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Interim Report

A Review of the Property Value Approach to Measuring the Welfare Impact of an Externality

Excerpt from NUREG/CR-0989, PNL-2952
Vol. II Appendix B

R. C. Adams

August 1980

Prepared for
the U.S. Nuclear Regulatory Commission

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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PACIFIC NORTHWEST LABORATORY
operated by
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SUMMARY

This paper reviews 1) the quantitative measurement of the welfare impact due to an externality and 2) the empirical estimation of the welfare impact of an externality using the property value approach.

The welfare impact on an individual can be measured in two ways. First, the welfare impact equals what the individual would be willing to pay to prevent the introduction of a negative externality (or, in the case of a positive externality, what he would be willing to pay to attain the welfare impact). Second, the welfare impact equals what the individual would be willing to accept in compensation to have a negative externality imposed upon him (or, in the case of a positive externality, what he would be willing to accept in compensation if he were prevented from receiving the welfare impact). The correct measure of the welfare impact of an externality depends upon the assignment of property rights as determined by society.

One methodology used to empirically estimate a willingness-to-pay measure of the welfare impact of an externality--the property value approach--is then examined. It was concluded that property value studies may be of little value for environmental change welfare impact estimation (including the welfare impact due to visual change). This conclusion is based on the existence of a set of extremely restrictive assumptions and practical constraints corresponding to the property value approaches discussed. However, this conclusion is tempered with the note that information is needed on the extent to which the restrictive assumptions cause the property value proxy of welfare impact to deviate from the neoclassical theoretical measure. If the deviation between these two measures is small, then the property value approach may provide a meaningful approximation of the welfare impact of an externality.

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FOREWORD

This report results from a Nuclear Regulatory Commission sponsored project to determine the socioeconomic consequences from people viewing alternative closed cycle cooling systems on nuclear power plant landscapes. This was accomplished by measuring individual perceptions of visual aesthetic differences among alternative cooling systems and relating the perceived differences to individual willingness to pay and be compensated for the differences.

The contents of this report are contained in Appendix B of the following two-volume final report.

Currie, J. W. 1979. The Visual Impact of Alternative Closed Cycle Cooling Systems, Executive Summary. NUREG/CR-0989, PNL-2952, Pacific Northwest Laboratory, Richland, Washington.

Adams, R. C., et al. 1979. The Visual Impact of Alternative Closed Cycle Cooling Systems, Main Report. NUREG/CR-0989, PNL-2952, Pacific Northwest Laboratory, Richland, Washington.

J. W. Currie
Project Manager

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A REVIEW OF THE PROPERTY VALUE APPROACH TO MEASURING THE WELFARE IMPACT OF AN EXTERNALITY

INTRODUCTION

This report documents one segment of a Nuclear Regulatory Commission (NRC) sponsored project conducted by the Pacific Northwest Laboratory (PNL) to evaluate the visual impact of alternative closed cycle cooling systems. In this report, the "property value approach" is reviewed as a potential measure of social welfare change due to an environmental change.

Following the conclusions and recommendations, the first major section of this report is subdivided into three parts. The first defines and discusses external goods (externalities). The second part addresses the question of how to measure an externality's impact on an individual consumer. The third part generates a dollar equivalent measure of the externality's impact on the consumer.

The next major section discusses three approaches to measuring the social value of an externality using property value data. These three approaches are analyzed in terms of their potential viability for empirically measuring the visual impact (social welfare change) due to alternative closed cycle cooling systems.

In theory, the price system of an unregulated economy operates in response to decisions made by consumers and business firms acting as individuals. In deciding what is and is not to be produced, the price system reacts to individual wants and satisfactions.

It can be shown that competitive markets will lead to an efficient allocation of society's resources. When in equilibrium, the price system will equate the willingness of consumers to pay for a good (as reflected in the demand curve) and the cost of producing the good (as reflected in the supply curve). That is, at equilibrium, the social marginal (extra) benefit derived from consuming the last unit of output is just equal to the social marginal cost of producing the last unit. Any output less than or greater than this equilibrium output would not equate marginal benefits with marginal costs and, therefore, would cause an inefficient allocation of society's resources.

This framework rests upon the important assumption that all the benefits and costs associated with the production and consumption of each product are fully reflected in the demand and supply curves. This assumption implies that no externalities are associated with the production or consumption of each product. If an externality occurs, then some of the benefits or costs associated with the production or consumption of a good fall on a third party and, therefore, are not reflected in the good's demand and supply curves. It follows that the presence of an externality will lead to an inefficient allocation of resources.

The most obvious examples of externalities involve environmental residuals. Industries discharging wastes in rivers and streams sometimes impose costs on individuals downstream. Industries that erect towers for smoke or water vapor emission sometimes impose costs (e.g., health, visual) on individuals surrounding the plant.

Given a measure of the social value of externalities, it may be possible to promote a more efficient allocation of resources in a society with external goods (externalities). If the change in social welfare due to the externalities of a product could be measured, then it may be possible, through various corrective policies, to reach a position in which marginal social benefits are equated with marginal social cost--an efficient condition.

CONCLUSIONS AND RECOMMENDATIONS

The neoclassical measure of the welfare impact of an externality is equal to the summation of the changes in producer and consumer surplus in all affected markets. The property value approach is applied using the assumption that the real estate market will reflect the total externality welfare impact in all markets.

Two property value approaches were discussed. The first involved measuring an externality's welfare impact with the product of real estate price change due to the externality and the stock of real estate. The Bahl and the Lind theoretical bases for this first approach were discussed. The assumptions required for the price change times real estate price measure to equal the neoclassical welfare impact measure were identified for each theoretical basis. It was concluded that the assumptions required in each case were restrictive and unrealistic.

The second property value approach measured welfare impact by the area under an estimated marginal benefit function for changes in the level of the externality. The application cost of using this approach would be extremely high because extensive data, which are not available from secondary sources, would be required. It was concluded that, given the cost, the application of this approach may be unreasonable.

Application of economic principles to empirical problems often results in a situation in which somewhat unrealistic or questionable assumptions are required. It is recommended that research be carried out to determine the extent to which the nature of the assumptions causes a deviation between the change in price times stock estimate and the actual welfare impact measure. Given the required resources, a valuable exercise would be one in which the marginal benefit function approach and the price times stock approach were applied to the same area. The results of this experiment should provide valuable information on the relationship between the nature of the assumptions and the deviation between the change in price times stock estimate and the actual welfare impact of an externality. This type of information is required before conclusive statements can be made concerning the viability of the property value approach.

QUANTITATIVE MEASUREMENT OF THE WELFARE IMPACT OF AN EXTERNALITY

In this section, external goods (externalities) are defined and discussed. Next, techniques are presented for measuring an externality's impact on a consumer. Finally, a dollar equivalent measure of the externality's impact on a consumer is generated.

DEFINITION OF A NONPECUNIARY EXTERNALITY AND SOCIAL COST

In many situations, the actions of one producer or consumer affect the welfare of others. The actions taken by a consumer may benefit or harm other consumers. The actions taken by a producer may benefit or harm consumers or other producers. By definition, such situations involve externalities.

One type of externality is the nonpecuniary externality. By definition, the effects of a nonpecuniary externality are not directly reflected in price. Consider, for example, the impact of industrial exhaust. Some of the damages caused by smoke emitted from a factory are not included in the price of the final product produced by the factory and are, therefore, external to the firm.

The existence of nonpecuniary externalities implies that two types of costs exist in the economy. First, there are private costs, which include all production inputs for which the producer has to pay a price. Second, there are additional costs from a social standpoint due to nonpecuniary externalities that are part of the cost of production (external costs). Social cost is defined as private cost plus uncompensated damage to others.[a] Thus, a nonpecuniary externality exists if the social cost of production is not equal to the private cost of production.

The existence of a nonpecuniary externality also implies that equality between marginal private benefits and marginal private costs does not insure an efficient allocation of resources in the economy. To determine the point

(a) Use of the term uncompensated damage is not meant to exclude the positive externality case in which the external good creates a net benefit and social cost is less than private cost.

at which marginal social benefits are equal to marginal social cost, the value of the uncompensated damage to others due to the externality must be determined. The uncompensated damage is referred to as the welfare impact of the externality.

MEASURING THE WELFARE IMPACT OF AN EXTERNALITY

The effect of a nonpecuniary externality on an individual consumer can best be illustrated by using a basic concept in consumer behavior theory, indifference curve analysis. Assume that a cooling tower is placed in operation in a community. Further assume that the visual impact of the tower affects the residents negatively.

Figure 1 shows a resident's initial equilibrium position. This figure assumes the resident consumes only two goods, X_1 and X_2, and that all his income is spent on these two goods. (Although these assumptions are unrealistic, they do not invalidate the analysis. Rather, they permit the illustration of a simplified analysis of consumer behavior on an X,Y plane.) Given this resident's indifference curves and price line, he will maximize his total utility by consuming (a) units of X_1 and (b) units of X_2.

The visual impact of the introduction of the cooling tower and plume causes this resident's entire indifference curve schedule to shift outward.[a] That is, the negative visual impact causes this resident to receive a lower level of utility with the same price line.[b] The effect of the visual impact is shown in Figure 2.[c] The indifference curve U_2' now occupies the position previously occupied by indifference curve U_1.

(a) A positive external impact would cause the indifference curves to shift inward.
(b) The indifference curves shift because the consumer cannot voluntarily purchase more or less of the externality. The impact is imposed on him and, thus, his quality of life (level of utility) changes.
(c) This analysis assumes that all other factors affecting the individual are held constant.

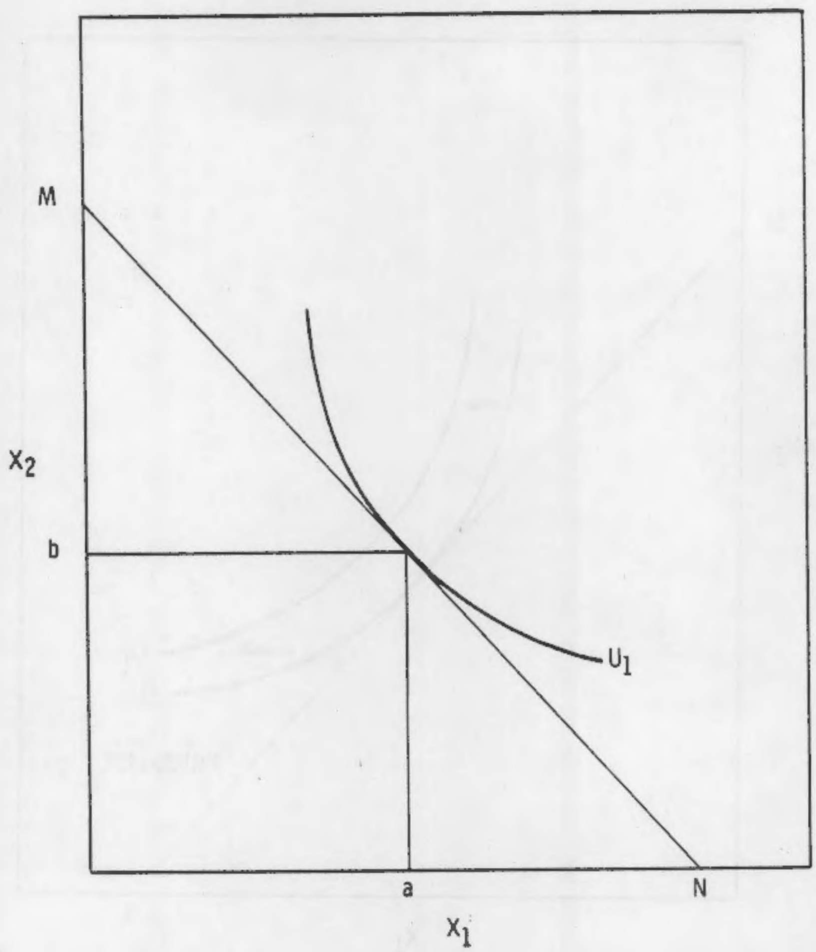

FIGURE 1. Consumer Equilibrium Position Before Cooling Tower and Plume Introduction

The indifference curve U_1' has the same total utility associated with it as the indifference curve U_1 in Figure 1. The indifference curve U_2' has a lower level of total utility associated with it than indifference curve U_1' or U_1.[a]

Figure 2 indicates that a lower level of total utility, the utility associated with indifference curve U_2', becomes the maximum level of total utility attainable after the indifference schedule shifts outward. Thus, an externality changes an individual's own perception of his well-being.

(a) In Figure 2, the prime (') is used to indicate that the externality has been introduced. An indifference curve without a prime indicates the position of these curves before the introduction of the externality.

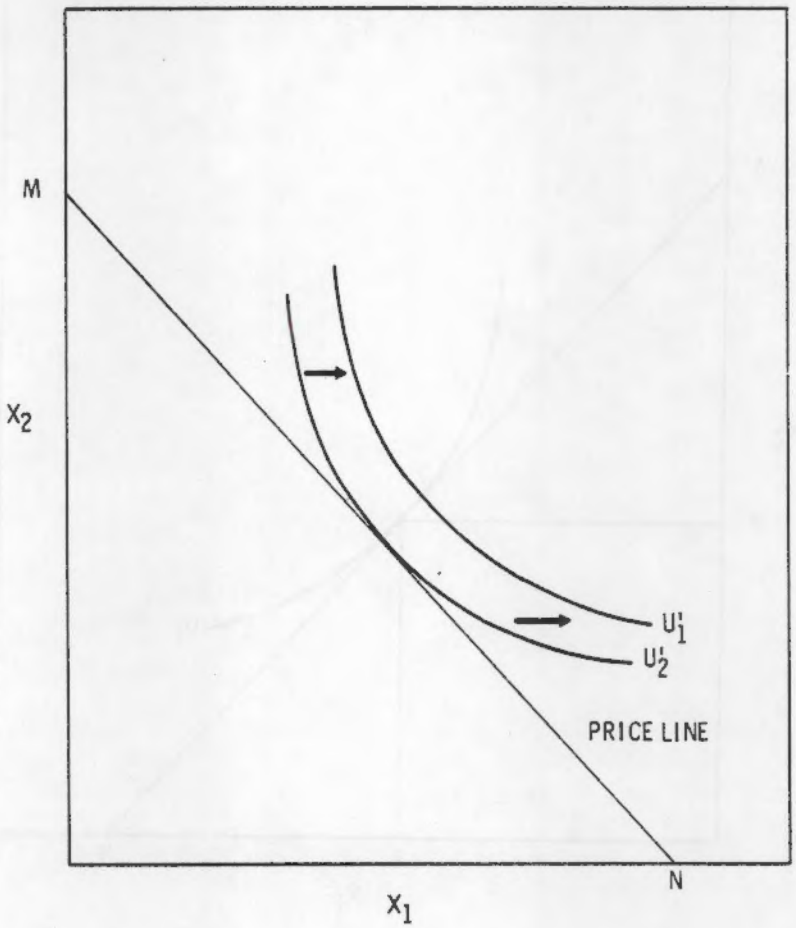

FIGURE 2. Consumer Equilibrium Position After Cooling Tower and Plume Introduction

DOLLAR EQUIVALENT MEASUREMENT OF THE WELFARE IMPACT OF AN EXTERNALITY

The preceeding section showed that the introduction of a negative externality causes, ceteris parabus, a decrease in the total utility derived from consumption. The external cost imposed upon the individual is clearly equal to the reduction in the level of utility he receives; i.e., the total utility associated with the indifference curve U_1 minus the total utility associated with indifference curve U_2'.

The value to the consumer of this decrease in total utility (the welfare impact of the externality) can be determined from the indifference map. This is accomplished by finding a budget differential such that the consumer is indifferent between 1) his final position on U_2' and a lower budget with no externality, or 2) his initial position on U_1 and a higher budget with the additional cost of the externality. The budget differential is then a measure of the value (welfare impact) of the externality to the consumer.

In the first case listed above, the appropriate task is to determine how much the consumer would be willing to pay to prevent the introduction of the externality. A new budget line, $\overline{M'N'}$, can be found such that the individual will maximize his utility at indifference curve level U_2 (where U_2 has the same total utility associated with it as U_2') if the externality had not been introduced (see Figure 3). Note that the slope of the new budget line $\overline{M''N''}$ equals the slope of the old budget line $\overline{MN}$, indicating that the prices of X_1 and X_2 are unchanged; only income is altered. The consumer is indifferent

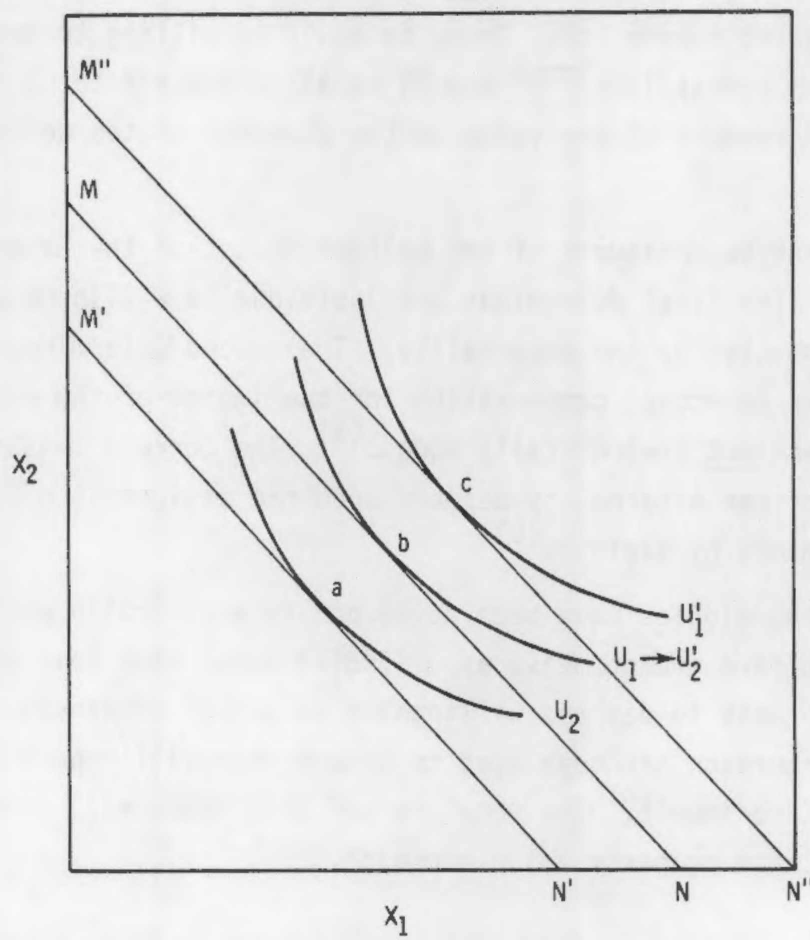

FIGURE 3. Dollar Equivalent Measurement of the Welfare Impact of an Externality

between no externality but reduced income [point (a) in Figure 3], and his position after the externality is imposed on him (b). Thus, he would be willing to pay the differential between the budget lines $\overline{M'N'}$ and $\overline{MN}$ to prevent being impacted. This is one measure of the value to the consumer of the welfare impact of the externality.

In the second case listed above, the appropriate task is to determine that increase in income which the individual regards as sufficient to fully compensate him for the negative impact. A new budget line, $\overline{M''N''}$, can be found such that the individual will maximize his utility at the level associated with indifference curve U_1' (where U_1' has the same total utility associated with it as U_1). The consumer is indifferent between his initial position with no externality [point (b) in Figure 3] and his position with the externality but increased income (c). Thus, he would be willing to accept the differential between budget line $\overline{M''N''}$ and $\overline{MN}$ to allow himself to be impacted. This is a second measure of the value to the consumer of the welfare impact of the externality.

At this point two measures of the welfare impact of the externality have been discussed. The first determines the individual's willingness to pay to prevent being impacted by the externality. The second determines an individual's willingness to accept compensation for the impact of the externality. These measures are <u>not</u> theoretically equal.[a] The correct measure of the welfare impact of the externality depends upon the assignment of property rights as determined by society.[b]

Several methodologies have been developed to empirically estimate one or both of these welfare impact measures. Bidding games have been used to measure both willingness to pay and willingness to accept compensation. The property value approach has been used to determine a willingness to pay measure of the welfare impact. The remainder of this paper will examine the latter methodology, the property value approach.

(a) See R. Willig, "Consumer's Surplus Without Apology." <u>Amer. Econ. Rev.</u> <u>66</u>:587-597, 1976.

(b) See A. Randall and D. S. Brookshire, "Public Policy, Public Goods, and Contingent Valuation Mechanisms." Staff Paper 68, Department of Agricultural Economics, University of Kentucky, Lexington, KY, June 1978.

THE PROPERTY VALUE APPROACH

In this section, the property value approach to estimating the welfare impact of an externality is evaluated within the context of the fundamental concepts presented in the previous section. Property value approach is a generic term, which is defined, for use in this report, as a methodology that uses information from the real estate market to determine the welfare impact of an externality. The implicit assumption within this methodology is that the real estate market has the potential to reflect an externality's welfare impact in all markets.

Information from the real estate market has been used in at least two ways to assess an externality's welfare impact. In terms of the discussion in the previous section, both approaches essentially involve estimating a willingness-to-pay-to-prevent-or-remove measure of welfare impact. The most widely used approach involves determining the change in real estate prices due to the externality. This price change is then multiplied by the stock of housing affected by the externality to generate an estimate of the welfare impact of the externality. This approach will be referred to as the price times stock approach.

A second approach discussed in this report was developed by Freeman.(1) He has developed a multi-step procedure that uses real estate market information to estimate an externality's marginal benefit function. The welfare impact of an externality can be derived from the area under the marginal benefit function. This approach will be referred to as the marginal benefit function approach.

The correct neoclassical theoretical measure of the welfare impact of an externality is equal to the summation of changes in producer and consumer surplus (i.e., the change in the payment to factors of production that is above the minimum necessary for work inducement plus change in the difference between what consumers actually pay for a product and what they would be willing to pay) within all affected markets. The basic purpose of the following discussion is to investigate the conditions under which both types of property value approaches discussed above will provide an externality welfare impact measure that is equal to the neoclassical theoretical measure.

This discussion emphasizes the theoretical basis of the two types of property value approaches. Some empirical considerations will also be discussed.

PRICE TIMES STOCK APPROACH

This approach has been discussed extensively in the literature.[2-8] Two different theoretical bases have been developed for this type of approach. The theoretical basis that is discussed first is referred to as the Bahl basis. The second was developed by Lind[5] and is referred to as the Lind basis. The theoretical bases will be discussed first, followed by a discussion of the empirical application of the price times stock approach.

The Bahl Basis

If the real estate market were to work perfectly, real estate prices would equal the present value of future net benefits derivable from the real estate. The introduction of a negative externality (e.g., visual impacts) represents a cost. The cost will be reflected in real estate prices because it reduces future net benefits of the real estate.

Figure 4 illustrates the demand and supply conditions in a real estate market. The introduction of a negative externality will cause a decrease in the demand for real estate, holding other demand-affecting factors constant. Assume the demand curve (D) shifts to D' as a result of the externality.

The neoclassical measure of the welfare impact in the real estate market, change in consumer surplus (CS) plus change in producer surplus (PS), can be seen in Figure 4. CS is the area above the price line and below the demand curve. PS is the area below the price line and above the supply curve. CS plus PS before the introduction of the externality equals the area ABS'O. CS plus PS after introduction of the externality equals the area A'B'S'O. Thus, the neoclassical welfare impact measure equals area ABS'O minus area A'B'S'O. The change in the price of real estate is P minus P'. The change in the stock of real estate is K minus K'.

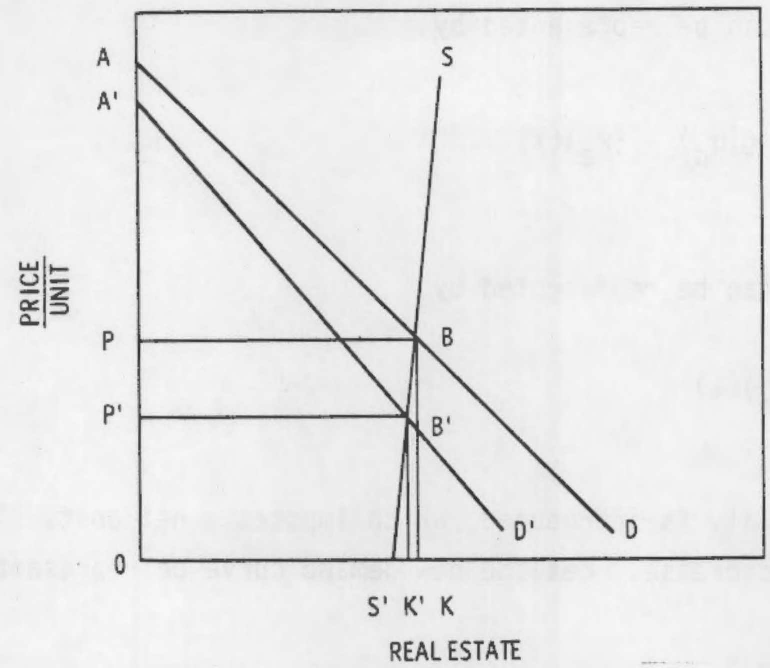

FIGURE 4. Real Estate Market

Bahl(8) shows that, under certain conditions, the real estate price change due to the externality multiplied by the stock of housing will equal the neoclassical welfare impact measure. To do this Bahl uses a simple mathematical model of the real estate market. Assume the area to be impacted has the following demand for real estate:

$$q_d = g(q_d) \qquad (1)$$

and, further, assume the supply of housing is constant:

$$q_s = k \qquad (2)$$

The equilibrium market price (P_e) can be represented by

$$P_e = f_1\left[g(q_d),k\right] \qquad (3)$$

Consumer surplus can be represented by

$$CS = \int_0^k g(q_d) - (P_e)(k) \tag{4}$$

Producer surplus can be represented by

$$PS = (P_e)(k) \tag{5}$$

Assume an externality is introduced, which imposes a net cost. The demand for real estate will decrease. Let the new demand curve be represented by

$$q_d = h(q_d) \tag{6}$$

The new consumer surplus (CS') can be represented by

$$CS' = \int_0^k h(q_d) - (P_e')(k) \tag{7}$$

where P_e' is the new equilibrium real estate price,

$$P_e' = f_2\left[h(q_d), k\right] \tag{8}$$

The new producer surplus (PS') can be represented by

$$PS' = (P_e')(k) \tag{9}$$

The neoclassical welfare impact measure (ΔB) equals

$$\Delta B = (CS' - CS) + (PS' - PS) = \left[\left(\int_0^k g(q_d) - (P_e)(k)\right) - \left(\int_0^k h(q_d) - (P_e')(k)\right)\right]$$

$$+ \left[(P_e)(k) - (P_e')(k)\right] \qquad (10)$$

$$= \int_0^k g(q_d) - \int_0^k h(q_d) \qquad (11)$$

Bahl states that, given the following five assumptions, ΔB can be shown to be equal to $(P_e - P_e')(k)$, the price times stock approach welfare impact measure.

1. The shift in the real estate market demand curve due to the introduction of the externality is a parallel shift.

2. The supply of real estate is perfectly inelastic.

3. Homeowners are perfectly mobile.

4. Only individuals owning real estate within the impact area of the externality are affected; e.g., transients are not affected.

5. There are no offsetting real estate value effects outside the impact area of the externality.

In Figure 5 the neoclassical welfare impact measure defined by Equation (11) equals the area ABB'A'. That is,

$$\int_0^k g(q_d) - \int_0^k h(q_d) = \text{area ABB'A'} \qquad (12)$$

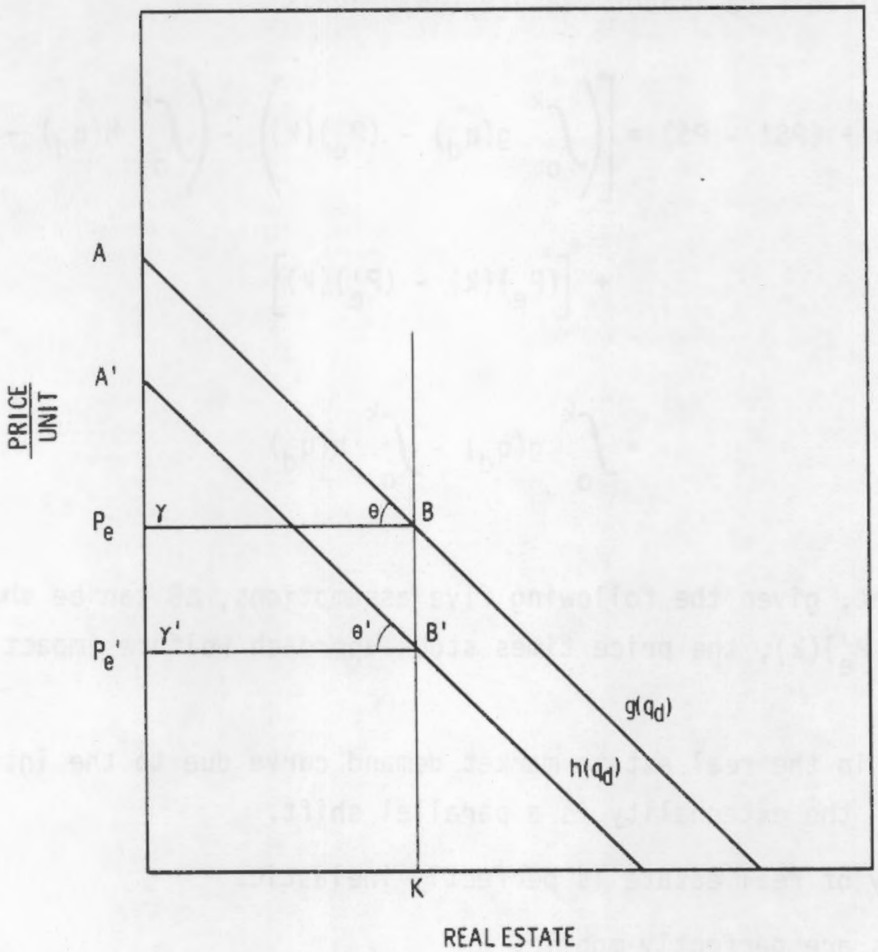

FIGURE 5. Conditions Under Which the Price Times Stock and Neoclassical Welfare Impact Measurements are Equal

It is assumed that demand curves $g(q_d)$ and $h(q_d)$ are parallel and that supply is perfectly inelastic. Given these conditions, the following conclusions can be drawn concerning Figure 5:

(1) $\theta' = \theta$ (13)

(2) $\overline{B'P'_e} = \overline{BP_e}$ (14)

and

(3) $\gamma' = \gamma$ (15)

These are sufficient conditions to guarantee that the areas $A'B'P_e'$ and ABP_e are equal. By construction, it is evident that

$$ABB'P_e' - A'B'P_e' = AA'B'B \tag{16}$$

and

$$ABB'P_e' - ABP_e = P_e'P_eBB' \tag{17}$$

Because

$$ABP_e = A'B'P_e' \tag{18}$$

it follows that

$$AA'B'B = P_e'P_eBB' = (P_e - P_e')(k) \tag{19}$$

Thus, the real estate price change times the real estate stock equals the neoclassical measure.

If any of the five assumptions specified by Bahl were relaxed, Equation (19) would not be valid. If $g(q_d)$ were not parallel to $h(q_d)$, i.e., if the demand curve shift were not parallel, then $\theta' \neq \theta$. Under these conditions, area ABB'A' would not equal $(P_e - P_e')(k)$. Likewise, if the supply of real estate were not perfectly inelastic, then $P_e'B' \neq \overline{P_eB}$ and area ABB'A' $\neq$ $(P_e - P_e')(k)$.

Consider the effects of relaxing the perfect mobility assumption. If homeowners are perfectly mobile, then it is possible that homogenous communities exist, in which each individual is being correctly compensated (or charged) for the different externality levels among communities. If homeowners are not perfectly mobile, then communities exist in which individuals are not correctly compensated (or charged) for the different externality levels. Individuals who are not being correctly compensated (or charged) may choose to allow that situation to persist rather than incur significant moving costs. In terms of the real estate market, relaxing this assumption means the demand shift due to the introduction of the externality will not reflect the actual change in willingness to pay for real estate.

Bahl's fourth assumption requires that only real estate owners within the impacted area be affected. Transients who come into contact with the externality may also be affected. The welfare impact on this group will not necessarily be reflected in the real estate market demand curve shift.

Assumption 5 states that there are no offsetting real estate value effects outside the impact area of the externality. Consider the introduction of alternative closed cycle cooling systems. Real estate within view of the tower may fall in value but property values outside the impacted area are assumed to be constant. However, due to the substitute nature of property inside and outside the impacted area, it is possible that real estate values outside the impacted area will rise. Thus, the real estate market within the impacted area may not reflect the total welfare impact of the externality.

The assumptions required appear to be somewhat unrealistic for most real estate markets. First, there is no a priori reason to hypothesize a parallel shift in demand due to the externality. Second, the elasticity of the supply curve depends on the time period being investigated. The longer the time period, the more elastic the supply function will tend to be.

Third, for most households the purchase of real estate is a large investment. As a result, households would be expected to gather extensive amounts of information before buying. However, after the purchase, large search and information costs may lead households to drop out of active participation in the real estate market. This is one of the reasons howeowners do not approach perfect mobility. The applicability of the fourth and fifth assumptions depends to a large extent upon the characteristics of the externality and the real estate market.

One final assumption mentioned previously will be reiterated here. It has been implicitly assumed that real estate values capture the entire welfare impact. It is reasonable to expect that other prices in addition to real estate values may vary due to the externality; e.g., wage rates. The real estate market will not necessarily reflect the welfare impact brought about by all price changes.

The Lind Basis

More recent attempts to justify the use of the price times stock approach have been somewhat more rigorous. Lind[5] has developed an analysis that deals with two questions: whether welfare impacts are significant in markets not directly impacted by the externality, and whether the welfare impact of an externality can be measured through real estate price changes. This discussion focuses on the second question, which essentially asks if the welfare impact of an externality can be equated with the price differential in the real estate market, due to change in the amount of the externality, multiplied by the supply of real estate.

Lind's approach is based on an optimal assignment model. His results show that, in general, the change in land values due to the introduction of an extra-market good represents an upper bound on the welfare impact of the externality, assuming 1) land rent has been established to eliminate consumer and producer surplus and 2) in moving from an initial equilibrium to the new equilibrium, all other market prices remain unchanged.

Lind's analysis begins by developing the assignment model approach to determining activities on various parcels of land. This approach assigns (n) activities to (m) parcels of land in such a way that the sum of a_{ij}, where a_{ij} is the amount a firm or household would pay for activity (i) or location (j) over all parcels of land, is maximized. That is, the approach maximizes

$$\sum_{ij} a_{ij} \xi_{ij} \qquad (20)$$

given that

$$\sum_{i} \xi_{ij} \leqq 1, \quad \sum_{j} \xi_{ij} \leqq 1 \qquad (21)$$

where $\xi_{ij} = 1$ if activity i is assigned to location j and $\xi_{ij} = 0$ otherwise.

The benefits obtained by assigning activity i to location j are given by a_{ij}. The optimal assignment of activities to land parcels, given a set of parcel rental prices p_j, is the one that maximizes benefits (a_{ij}) to the community.

The benefits associated with an assignment of activities to parcels ($\sum_{j=1}^{n} a_{jj}$ where, for convenience, it is assumed that activity j locates on parcel j) may be divided into two parts:

$$\sum_{j=1}^{n} a_{jj} = \sum_{j=1}^{n} S_{jj} + \sum_{j=1}^{n} P_j \tag{22}$$

where S_{jj} equals the consumer surplus associated with activity j on location j or the return to factors other than land from activity j on location j for individuals and firms, respectively. P_j represents the rental value of parcel j. Thus, the existence of returns to factors other than land and consumer surplus creates a discrepancy between real estate (rental) value and the benefits associated with a given assignment of activities.

Now consider the effect of an extra-market good (externality) that reduces the value of land. This will lead to new levels of productivity on the land (a'_{jj}), a new set of equilibrium rental values (P') and a new set of consumer surpluses (S'). If

$$A = \sum_{j=1}^{n} a_{jj} \tag{23}$$

then

$$A'-A = \sum_{j=1}^{n} (P'_j - P_j) + \sum_{j=j'=1}^{n} (S'_{jj'} - S_{jj}) \tag{24}$$

where j' is an index of the location occupied by activity j, given the new equilibrium.

A'-A is equal to the neoclassical measure of the welfare impact of the externality (change in consumer surplus plus change in producer surplus). Note that A'-A will not equal the change in total land values (ΔP times housing stock) unless the surplus term on the right is zero. Thus, it would have to be assumed that land rents eliminate the surpluses. Also, all other market prices must remain unchanged because A'-A will not necessarily reflect welfare changes in other markets.

Questions concerning the realism of Lind's assumptions have been raised by Freeman.[4] He argues that it is unlikely that both assumptions necessary for Lind's analysis (land rents eliminate surpluses and other market prices remain unchanged) could hold at the same time, in which case Lind's results are of limited practical significance for empirical estimation of welfare impact.

Consider a neighborhood with quiet and noisy housing.[a] Let P_1 represent the price of housing in the noisy area and P_2 the price of housing in the quiet area. (Implicit is an assumption of a community of like tastes, similar houses, and varying incomes.) Clearly, $P_2 > P_1$ because if they were equal, no one would wish to occupy a noisy house.

Now, suppose the noise is eliminated in the neighborhood. The new price of housing is represented by P_3. If $P_2 > P_3 > P_1$, then either those individuals who formerly paid P_2 are receiving consumer surplus, or other market prices changed to compete away that surplus. Either way, one of Lind's basic assumptions is violated. If $P_2 = P_3$, then there will be no change in consumer surplus. However, this implies an upward sloping demand curve for quiet housing or identical demand for quiet and noisy housing, which can be ruled out *a priori*.

(a) This example is considered in: E. J. Mishan, Cost-Benefit Analysis. Praeger Publishers, New York, N.Y., Chapters 47-48, 1976.

Application of Price Times Stock Approach

The change in real estate price times stock approach has been applied to specific cases to measure the welfare impact of an externality.(5,6,10-17) The real estate price change is typically estimated using regression analysis. The following type of equation,

$$V = f(Q, HC, NC) \qquad (25)$$

where

V = real estate value

Q = level of the externality

HC = house characteristics

NC = neighborhood characteristics

is statistically estimated using historical data. Given certain assumptions (including the assumptions that people expect present conditions to remain unchanged in the future and that the model is properly specified), it is possible to derive an estimate of the change in V given a change in Q($\partial V/\partial Q$). If the required assumptions prove to be unrealistic, the estimate of $\partial V/\partial Q$ from Equation (25) would deviate the actual measure. The appropriate change in property value estimate ($\partial V/\partial Q$) is then multiplied by the existing housing stock to estimate the welfare impact of the externality.

MARGINAL BENEFIT FUNCTION APPROACH

The marginal benefit function approach discussion will first consider the procedure for deriving an externality's welfare impact. The assumptions required for this approach to provide an estimate that is theoretically equal to the neoclassical welfare impact measure will be included. Second, the application of this approach will be discussed.

Welfare Impact Estimation Procedure

This procedure, developed by Freeman,(1) requires a data base covering a number of regions. Given this data base, the first step is to estimate rent functions for each region separately. The rent function takes the functional form,

$$V_i = f(Q_i, HC_i, NC_i) \quad (26)$$

where V_i is the annual equivalent of the market price at residential site i, with externality level Q_i, household characteristics HC_i and neighborhood characteristics NC_i. Note that Equation (26) is essentially Equation (25). That is, the first step of this procedure is essentially what must be done for the price times stock approach. The partial derivative of the rent function with respect to Q_i is, by definition, the marginal purchase price function $R(Q_i)$. This function specifies the cost of changing Q_i.

The next step is to derive the household's income compensated demand curve for the externality, $D_i(Q_i)$. $D_i(Q_i)$ specifies the willingness to pay for changes in Q_i and therefore can be interpreted as a marginal benefit function.

Assuming household response to real estate values does not vary among urban areas, the equation

$$Q_i = g\left[R^j(Q_i),\ SE_i \right] \quad (27)$$

can be estimated using combined household data for all urban areas, where

$R^j(Q_i)$ = marginal purchase price of Q in the j^{th} city
SE_i = a vector of socioeconomic characteristics including income and age.

The coefficient on variable $R^j(Q_i)$ may be interpreted as the slope of the marginal benefit function, $D_i(Q)$ (assuming the equation was estimated in linear form). Given Q_i, $R^j(Q_i)$ and the slope of $D_i(Q)$, it is possible to derive benefits for changes in Q_i. The Q_i change benefits would be measured by the area under $D_i(Q_i)$ over the relevant Q_i range.

At least two assumptions are associated with this approach. First, real estate values must capture the entire welfare impact of the externality. Second, household response to real estate values does not vary among urban areas. These assumptions appear relatively reasonable compared to the assumptions required for the price times stock approach.

Application of the Marginal Benefit Function Approach

Assume that Q_i increases as the level of a negative externality decreases. Then the empirically estimated rent function, $V_i(Q_i)$, will appear similar to the one depicted in Figure 6. $R(Q_i)$, which is derived directly from $V(Q)$, would then be a monotonically increasing function as shown in Figure 7. $D_i(Q_i)$ would then be derived using Equation (27).

The benefits of a marginal change in Q_i can be approximated without information on $D_i(Q_i)$. The marginal change in Q_i from Q_i' to Q_i'' will result in marginal benefits which are approximately equal to $\partial V_i/\partial Q_i$. It would be inappropriate, however, to use the same benefit measure for nonmarginal changes in Q_i. A change in Q_i from Q_i' to Q_i''' will result in benefits equal to

$$\int_{Q_i'}^{Q_i'''} D_i(Q_i)\, dQ_i, \tag{28}$$

the area under the marginal benefit curve between points Q_i' and Q_i'''.

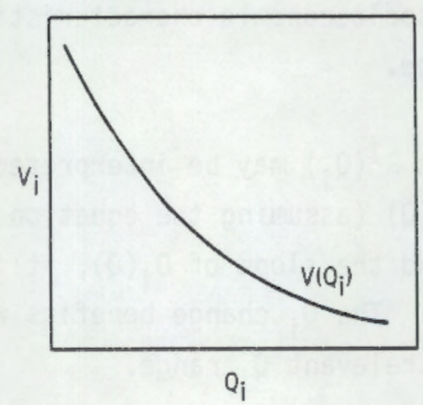

FIGURE 6. Rent Function

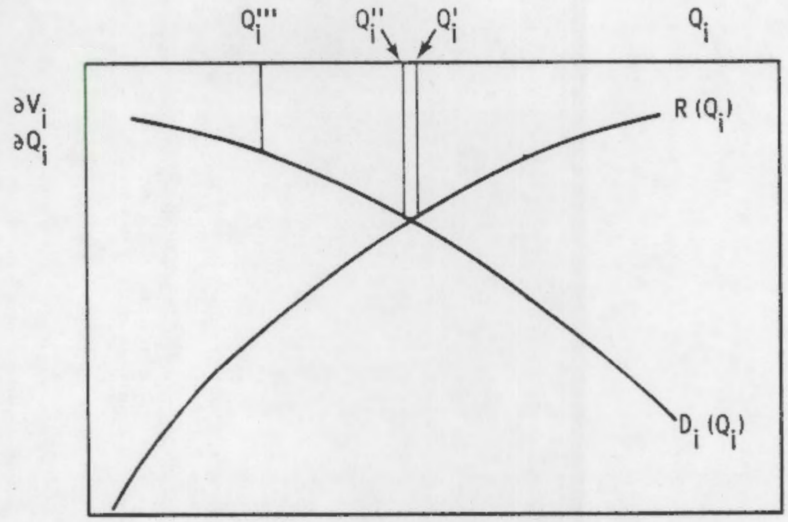

FIGURE 7. Demand and Supply of Externality Level (Q_i)

There are significant practical constraints to this approach. The resources required to estimate the marginal benefit function would be substantial. The major cost would be the data gathering required. The author is not aware of any previous applications of the marginal benefit function approach.

FIGURE 7. Demand and Supply of Externality Level (Q_1)

There are significant practical constraints to this approach. The resources required to estimate the marginal benefit function would be substantial. The major cost would be the data gathering required. The author is not aware of any previous applications of the marginal benefit function approach.

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