000
Log (County Expenditures on Roads)	11.3258000	19.4160400	14.9893251	1.1772524

Table 2. Parameter Estimates When In (Country Expenditures on Roads) is the Dependent Variable.

Independent Variables	First Subsample 1972	Second Subsample 1986	Pooled 1972 and 1986
Constant	9.05* (2.00)	7.62* (2.30)	8.33* (1.54)
ln(Nonfarm per Capita Income)	0.48* (0.17)	0.21*** (0.15)	0.35* (0.13)
ln(Tax per Capita)	-0.25* (0.10)	-0.19* (0.07)	0.02 (0.03)
ln(AADT)	0.15** (0.07)	0.30* (0.09)	0.14* (0.057)
Crowding Parameter	0.2* (0.09592)	0.37* (0.1621)	0.14* (0.05468)
Rural Roads Mileage	0.003* (0.001)	0.003* (0.001)	0.004* (0.0007)
County Area	0.00024* (0.0001)	0.00017** (0.00009)	0.00016* (0.00006)
Agricultural County	-0.45* (0.13)	-0.30* (0.12)	-0.43* (0.09)
Metropolitan County	0.50* (0.13)	0.54* (0.14)	0.70* (0.11)
Population Density	0.0003* (0.00006)	0.0002* (0.00005)	0.0002* (0.00005)
R ² adjusted	0.59	0.62	0.57
White's Test	1,466,092	599,546	239,001
Wald Test		39.09	
Chow's Test		11.13	

Standard errors computed from White's heteroskedasticity consistent covariance matrix are given in parentheses.

* denotes statistically significant at 1%.

** denotes statistically significant at 5%.

*** denotes statistically significant at 15%.

APPENDIX

Misspecification Tests

This appendix explains the tests for heteroskedasticity and structural change.

Heteroskedasticity

Given the cross-sectional nature of our data, heteroskedasticity would be expected. White's general test for heteroskedasticity without any prior knowledge of its structure is therefore a recommended required test. Although, OLS estimates will be consistent under heteroskedasticity, the estimated covariance matrix of the estimated parameters will depart from its true value even in the case of a large sample. Consequently, any statistical inference about the estimated coefficients based on its covariance (e.g. t-test for statistical significant of the parameters estimated by OLS) will be inaccurate. However, White (1980) showed that a heteroskedasticity consistent estimate of the covariance can be obtained from OLS residual

$$\text{Var}[\hat{\beta}] = n(X'X)^{-1}S(X'X)^{-1} ,$$

where

$$S = \frac{1}{n} \sum_{i=1}^n e_i^2 x_i x_i' , \text{ and } e_i \text{ is OLS residual; } i = 1, \dots, n.$$

Structural Change

A Wald test is performed instead of a simple Chow's test in order to test the stabilization (over time) of the estimated coefficients (i.e. to test whether two sets of OLS estimators are the same). It is well known that the Chow's test will be invalid in the case where the two models have unequal variances (i.e. when heteroskedasticity is present). The result of the Chow's test will reject the null hypothesis of no structural change "too" often, or Type I Error. Since, our sample is reasonably large, the Wald asymptotical tests were calculated with an assumption that the disturbance terms from the two separate regressions are independently and normally distributed. This condition is plausible

because the two sample periods are fifteen years apart, consequently it is reasonable to believe that the errors are unlikely to be correlated. The result of the Wald test will be valid whether the two error variances are equal or not.

$$W = (\hat{\beta}_1 - \hat{\beta}_2)'(V_1 + V_2)^{-1}(\hat{\beta}_1 - \hat{\beta}_2) \underset{H_0}{\sim} \chi_K^2,$$

where

$\hat{\beta}_i$, $i = 1$ and 2 , is the vector of OLS estimators from two separate regressions,

V_i , $i = 1$ and 2 , is the estimated covariance matrix of the OLS estimates,

K , is the number of parameters estimated (i.e., dimension of $\underline{\beta}$).

The Wald statistic, W , is asymptotically distributed as a Chi-Square with K degree of freedom under the null.