

Chapter 11

BENEFIT ESTIMATION FOR COMPLEX POLICIES

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1 INTRODUCTION

While the idea and some of the analytics of benefit cost analysis have a lengthy history (e.g., Dupuit, 1844), its domain and influence have expanded in recent years. BCA has been firmly grounded in the Hicks-Kaldor compensation test and the potential Pareto-improvement (PPI) criterion. This welfare-theoretic base permits two rather different economic interpretations of what it means to say that a proposal passes a BC test. First, it implies that, for the affected population, the interpersonal sum of self-evaluated prospective gains and losses is positive. Second, the proposed innovation could potentially (i.e., in an environment of completely-specified property rights and low-friction markets) be implemented via voluntary exchange among the affected population. These economic interpretations have direct counterparts in political philosophy: the first implements one version of the classical utilitarian test, while the second identifies proposals that could potentially (i.e., if acceptable compensation were actually paid to those who would otherwise lose) gain unanimous consent. Both the classical utilitarian test and the test of hypothetical compensation are, of course, controversial among political philosophers. To argue that BCA has standing in political philosophy is a far cry from claiming that it is generally noncontentious.

*The authors acknowledge research support from the National Science Foundation (Grant No. SES-8309157), U. S. Environmental Protection Agency (Cooperative Agreements 807768-01-0 and CR 811056-01-0), Resources for the Future, Inc. (Small Grants Program), The Ohio Agricultural Research and Development Center, and the Agricultural Experiment Stations of Kentucky and Michigan.

These welfare-economic roots expand the purview of BCA beyond its earlier applications in evaluating public works projects, to encompass virtually any conceivable public project, program or policy. The links between BCA and political philosophy extend the influence of BCA beyond economics and accounting, and into the mainstream of policy discussion. In a large and complex society the portfolio of existing public policies, programs, and projects is enormous. At any given moment, there is a multitude of proposals for additions, modifications, and deletions to that portfolio. Nevertheless, standard BC procedures examine each proposal in isolation, effectively treating it as the single proximate increment to the existing portfolio.

Applied economists have shown some awareness of the distortions that might be introduced into empirical BCA's via the "in isolation" assumption. Oscar Burt and Durwood Brewer (1971), and Edward Morey (1981) have been concerned to evaluate proposed recreation sites with full cognizance of existing sites that users might consider substitutes. Ronald Brautigam and Roger Noll (1984) have examined the influence of substitutes on the estimated welfare impacts of surface freight regulation. Lester Lave (1984) argued that the relative independence of single-purpose regulatory agencies encourages them to ignore "contradictions" among the policies that each pursues. Using welfare weights, he outlines a simultaneous optimization procedure that considers the impacts of policies addressed to different objectives, and illustrates with an example concerning automobile fuel consumption and passenger safety.

Here, we pursue several purposes. In section 2, we demonstrate, in general, the distortions that inevitably arise when a multitude of proposals is on the policy agenda at any time and each proposal is evaluated independently to determine its PPI status. We identify a valid welfare change measure and show how it deviates from the invalid "in isolation" measure. There are two sources of deviation: (1) substitution and complementarity relationships among the components of complex policy, which may lead the "in isolation" measure to overstate or understate the true benefits of the policy; and (2), as the number of policy components grows large, resource scarcity unambiguously reduces true benefits of complex policy below the estimate that would be obtained by aggregating the "in isolation" estimate. The valid welfare change measure may be estimated holistically in one-shot fashion, or by imposing an (often arbitrary) implementation sequence on the array of components.

It may be that neither of these alternatives is appealing. New one-shot holistic estimates for each and every configuration of complex policy may seem overly expensive.

Holistic estimates will not yield component benefit estimates that would be useful in fine-tuning the policy package. Arbitrary sequencing will ensure a valid aggregate BCA of the complex policy, but may be misleading with respect to benefits and costs of individual policy components. Furthermore, the valid benefit measure for complex policy does not seem to permit the use of "in isolation" benefit estimates for policy components, even where an inventory of such estimates is readily available. In section 3 we outline a procedure for econometrically approximating the valid welfare change measures for many configurations of complex policy using valid holistic BC estimates for a sample of such policies. Further, we suggest a possible modification of this procedure to approximate, roughly, the valid holistic benefit measure, using existing "in isolation" benefit estimates for individual policy components and some additional information about substitution relationships among components.

2 THEORY

Consider an economy where individuals value market goods and environmental services, and the level of environmental services is controlled by policy. Household preferences across market goods, \mathbf{x} , and environmental services, \mathbf{q} , are described by a utility function, $u = u(\mathbf{x}, \mathbf{q})$, (where boldface characters indicate vectors) that is strictly increasing, continuous, and strictly quasiconcave. Given income, m , market prices, \mathbf{p} , and access to environmental services, \mathbf{q} , the level of well-being attained by a household is described by an indirect utility function.

$$u = v(\mathbf{q}, m) = \{u: u = \max u(\mathbf{x}, \mathbf{q}) \text{ s.t. } m = \mathbf{p}\mathbf{x}\} \quad (1)$$

where the constant price level, \mathbf{p} , is left implicit in $v(\cdot)$. At an initial level of income, m^0 , and an initial level of environmental quality, \mathbf{q}^0 , initial utility is $u^0 = v(\mathbf{q}^0, m^0)$.

The household's expenditure function is

$$e(\mathbf{q}, u) = \{e: e = \min \mathbf{p}\mathbf{x} \text{ s.t. } u(\mathbf{x}, \mathbf{q}) \geq u\} \quad (2)$$

where the constant price level is left implicit in $e(\cdot)$. The expenditure function is strictly decreasing and strictly convex in \mathbf{q} . The expenditure function states the minimum expenditure on market goods that sustains a utility level u at market prices \mathbf{p} and environmental quality \mathbf{q} . At an initial level of environmental quality, \mathbf{q}^0 , initial income is

just enough to maintain initial utility: $m^0 = e(\mathbf{q}^0, u^0)$. For notational simplicity, let \mathbf{q} be a 2-element vector, $\mathbf{q} = (q_1, q_2)$.

Now we introduce a single-impact policy that would change the level of q_1 from q_1^0 to q_1^1 while leaving q_2^0 unchanged. The Hicksian compensating measure of benefit, HC, is the amount of income, paid or received, that would leave a household at a pre-policy level of well-being while enjoying the post-policy level of environmental quality. For the single-impact policy defined above,

$$HC(q_1^1, q_2^0; \mathbf{q}^0) = e(\mathbf{q}^0, u^0) - e(q_1^1, q_2^0, u^0) = m^0 - e(q_1^1, q_2^0, u^0). \quad (3)$$

If the policy change is beneficial to the household, HC measures the household's willingness to pay (WTP) for the change; if the policy is detrimental, HC is negative and -HC measures WTA, the compensation that the household is willing to accept.

Now, consider a multipart policy that changes the levels of both elements of \mathbf{q} . For a two-element change from q_1^0 to q_1^1 and q_2^0 to q_2^1 , the conventional BCA procedure would evaluate the two changes independently--perhaps in different studies conducted by independent research teams--and then aggregate the "in isolation" benefit estimates to calculate the benefits of the two-part policy. We denote this procedure IVS, for independent valuation and summation. For the policy change posited above, IVS would generate the benefit measure

$$IVS(q_1^1, q_2^1; \mathbf{q}^0) = HC(q_1^1, q_2^0; \mathbf{q}^0) + HC(q_1^0, q_2^1; \mathbf{q}^0) \quad (4.1)$$

$$= m^0 - e(q_1^1, q_2^0, u^0) + m^0 - e(q_1^0, q_2^1, u^0) \quad (4.2)$$

where $m^0 = e(\mathbf{q}^0, u^0)$.

A conceptually valid benefit evaluation design is derived directly from the definition of HC. That is, HC is the amount of income paid or received that would leave an individual household at the initial level of utility subsequent to the multiple impacts of policy. For the multipart change from \mathbf{q}^0 to \mathbf{q}^1 , HC is

$$HC(q_1^1, q_2^1; \mathbf{q}^0) = m^0 - e(q_1^1, q_2^1, u^0). \quad (5)$$

Equation (5) summarizes the structure of a valid benefit evaluation design. First, as the difference between initial income, m^0 , and the well-defined function $e(\cdot)$, HC is unique

for any multipart change in policy. There is a single measure of HC for any given policy. Second, HC encompasses the overall impact of policy in a single, one-step valuation. A contingent valuation format could be designed to value, ex ante, the multipart policy in a one-step, holistic valuation.

Equation (5) can be decomposed into separate valuations of the two components of policy. To carry out this disaggregation, a sequential path of valuation is selected. The only requirement of a valid sequence of valuation is that it begin with $q^0 = (q_1^0, q_2^0)$ and that it end at $q^1 = (q_1^1, q_2^1)$. One admissible sequence of valuation would value the change from (q_1^0, q_2^0) to (q_1^1, q_2^0) first, and the change from (q_1^1, q_2^0) to (q_1^1, q_2^1) second. Using this path of valuation, HC is

$$HC(q_1^1, q_2^1; q^0) = m^0 - e(q_1^1, q_2^0, u^0) + e(q_1^1, q_2^0, u^1) - e(q_1^1, q_2^1, u^0) \quad (6.1)$$

$$= m^0 - e(q_1^1, q_2^1, u^0). \quad (6.2)$$

For expositional convenience, the multipart policy addressed above is confined to two elements. However, some complex policy packages may well impact many elements of environmental quality. For a g -impact policy, the structure of the valid HC measure of benefits would be analogous to that in equations (6). The valuation sequence would be g items long and the i^{th} impact in g would be evaluated as though the $i-1^{\text{th}}$ policy component was already in place.

We have elsewhere developed and proved three theorems that detail the relationships between the conventional IVS benefit measures and the valid HC measures for multiple-impact policies (Hoehn and Randall, 1986). Here, we simply state these theorems and discuss, at an intuitive level, their implications.

Theorem 1: HC (as defined in equations 5 and 6) is a valid benefit measure for multipart policy. HC is unique for a given multipart policy. If HC is calculated by aggregating the sequenced valuations of the components of policy, HC for the multipart policy is unique; however, the valuations of individual policy components are not unique, but depend on their place in the valuation sequence. Further, HC for the multipart policy is in general not equal to IVS.

This result defines a valid benefit measure for multipart policy, shows that the conventional measure is invalid, and suggests two approaches to empirical evaluation of multipart policy: first, a holistic one-shot evaluation; and, second, a sequenced valuation procedure that considers the policy components separately but in some particular sequence. For ex ante evaluation of complex policy proposals, contingent valuation has obvious advantages, deriving from the flexibility afforded the researcher in constructing and communicating scenarios. We see no insurmountable difficulties in developing contingent valuation scenarios for holistic and sequenced valuation of complex policy proposals. Opportunity exists for evaluating a number of alternative sequences, which is clearly useful if component valuations are of interest and no particular valuation sequence seems self-evident. We recognize, of course, that a variety of questions remain, concerning the susceptibility of contingent valuation to various sources of error and bias.

For ex post evaluation of complex policies, the contingent valuation method is available. In addition, hedonic price analysis may be effective for holistic valuation. Where policy has local or regional application, multi-market, wage-rent hedonic analysis may be effective; repeat sales analysis may be serviceable, where one can obtain observations both before and after policy implementation and within and beyond the policy impact area.

There may be cases in which the vector of policy components had been implemented piecewise with some considerable lags between components. In such cases, ex post analyses of component benefits using hedonic or weak complementarity methods may satisfy the requirements of a valid valuation structure. More typically, we fear, there will be little opportunity to use these methods for ex post evaluation of valid policy component benefits.

Theorem 1 states that HC is in general not equal to IVS. If policy components are substitutes for each other, IVS would tend to overstate policy benefits, but if they are complements IVS would tend to understate the benefits of complex policy. Theorem 2 identifies a situation in which the error from IVS is systematic.

Theorem 2: Let there be many potential policy components, each with positive benefits if implemented in isolation. Then, as the number of such components included in a multipart policy grows large, the error from using IVS evaluation becomes systematic: IVS overstates HC for the multipart policy and for at least some of its components.

While the first two theorems demonstrate that IVS introduces error into the benefit estimates for complex policy, a question remains about the benefit cost ratio or net present value. Are there circumstances in which the IVS procedure would misidentify the PPI/non-PPI status of proposals?

Theorem 3: Let each policy component impose a resource cost on the economy. Then, as the number of policy components becomes large, the IVS procedure misidentifies some non-PPI complex policies as PPI and some non-PPI policy components as PPI.

These results show that the conventional IVS procedure introduces errors that become systematic as the number of policy components becomes large: some non-net-beneficial policies and policy components pass an IVS BC filter. With routine use of IVS procedures, the portfolio of public policies could grow wastefully large.

Two economic phenomena are involved. First, for any number of policy components, small or large, some policy components may be substitutes for or complements with others. IVS fails to consider these possibilities. Second, as the number of policy components becomes large, resource scarcity makes the error in IVS systematic. Scarcity eventually forces the dominance of substitution effects.

3 TOWARD EMPIRICAL APPLICATION

It is easy to understand the popularity of IVS. It is convenient in application and adaptable to all of the acceptable non-market valuation tools, and it allows the accumulation and re-use of an inventory of benefit estimates. Often, *ex ante* benefit estimates for a complex proposal are calculated by IVS using of component benefit values, estimated (perhaps, *ex post*) by independent teams of researchers using different methods. Compared with *de novo* empirical benefit estimates for each and every complex proposal under consideration, the savings from using IVS are obvious. However, our theoretical results demonstrate general, perhaps large, and ultimately systematic errors from IVS.

Here, we explore the possibilities of designing practical methods to approximate the valid HC measure of benefits while economizing on research effort. We consider two practical problems: first, rather than *de novo* holistic benefit evaluation of each and every conceivable complex policy configurations, a method to approximate the benefits of many complex policy packages from valid benefit estimates for a sample of packages would be helpful; and, second, it would be desirable to find ways to use an inventory of

component benefit estimates to calculate approximately valid benefit estimates for complex policies.

We begin by developing an econometric structure for the benefits of a complex policy that changes the vector of environmental services from \mathbf{q}^0 to \mathbf{q}^1 . The valid benefit measure for that policy is

$$\text{HC}(\mathbf{q}^1; \mathbf{q}^0) = m^0 - e(\mathbf{q}^1, u^0). \quad (7)$$

Rearranging and taking natural logarithms, we obtain

$$\ln(m^0 - \text{HC}) = \ln[e(\mathbf{q}^1, u^0)]. \quad (8)$$

A second-order Taylor series expansion of (8) about $\ln(m^0)$ yields

$$\ln(m^0 - \text{HC}) = \ln(m^0) + \mathbf{ln}(\mathbf{a}^1)' \beta + \mathbf{ln}(\mathbf{a}^1)' \mathbf{B} \mathbf{ln}(\mathbf{a}^1) \quad (9)$$

where $\mathbf{ln}(\mathbf{a}^1) = (\ln(q_1^1/q_1^0), \dots, \ln(q_g^1/q_g^0))$ is a g -element vector, β is a matrix of coefficients conformable to $\mathbf{ln}(\mathbf{a}^1)$, and $\mathbf{B} = (b_{ij})$, $i, j \in (1, \dots, g)$ is a g^2 -element symmetric matrix. Equation (9) is essentially a translog approximation to the expenditure function. If a policy component q_i is unchanged (i.e., $q_i^1 = q_i^0$) in the proposed policy scenario, q_i vanishes from the right-hand side of (9). One need only consider the policy components that would be changed by the proposed policy.

Equation (9) imposes no arbitrary restrictions on the degree of substitution or complementarity between policy components. Consider the problem of an agency exploring an array of combinations and permutations of multipart policy. If one had valid HC benefit estimates for a sample of multipart policies under consideration (perhaps estimated by contingent valuation), one could estimate the degree of substitution and complementarity from the sample data (Hoehn 1987). By estimating (9), one could calculate the valid HC benefit measure for any multipart policy within the sample range.

If, on the other hand, one has information on base income, m^0 , and an inventory of "in isolation" benefit estimates for policy components, it is possible to approximate the valid HC benefit measure for multipart policy if one is willing to impose some further restrictions on the econometric structure and if some additional data can be obtained. First, assume the diagonal terms in \mathbf{B} are zero. Second, since it can be shown that the off-

diagonal terms of \mathbf{B} are functions of $\beta_i\beta_j$, assume that b_{ij} is simply proportional to $\beta_i\beta_j$, that is, $b_{ij} = \delta\beta_i\beta_j$. A positive δ implies the q_i and q_j are substitutes in valuation.¹

Rearranging (9), one finds, for β_1 , that

$$\beta_1 = \ln\{[m^0 - HC(q_1^1, q_2^0; q^0)]/m^0\} / \ln(q_1^1/q_1^0) \quad (10)$$

where q_2^0 indicates that all elements of q other than q_1 are unchanged. Using equation (10) to estimate the elements of β , only the parameter, δ , remains unknown. Obviously, the substitution parameter could be estimated in an empirical research project initiated for that purpose. Or, perhaps, previous research may yield an array of plausible values for δ . In the worst case, a value for δ may simply have to be assumed.

This simplified version (equation 10) of the econometric structure for valid benefit estimation (equation 9) permits the use of "in isolation" component benefit estimates, e.g., $HC(q_1^1, q_2^0; q^0)$, to calculate an approximation of the valid benefit measure for complex policy. In addition to the "in isolation" component benefit estimates, one needs estimates of the base income level, and the substitution parameter.

It is important to recognize that this simplification substitutes structure for information. In particular, simplifying assumptions are imposed about the nature of the substitution/complementarity relationships among policy components. In the extreme, where all off-diagonal terms in \mathbf{B} are zero and all $b_{ij} = \delta\beta_i\beta_j$, the substitution relationships are assumed to be identical for all pairs of policy components. A less restrictive approach might seek to measure, in a set of demonstration projects, a vector of substitution parameters for at least the major pairs of components of environmental policy.

¹ To verify this assertion, consider the case of a two-component policy, where both q_1 and q_2 are desired amenities. Equation (9) reduces to:

$$\ln(m^0 - HC) = \ln m^0 + \beta_1 \ln a_1^1 + \beta_2 \ln a_2^1 + \delta \ln a_1^1 \ln a_2^1.$$

A positive δ implies that the marginal effect of interaction between the policy components is to increase $\ln(m^0 - HC)$, i.e. to reduce HC. Thus a positive δ implies q_1 and q_2 are substitutes.

4 CONCLUDING COMMENTS

We have shown that conventional BCA procedures are invalid for evaluating complex policy. Where the number of policy components under consideration is very large, conventional IVS procedures would provide a systematically biased filter and, as a result, a wastefully large portfolio of policies may be implemented. We have, however, defined valid BCA structures that would eliminate this problem.

We are conscious that the valid BCA structure is informationally demanding, allows no use of "in isolation" component benefit estimates collected from previous research, and seems poorly adapted to the use of the hedonic and weak complementarity methods that are favored by some environmental economists. Our exploratory efforts to develop flexible and simplified econometric structures for approximating the valid benefit measures are addressed to these difficulties. We have planned some initial empirical research along these lines, but it will be some time before the results are available.

In the case where a single agency has control of a manageably-small number of policy components, an important concern raised by our work is the need to identify and properly consider substitution and complementarity among policy components. Since Burt and Brewer (1971), economists have been conscious that multiple recreation facilities may be substitutes for one another. However, complementary relationships may also be important. Consider forest wildland management, where water quality, scenic integrity, atmospheric visibility and ecological diversity may all be complements. For the "small numbers" case, our work focuses attention on the importance of substitution and complementarity among policy components, and suggests some strategies for empirically accounting for such relationships, more and less precisely.

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