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GOVERNMENT SPENDING & LAND VALUES

Public Money & Private Gain

Edited by

C. LOWELL HARRISS

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9 Roy W. Bahl, Stephen P. Coelen, and Jeremy J. Warford

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LAND VALUE INCREMENTS AS A MEASURE OF THE NET BENEFITS OF URBAN WATER SUPPLY PROJECTS IN DEVELOPING COUNTRIES

THEORY AND MEASUREMENT

I. Introduction

The subject of this paper is the extent to which the benefits of urban water supply projects are capitalized into land values.[1] Its focus will be the theoretical conditions necessary for such capitalization in a developing country context. In a later section of the paper, we present a brief anatomy of the kind of empirical approach which seems appropriate to test this model.[2]

It is generally acknowledged that the fundamental problem of cost-benefit analysis is that benefit measurement is either difficult or not possible in many sectors of activity. Economic rates of return, therefore, cannot be used to assist intersectoral allocation of funds. Moreover, the difficulties of benefit measurement vary considerably between sectors. In particular, it is alleged that water supply projects fare relatively badly according to such tests. This is in marked contrast to agricultural projects, for example, where demand can often be assumed to be perfectly elastic, or to transportation projects, where a large part of the benefits are often cost saving. In these cases, much, if not all, of the consumer's surplus area may be estimated.

The demand for water supply projects is generally thought to be

1. The views expressed in this paper are the authors' own and do not necessarily reflect opinions held by their respective institutions.

2. This paper is preliminary in the sense that it reflects our thinking in the early stages of a larger research project involving such empirical measurement in case studies of Nairobi, Kenya, and Kuala Lumpur, Malaysia. The larger research project is being undertaken through the Metropolitan and Regional Research Center of the Maxwell School at Syracuse University.

highly inelastic, and the consequent presence of consumer surplus on a large scale means that revenue from water sales—the benefit measure which is most often used—gives a considerable underestimate of true benefits. In addition, there is an observed reluctance of water authorities to charge prices for water that represent a true (that is, long-run marginal) cost of supply. Revenue, a conservative indicator of benefits at best, therefore becomes particularly inadequate. It follows that economic evaluation according to estimates of revenues likely to be derived provides a much less attractive view of water supply projects than of other projects.

The constancy of water pricing over time within an area, or over a cross section among several areas, further limits the type of benefit measurement possible. While the supply curve is most likely identified by observable market transactions, the constancy in the supply curve prohibits identification of the demand curve. Any attempts to estimate, by traditional demand-supply analysis, the willingness-to-pay area under the demand curve are thus thwarted.

The market for water services does not permit benefit estimation of the willingness of individuals to pay for public improvements in water; consequently, it is necessary to define a proxy market wherein preferences for these facilities are revealed. The residential land market may fit this need for water supply services. Water investments improve the quality of a particular site, thereby raising present values and increasing sales prices. From the point of buyers, these sales price increments would seem a reasonable measure of the market value placed on such improvements. Empirical analysis of these effects is more appropriate in developing countries where installation of these facilities often takes place after houses have been occupied, whereas in developed countries the facilities are installed before construction, and changes in land prices are more typically the outcome of bilateral monopoly bargaining where the resulting price has little welfare significance.

In general, the use of the housing market as a proxy for the water market implies the possibility that the consumers' surplus in the water market is transferred to the housing market. There are serious problems with developing such an approach. The immense empirical difficulties, which are not dealt with here, include a requirement to abstract from all other factors which could affect housing values. The conceptual difficulties, which are dealt with here, require the argument that the land market[3] is not characterized by imperfections

3. We will use the terms *land market, housing market,* and *property market* interchangeably. While distinctions between the terms can be drawn, it seems point-

which make it no better for these purposes that the water market. It is clear, however, that there are imperfections in the land market. Land is not generally homogeneous, knowledge and mobility are not perfect, and buyers and sellers may not be numerous. It is possible, on the other hand, that disaggregation of the land market into submarkets (for residence, for businesses, for single family homes, for certain areas of the city) may increase the homogeneity of land and market knowledge to a point where the market might be relatively free of imperfections.[4] In general, we will take the position that the major imperfections, if they cannot be overcome for these purposes, can at least be taken into account in terms of estimates of their effects on the results of this analyis.

II. The Model

The basic assumption here is that supplying piped water to a home will raise its market value and that the increase will correspond to the present worth of the consumers' surplus that is expected to be derived from purchases in the water market. Assuming perfect rationability, a person would be willing to pay only an additional $100 for a house because it had water facilities, if the difference between the present worth of the utility he gets from the water and the present worth of the amount he expects to pay for the water (that is, the consumers' surplus) equals $100. If the amount that he expects to pay for water exactly corresponds to the benefits he personally derives from it, there is no reason to expect him to bid up the price of the house. Clearly, the area under the demand curve for property must increase by whatever amount the consumers's surplus in the water market increases. This is given by the traditional concept that the area under a demand curve for a good describes the willingness to pay.

The question that we now face is whether increasing values in the property market correctly capture the effects of the demand shift. That is, we assume that the increased consumers' surplus area in the water market is "transferred" into an equivalent shift in area under

less here. All increments in valuation are perceived to be attributable to the land itself. Increasing land values should have only limited effectiveness on increasing housing structure values, since the housing structures for developing countries are typically already built before the project is implemented. The exception is water supply delivery which encourages additions such as bathrooms to existing structures. This is probably of minor importance, and for our present methodological discussion we shall ignore it.

4. See John M. Copes, "Reckoning with Imperfections in the Land Market," in *The Assessment of Land Value,* ed. Daniel M. Holland (Madison: University of Wisconsin Press, 1970), p. 56.

the property market demand curve. We would like to determine whether expenditures on property also increase by this common amount. If they do, then the observations on property sales may identify for us the extent to which water benefits are undervalued by revenues derived from water sales.

A. Theoretical Framework

A simple and familiar model suggests that there are, at least, certain assumptions under which benefits and increased expenditures on property are equal. Consider the case where the consumers' surplus in the property market remains constant so that the following algebraic model is illustrative of full capitalization. In an area receiving new water supply (the project area), the housing demand function (before the project) is written generally as:

$$q_d = g(q_d) \tag{1}$$

and, again, for simplicity the housing supply is a constant:

$$q_s = k. \tag{2}$$

It follows that the market equilibrium price can be derived as:

$$p_e = f_1\{g(q_d), k\}. \tag{3}$$

A measure of consumers' surplus is:

$$c = \{{}_0\!\int^k g(q_d)\} - p_e k. \tag{4}$$

The effect of a water supply project providing each house with water can be shown through a shift in the demand curve from its initial position. For the same fixed quantity of housing, residents would now be willing to pay a higher rent—the demand curve has shifted upward. Let us assume that the new demand is:

$$q_d = h(q_d). \tag{5}$$

Consumers' surplus is now measured

$$c' = [{}_0\!\int^k h(q_d)] - p_e'^k \tag{6}$$

where p_e' is defined:

$$p_e' = f_2[h(q_d), k]. \tag{7}$$

The increase in consumers' surplus between the two periods (Δc) is:

$$\Delta c = c' - c = [{}_0\!\int^k g(q_d)] - p_e'k - \{[{}_0\!\int^k h(q_d)] - p_e k\} \tag{8}$$

$$\Delta c = [{}_0\!\int^k g(q_d) - {}_0\!\int^k h(q_d)] - \Delta p_e k$$

where $\Delta p_e = p_e' - p_e$.

The increase in net benefits (ΔB) of the water project to residents of the area is equal to the increase in price times the quantity supplied ($\Delta p_e k$) plus any increase in consumers' surplus, that is,

$$\Delta B = \Delta p_e k + \Delta C = [{}_0\int^k g(q_d) - {}_0\int^k h(q_d)] - \Delta p_e k + \Delta p_e k \qquad (9)$$
$$\Delta B = [{}_0\int^k g(q_d) - {}_0\int^k h(q_d)]. \qquad (10)$$

If the shift in the housing demand function is such that ΔC is zero, that is, consumers' surplus remains constant, then from (8):

$$\Delta C = [{}_0\int^k g(q_d) - {}_0\int^k h(q_d)] - \Delta p_e k = 0 \qquad (11)$$
$$\Delta p_e k = [{}_0\int^k g(q_d) - {}_0\int^k h(q_d)] \qquad (12)$$

and from (10):

$$\Delta p_e k = \Delta B. \qquad (13)$$

If the assumptions behind this simple model are valid, then the benefits of a water supply project will be fully measured in two steps. The first is revenues derived directly through sales in the water market. The second is a measure of the transferred consumers' surplus, from water to property markets, and is defined by equation (13). Their sum gives an unbiased measure of project benefits. In equation (13), ΔB is proportional to the increase in house prices, where the constant of proportionality is the stock of housing. If equation (11) does not hold, then there is both a change in housing prices and a change in consumers' surplus and the net benefits of the project are measured as in equation (10).

B. Required Demand and Supply Conditions

Since the total increase in benefits must be equal to the sum of the price increase and any increase in consumer surplus, a number of conditions must be present for the land value increment to exhaust totally the benefit increment. The first is that the slope of the demand curve for housing in the project area does not change, and a second is that the supply curve is perfectly inelastic. Consider the implications of these assumptions. First, if the demand schedule for housing in the project area changes, one would expect it to become relatively more inelastic—there are fewer good substitutes now that the house has piped-in water. That is, it would take a greater price increase to bid an individual away from a house with water than it would when the same house did not have public water supply. The implications of such a change in the slope of the demand schedule are that consumer surplus will increase, that is, the difference between the individual's and the market's valuation of the property will increase. This would mean that the sum of revenues from water sales and the property value increment due to a new water supply underestimates the true benefits of a water project. The unmeasured benefits are a return to labor—the consumer—since it is only he who can gain from the consumers' surplus as he lives on the property.

For the supply conditions, it is possible that a perfectly inelastic supply is unrealistic. Some elasticity to supply would imply that, as the price of properties in the affected area is bid up, property owners in the area would be induced to offer a greater amount of housing,[5] and *ceteris paribus*, causing land value increments to understate the increase in net benefits. More specifically, with any supply elasticity, the increase in demand (regardless of how the slope of the demand schedule changes) will be accompanied by an increase in total consumers' surplus. Whether average consumers' surplus, that is, the average return to a typical consumer, increases is not quite so clear. Similarly, we can be sure that with a supply curve having less than perfect elasticity there will be an increase in producers' surplus,[6] and hence a return to capital.

If either the supply or demand conditions in this simple framework are violated, it is quite likely that the sum of land value increments and revenue from water sales will be an inaccurate measure of true benefits of a water supply. The two measures together, however, will necessarily be more accurate than water sales revenue alone, and, on the basis of the arguments presented above, the error is likely to be on the conservative side.

III. Other Land-Value Studies

The use of land value models is not new, and the effects of infrastructure investment on land values has long been a subject of the literature in economics. Such a great deal of material has been written that it would be impossible to review it all. We shall attempt only to highlight a few studies and develop their relationship to the present work.

Early studies, such as that by Mohring and Harwitz on transportation,[7] neither looked at property value changes as a direct benefit

5. In this case, the offering of a greater amount of housing implies an increase in the number of occupancy units offered rather than an increase actually due to physical construction. The former could be accomplished by increasing the density of rental units, converting existing nonresidential to residential uses, and so on.

6. This type of analysis is applied to property taxes by R. E. Grieson, "The Economics of Property Taxes and Land Values," Working Paper 72, Department of Economics (Cambridge, Mass.: Massachusetts Institute of Technology, 1971).

7. Herbert Mohring and Mitchell Harwitz, *Highway Benefits: An Analytical Framework* (Evanston, Ill.: Northwestern University Press, 1962).

measure nor considered the effects of different capitalization rates on the model. Using Mohring and Harwitz's work as an example, however, we can transform these studies into a style that does explicitly treat land value changes. Further it is easy to expose implicit assumptions that point to a rather rigid consideration of capitalization models. Mohring and Harwitz explain observed variance in rent as a function of travel time differentials. Their treatment of the benefits of highway investments requires that the value of time savings be totally capitalized into land values. Their basic equation[8] describing such benefits is:

$$R_i - R_j = 2N(T_j - T_i)V_T \tag{14}$$

where R_i, R_j = site rents at i, j

N = number of trips taken to the central area

T_i, T_j = travel time from i and j to the central area

and V_T = value of travel time.

While, empirically, many other considerations of site attractiveness must be entered into the equation, equation (14) can be solved for V_T,

$$\frac{R_i - R_j}{2N(T_j - T_i)} = V_T\,. \tag{15}$$

In this context, the benefits of a transport improvement—the value of time saved—may be described as:

$$\Delta T.V_T = \Delta T.\ \frac{R_i - R_j}{2N(T_j - T_i)} \tag{16}$$

where ΔT is the reduction in time necessary to get from i or j to the central area.

The assumption of full capitalization of time-saving benefits into site rents is made clearer by assuming that i and j are the same property but i is before and j after the transportation project. The value of time is assumed to be a constant and the net change in total time spent in getting from the property in question to the central area is $2N(T_j - T_i)$, that is,

$$\Delta T = 2N(T_j - T_i). \tag{17}$$

Applying (17) to (16) we can obtain time-saving benefits:

$$\Delta T.V_T = R_i - R_j = \Delta R \tag{18}$$

8. Ibid., p. 147.

where ΔR is the land value increment associated with this property and due to the transportation project. All benefits are reflected in this increment, that is, there is an assumption of 100 percent capitalization of benefits.

Later studies have begun to relate increasing land values and investments in a more direct way. The types of investment involved have varied widely from Nourse's work on public housing;[9] Dobson,[10] Phares,[11] and Wihry[12] on racial integration; Paul on noise pollution;[13] Oates on property taxes;[14] and Spore[15] and Ridker and Henning[16] on air pollution. The list could easily be expanded both into different investment types and into different authors working within the same investment types. Only recently, however, have any of these studies worried about capitalization rates and land value changes.

Ridker[17] and Ridker and Henning, for example, have only recently come under attack for failing to consider capitalization. Ridker and Henning's results emphasize the negative effects of increasing pollution levels on land values.[18] They estimate an \$83 and \$245 increase in valuation per site as pollution levels are cut back by .25 mg per 100 cm^{19} per day (but not below .49 mg per 100 cm^2 per day).[19] Two problems hamper interpretation of these results. First, property values are

9. Hugh O. Nourse, "The Effect of Public Housing on Property Values in Saint Louis" (Ph.D. diss., University of Chicago, 1962).

10. Allen Dobson, "Price Changes of Single Family Dwelling Units in Racially Changing Neighborhoods" (Ph.D. diss., Washington University, 1970).

11. Donald Phares, "Racial Change and Housing Values: Transition in an Inner Suburb," *Social Science Quarterly* 62 (December 1971) : 560–73.

12. David Wihry, "Price Discrimination in Metropolitan Housing Markets," *Proceedings of the American Real Estate and Urban Economics Association*, vol. 4, 1969, pp. 69–101.

13. M. E. Paul, "Can Aircraft Noise Nuisance Be Measured in Money?" *Oxford Economic Papers* 23 (November 1971) : 297–322.

14. Wallace E. Oates, "The Effects of Property Taxes and Local Public Spending on Property Values: An Empirical Study of Tax Capitalization and the Tiebout Hypothesis," *Journal of Political Economy* 77 (November–December 1969) : 957–71.

15. Robert L. Spore, "Property Values and Air Pollution Damage Costs: Some Results for the Pittsburgh Metropolitan Area" (Ph.D. diss., Pennsylvania State University, 1972).

16. Ronald G. Ridker and John A. Henning, "The Determinants of Residential Property Values with Special Reference to Air Pollution," *Review of Economics and Statistics* 69, no. 2 (May 1967) : 246–57.

17. Ronald G. Ridker, *Economic Costs of Air Pollution* (New York: Praeger, 1967).

18. Ridker and Henning, "Determinants of Residential Property Values," pp. 246–57.

19. Ibid., p. 254.

determined by an interaction between supply and demand for property. Benefits, on the other hand, are reflected only on the demand size. A capitalization model is required to relate the equilibrium market prices to benefit-related demand shifts. Without a capitalization model, it is impossible to separate supply and demand factors, and, consequently, to identify the land value-benefit relationship. Second, in a *ceteris paribus* regression analysis such as Ridker and Henning's, the coefficients must be interpreted as those that result when pollution levels are reduced on only one property—we cannot conceive of a simultaneous reduction in pollution levels over all areas with the model. Since pollution abatement projects will typically affect many properties, we must know how property values (within a wide, geographical area) change with a project.

Edel[20] and Freeman[21] each make the same criticism of the general land value approach. Freeman, on the first point argues:

In any urban area this relationship [property value-air quality] is the result of the interaction between the availability of land with different levels of air quality (supply factor) and tastes and preference, other prices, income and its distribution (demand factors). For any given set of demand factors different supply factors will lead to different patterns of property values and different regression results.[22]

On the second point Freeman continues:

The [Ridker and Henning regression] equation only purports to explain the variation in mean property values among observations. The air pollution coefficient can be used to predict the difference in property values between two properties within a system under *ceteris paribus* conditions, and these conditions must include no change in air quality over all other land in the system. But the regression equation cannot be used to predict the general pattern of property values or changes in the value of any given property when the pattern of air quality over the whole urban area has changed.[23]

Edel makes the same criticisms. In regard to the first object mentioned above, Edel relates nearly the same message as Freeman:

This regression analysis . . . can be interpreted in one of two ways. It may measure the costs imposed on households by pollution, estimated on the as-

20. Matthew Edel, "Land Values and the Costs of Urban Congestion: Measurement and Distribution" (Paper presented at "Man and His Environment," a Symposium on Political Economy of Environment, Paris, France, July 1971).

21. A. Myrick Freeman, "Air Pollution and Property Values: A Methodological Comment," *Review of Economics and Statistics* 73, no. 4 (December 1971): 415–16.

22. Ibid., p. 415.

23. Ibid.

sumption that the prices households bid for land will rationally reflect the true cost and disutility of dirty air. Or it may measure the extent to which the market and bid prices offered by families really capture these costs.[24]

For the second objection Edel continues:

If pollution in all districts of St. Louis were reduced to the 0.49 mg. "background" level, demand for space in formerly most polluted neighborhoods would certainly increase. But this increase might come at the expense of demand in census tracts that formerly had a unique advantage in low pollution levels. The $82,790,000 estimate assumes that demand will increase in the newly cleaned areas to equal demand elsewhere now, without the balancing effect of demand reduction. It is therefore almost certainly an overestimate.[25]

Many early studies on public investments and land values are difficult to interpret. Problems of interpretation notwithstanding, the Ridker and Henning study serves to exemplify what future changes in research methodology are required. However, little purely theoretical work has been attempted in this area. Strotz,[26] an exception, directly attacks some of the problems that are involved. Unfortunately several strong assumptions limit the realism and usefulness of his analysis.

Strotz's work approaches the second problem listed above in reference to the Ridker and Henning study. How do land values relate to welfare; how do offsetting land values in nonproject areas affect welfare. In building his model, Strotz hypothesizes an area where a pollution abatement project has had the effect of increasing land values by $1,000,000 in the project area and decreasing land values by $700,000 in the nonproject area. He makes the following assumptions:

(a) Air pollution affects every part of a region equally.

(b) A pollution abatement project changes the north half of the town for the better so that there is a shift in demand, causing rents to increase by $1,000,000 in the north and decrease by $700,000 in the south.

(c) There are no moving costs.

(d) Each person occupies some land in both the North and South (to assure convexity in the indifference surfaces).

24. Edel, "Land Values and the Costs of Urban Congestion," p. 10.
25. Ibid.
26. R. H. Strotz, "The Use of Land Rent Changes to Measure the Welfare Benefits of Land Improvements," mimeographed (Washington, D.C.: Resources for the Future, July 1966).

(e) Each person has an identical quantity, $\bar{x}$ of "bread" (all other goods-money) at his disposal.

(f) No land is owned, but is rented from the real estate company.

(g) Each person receives equal shares π and ρ of profits from the bread exchange and the real estate company, respectively.

(h) Each individual maximizes his utility subject to the budget constraint.

(i) The bread exchange buys bread at price, p, sells it at normalized price, l; r_n is the rental price of land in the North, r_s of land in the South.

(j) n^i, s^i, x^i are quantities of northern land, southern land, and bread, respectively, bought by the i^{th} individual.

(k) α is an index of relative attractiveness of land in the north versus the south. α is assumed to shift in response to differential impact of public investments.

(l) The change in welfare (W) given a change in α is defined to be

$$\frac{dW}{d\alpha} = \Sigma \frac{1}{u_x^i} \frac{du^i}{d\alpha};$$

where u_x^i is the partial derivative of u^i, the utility function for the i^{th} individual, with respect to x.

Based on these assumptions he correctly concludes that the change in welfare, $dW/d\alpha$, will be obtained by adding the \$1,000,000 increase in land values in the North to the \$700,000 decrease in welfare in the South. Strotz therefore arrives at the somewhat surprising conclusion that the net effect is not, as might be supposed a priori, a net welfare gain of \$300,000 or even \$1,000,000, but one of the \$1,700,000.

However, the Strotz assumptions, particularly with reference to property ownership—(f) and (g)—are questionable. These departures from reality, coupled with the assumption (d) that all individuals occupy land in both the North and South, produce the seemingly paradoxical conclusion which Strotz reaches. Residents are indifferent to the absolute level of prices; they are concerned only about relative prices. In effect, since there is no quality change in southern land, the southern land becomes a numeraire for the system. The quality change of northern land is judged by the relative change in its price as compared with southern land. Consequently, Strotz obtains a net welfare change of \$1,700,000. The result is internally consistent with the assumptions and model which he draws. However, Strotz's assumptions do not approximate the normal case, and therefore his solution may not be inferred to the more general problem of how to account for the effects of land value changes (resulting from a public investment project) outside the project area.

IV. Measurement

The empirical testing of the conceptual model described above requires measurement of those land value increments which are both in the project area and are due to the water project. The most difficult measurement problem is that of isolating project effects on land values from all other factors that might influence land values. There are two possible approaches to such empirical measurement. One is a regression model where dummy variables might be used to indicate properties in a project area.

This is represented as a regression of property values in the project area, ${}_{proj}PV_t$, on a set of exogenous variables, X_{it}, and a dummy variable, D_t which equals zero before the investment and equals one after the investment. The subscript t represents time:

$$ {}_{proj}PV_t = a + bD_t + c_iX_{it}. \tag{19}$$

The other approach is a control area analysis where the control area is expected to be similar to the project area in all respects except the water project itself. If the two areas are similar, they will respond to all other factors in the same way. It should follow that comparing rates of growth in land values in the control and the project areas will effectively isolate the increments which are attributable to the projects. This is done by subtracting control area values, ${}_{con}PV_t$, from project area, ${}_{proj}PV_t$, and explaining them simply with a single dummy:

$$ {}_{proj}PV_t - {}_{con}PV_t = a + bD_t. \tag{20}$$

The choice between these models must depend upon: (a) the randomness of land value determinants between areas, (b) the size of the variances in these factors, and (c) the availability of data. The control area method in (20) conserves significantly on data, but will fail badly when the project and control areas are not strictly comparable. The regression method in (19) can control for nonrandomness between project and control areas, but is very expensive of data.

The two methods could, of course, be combined to yield a system that utilizes the best advantages of both. That is, a subset, J, of the exogenous variables X_t used in (19) would be selected for use in a modified regression-control area method:

$$ {}_{proj}PV_t - {}_{con}PV_t = a + bD_t + c_j({}_{proj}X_{jt} - {}_{con}X_{jt}). \tag{21}$$

This will reduce the data requirements and maintain a satisfactory reduction of variance in the property values that is due to the non-random occurrences (between areas) of X_{jt}.

These techniques would be applied to a combined cross-section, time series data set. By combining data at least one of the faults of purely cross-sectional studies, criticized above, is eliminated. That is, with time series data it is possible to evaluate the land-improving water investment not as a *ceteris paribus* analysis; rather, the general equilibrium effects of offsetting land values might be isolated. With time series, cross-section data, a property whose values have increased can be compared with unimproved properties in the same time period. It may also be compared with itself before the project was implemented.

The usefulness of combining the control area and regression methods is clearly demonstrated by their abilities to isolate jointly the land value increment due to a project area. The idea is to compare values of a project area property (or project area index[27]) with itself, before and after the investment. This can be done by application of a simple dummy variable analysis model. The coefficient of the dummy will reflect the land value increment due to the project if the dummy takes on the values of 0 for all times before the project and 1 for all time after the project. A problem in identifying the true increment occurs as the values in the project area are inflated or deflated by exogenous forces to different extents over time.

The variance caused by the exogenous forces will reflect itself in secular and cyclical movements in the project area property values. Many of these exogenous variables will have metropolitan wide impact. It is reasonable that these variables will have the same systematic influence on project and control areas. The control can then effectively be used to abstract from these factors by "residualizing" the project area values with some forecasted control area values. That forecast would be made on some mechanical basis such as a best polynomial regression fitting time and the value of time exponentiated, $(\text{time})^2$, $(\text{time})^3$, . . . to the control area indices. "Best fit" might be defined as that regression having the lowest overall standard error of

27. Project area indices may be calculated by using repeat sales data on all properties within an area by weighting all observations into the index. The method is simplified and statistical properties are enhanced by performing the weighting with a least squares regression technique. An example of this is given in Martin J. Bailey, Richard F. Muth, and Hugh O. Nourse, "A Regression Method for Real Estate Price Index Construction," *American Statistical Association Journal* 58 (December 1963): 933–42.

estimate or highest (corrected for degrees of freedom) $\bar{R}^2$. "Residualization" would simply subtract from the actual project area values those forecasted control area values. On the residualized project area values, a dummy variable analysis would then finally be performed. This analysis would be similar to splitting the project area values into two groups—divided at the point in time when the project was implemented—and running a statistical test for differences in means for the two groups of data.

Additional refinements may be made to enhance the explanatory powers of the model. With the methodology that has so far been described, it is necessary that we consider any variance that is local to either project or control areas as having a purely random character. It is quite reasonable that the model so far developed will however have biased effects from local, nonrandom exogenous changes. These will prevent the model's identification of the true project effects. However, if each data set on the control and project areas is independently subjected to regression procedures fitting local variables to the property values, we can control for these biasing effects. This specifically would reduce the variance of the property value indices by controlling the local variable variance. Indices would be constructed from the reduced-variance property values and then the control area residualization and dummy variable techniques would be applied.

V. Other Problems

The theory and measurement techniques described in the above sections provide only a broad outline for a research plan that has commanded and will continue to command extraordinarily detailed methodology. In this paper, we have touched only the major areas of concern. Many behavioral and institutional relationships also will have an effect on the investment-land value nexus. These include the diverse considerations of property tax effects, externalities, site improvements, zoning, and migration. We shall only briefly suggest their role in the general model.

A. Property Taxes

Our theory above provides an analysis whereby property values increase as investment occurs. With most types of property tax systems, these increasing values will, in practice, raise the property tax base. That is, the increment in property values will also be subject to a tax.

Oates,[28] Upton,[29] and others have recognized that, because of the existence of a tax, land values are, *ceteris paribus,* lower than they would be without a tax. A simple extension of this argument on our model implies that whereas land values would have risen, for example, by $b, in the absence of a tax, they will rise by somewhat less than $b in the presence of a tax. The problem, obviously, is how can we standardize benefit measurement across areas subject to varying tax levels. Once again there exists a need to know the rate of capitalization, this time of taxes into (reduced) land values.

B. Externalities

Externalities will inevitably occur from an investment in water supply. These reflect the fact that people living in areas adjacent to a project area are less likely to be infected by disease as the health of project area residents improves. Externalities also exist in the form of a reduced cost for future provision of public water supply to current nonproject areas.[30] Presumably there would be other factors which would similarly affect neighboring, nonproject properties. Each externality may be capitalized into neighboring properties just as direct project effects are capitalized into project properties. Since we would like to measure these as a part of the benefits from the project, they force us to accept a wider, spatial, group of properties to treat as we have treated project area properties. Aggregate benefits would necessarily be the summation of land value increments not only over project properties, but also over some nonproject, but neighboring, properties that are subject to externalities.

The existence of externalities also implies a danger in selecting a control area. It must be an area not subject to a project's effects. There exists, therefore, a conflict in choosing a control. On grounds that the control and project are desired to be similar, there is a tendency to select contiguously neighboring areas. However, on grounds that the control should be free of externalities, there is a desire to choose more distant properties. The resultant choice of a control area must com-

28. Oates, "Effects of Property Taxes and Local Public Spending on Property Values," pp. 957–71.

29. Charles Upton, "The Provision of Local Public Goods: The Tiebout Hypothesis," Urban Economics Report No. 44 (Chicago: University of Chicago, November 1970).

30. Alternatively these externalities reflect a higher probability that adjacent nonproject areas will be given water in the future since the public water mains have now been extended nearer to the nonproject areas.

promise between the alternatives. Any choice may be criticized that it is not similar enough to project areas and that it is subject to some externalities.

C. *Site Improvements*

Site improvements may naturally arise in connection with water projects. These, of course, are of central importance when the project and new construction are simultaneously undertaken. However, they will also occur even when housing already exists on project property. An example is given by a property receiving water but needing to build a bathroom or to install other plumbing in order to utilize fully the new public supplies.

The benefits of these improvements will be capitalized and reflected in land values. These are benefits which should be attributed to the project. However, they are overstated if a correction is not made for the costs of the improvements, since associated costs are just as closely related to the project as are the benefits of the improvements. We wish to attribute only net site improvement benefits to the project. Hence, we must find the cost of the improvements and subtract the capitalized value of these costs from the measured land value increment.

D. *Zoning*

Water projects (and to a larger extent sewer projects) can have an effect of changing the institutional zoning requirements. These changes automatically add another complicating dimension to benefit evaluation. That is, a zoning change implies a shift in the supply curve (as opposed to a move along it). Certainly, zoning regulations are considered as a constant "background" condition against which a supply curve is drawn. A change in zoning or any other background variable suggests a supply shift. Intuitively, it now becomes cheaper at any given time to subdivide and increase the supply of residential properties from a given fixed physical area. Consider the owner of a three-fourths acre plot faced in one situation with one-half acre minimum density zoning and faced in another situation with one-fourth acre zoning. In the first case, he must speculatively buy other properties if he wishes to subdivide. This quite possibly means that he will face a risk premium, raising the cost of subdivision. In the second case, he can readily subdivide the original property into three one-fourth acre plots without any risk.

The resultant change is an outward shift in the supply curve. Without doubt, this represents an increase in welfare to the community since it permits an increase in density (which will only be increased if it is desired) without any changes in the technological capacity to produce other goods. It may be interpreted as an outward shift in the community's production possibility surface. Harberger suggests that evaluation of this benefit is no more difficult than evaluation of other benefits; he suggests using a compensating or equivalent " 'income effects' of changes in resources, technology or trading conditions."[31]

The conceptual problem arises in determining whether these benefits should really be attributed to the project. The real question is whether the decision to reduce zoning requirements simultaneously with investment is purely arbitrary, an institutional decision. If it is, then these benefits are not project related. However, if the zoning reduction creates density increases that are only tolerated because of the project, then the benefits are investment-induced and we should want to count them. The decision on how to handle zoning changes is a difficult one.

E. Mobility

In developing countries, rural to urban migration is common. The existing migratory patterns should adjust to the investment project, increasing rates of migration for project area properties relative to nonproject area properties. In a dynamic and realistic sense these patterns provide at least a portion of the shift in relative demand that is observed. We should need also to know whether the total rate of migration has been affected and whether the investment does distort rates of migration in the control and project areas by more than the relative effect of the investment on control and project areas.

VI. Summary

The model presented here proposes that revenues derived from the sale of water in the urban water market underestimate the true benefits of water supply. In evaluating many different types of projects, the consistently conservative measures used for water projects will put these at a disadvantage relative to other projects that are more correctly evaluated. While in practice it is preferable to underestimate rather than overestimate benefits, this paper attempts to explain the systematic underestimation for water supply project benefits.

31. Arnold Harberger, "Three Basic Postulates for Applied Welfare Economics: An Interpretive Essay," *Journal of Economic Literature* 9, no. 3 (September 1971): 785–97; see especially p. 793.

Two questions are raised by this research. First, what methods can be devised which will totally measure the underestimation of benefits. Second, what methods can be easily applied to improve the measurement process but which will, if in error, still underestimate rather than overestimate benefits.

The solutions for both questions are provided by our hypothesis that any consumers' surplus in the water market will be transferred to the land market. Specifically, for the first question, the econometric estimation of the demand curve for property will yield the desired solution. All benefits not measured by the revenue technique will shift the demand curve for housing outward. The integral value of this shift totally measures the extent of the underestimation. This method, however, may be of more value as a heuristic device than as an applied measurement concept.

Consequently, for applied benefit measurement, it is important to be able to determine the extent to which outward shifts in the demand curve are capitalized by the market. If the effect of water projects on property values can be isolated, then the result can be added to the initial measure of water revenues. The sum of the two measures must be less conservative than water revenues are by themselves. Yet, if the two fail to measure benefits exactly, they will fail in underestimation. This conforms to the criteria that the applied benefit measure must meet.

Finally, although the generalizations have not been made here, we hope that this method will be applicable to other types of investment and not just to water. If these techniques can be used in analyzing other investments, the wide spectrum of methodologies used for benefit analysis can be made smaller. This would facilitate the comparison of benefits measured both across different projects and between time and space. The present limitations of cost-benefit analysis in these respects severely restrict its usefulness. If this paper can be regarded as a step in the direction of providing a standard methodology for benefit measurement, then its own value will have increased tremendously.