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Incorporating Distributional Issues into Benefit Cost Analysis: Why, How, and Two Empirical Examples Using Non-market Valuation

John B. Loomis

Abstract

This article reviews the rationale for and various approaches used by economists to incorporate distributional consequences of projects or policies into benefit-cost analyses. Approaches reviewed include distributional weights and metrics based on the Lorenz curve. Analysis of distributional issues in partial equilibrium and general equilibrium settings are briefly reviewed. We present an empirical demonstration of how the contingent valuation method (CVM) and hedonic property methods (HPM) can be used to quantify how non-market environmental benefits are distributed by income and ethnicity. Using CVM, the distribution of non-market benefits can be cross-tabbed with respondent demographics, so that a variety of "distributions" of benefits by relevant demographic groups can be calculated. Using the HPM, the analyst can statistically test to see if the implicit price gradient varies with differences in income and ethnicity. In our empirical example, we find that ethnicity and income interaction terms on the implicit price gradient are statistically significant suggesting differential effects of National Forest fire suppression policies on Hispanics and low income households.

KEYWORDS: contingent valuation method, distribution, equity, environmental justice, hedonic property method, Lorenz Curve

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I. Why Distributional Issues Are Important in Theory and Practice

The origin of Benefit-Cost Analysis (BCA), in both theory and practice, has its historical roots in the pursuit of economic efficiency, with less attention paid to distributional concerns. In the last decade there has been growing interest among federal and state agencies in displaying elements traditionally omitted from BCA, such as how the benefits and costs are distributed geographically, by income groups, and by ethnicity. In the case of applying BCA to evaluate social policies from pre-school education to prison reform, distributional goals are often an explicit part of the policy design (Vining and Weimer, 2010; Long, et al. 1981). The thrust of this paper, and recent papers by others (Zerbe, 2007; Vining and Weimer, 2010; Schmitz and Schmitz, 2010), is that the information provided by BCA should be broadened to explicitly include discussion and display of the distributional effects of the project.

For purposes of this paper, distribution is an extension of positive economic analysis to quantify who gains (and by how much) and who loses (and by how much). Equity deals with the more normative issue of whether the distribution of these benefits and costs is "fair" or not using criteria such as ability to pay. While this paper will address both distribution and equity, the empirical examples will focus on how to monetize the distribution of benefits from non-market goods and resources. For purposes of this paper, distributional consequences or effects primarily refer to how the benefits and costs are distributed by some classification of interest to the decision makers such as income levels, ethnicity, age, etc. Benefits are typically defined as net willingness to pay. Costs include real resource costs incurred by society. In some cases the analyst is also interested in how the burden of financing (e.g., taxes or fees paid) those real resource costs are distributed relative to the benefits. That is, how the real resource costs are paid for may moderate or exacerbate the distributional consequences of net benefits. When the term distributional consequences is used in the paper, the context of the discussion will usually make apparent whether financing issues are being included or not.

The requirements to perform a distributional analysis as part of a BCA are now reflected in federal policies. Agencies are statutorily required to consider impacts on different groups: small businesses (Regulatory Flexibility Act of 1980, amended 1996); children (Food Quality Protection Act, E.O. 13045); vulnerable populations (Clean Air Act), and impact on state, local or tribal governments (Unfunded Mandates Reform Act of 1995).

To set the stage for one of this paper's case study, we will examine the federal requirement to assess environmental effects on minorities and low income populations. This requirement came about as a result of concerns raised by the NAACP regarding environmental racism in the siting of powerplants, landfills, and petro-chemical facilities (especially in Louisiana). In 1994 President Clinton signed Executive Order (EO) 12898. Section 1-101 of the EO requires that "*…each Federal agency shall develop an agency-wide environmental justice strategy, ... that identifies and addresses disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.*"

Agencies such as the U.S. Environmental Protection Agency (EPA) in their "Guidelines for Preparing Economic Analysis" (USEPA, 2000), provide a chapter on Distributional Issues. Within that chapter there is specific attention paid to the determination of whether environmental effects of changes in the natural or physical environment are adverse and disproportionately high to minority and low income populations (USEPA, 2000: 166). The disproportionate standard is relative to effects on the general population. This discussion appears geared toward determining health risks of environmental effects in a quantitative sense (e.g., ppm concentration of a pollutant or acres mined near low income or minority residents versus higher income areas) but not in a monetary sense.

But how to monetize the distribution of health and environmental effects not priced in the market can be challenging. Little has been written on this topic. The purpose of this paper is to show how to adapt two non-market valuation techniques in order to monetize the non-market benefits to different income and ethnic groups in order to address distributional issues agencies are required display in their analysis. The paper proceeds as follows. First, we briefly set the stage for why distributional issues are important from a theoretical perspective. Next we highlight the general issue of partial equilibrium and general equilibrium approaches to calculating and displaying distributional effects. This is followed by a discussion of alternative approaches to incorporate distributional concerns and equity into BCA. The next to last section discusses and provides empirical examples of how two non-market valuation methods can be used to calculate distributional effects. The paper concludes with a summary of the findings of this paper.

Distribution Matters in Economic Theory

For economists, social well being is composed of two factors, economic efficiency and equity. By efficiency, economists mean selecting policies that maximize consumer well being from use of given amount of market and non market scarce resources. Economists talk about economic efficiency as a positive or objective analysis, and it takes the distribution of income and resulting prices as given unless there are market failures such as monopoly or pollution (then shadow prices are used to correct for these distortions in the BCA). How project

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benefits and costs are distributed among different income or ethnicities is also a positive analysis.

The second factor is equity or fairness of the distribution of these goods and services. Using information on how benefits and costs are distributed to assess equity or fairness is a normative analysis as it requires society or its representatives (usually an elected official) to compare the well being of a dollar's worth of benefit to one person versus another. While the choice of how to weight or trade-off benefits to people of different incomes is a societal choice, many people in society (but not all) would agree that publicly financed projects or policies should not seriously worsen the distribution of income. For an economist, nirvana would exist when an "optimum optimorum" (Boadway, 1979: 23) is achieved. Such an optimum requires attaining both efficient production and consumption (the first optimum), and a social welfare maximizing distribution of those consumption goods and income (the second optimum). To obtain the second optimum regarding equity requires a social welfare function that reflects the relative contribution of each person's utility to social welfare. Of course such a function is generally considered a theoretical (not empirical) construct, and one that would be normative if empirical construction was possible. However, the concept of a social welfare function brings to the forefront the fact that economic theory is not just concerned with economic efficiency, but that it includes attention to equity as well. In fact, some economic policies are specifically designed to lessen the unequal distribution of income arising from the market economy, even if there is a cost in reduced economic efficiency. An example of one such policy is a progressive income tax along with income transfers to low income households.

In a first best world with perfectly competitive (price taking) firms, and the ability of the government to offset any negative distributional effects through lump sum (non-distortionary) taxes and transfers (at little or no transactions costs), economic efficiency and equity can be separated. In this case BCA should focus on identifying economically efficient projects (Tresch, 1981).

However, in many instances where a benefit cost analysis is to be performed, the relevant industry structure is not perfectly competitive. Neither is the government able to engage in non-distortionary taxation of the high income project beneficiaries in order to transfer these tax revenues to low income households adversely affected by the project. In this more realistic, but what economists call "second best world," attainment of social wellbeing requires ranking projects by both their levels of economic efficiency and equity (Tresch, 1981). Thus, we focus the remainder of the paper on investigation of different means to conduct a distributional analysis that lays the foundation for an evaluation of the equity of a particular project or program.

Addressing Distribution in BCA in Partial and General Equilibrium Analyses

If the majority of the effects of a policy or project are limited in economic scope (i.e., primarily affecting one sector) or one relatively small geographic area, then a BCA limited to that sector or area is sufficient. That is, a partial equilibrium analysis may be sufficient to capture the vast majority of the effects. To incorporate distributional effects in a partial equilibrium analysis one approach is to adopt the "stakeholder accounting approach" (Jenkins, 1999; Krutilla, 2005). In this approach, the benefits and costs to each group of interest (i.e., stakeholders) are displayed in a table format. This approach lends itself to allowing decision makers to decide how much weight to give each group.

However, oftentimes policies have widespread effects with backward linkages affecting suppliers of inputs to the project and forward linkages to end users of the project. For example construction of a large hydro-electric dam could reduce the cost of electricity used by multiple industries. Or a national policy to reduce air pollutants from petroleum refining could affect prices of diesel fuel for airline and trucking industries and gasoline prices for consumers. In these examples a multi-market analysis is needed of the distributional effects to the relevant parties, as there will be multiple industries affected. In addition, there may be pecuniary spillover effects from these industries to those producing complement and substitute goods. Essentially, the interconnection of airline and trucking industry on other industries must be explicitly accounted for when performing a distributional analysis. Economists have developed models to allow for multi-market BCA (Berck and Hoffmann, 2002; Just, Hueth and Schmitz, 1982). Large policy changes (e.g., a cap and trade on carbon emissions) that have major economy wide effects justify use of non linear computable general equilibrium simulation models (CGE). A properly constructed CGE simulation model allows an analyst to trace the effects of new policies on prices and quantities, labor, taxes, etc. throughout the entire economy (Berck and Hoffmann, 2002). This allows for a comprehensive analysis of both the economic efficiency and distributional consequences a pervasive policy change. In both the multi-market and CGE analysis, there may be several industry and consumer good specific equity measures calculated, as well as one "net effect" measure. For example, new fuel economy standards will raise new car prices, but save consumers gasoline purchases over the life of the car. Further, the increase in new car prices may stimulate demand for used cars, boosting their price. Since the poor tend to buy used cars, this could have an unintended adverse equity effect, even though a single market analysis might show little affect since the poor usually do not purchase new cars. Fullerton (2009) provides a series of papers that illustrate the application of multiple market and general equilibrium analyses to analyze the distributional effects of energy and environmental policy. In sum, it is important to keep in mind when a multiple market or CGE analysis is warranted and perform such an analysis when appropriate. If a short-cut analysis using only the most directly affected market is performed, then these limitations discussed above should be discussed qualitatively based on the concepts of backward and forward linkages as well as substitute and complement goods. We now turn to the practical matter of possible ways distribution and equity concerns might be incorporated into a benefit-cost analysis.

II. Approaches to Incorporate Distribution and Equity into BCA

There are several approaches to weighting benefits and costs based on income, ethnicity, or any other criteria. The more explicit the weights are, the more there is room for disagreement regarding the value judgments that underlie these weights. Nonetheless, differential weighting of benefits and costs may occur at some point in the policy process, and it behooves us as economists to help steer decision makers away from obvious pitfalls that can arise with the use of weights. Some weighting schemes by being very explicit may be more controversial than others (some may recall the flap over the “senior discount” to the value of statistical life). As Harberger (1984) points out, there is an implicit efficiency cost associated with using differential weights for different groups. That is, the greater the range of weights between groups (e.g., a factor of four as in his example), the more possible it is for projects that provide significant benefits to a higher weighted group to pass a benefit cost test even if overall economic efficiency is inadequate (e.g., BCR<1). We now review these different weighting schemes.

Implicit Weighting by Decision Makers

One of the easiest ways to account for distributional issues in a BCA is simply to display the benefits and costs disaggregated by income classes, rural versus urban, ethnicity, or whatever groups are relevant for this analysis (Zerbe and Dively, 1994; Jenkins, 1981; Krutilla, 2005). This “stakeholder” approach is also the easiest for decision makers to understand. Most importantly, the decision makers can then apply their own weighting regarding the relative emphasis to put on each grouping.

Like many elements in a BCA, such an approach is simple in concept, but can be difficult in practice. How does the analyst know how much of the benefits received or the costs paid/incurred are associated with different income classes or ethnicities? On the cost side, some of this may be known from the project financing. If the project is to be financed by user fees, then surveys of users may reveal the incomes, ethnicities, etc. of frequent versus infrequent users. From this the analyst could calculate the percentage of the project cost to be borne by each

. https://doi.org/10.2202/2152-2812.1044

group of interest. If the project is to be financed by income taxes, sales taxes or property taxes, there is an extensive literature in public finance and tax journals on how these taxes are distributed by income.

On the benefit side, surveys can be used to estimate how the benefits vary with groups of interest (e.g., stakeholders) in the distributional analysis. As illustrated below, most surveys contain, or can be designed to contain, an extensive list of demographic characteristics such as age, education, gender, ethnicity, income, or whatever group the analyst thinks is relevant for distributional analysis of this project or policy (e.g., handicap status, single parent households, etc.). Benefits estimated by usage, willingness to pay, or other indicators can then be cross-tabbed with any of the demographic characteristics used in the survey. The analyst can even calculate and display multiple within group, and between group categories, e.g., single parent households by ethnicity, senior citizens by race, etc. In this way, the analyst can display multiple distributional measures that may be of political interest to elected officials. Combining these per capita effects based on the survey data with the number of households in each of the categories allows for a population level incidence analysis. Once information on how benefits and costs are distributed has been assembled, a useful summary statistic is how the difference between benefits and costs, i.e., net benefits, are distributed by each distributional strata of interest to the policy makers (Graham, 2008; Hammitt 2009). Net benefits involves combining information on the amount (if any) of project benefits to a typical individual in the group of interest (e.g., income class, ethnic group) along with the costs (e.g. higher prices, taxes, etc.) borne by a typical individual in those same groupings. Krutilla (2005) provides a tableau format that illustrates this approach for disaggregating project benefits, costs and net benefits for groups that are classified into residents, consumers, producers, taxpayers, and state government.

A second way to determine if the benefits do vary with key demographic characteristics is to include demographic variables in the statistical analysis used to estimate benefits. Many BCA calculate benefits from demand or supply functions. If the analyst is using data to estimate these demand or supply functions, he or she can include variables such as income, age, gender, etc. in the demand or supply equations to statistically test (e.g., t-test) whether the usage, and hence the benefits, vary with these characteristics. If a demographic factor is significant, then the differential benefits received by each group can be calculated by setting that variable at the different levels of interest for that group. For example, if it is a dummy variable for gender, then the consumer or producer surplus could be calculated twice, once for males and once for females. The same approach would work for income quintiles. If a particular demographic factor is not statistically significant, then the fact that benefits do not vary with that demographic characteristic should be conveyed to the decision maker. Knowing what distributional factors are not important can be valuable information to a decision maker. We illustrate this approach below using the hedonic property method for determination of the changes in residential house prices in response to nearby forest fires. A parallel type of statistical analysis can be conducted in estimating the effects on suppliers, e.g., including whether the firm is a small business, minority owned business, etc.

Even if the analyst does not estimate his or her own demand and supply functions, often time the analyst is using someone else's demand or supply function to calculate benefits. Inspecting that function for significance of demographic factors will aid in determining if a particular demographic characteristic influences the benefits of the project. Even if an analyst uses elasticities or consumer surplus and/or producer surplus per unit of output, these are often derived from an underlying statistical function which can be inspected to determine if benefits vary by demographic variables of interest. If so, the benefits can be calculated for each relevant group by setting that variable at the levels of interest (e.g., income quintiles). The resulting distribution of benefits then can be displayed in a table for the decision maker to review and implicitly weighted by the decision maker in any way they want (including no differential weights at all).

Explicit Weighting of Net Benefits

One method to empirically incorporate equity or distributional concerns in the calculation of net benefits (i.e., benefits-cost) is to apply different weights to the net benefits of each group. Using an ad hoc pragmatic definition of groups, they could be any stakeholders of interest to the policy maker. For example, the groups could be income classes (e.g., quintiles), ethnicities, gender, or rural versus urban consumers. Some groups have natural divisions such as gender or ethnicities, while for others it becomes the choice of the analyst. However, in the case where the grouping is chosen by the analyst, sensitivity analysis can be performed to determine if the segmentation of groups matter to the ranking of project or policy alternatives. Applying the weighting to net benefits has the advantage of incorporating the same weights on benefits and costs together in one number. However, displaying the original benefits and costs is often useful as well, as these essentially have a weight of one given to all income categories. This allows the decision maker to see how the benefits and costs change from the baseline case of equal weights when alternative weights are applied. Weighted and unweighted net benefits need not be mutually exclusive, and together they may provide a more complete picture of the economic efficiency and equity dimensions of a project or policy.

However, ad hoc weights can undermine the utility theoretic foundation of benefits and costs as a measure of welfare or well being. Prior to weighting, the theoretical measures of benefits and costs have a strong link to individual utility and well being. Good practitioners strive to maintain the link between theory and empirical measurement of benefits and costs through estimation of demand functions consistent with utility maximization, for example. In order to link monetary net benefits to the social welfare function, the empirical distributional weights should reflect the marginal utility each distinct group receives from their net benefits. Drawing upon Starrett (1988), one way to do this is to weight the monetary net benefits received by each group by their marginal utility of income. If per capita incomes of each group are unequal, and there is diminishing marginal utility of income, then different income groups' monetary net benefits will be weighted differently in the social welfare function (Starrett, 1988).

But how strong is the case for diminishing marginal utility of income? Certainly it has some intuitive appeal in terms of the differences in utility of another $100 of income to a rich person versus a homeless person. Empirical observations of risk aversion when people make choices between uncertain outcomes is consistent with diminishing marginal utility of income. While Starrett lays out other rationales for diminishing marginal utility of income, in the end this is ultimately a value judgment. But of all the possible ways to weight benefits and costs, income related weights have the tightest link to the underlying economic theory of welfare measurement. Thus, with income based weights, the resulting net benefit measure is an attempt to provide a weighted sum of utilities to society. Alder (2008) suggests that benefit-cost analysts look to the optimal tax literature for a range of plausible social welfare functions. Along these lines Alder proposes risk-equity analysis of health and safety regulations that is "grounded" in the concept of the social welfare function.

A Revealed Preference Option for Calculating the Weights

Where might an analyst find empirical measures of these distributional weights? Herein lies the rub. One source of weights would be past government decisions involving equity trade-offs between groups. The differential tax rates in the U.S. progressive income tax system might serve as a possible source of relative income weights (Gramlich, 1981). Thus, in the 2009 income tax year, a household with adjusted gross income of $10,000 pays a tax rate of 10%, with this tax rate increasing to 12% when income doubles to $20,000. A household earning $100,000 has a marginal tax rate of 28% on the earnings over $100,000 but less than $170,000. Households with earnings over $170,000 pay a marginal tax rate of 33% on this excess, up to $373,000. Earnings in excess of this amount are subject to a 35% marginal tax rate. There are of course numerous loopholes, including preferential treatment of capital gains, and clever accounting tricks to make the effective rate somewhat less for high income households. Nonetheless, for the purposes of determining an explicit weighting of net benefits to each group, these tax rate percentages did reflect a consensus by a majority in Congress, with concurrence from the President of the United States, of a relative comparison of marginal utilities of income to different income groups. To use the tax rates as weights in a BCA, one would need to calculate the relative weights as the ratio of tax rates (Gramlich, 1981). For example, if we normalize on a 16% tax rate facing a middle class household ($50,000), then each dollar of benefit to the lowest income household ($10,000) would be weighted by 1.6. Likewise, a dollars worth of benefits to an upper income household ($100,000) would be weighted by .57, and just .46 to richest households earning more than $373,000.

An advantage of relying upon on a single nation-wide weighting standard is that it provides consistency in the weighting system used across projects and allows for greater comparability of the resulting benefit-cost ratios. This avoids a concern about individual project by project weights chosen by decision makers (a local agency official or locally elected representative with a stake in the outcome) which would not be comparable across projects.

A Relativist Approach to Calculating Weights

Brent (1996) discusses an approach by Thompson et al. (1984) to deal with equity in quantifying the net public benefits of reducing a health problem (i.e., different forms of arthritis) to patients. Thompson et al. used a stated preference type contingent valuation method survey to measure of benefits in terms of willingness to pay (WTP). However, these authors were concerned that absolute dollar magnitude of WTP might strongly influenced by income or ability to pay.[1]

If a strong positive link between WTP and income is believed to be the case, then Thompson et al. showed two ways to minimize this effect on benefit estimates. One is upfront in the survey itself, where in addition to eliciting the usual dollar amount of WTP, they also asked for WTP as a percentage of income. This willingness to pay a percent of income would not be constrained by the absolute level of income. Arraying these percentages by income class would provide a relative comparison of the benefits to each income class. Second, the authors extended this first approach by multiplying the sample average percentage WTP by the ***total*** sample income to calculate the overall sample average dollar amount of WTP.

Brent suggests this approach by Thompson et al. is similar to calculating a weight for each group based on a comparison of the group income to the overall average income. Thus a low income group with $20,000 per household income

[1] Not all health or even environmental CVM studies find a strong link with income, suggesting that substitution rather than income effects are often driving stated choices—see Loomis, et al. 2009, and Loomis and duVair, 1993 and a meta analysis by Costa-Font, et al. 2009.

relative to the population average of say $40,000 would have its net benefits weighted by two (W_i=(Avg Income/Income_i)). Alternatively, net benefits to a high income group with an income of $80,000 would get a weight .5.[2]

One advantage of this method is that the weights sum to one, so that total net benefits are not overstated as would be the case if the weights summed to more than one, or understated if the weights summed to less than one. Another possible advantage is that since the weights are calculated as the ratio of household income of each group to the population's average income, the same weights could be applied across all project or policy BCA's. This provides consistency in the weighting system used across projects and allows for greater comparability of the resulting benefit-cost ratios.

Any of these approaches to weighting are not without their limitations. As such, regardless of the exact form of weights chosen, it is important to perform a sensitivity analysis using different weights to evaluate whether the ranking of projects by NPV's (or BCR's) is overly sensitive to a reasonable range of weights. One of those weights can be one for all groups, and hence would reflect the original benefits and costs. This can allow the decision maker to see how the original benefits and costs change from the baseline case of equal weights when alternative weights are applied. If the BCR's or NPV's are not overly sensitive to the different weighting schemes chosen, then the analyst and decision maker can have some confidence that the ranking of policy or project alternatives is not overly sensitive to how distribution concerns are treated. However, if the ranking of alternative projects is sensitive to the choice of weights, this too is important information for the decision maker to know, as it focuses his or her attention on equity. Thus such a finding of sensitivity suggests the decision maker devote some serious thought to what specific weights should be assigned to each group.

Lorenz Curve Based Approaches to Measure Distributional Effects

The inquiry regarding distributional concerns in economics is far broader then just BCA. As such, some measures of inequality that are commonly used to measure how equal or unequal the distribution of income is, can be useful for BCA. The Lorenz Curve plots the cumulative percentage of income against the cumulative percentage of the population. If income was equally distributed, the relationship would be a straight line with a slope of 1. Of course it is not a straight line, as the first 20% of the population receives only about 4% of the income, and the upper 20% receives about 50% of the income. Farrow (forthcoming) suggests this current relationship between income and population could be compared to a

[2] A further refinement of this method would be to include an exponent on the W_i so that it is not just a linear function of the group's relative income.

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similar relationship for the project. In the case of the project, presumably the plot would be the cumulative percent of the income versus cumulative percent of project beneficiaries. If there is equal distribution of project benefits across the beneficiaries then the Lorenz curve would be a straight line with a slope of 1. The more the actual Lorenz curve bows or dips below this straight line, the more unequal the distribution of project benefits is. A further refinement of this procedure for policies that would have substantial effects on societal income would be to calculate what the Lorenz curve looks like before the new policy (i.e., the current situation), and then what the Lorenz curve would look like if the policy were implemented. This might provide a more complete and easily interpreted picture of the income distributional effects of such a major policy change.

One often over-looked aspect of BCA is that the results can provide feedback to project planners or policy analysts to modify the project or policy to make it more efficient or equitable. One way to apply the Lorenz curve to evaluate the distributional aspects of a project would be to display the distribution of **net** benefits of a project by income class. The resulting project Lorenz curve would be compared to the societal Lorenz curve of how income is distributed in the population to determine if the distribution of net benefits of a project would worsen the distribution of income. Such a calculation also illustrates how information on the distribution of benefits and costs of a project can be used to re-design elements of a project or its financing to change the distributional effects. If the project or policy has undesirable equity affects, then it may be possible to change the financing of the project to one emphasizing income taxes, rather than say sales taxes (as often used to finance open space, sports stadiums) or user fees (often used to finance mass transit). Alternatively, the beneficial projects such as light rail lines could have additional stops in poor neighborhoods so that poor households without cars could walk to stations. Of course the flip side would be projects with undesirable distributional effects (e.g., new refineries) could be located further from poor neighborhoods.

A summary statistic that is derived from the Lorenz curve is called the Gini coefficient. This coefficient is defined as the ratio of two areas under the Lorenz curve. The numerator of the ratio is the area of the gap between the empirical Lorenz curve and the straight line. The denominator of the Lorenz curve is the total area under the straight line. The higher the Gini coefficient, the greater the inequality in the distribution. In the spirit of Farrow's above suggestion, the Gini coefficients could be compared between the project and the current income based Gini coefficient to determine whether the project contributes to worsening or improving the distribution of income.

The Suits Index (1977) is another measure of progressivity that can be applied to broad policies or changes in broad based taxes, or to specific taxes (Loomis and

Revier, 1988). As such, it has potential to provide an index of how project benefits vary with income and how specific taxes used to finance the project would vary with income. This information could provide feedback on modifying features of a project or policy, as well as the financing to improve equity.

Generating the type of data needed to calculate Lorenz curve measures can be accomplished using numerous techniques. As discussed in the previous sections, there can be single market or multiple market analyses, or economy wide simulation models such as CGE. There is an extensive literature on empirically evaluating the distribution of market benefits and market costs on everything from energy sector (i.e., natural gas—see Loury, 1983; gasoline—see Hughes, 1987) to minimum wages (Gramlich, 1990) to agricultural programs (Leuthold, 1969); However, for evaluating policies whose major benefits and costs are non-market in nature such as health or non-game wildlife, etc., these market based models may be limited. While there has been recent research attempting to incorporate non market values into CGE models (Espinosa and Smith 1995), below we suggest adaptation of commonly used non-market valuation methods such as contingent valuation surveys and hedonic property models.

III. Empirical Examples of Incorporating Non Market Distributional Concerns into BCA

Using Survey Demographics to Display How Non Market Benefits Vary by Income

To illustrate the reliance upon surveys to display and evaluate whether there is any pattern of environmental benefits by income class, an example is developed in this section. Contingent valuation method (CVM) surveys are frequently used to quantify WTP for environmental quality (e.g., air quality, water quality, health, recreation) and can be framed to explicitly incorporate WTP for providing public goods to other low income families (Loomis, et al. 2009) or for improving distributional consequences of a program (Vining and Weimer, 2010). In our case study the survey asked respondents for their WTP for river based recreation and Total Economic Value (use and passive or non-use value). Respondent WTP was then partitioned by income groups using survey respondent demographics. Of course CVM estimates of WTP are subject to significant controversy over their validity (Portney, 1994; Hanemann, 1994; Diamond and Hausman, 1994). But for our purposes, it is the relative distribution of benefits across income groups that may be informative to decision makers as there is no reason to believe the hypothetical bias varies with income.

As an illustration of this approach, consider the results from a mail survey of Fort Collins, Colorado residents. The survey had a relatively high response rate

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of 65% of deliverable surveys. Of course a further check of the representativeness of the demographics contained in this sample could be conducted by comparing the sample demographics to the Census Bureau estimates of these same demographics, and weighting the sample demographics to reflect the population estimates.

In the CVM survey, residents were asked the maximum amount they would pay annually to avoid a 50% reduction in peak summer river flows. Visitors were also asked the maximum they would pay for a visit to the river as it flows through town. Table 1 illustrates the distribution of total economic value (use plus passive use) and recreation benefits of maintaining peak May-July instream flows in the Poudre River through the City of Fort Collins, Colorado by income level. Respondents were told the current May-July flows would protect riparian vegetation, as well as fish and bird populations. In addition, a paved bike path follows the river that thousands of residents use. During the high flow periods, the river provides locals with water-based recreation opportunities such as tubing and fishing.

Table 1. Distribution of Households' Total Economic Value and Visitors' Recreation Value by Income

Income	Total Economic Value (annual)	Recreation Value per trip
$ 7,500	$235	$3
$ 15,000	174	11
$ 25,000	85	6
$ 35,000	93	6
$ 45,000	73	13
$ 55,000	81	17
$ 68,000	125	9
$ 88,000	167	23
$ 125,000	144	10
$ 175,000	95	10
$ 250,000	90	6
$ 350,000	500	0

Source: Loomis, 2008.

As illustrated in Table 1, there is no real pattern of total economic values or recreation use values by income. This suggests that there would be no concerns on the distribution of benefits for either visitors or households of a policy that would maintain the current levels of instream flows.

However, on the cost side, the distributional burden may depend on how maintaining instream flows is to be financed. To address the cost side, the field of public finance can provide some insights. If maintaining instream flows was financed by increasing the sales tax rate or water bills, then it may be considered a regressive tax in that the tax would be a higher percentage of poor households' income, than that of affluent households. If the instream flow program was financed by increasing property taxes, since housing expenditures rise with income (although the income elasticity is less than one (see Zabel, 2004 for a review)), property taxes rise with income. However, given the income elasticity, financing by property taxes could still be regressive.

How the Hedonic Property Method Can Aid in Quantifying Distributional Impacts of Environmental Effects

As noted previously one way to determine if there are distributional differences in benefits or costs when using a statistical method such as multiple regression is to test whether the coefficient on different demographics is statistically different from zero. For example, is the coefficient on income or gender statistically significant? If not, then one could interpret this as no significant difference in response to price or consumer surplus calculated from the demand curve by income levels. To illustrate this procedure we use the Hedonic Property Method or HPM. This method utilizes data from real estate transactions to infer how house prices change with changes in dozens of attributes surrounding a neighborhood. Using multiple regression of differences in house prices across different neighborhoods, HPM can estimate the absolute and percentage change in house prices related to, for example, reduction in air pollution, improvements in public transit, reduction in crime, improvement in school quality, etc. Comparing the percentage change in house prices in low income neighborhoods to other neighborhoods that arise due to a government permitting a new landfill would allow for identification of distributional effects on low income residents relative to the general population.

More specifically, the HPM uses multiple regression to quantify how house prices fall with proximity to a waste site, source of pollution or adverse land use (e.g., landfill, oil refinery). A variable for distance to the pollution source is one way to measure the effect of pollution on house prices. If minority or low income households are located closer to these pollution sources, the relative adverse effect of the pollution source on house prices would be substantially greater on these nearby houses than would be the effect on houses located further away. For example, if prices of similar size homes in a minority neighborhood

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located a half a mile from the pollution source are 20% lower than house prices in a non-minority neighborhood located two miles away from the pollution source, then one might conclude the environmental costs of this pollution source are disproportionately borne by nearby minority residents. However, on the flip side, a government clean-up program or order to the owner of the pollution source to reduce emissions would provide a disproportionate benefit to minority households, a desirable distributional effect, since minority owned houses would rise in value by 20%.

Like many modeling analyses, this one would require certain assumptions be met for the results to be accurate. First, that most minority households are owners rather than renters, a condition that may not be met. If minorities are renters then any change in residence price accrues to the landowner. However, even in this case, the change in monthly rental rate may provide some indication of the gain from a government clean up program to the renters. Second, to rely upon the marginal implicit prices that are estimated from the simple first stage regression requires that policy being evaluated is not so major that it changes the structure of the housing market. For large non-marginal changes in the housing market, the marginal implicit prices will overstate the value of gains, and understate the value of losses. In addition, there may very well be changes in relative mean incomes in the area (Banzhaf and Walsh, 2008) due to a shifting composition of households as a result of the public or environmental changes in the area brought about the policy.

The strength of HPM is its utilization of actual market data on house prices to infer WTP for improving neighborhood attribute like air quality, public transit, public safety, etc. In order to determine how much of the house price is related to pollution or crime versus the features of the house (e.g., number of bedrooms, bathrooms, lot size) and locational attributes (e.g., distance to work centers, recreation, and schools), a multivariate relationship is specified of the form:

$$(1) \qquad P = \text{func}\ (E, S, N)$$

Where P is the house price, E are the location specific attributes such as distance to amenities like public transit stations or disamenities such as landfills, or refineries or localized pollution concentrations in the area.
S are the house characteristics such as the number of bedrooms and bathrooms.
N are neighborhood social and demographic variables such as percent non-white, income, and education levels. These are typically tied to zip code or Census Tract.

As shown in equation (2) below, it is by interacting the minority variable or income variable with the policy variable of interest (e.g., pollution, public transit) that allows an analyst to determine if there is a differential effect of the policy variable on house prices of low income or minority households. Equation (2) provides an example of such a specification:

(2) Log (Real Sale Amount) = $\beta_0 + \beta_1$*(Distance to Refinery) +
β_2*(Square Feet of House)+ β_3* (Median Household Income)+
β_4*(Distance to Refinery * Median Household Income)
+ β_5* (% Non White) + β_6*(% Non White * Distance to Refinery)
+ …..

From this model, the coefficient β_1 indicates how house prices increase as the distance the house is located from the refinery increases (since pollution would decrease). Whether that house price increase is different for houses located in low income neighborhoods would be tested by whether the interaction term on β_4 is significantly different from zero. The same test on β_6 would indicate whether there is a differential effect on house price increase for minority neighborhoods.

Using the coefficients (the β's) in equation (2) an analyst can calculate the dollar change in house prices related to changes in environmental quality. This dollar change can be standardized into the percentage change in house prices making a relative comparison that adjusts for different house price values of minorities or low income residents relative to the general population.

Thus, HPM provides an economic model that monetizes the distribution of pollution costs or clean up benefits to minority or low income populations in urban areas. While the HPM is typically estimated on residential housing (e.g. single family homes), it has been applied to monthly rental rates paid at rental properties such as apartments.

Example of Hedonic Property Value Analysis of the Effect of Nearby Forest Fires on Hispanic and Low Income Residents Home Prices

House price sales data were collected in the foothills region of Los Angeles including high income areas such as Pasadena and lower income areas such as San Fernando. Both of these areas were near two different, but equivalent size fires. House Sale Amount is hypothesized to be related to:

- Distance the house is from the forest fire (which is treated as our hazard)
- Square footage of the house
- Percent of the Census block that is Hispanic

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- Interaction of percent Hispanic with Distance to the Fire (to test for a differential effect of distance of forest fire on neighborhoods that have a higher percentage of Hispanics)
- Median Household Income of the Census block
- Interaction of Median Household Income with Distance to the Fire (to test for differential effect of distance to forest fire by income)

Three environmental control variables are included:

- Distance to U.S. Forest Service land (i.e., National Forest),
- Distance to City of Los Angeles (the major employment center)
- Elevation above sea level.

Equation 3 provides the multiple regression that is used to estimate the β's:

(3) Ln (House Sale Amount) = $\beta_0 + \beta_1$*(Distance to Fire) + β_2*(House Square Footage) - β_3* (% Hispanic) + β_4*(% Hispanic * Distance to Fire) + β_5* (Median Household Income) + β_6**(** Median Household Income* Distance toFire) +β_7**(** Distance to U.S.F.S. Land) + β_8*(Distance to Los Angeles) + β_9 *(Elevation)

The slope coefficient β_1 is the baseline increase in house price as distance from the forest fire area increases. Statistical differences from the baseline effect of a forest fire on house prices between White and Hispanic neighborhoods are tested by whether β_4 is significantly different from zero using a t-test. The same t-test is employed on β_6 to determine if the effect of a forest fire varies with income.

The R-squared reported in Table 2 indicates the estimated model explains 50% of the variation in house prices in this area of Southern California. The house square footage is statistically significant and of the expected sign (e.g., as house square footage increases, house prices increase). The Hispanic-Distance to Fire interaction term is statistically significant and negative. This suggests that houses prices in neighborhoods with a higher percent Hispanic populations have a significantly ($p<1\%$) different magnitude of response than White neighborhoods to nearby forest fires. The same pattern is evident with respect to low income neighborhoods. That is, the house price response to a nearby forest fire in low income neighborhoods is statistically different ($p<1\%$) than house price response in higher income neighborhoods. To test the sensitivity of this analysis to one of the assumptions listed above with respect to owner versus renter occupied homes, the regression was re-run with percent renter occupied as one of the variables.

This variable was statistically insignificant (p=.1483). Only about 24% of the residences in the study area were occupied by renters, so most of the benefits and costs of fire management is borne by owners of the properties who live there.

Table 2. Relationship between House Prices and Distance to Forest Fires, Hispanics and Income

Dependent Variable: Log House Sale Price, N=7664

Variable	Coefficient	Std. Error	t-Statistic	Probability
Constant	11.50900	0.2183	52.702	0.0000
Log(Distance to Fire)	0.087687	0.0272	3.2165	0.0013
Elevation	-0.00023	1.38E-05	-17.117	0.0000
House Sq Feet	0.00032	5.84E-06	56.057	0.0000
% Hispanics	-0.00347	0.0005	-6.1571	0.0000
%Hisp* Distance to Fire	-5.59E-07	1.97E-07	-2.8404	0.0045
Household Income	4.00E-06	4.22E-07	9.4696	0.0000
Income*Distance to Fire	-5.77E-10	1.31E-10	-4.4156	0.0000
Distance to USFS Land	-1.19E-05	3.73E-06	-3.1979	0.0014
Distance to Los Angeles	-1.63E-06	4.82E-07	-3.3760	0.0007
R-squared	0.508	Mean dependent var		12.38563
Adjusted R-squared	0.507	S.D. dependent var		0.48238
F-statistic	879.500	Prob(F-statistic)		0.00000

However, statistically significant differences between income groups or races are only part of the story. Whether those statistically significant differences are economically significant is equally important. We can convert the coefficients to an absolute change in house price by multiplying the coefficient times mean house price ($239,338 in 1993 prices). Houses in White neighborhoods adjacent to a forest fire are worth $7,884 less than houses a mile away, holding all other factors constant. This is due homebuyers' perceived higher risk of being close to an area with forest fires. However, for predominantly Hispanic neighborhoods adjacent to an area that has experienced a forest fire, the reduction in house price is smaller, at $4,539 less than houses a mile away. Thus forest fires have about half the effect on house prices in a predominately Hispanic neighborhood as that of White neighborhoods. Considering house prices in predominantly Hispanic neighborhoods sell for less ($218,533, as our coefficient on percent Hispanic suggests), the percentage drop in house price next to the fire represents a 2% loss in house price for Hispanic neighborhoods versus 3.3% for White neighborhoods. Expressing this percentage reduction in house price as a percent of income, the loss in house price represents about 9% of income for Hispanic households and about 11% for White households. Similar calculations of the effect on house

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prices for lower income neighborhoods show that low income neighborhoods (those with incomes $20,000 less than our median) would lose $5,212 by being adjacent to a fire versus a mile away. This too is smaller than the drop in house prices of median income neighborhoods.

These hedonic property analysis results can be utilized in two different ways. First, the impact of a Federal government "let it burn" policy that has been applied to naturally started forest fires (e.g., lightning), especially those in Wilderness areas (some of which are adjacent to Wildland Urban Interface areas) would not have serious distributional concerns. Specifically, the absolute and percentage loss in house prices from being adjacent to a forest fire, is about half for minority and low income neighborhoods compared with White and median income neighborhoods. On the flip side, government agency expenditures on forest fire prevention projects that would reduce forest fires adjacent to White and Hispanic neighborhoods would yield larger absolute and percentage gains in value in White neighborhoods than in Hispanic neighborhoods. This might raise distributional concerns depending on how the government forest fire prevention programs were financed. Nonetheless, this example illustrates how the Hedonic Property Method can be used to evaluate the absolute and relative effects of forest fire management decisions on minority and low income households.

IV. Conclusions

Government agencies are increasingly required to address distribution and equity in their economic analysis of projects, policies, and regulations. This paper has presented a wide range of approaches to provide information on the distribution of benefits and costs by displaying the differential effects by income classes, age groups or ethnicity or any other stakeholder group of interest. Quantitative comparisons of the distributional consequences can also be made using a Gini coefficient, so as to formalize comparisons of distributional effects across BCA alternatives. In addition, specific weighting of net benefits can be performed to reflect judgments about relative importance of a dollar's worth of benefits to different income class, ethnicities or any other relevant stakeholder group characteristic. To judge the effects of major policies that affect market goods in multiple markets throughout an economy, simulation models of the economy such as computable general equilibrium models may be necessary. For the case of non-market goods, econometric methods and surveys provide a means to statistically test if non-market benefits such as health or environmental benefits vary by income, gender, age, ethnicity, etc. Contingent valuation surveys which collect demographic data on respondents are a natural way to quantify how benefits and costs vary for each group of interest. This paper illustrated the application of contingent valuation to measure the benefits to different income households by way of an empirical example of the benefits of protecting instream flows in an urban area. The paper also illustrated how a hedonic property model can statistically test for and quantify differential effects of public policies or programs on house prices of minority or low income owners. In the end, BCAs are likely to contribute more relevant information to decision makers, and carry more weight in the ultimate decisions if we extend our BCAs to reflect distributional concerns associated with a project or policy.

References

Alder, M. 2008. Risk Equity: A New Proposal. *Harvard Environmental Law Review* 32: 1-47.

Banzhaf, S. and R. Walsh. 2008. Do People Vote with Their Feet? An Empirical Test of Tiebout's Mechanism. *American Economic Review* 98(3): 843-863.

Berck, P. and S. Hoffmann. 2002. Assessing the Employment Impacts of Environmental and Natural Resource Policy. *Environmental and Resource Economics* 22: 133-156.

Boadway, R. 1976. Integrating Equity and Efficiency in Applied Welfare Economics. *Quarterly Journal of Economics* 90: 541-556.

Boadway, R. and D. Wildasin. 1984. *Public Sector Economics*. Little, Brown and Company. Boston, MA.

Brent, R. 1996. *Applied Cost-Benefit Analysis*. Edward Elgar, Brookfield, VT.

Cornes, R. and T. Sandler. 1996. *The Theory of Externalities, Public Goods and Club Goods*, 2nd ed. Cambridge University Press, NY.

Costa-Font, A. McGuire and T. Stanley. 2009. Health Care as a Luxury: Winner's Curse and Publication Selection Bias. Unpublished manuscript, London School of Economics and Political Science, London, U.K.

Diamond, P. and J. Hausman. 1994. Contingent Valuation: Is Some Number Better than No Number? *Journal of Economic Perspectives* 8(4): 45-64.

Espinosa, A. and V.K. Smith. 1995. Measuring the Environmental Consequences of Trade Policy: A Nonmarket CGE Analysis. *American Journal of Agricultural Economics* 77(3): 772-777.

Farrow, S. Forthcoming. Incorporating Equity in Regulatory and Benefit-Cost Analysis Using Risk Based Preferences. *Risk Analysis*

Fullerton, D. 2009. *Distributional Effects of Environmental and Energy Policy.* Ashgate Publishers.

Graham, J. 2008. Saving Lives Through Administrative Law and Economics. *University of Pennsylvania Law Review 157: 395-538.*

Gramlich, E. 1990. A Guide to Benefit-Cost Analysis. Prentice Hall, Englewood Cliffs, NJ.

Hammitt, J. 2009. Response—Saving Lives: Benefit-Cost Analysis and Distribution. *University of Pennsylvania Law Review 157: 395-538.*

Hanemann, M. 1994. Valuing the Environment Through Contingent Valuation. *Journal of Economic Perspectives* 8(4): 19-43.

Harberger, A. 1984. Basic Needs versus Distributional Weights in Social Benefit Cost Analysis. *Economic Development and Cultural Change* 32(3): 455-474.

Howe, C. 1971. Benefit-Cost Analysis for Water System Planning. Water Resources Monograph 2, American Geophysical Union, Washington DC.

Hughes, G. 1987. The Incidence of Fuel Taxes: A Comparative Study of Three Countries. In D. Newbery and N. Stern (eds). *The Theory of Taxation for Development.* Oxford University Press, New York.

Just, R., D. Hueth, A. Schmitz. 1982. *Applied Welfare Economics and Public Policy.* Prentice-Hall Inc., Englewood Cliffs, NJ.

Krutilla, K. 2005. Using the Kaldor-Hicks Tableau Format for Cost Benefit Analysis and Policy Evaluation. *Journal of Policy Analysis and Management* 24(4): 864-865.

Leuthold, R. 1969. Government Payments and the Distribution of Income in Agriculture. *American Journal of Agricultural Economics* 51(5): 1520-1523.

Long, D., C. Mallar and C. Thornton. 1981. Evaluating the Benefits and Costs of the Job Corps. *Journal of Policy Analysis and Management* 1(1): 55-76.

Loomis, J. 2008. Estimating the Economic Benefits of Maintaining Peak Instream Flows in the Poudre River through Fort Collins, Colorado. Dept. of Agricultural and Resource Economics, Colorado State University, Fort Collins, Colorado.

Loomis, J. and C. Revier. 1988. Measuring Regressivity of Excise Taxes: A Buyers Index. *Public Finance Quarterly*, 16 (3): 301-14.

Loomis, J. and P. duVair. 1993. Evaluating the Effect of Alternative Risk Communication Devices on Willingness to Pay: Results from a Dichotomous Choice Contingent Valuation Experiment. *Land Economics* 69(3): 287-298.

Loomis, J., P. Bell, H. Zita-Cooney and C. Asmus. 2009. A Comparison of Actual and Hypothetical Willingness to Pay of Parents and Non-Parents for Protecting Infant Health: The Case of Nitrates in Drinking Water. *Journal of Agricultural and Applied Economics* (3): 697-712.

Loury, G. 1983. Efficiency and Equity Impacts of Natural Gas Regulation in R. Haveman and J. Margolis (eds). *Public Expenditure and Policy Analysis, 3rd Edition.* Houghton Mifflian, Boston MA.

Portney, P. 1994. The Contingent Valuation Debate: Why Economists Should Care. *Journal of Economic Perspectives* 8(4): 3-17.

Sassone, P. and W. Schaffer. 1978. *Cost-Benefit Analysis: A Handbook.* Academic Press, NY.

Schmitz, A. and T. Schmitz. 2010. Benefit-Cost Analysis: Distributional Considerations under Production Quota Buyouts. *Journal of Benefit-Cost Analysis* 1(1): DOI: 10.2202/2152-2812.1002.

Starrett, D. 1988. *Foundations of Public Economics*, Cambridge University Press, NY.

Stavins, Robert. 1998. What Can We Learn from the Grand Policy Experiment? Lessons from the SO_2 Allowance Trading. *Journal of Economic Perspectives* 12(3): 69-88.

Suits, D. 1977. Measurement of Tax Progressivity. *American Economic Review* 67: 747-752.

Tresch, 1981. *Public Finance: A Normative Theory*. Business Publications, TX

Thompson, M., J.S. Read, M. Liang. 1984. Feasibility of Willingness to Pay Measurement in Chronic Arthritis. *Medical Decision Making* 4(2): 195-215.

U.S. Environmental Protection Agency. 2000. Guidelines for Preparing Economic Analyses. EPA 240-R-00-003, Washington DC.

U.S. Water Resources Council. 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. U.S. Government Printing Office, Washington DC.

Vining, A. and D. Weimer. 2010. An Assessment of Important Issues Concerning the Application of Benefit Cost Analysis to Social Policy. *Journal of Benefit-Cost Analysis* 1(1): DOI: 10.2202/2152-2812.1013.

Zabel, J. 2004. The Demand for Housing Services. *Journal of Housing Economics* 13: 16-35.

Zerbe, Richard Jr. and Dwight Dively 1994. *Benefit-Cost Analysis in Theory and Practice.* Harper Collins. New York.