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Applying the Contingent Valuation Method in Resource Accounting: A Bold Proposal

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Abstract

Resource accounting involves complementing conventional national accounts with changes in environmental and natural resource capital valued in monetary terms. By adopting the Ramsey device of "Bliss", we derive a theoretically consistent environmentally adjusted NDP (Net Domestic Product) measure. The measure indicates sustainable future consumption that an economy can support along the optimal path approaching "Bliss", or "sustainability" determined by national environmental goals. The goals accepted by the Swedish parliament are used to show the applicability of the contingent valuation method to elicit non-market benefits of an economy approaching the sustainability targets. We investigate the compatibility of marginal willingness to pay measures derived on hypothetical markets with market prices used in national accounts. Finally, we raise certain issues of survey design, e.g. to take advantage of the CVM as a democratic device for value estimation over time.

Keywords: *Sustainability goals, Ramsey device, Contingent valuation, Environmental budget, Marginal willingness to pay, Survey design.*

JEL Classification:

D60 **(Welfare economics, general)**

O4 **(Economic growth and aggregate productivity)**

Q26 **(Contingent valuation)**

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1. Introduction

Social accounting attempts to augment the national accounts to obtain an indicator of the nation's economic performance that could be an alternative to the traditional GDP (gross domestic product) measure. The motivation is that GDP is often misinterpreted as a measure of societal welfare. An important part of extending the existing national income and product accounts framework is to integrate environmental aspects into the economic accounts. Hence, the integrated accounts would also provide information about how the economy performs from an environmental point of view and how the economic and environmental policy adopted (green taxes, regulations) affects welfare over time. Quantifiable environmental data would then be comparable to other policy decisions. The interest in monetary environmental accounts is also explained by the fact that many countries consider using economic instruments to a larger extent than before to co-ordinate national and international energy and environmental policy.

In 1993, the London Group on Environmental Accounting was created to provide an informed forum for practitioners to share their experience of developing and implementing environmental satellite accounts linked to the economic accounts of the System of National Accounts (SNA, 1993). A result of this work is the handbook Integrated Environmental and Economic Accounts, "SEEA 2003", currently in press. In principle, SEEA 2003 gives a framework for monetary environmental satellite accounts, linked to the SNA. However, the current experience in large-scale valuation exercises and calculations of environmentally adjusted national account aggregates is very limited. It seems evident that an aggregate such as a "green" Net Domestic Product (NDP) cannot be the ultimate goal of compiling environmental accounts. More specifically, the following excerpt from SEEA 2003, (ch.10, para 10.254) reflects the prevalent consensus among accounting practitioners: "… economic aggregates from the SEEA will be necessarily less precise than those coming from the SNA. Collaboration with users as new versions of the accounts are developed is important to allow external review of the techniques adopted and the quality of the results and also to avoid raising unrealistic expectations among users."

The SEEA handbook discusses alternative methods of valuing environmental degradation, i.e. decline in resource quality rather than quantity, specifically air and water quality. One of the potential monetary valuation methods mentioned is the Contingent Valuation Method (CVM, cf. Mitchell and Carson, 1989 or Bjornstad and Kahn, 1996), which has now been in use for more than 35 years, and more than 2000 papers can be found on this topic (Carson, 2000). In terms of number of publications, CVM is currently the dominating method for nonmarket valuation.

Nevertheless, there is no established agenda for the application of CVM in a green accounting context.The SEEA 2003 handbook states that: "The possibilities of incorporating adjustments for depletion and defensive expenditure into the flow accounts [*using market prices, our note*] are much more promising for a statistical office at this time though even here there may be reservations about proceeding with the work on theoretical or practical grounds. By contrast, it seems that work on degradation will stay mainly in research field for some time" (SEEA 2003, ch.10. para 10.251). Accordingly, it is important to acknowledge the very experimental nature of the suggested application, and that it is only one part of a larger picture of physical and environmental economic accounting. Bearing this reservation in mind, the following requirements for satellite accounts with environmental valuation are crucial for our exercise:

- consistency with accounting principles in terms of valuation methods used and in terms of accounting periods (one year) and coverage (economic territory, domestic economy),
- consistency as far as possible with economic theory or theories,
- availability of the basic data,
- relevance of the results for decision making,
- appropriateness of the results for the environmental issues covered, and
- comprehensiveness in coverage of phenomena and values.

To meet these requirements by using CVM for valuation of environmental effects is not a trivial issue. There are several critical factors associated with contingent valuation in the national accounting context. First, a typical welfare measure derived from CVM studies is a Hicksian consumer surplus measure. However, including these welfare measures as such in environmental satellite accounts would not be consistent with the national accounts that use equilibrium market prices in valuation. Therefore, one should aim at deriving a marginal willingness to pay measure per given emission/environmental unit valued. Second, in national environmental accounts large-scale, multiple goods valuation is required instead of a single product/project valuation. There are at least two potential problems with multiple valuation: sequencing of valuation of environmental goods, and the overall budget constraint for consumption of private goods and environmental commodities. Third, the microeconomic foundations of CVM and green accounting based on welfare theory should be merged in a consistent manner. Finally, an important issue is the comparability of the derived values over time. We discuss and present potential solutions for overcoming these problems. A resulting set of CVM data would then have the following characteristics:

a) a marginal valuation of avoiding environmental degradation,
b) a disaggregation into a vector of marginal values for different types of environmental degradation, and
c) repeated and intertemporally consistent estimates of a) and b).

The purpose of this paper is to derive a theoretical and methodological approach that is amenable to these data requirements.

Standardized guidelines for CVM applications in general were set out by the NOAA (1993) panel. Most of these guidelines apply to a resource accounting application as well. However, in the years that have passed since the work of NOAA, much progress has been made in the field of CVM. In the following sections, we will review the welfare economic basis for contingent value estimation, as well as relevant theoretical and methodological developments. In addition, we will try to meet the challenge to match CVM with the welfare economic analysis of green accounting developed during the recent years. The theoretical foundations of this type of 'extended' welfare accounting have been actively discussed in the academic green accounting literature, by e.g., Weitzman (1976), Solow (1986), Hartwick (1990), Mäler (1991), Dasgupta *et al.* (1994), Asheim (1997), and Aronsson and Löfgren (1999).

The paper is structured as follows. Section 2 presents a theoretical framework for comprehensive national accounting that is applied in the empirical valuation experiment. With the help of the dynamic model, it is shown that environmentally adjusted NDP is a welfare index for sustainable future consumption. Section 3 addresses welfare theoretical foundations of contingent valuation. A measure of a representative consumer's marginal willingness to pay for an environmental good, comparable with market prices used in the national accounts, is derived. Section 4 discusses policy relevant environmental objects to be used in an empirical CVM application, survey design and certain methodological issues. Section 5 contains a discussion and concluding remarks.

2. The Resource Accounting Framework for the CVM Application

Comprehensive resource accounting should involve estimation of a value for production of environmental goods during an accounting period (normally a year). We therefore need a theoretical framework for carrying out the environmental accounting in a consistent way. Our approach follows the logic presented initially in Weitzman (1976), followed by Hartwick (1990) and Mäler (1991). The purpose of building a dynamic, optimal control model is to have a transparent framework which gives guidelines for separating different kinds of externalities (flows/stocks) to treat them in a correct way in annual accounts. Double counting is another concern, which can also be avoided if monetary environmental adjustments are based on a consistent model.

The whole accounting system relies upon the utility function, which has some specific features and components that are worth commenting. We start out from the assumption that society has decided on certain environmental goals that should be reached within a specified time frame. Moreover, we assume that these goals can be quantified in terms of various pollutants and the level of biodiversity in a country. These assumptions will be given an empirical motivation in section 4. From the point of view of the present analysis, such environmental goals can be viewed as a type of quantity index for environmental quality. Consequently, an individual consumer should arrive at the same solution irrespective of whether the utility maximization problem is solved with respect to the vector of all environmental problems in a country, or with respect to the environmental goals as an index good. We may think of such an aggregation as a two-stage budgeting process, where the consumption decision is first made with respect to the total environmental quality in a country, and then with respect to the subcomponents of total environmental quality. This is the case if the overall utility function is weakly separable and the subutility functions are homothetic. Homothetic preferences are also sufficient for aggregating demands in the sense of the representative consumer model (Varian, 1992; Boadway and Bruce, 1993).

We further hypothesize that the subcomponents of the overall utility function are selected to be independent in consumption, implying that the overall utility function is additively separable (Hoehn, 1991). A necessary and sufficient condition for additive (i.e. strong) separability is that the marginal rate of substitution between two goods, contained in two different subutility groups, is independent of the quantity of any other good contained in any other group than the two under consideration (Boadway and Bruce, 1993). Hoehn (1991) shows that environmental goods that are additively separable in utility are substitutes in valuation.[i] This occurs e.g. when consumption is spatially separated. For the whole economy, let us denote the utility of consumption, C, by $U(C)$, disutility function for the vector of emissions and concentration of pollutants, $\boldsymbol{E}$, by $\alpha(\boldsymbol{E})$, the utility function for preservation of biodiversity, P, by $\beta(P)$, and the utility function for the composite vector of remaining (not including pollutants and biodiversity) environmental and natural resource goods and services by $v(\boldsymbol{R}^{-}(t))$. The set of all environmental goal objects is implicitly defined as $\boldsymbol{R} = \{\boldsymbol{R}^{-}, \boldsymbol{E}, P\}$. The separability assumption then implies that e.g. the utility of biodiversity is unaffected by changes in the disutility of emissions and vice versa.

Another issue regarding our utility function is that we assume that the economy approaches indefinitely the sustainability goals approved by the government. Accordingly, to formulate our objective function we adopt the Ramsey device of "…the maximum obtainable rate of enjoyment or utility…", or "Bliss" (Ramsey, 1928, p. 545), denoted B. Thus, $[B - U(C(t)) - v(\boldsymbol{R}^{-}(t)) + \alpha(\boldsymbol{E}(t)) - \beta(P(t))]$ represents the amount by which utility falls short of Bliss or sustainability, and this should be minimized. To formulate our problem as maximization of utility, which is integrated throughout time, we write

$$\max \int_0^\infty [U(C(t)) + v(\boldsymbol{R}^{-}(t)) - \alpha(\boldsymbol{E}(t)) + \beta(P(t)) - B]dt$$

subject to $\dot{K} = f(K(t), \boldsymbol{E}(t)) - C(t) - h(\boldsymbol{R}^{-}(t)) - g(P(t)) - \delta K(t)$

$K(0) = K_0$

$0 \le C(t) \le f(K(t), \boldsymbol{E}(t))$

where $\boldsymbol{E}$ = emission/concentration of pollutants (tons or micrograms/m^3)

P = land area reserved for biodiversity purposes (hectares); crowds out investments in man-made capital, $g(P)$

$\boldsymbol{R}^{-}$ = composite vector containing the complement set of environmental and natural resource goods and services, not including $\boldsymbol{E}$ and P; crowds out investments in man-made capital, $h(\boldsymbol{R}^{-})$

δ = depreciation rate of capital stock

K = stock of man-made capital

K_0 = initial level of capital (given) and $U_C>0,\ \nu_{\boldsymbol{R}^-}>0,\ \alpha_{\boldsymbol{E}}>0,\ \beta_P>0, f_K>0, f_{\boldsymbol{E}}>0,\ h_{\boldsymbol{R}^-}>0,\ g_P>0$

The production factor ***E***, emissions, could be interpreted in terms of the use of energy and other emission-generating substances. The generated emissions contribute to the concentration of pollution in different media (air, soil, water) in various degrees, dependent on the pollutant and the media. For simplicity, the specific links between emissions and concentrations are disregarded.

The current value Hamiltonian is

$$\begin{aligned} H(t) &= U(C(t)) + \nu(\boldsymbol{R}^-(t)) - \alpha(\boldsymbol{E}(t)) + \beta(P(t)) - B + \\ &+ \lambda(t)[f(K(t),\boldsymbol{E}(t)) - C(t) - h(\boldsymbol{R}^-(t)) - g(P(t)) - \delta K(t)] \end{aligned} \tag{1}$$

We derive the necessary conditions for the optimization of this problem to interpret the marginal utility of consumption with respect to the environmental goods.

$$\partial H(t)/\partial C(t) = U_C - \lambda(t) = 0 \tag{2}$$

$$\partial H(t)/\partial \boldsymbol{R}^-(t) = \nu_{\boldsymbol{R}^-} - \lambda(t) h_{\boldsymbol{R}^-} = 0 \tag{3}$$

$$\partial H(t)/\partial \boldsymbol{E}(t) = -\alpha_{\boldsymbol{E}} + \lambda(t) f_{\boldsymbol{E}} = 0 \tag{4}$$

$$\partial H(t)/\partial P(t) = \beta_P - \lambda(t) g_P = 0 \tag{5}$$

$$\dot{\lambda}(t) = -\lambda(t)(f_k - \delta) = \lambda(t)(\delta - f_k) \tag{6}$$

$$\lim_{t\to\infty} k(t) = \hat{k} \tag{7}$$

Hence, the marginal utility of consumption, U_C, equals the shadow price of capital, $\lambda(t)$. In addition, the marginal disutility of emissions, $\alpha_{\boldsymbol{E}}/f_{\boldsymbol{E}}$, the marginal utility of preserving an additional unit of biodiversity, β_P/g_P, and the marginal utility of preserving an additional unit of composite environmental and natural resource goods and services, $\nu_{\boldsymbol{R}^-}/h_{\boldsymbol{R}^-}$, must equal the marginal utility of consumption.

By linearizing the Hamiltonian (suppressing *t*) and dividing through by the marginal utility of consumption, U_C, we have

$$H^* = H / U_C = C + \dot{K} + (\nu_{\boldsymbol{R}^-} / U_C)\boldsymbol{R}^- - (\alpha_{\boldsymbol{E}} / U_C)\boldsymbol{E} + (\beta_P / U_C)P - \hat{C} \tag{8}$$

Note that $C = U(C)/U_C = U_C C / U_C$ and $\hat{C} = B / U_C$. If we now apply the transversality condition *H(t)*=0, we can readily derive the optimal income in consumption units for the economy:

$$\hat{C} = C + \dot{K} + (\nu_{\boldsymbol{R}^-} / U_C)\boldsymbol{R}^- - (\alpha_{\boldsymbol{E}} / U_C)\boldsymbol{E} + (\beta_P / U_C)P \tag{9}$$

and by using the first order conditions equation (9) can be rewritten as

$$\hat{C} = C + \dot{K} + h_{\boldsymbol{R}^-}\boldsymbol{R}^- - f_{\boldsymbol{E}}\boldsymbol{E} + g_P P \tag{10}$$

The first two terms on the right-hand side of equation (10) correspond to conventional NDP. To adjust the NDP so that it corresponds to the optimal level of income of the economy, the value of increased biodiversity and other increases in environmental and natural resources should be added to, and the value of harmful pollution *flows* generated during an accounting year should be subtracted from, consumption and investment. Essentially, equation (10) is a reformulation of the Keynes-Ramsey rule for dynamic efficiency (Ramsey, 1928), yielding an NDP measure that equalizes the marginal cost of quicker convergence to Bliss to the marginal benefit of doing so. These are logical adjustments since the goal of the economy is to reach the sustainability goals for biodiversity, emissions, and other environmental and natural resources. Ceteris paribus, as Bliss is approached, $h_{\boldsymbol{R}^-} \to 0$, $f_{\boldsymbol{E}} \to 0$, and $g_P \to 0$, since the marginal utility of further environmental improvements will approach zero. Moreover, $\dot{K} \to 0$ as all output is consumed at Bliss, and $C \to \hat{C}$. In general, NDP will approach current consumption as Bliss is approached. More specifically, equation (10) will approach conventional NDP as the sustainability targets are approached.

Using equation (10), we have a tool to compare conventional NDP with the optimal income of an economy approaching the sustainability goals. There are several methods for how the suggested adjustments in NDP can be done in monetary terms. We need information on conventional NDP, but also information on the shape of the utility function stipulated in the previous maximization problem. This function is not directly observable, and we therefore need a money measure to evaluate the marginal changes in utility given by equation (10). Since we use the contingent valuation method we in fact derive estimates of marginal willingness to pay (MWTP) for approaching the sustainability goals for the state of the environment. In the next section, we show how a representative consumer maximizes utility such that at the aggregate level equation (9) holds. This means, in essence, that $(\nu_{\boldsymbol{R}^-}/U_C)\boldsymbol{R}^- - (\alpha_{\boldsymbol{E}}/U_C)\boldsymbol{E} + (\beta_P/U_C)P$ is the annual utility in consumption units for approaching the sustainability goals, and that $-(\alpha_{\boldsymbol{E}}/U_C)$ is the marginal utility measured in consumption units for reducing a ton or a microgram/m^3 of emissions, and β_P/U_C is the marginal utility measured in consumption units for preserving a hectare of land for biodiversity.

3. Theoretical Implications for Contingent Valuation

The CVM was originally developed for, and is mostly applied in, settings that differ significantly from the needs of resource accounting. More specifically, the typical CVM scenario is a one-shot measurement of the monetary value of a single marginal environmental project. That is, the study is performed only once, even though the willingness to pay (WTP) question may involve annual payments, so that the discounted stream of benefits from the project can be calculated. In addition, the assessed project is normally small, in order to avoid general equilibrium effects. Moreover, the typical CVM study only assesses one single environmental project, e.g. the value of improved water quality (Whitehead, Haab and Huang, 1998).

This section will address the microeconomic theory underlying CVM, specifically aspects relevant to the resource accounting requirements. In order to obtain an equivalent to a market price it is necessary to have information about demand for, and supply of, the environmental good. A CVM study can contribute with information about the demand side for supply levels of interest. Assuming that the environmental good is a pure public good, the compensated (Hicksian) demand can be estimated by asking WTP or willingness to accept (WTA) compensation questions for a particular change in the supply of the good. CVM researchers are generally interested in a Hicksian measure, because the Marshallian consumer surplus of a specified change in utility will vary depending on the path chosen to adjust quantities or prices. There is no such path-dependency problem when employing the Hicksian demand concept. WTA measures are appealing in the sense that the implied property rights are assigned to the consumers of environmental quality, which is consistent with e.g. the Polluter Pays Principle. Nevertheless, respondents are not constrained by their budget when answering WTA questions. The resulting welfare measures can therefore be very large. WTA measures are thus not compatible with the monetary measures used in standard national accounts, i.e. market prices that have arisen from a demand that is restricted by income. Consequently, a WTP measure is more appropriate.

The WTP measure can be either of the compensating variation (*CV*) or equivalent variation (*EV*) type (Johansson, 1993). The choice depends on whether we are interested in WTP for an environmental improvement or WTP for avoidance of an environmental deterioration. We are interested in the latter, as it allows us to evaluate deteriorations in environmental quality relative to a path (e.g. a policy plan) approaching Bliss, which we will henceforth denote the "Bliss path". The reference level of utility (the Bliss path) does not change between accounting years, as would e.g. the utility from the "current" environmental quality. Using the Bliss path as reference utility level therefore allows for welfare comparisons between accounting years, through repeated surveys.

Assume now that society is on a sustainable Bliss (denoted by hats) path approaching the environmental goals, but there is some alternative nonsustainable path *i* (*i*=1,…,n), where *i* represents environmental deterioration. In principle, the macro model in section 2 can be interpreted at micro level as a consumer *j* comparing the direct utility difference between the following two paths (time, socioeconomic, and attitude variables are suppressed):

$$\Delta u = u^1\left(\hat{x}^j\right) + u^2\left(\hat{\boldsymbol{R}}^-\right) - u^3\left(\hat{\boldsymbol{E}}\right) + u^4\left(\hat{P}\right) - u^1\left(x_i^j\right) - u^2\left(\boldsymbol{R}_i^-\right) + u^3\left(\boldsymbol{E}_i\right) - u^4\left(P_i\right) \qquad (11)$$

In analogy with section 2, x is a consumption good, $\boldsymbol{E}$ denotes the vector of emissions/concentrations of all pollutants, P denotes biodiversity in terms of protected hectares of land, and $\boldsymbol{R}^-$ denotes the composite vector of "remaining" environmental goal objects. The level of x is determined by the individual consumer, and since there is only one single consumption good the budget constraint of the individual is given $\hat{y}^j = p\hat{x}^j$ and $y^j = px^j$, respectively (y is disposable income less savings and p is the fixed real price of the consumption good, see discussion below). Therefore, aggregate consumption expenditure, or consumption, in the economy is $\hat{C} = p\sum_{\forall j}\hat{x}^j = \sum_{\forall j}\hat{y}^j$ and $C = p\sum_{\forall j}x^j = \sum_{\forall j}y^j$. For convenience, the superscript j is omitted in the following. By assumption, the levels of $\boldsymbol{E}$, P, and $\boldsymbol{R}^-$ are the same for all individuals j.

Since direct utility is not observable, we need a monetary measure to evaluate the change in utility. We have previously assumed that the subutility functions are homothetic. A commonly used functional form satisfying these conditions is a linear utility function (Hanemann, 1984), which is in correspondence with the linearization in equation (8):

$$\Delta u = a\hat{x} + \boldsymbol{b}\hat{\boldsymbol{R}}^- - \boldsymbol{c}\hat{\boldsymbol{E}} + d\hat{P} - ax_i - \boldsymbol{b}\boldsymbol{R}_i^- + \boldsymbol{c}\boldsymbol{E}_i - dP_i \qquad (12)$$

The parameters (or vectors of parameters) a $\boldsymbol{b}$ $\boldsymbol{c}$ and d represent the marginal utility of each of the arguments in the utility function. The budget constraint of the consumer can be rewritten as $x = \frac{y}{p}$ and $\hat{x} = \frac{\hat{y}}{p}$, which allows us to express (12) in indirect utility terms, v:

$$\Delta v = a\frac{\hat{y}}{p} + \boldsymbol{b}\hat{\boldsymbol{R}}^- - \boldsymbol{c}\hat{\boldsymbol{E}} + d\hat{P} - a\frac{y}{p} - \boldsymbol{b}\boldsymbol{R}_i^- + \boldsymbol{c}\boldsymbol{E}_i - dP_i \qquad (13)$$

The utility function is not directly observable, and we therefore use the EV measure to evaluate this utility change. We want to measure the value to avoid environmental deteriorations, relative to the Bliss path:

$$a\frac{y - \hat{EV}}{p} + \boldsymbol{b}\hat{\boldsymbol{R}}^- - \boldsymbol{c}\hat{\boldsymbol{E}} + d\hat{P} = a\frac{y}{p} + \boldsymbol{b}\boldsymbol{R}_i^- - \boldsymbol{c}\boldsymbol{E}_i + dP_i \qquad (14)$$

Rearranging, we can solve for $\hat{EV}$ to avoid deviations from the Bliss path and obtain:

$$\hat{EV} = \frac{p\boldsymbol{b}\left(\hat{\boldsymbol{R}}^- - \boldsymbol{R}_i^-\right)}{a} - \frac{p\boldsymbol{c}\left(\hat{\boldsymbol{E}} - \boldsymbol{E}_i\right)}{a} + \frac{pd\left(\hat{P} - P_i\right)}{a} \qquad (15)$$

On the individual consumer level, equation (14) corresponds to equation (9). By assumption, we have initially endowed the consumer with the Bliss path level of environmental and natural resources. Therefore, the adjustments in NDP indicated by equation (9) should be measured in terms of deviations from the Bliss levels of $\boldsymbol{E}$, P, and $\boldsymbol{R}^{-}$, as indicated by equation (15) . The components $\frac{p\boldsymbol{b}}{a}, \frac{p\boldsymbol{c}}{a}, \frac{pd}{a}$ essentially convey the result by Mäler (1974), that the marginal willingness to pay (MWTP) for an environmental good can be expressed in terms of the price of any private good and the marginal utilities of that good and the environmental good. Exemplifying with biodiversity we have (Freeman, 1993):

$$MWTP_P = p\left(-\frac{\partial u / \partial P}{\partial u / \partial x}\right) \tag{16}$$

This corresponds to $\frac{pd}{a}$, since d is the marginal utility of biodiversity and a is the marginal utility of the private composite good. The price p is in the context of satellite accounts fixed, and determined by the price vector used in the national accounts during the year. Therefore, we can use, e.g., the consumer price index to compare WTP estimates obtained during different accounting years. If during each successive year t the economy is moving towards Bliss according to some policy plan, the estimate given by (16) each year can be interpreted as a Lindahl price for the public good in question (Varian, 1992). Equation (16) can also be viewed as an inverse demand curve based on Roy's identity (Kolstad and Braden, 1992). In the current setting, equation (16) is a Hicksian (compensated) demand concept, because income is adjusted to keep utility constant across the changes in P (Varian, 1992). Moreover, the marginal utility of income is a/p (cf. equation (13)) across all changes. MWTP is a counterpart to the market prices used in standard national accounts. It corresponds to what is sometimes referred to as a "virtual price" for the public good (Carson, Flores and Hanemann, 1998). In this light, we see that (15) essentially gives the expenditure on environmental goods as a function of virtual prices and quantity change. As is clear from equation (14), the price of the composite private good only determines the expenditure on environmental goods. Accordingly, the additive utility function allows for a two stage budgeting process, given by equations (14) and (15). In the first stage (14), the consumer determines his/her EV WTP to avoid a deviation from the policy plan (Bliss path) approaching Bliss, i.e. "achievement of the national environmental goals". This would give a total environmental "budget" each year that could be compared between accounting years, irrespective of whether specific environmental goods (or goals) are included or deleted from the valuation task in the future. In the second stage (15), the consumer allocates budget shares to each of the specific environmental problems. These budget shares are then determined by the respective parts in the sum (15). The WTP to avoid deviations from the Bliss path to level *i* for specific environmental problems, denoted ***ev*** or *ev*, are given by:

$$\hat{EV} = ev_i^{\boldsymbol{R}^-} + \boldsymbol{ev}_i^{\boldsymbol{E}} + ev_i^P \qquad (17)$$

If we know the budget share for a specific environmental problem, we can calculate the value of an environmental change from, say, i=1 to i=2. Exemplifying again with biodiversity:

$$\Delta ev^P = ev_2^P - ev_1^P = \frac{pd\left(\hat{P} - P_2\right)}{a} - \frac{pd\left(\hat{P} - P_1\right)}{a} = \frac{pd\left(P_1 - P_2\right)}{a} \qquad (18)$$

so that

$$MWTP_P = \frac{pd}{a} = \frac{\left(ev_2^P - ev_1^P\right)}{\left(P_1 - P_2\right)} \qquad (19)$$

The MWTP can be discretely approximated between two levels of supply by calculating the quota on the right hand side of (19). Alternatively, a WTP function can be estimated econometrically based on the model:

$$ev_i^P = \frac{pd\left(\hat{P} - P_i\right)}{a} = \frac{pd\hat{P}}{a} - \frac{pdP_i}{a} \qquad (20)$$

where $\frac{pd\hat{P}}{a}$ is a constant term.

Summing $\hat{EV}, ev_i^{\boldsymbol{R}^-}, \boldsymbol{ev}_i^{\boldsymbol{E}}, ev_i^P$, or $\frac{pd}{a}$, $\frac{(ev_2^P - ev_1^P)}{(P_1 - P_2)}$ across all individuals we obtain the aggregate WTP or MWTP estimates for a representative consumer (assuming a utilitarian welfare function; Johansson, 1993).

The correctness of the Hicksian demand concept outlined above hinges on prices and income remaining unaffected throughout the changes, and that the environmental objects are of a pure public good nature. If not, the effect of environmental changes on the utility of the household is also dependent on the effect of changes in prices and income. For environmental satellite accounting purposes, this contingent scenario is realistic. In this setting, respondents are assumed to reveal their *ex post* annual WTP to have obtained the environmental change in question during the year, conditional on the prices and incomes (and taxes) that were prevailing during that year. This is due to environmental accounts being satellites to standard national accounts, which employ prevailing market prices and income. Thus, any deviation from standard national accounts with respect to prices and income would render the WTP estimates incompatible with those accounts, and possibly also result in double-counting errors. Hence, we can derive the marginal values of environmental goods at different levels of provision for a specific accounting year. These values are the closest possible estimates comparable to market prices[ii].

Indeed, Backlund (2000) shows that a static MWTP measure of the type suggested here is useful for constructing a welfare indicator, especially when environmental quality is linear with respect to the stock of environmental "bads". The necessary information is how a consumer values a marginal reduction of environmental "bads" at time *t*. The static approximation is then revised repeatedly as new MWTP information becomes available. Backlund (2000) also shows that the MWTP measure should be revised more frequently if environmental quality is nonlinear with respect to the stock of environmental "bads".

4. Methodological Aspects on an Empirical Application

Next, the problem is what environmental goods should be included empirically and how they should be handled in the survey framework. The answer to this question is far from straightforward. For instance, in Sweden 15 very broadly defined national environmental goals have been stipulated.[iii] These goals should be reached by the year 2020 (Naturvårdsverket, 2000). Within these goals, at least 60 environmental public good "dimensions" can be identified. Valuing all these dimensions would be an enormous task. Some authors argue that one should not even try to value a large number of environmental goods in the same survey instrument, since the description of each good will by necessity become too brief for respondents to properly understand (Carson and Mitchell, 1995). Therefore, some sort of aggregation is necessary in order to reach a "manageable" number of environmental goods.

4.1. Valuation objects

In selection of environmental goods to be valued we have used the SEEA criteria as our guideline. To start from the relevance of the results for decision making, a list of environmental issues targeted in the 15 national goals can be cut down considerably by the limitation of availability of the basic physical data. Our focus will evidently be on those phenomena that can be measured in physical terms (such as pollutants and emissions in tons/micrograms per year). Therefore, our proposal covers achievement of the environmental goals in general, with special focus on:

- Climate change (emissions of CO_2 in tons)
- Acidification (emissions of SO_2 and NO_x in tons)
- Urban air quality (average concentrations of NO_2, soot, benzene, toluene and particles in microgram/m^3)
- Nutrification (emissions of N in tons)
- Biodiversity (hectares of protected forestland).

On behalf of the Swedish government, the Environmental Advisory Council has chosen these five objects as green indicators for Sweden with respect to emission levels and the state of the environment (Anon, 1999). These indicators "…are intended to reflect major environmental problems" and "…are intended to provide decision-makers and the public with readily comprehensible information." (Skr, 1999, p. 8). Even though the number of our valuation objects do not cover all possible relevant environmental issues in Sweden, we think that our subsample is not only manageable but also comprehensive in coverage of phenomena and values so that the CVM can be tested in an accounting context. In addition, the results for the environmental issues covered should be appropriate in the sense that about 20 national Swedish regulatory agencies and authorities have issued their first reports on how they intend to achieve the 15 overarching environmental goals adopted. General policies and concrete policy measures to meet the targets set up for environmental policy, including economic instruments, are currently planned and discussed actively both nationally and internationally. Thus, there is a policy relevant basis for formulation of CVM scenarios and WTP measurement with respect to the Bliss path and alternative future paths for environmental quality in Sweden. In the following we consider an empirical approach for measuring WTP as described in the theoretical sections.

4.2. Survey context

Firstly, as our application involves national environmental goals for Sweden, we are interested in a representative nationwide sample. This can be obtained through official Swedish registers. In the following sections we describe the general layout of the survey instrument, as it reflects our various considerations during the survey development process.

We are interested in estimating an "environmental budget" and marginal values for the five environmental objects previously mentioned (cf. equation (15)). Focus groups and a test survey revealed that a comprehensive survey including all five problems would be too demanding for the respondent to answer. Therefore, the survey is divided into several versions. Since we have five specific valuation objects, and three levels of change for each environmental object, we propose fifteen survey versions in total. All versions contain a question on WTP to achieve all 15 environmental goals. This is then interpreted as aggregate WTP to avoid deteriorations from the Bliss path (i.e. $\hat{EV}$). Each version would then contain a detailed description of one environmental problem (i.e. either of climate change, acidification, urban air quality, nutrification, or biodiversity) at one level of change. The respondent would be asked how much of his/her aggregate WTP for the environmental goals that should be allocated to the specific change. Furthermore, there would be one "rating" version of the survey, where the respondent is asked to allocate 100 "points" to all five problems depending on their relative importance. In this version, no detailed information would be given about the valuation objects, and no specific environmental changes are suggested. Consequently, the "rating" version would measure WTP to avoid deviations from the Bliss path for all five problems, evaluated simultaneously by the respondent.

Recalling that $\boldsymbol{R}$ is the universal set of all 15 environmental goal objects, we introduce the subscript l for climate change (l=1), acidification (l=2), urban air quality (l=3), and nutrification (l=4), respectively. For the three different levels of change relative to the Bliss path (i=1, 2, 3), the following information would then be obtainable from the individual respondent for the biodiversity survey version:

$$\hat{EV} = ev_i^{\boldsymbol{R}_P^-} + ev_i^P \qquad (21)$$

where $\boldsymbol{R}_P^- = \widetilde{P}$, and $\boldsymbol{R} = \{\boldsymbol{R}_P^-, P\}$.

For the climate change, acidification, urban air quality, and nutrification survey versions we have:

$$\hat{EV} = ev_i^{\boldsymbol{R}_l^-} + ev_i^{E_l} \qquad (22)$$

where $\boldsymbol{R}_l^- = \widetilde{E}_l$, and $\boldsymbol{R} = \{\boldsymbol{R}_l^-, E_l\}$.

Equation (21) or (22) then gives the aggregate WTP of the individual respondent for the Bliss path (environmental budget), and WTP to avoid deterioration from Bliss to i for valuation object P_i or E_l. All "other" valuation objects are included in $\boldsymbol{R}^-$, and WTP for them is implicitly given by $ev_i^{\boldsymbol{R}_P^-}$ or $ev_i^{\boldsymbol{R}_l^-}$. Using the approaches indicated by equation (19) or (20), MWTP can be estimated for a specific valuation object, based on WTP information for all three levels i.

Finally, for the rating version, the following information would be obtainable:

$$\hat{EV} = ev^{\boldsymbol{R}_{E,P}^-} + \boldsymbol{ev}^{\boldsymbol{E}} + ev^P \qquad (23)$$

where $\boldsymbol{R} = \{\boldsymbol{R}_{E,P}^-, \boldsymbol{E}, P\}$.

i.e. WTP for the Bliss path (environmental budget), and budget shares for all valuation object to avoid deterioration from Bliss. However, no MWTP estimates can be obtained from this survey version.

Equations (21)-(23) allows estimation of the different parts of equations (15) and (17). Furthermore, it gives an opportunity to test the effects on WTP from different framings of the valuation package. The information for the valuation task in the survey would be based on available Swedish policy information regarding the national environmental goals (SOU 2000:52), and thorough review by experts at e.g. the Swedish Environmental Protection Agency and the Swedish University of Agricultural Sciences. The reference utility (Bliss) level is set at a level above the environmental goals, meaning that it will not be reached in the near future, ensuring the possibility of repeated surveys using the same reference level. The lower levels would correspond to the national environmental goals, and two alternative levels. Each scenario would be formulated as a ten-year project, as this is the current first planning period for the national environmental goals in Sweden.

For the sake of completeness, we will briefly touch upon relevant extensions of the presented research, related specifically to CVM.

4.3. Further issues in a CVM application

The standard guidelines for a CVM scenario are: theoretically accurate, policy relevant, plausible, understandable and meaningful (Carson, 1992). One important aspect of a plausible scenario involves the inherent hypothetical nature of CVM surveys, i.e. that respondents are not faced with an actual monetary transaction when answering WTP questions. The debate has revolved around the question whether estimates based on such stated (hypothetical) choices correspond to actual choices (NOAA, 1993). In various empirical investigations, some authors have found substantial differences between actual and hypothetical valuation (e.g. Bishop and Heberlein, 1979; Bohm, 1994; Cummings, Harrison and Rutström, 1995; Seip and Strand, 1992), while others have not (e.g. Carson *et al.*, 1996; Smith and Mansfield, 1998). When detected, several arguments have been put forward to explain this seemingly unexpected difference, e.g. strategic behaviour (Bohm, 1994) or uncertainty (Bishop, Heberlein and Kealy, 1983). Moreover, the disparity between responses to hypothetical and actual WTP questions has in some situations been found to be systematic and predictable (Blackburn, Harrison and Rutström, 1994). [iv]

In our view, the solution to this problem lies in explicitly addressing issues such as question format, preference uncertainty, existing behavioral models, and respondent experience, when developing the survey instrument.

As pointed out in the introductory section, an important feature of the present CVM application is that it would be repeatable over time. Depending on the nature of the environmental goods to be valued, the relevant time interval between surveys may vary. Whitehead and Hoban (1999) develop a conceptual economic model based on behavioural intentions, explaining how WTP may be expected to vary over time in a reliable CVM survey instrument. They model WTP as a function of i.) individually perceived environmental quality, which in turn is a function of government policy towards the environment, attitudes (being influenced by demographic variables and time), and objective (i.e. actual) environmental quality, ii.) the utility level of the consumer, and iii.) time. If the underlying factors affecting WTP have not undergone significant changes between two surveys, a reliable CVM instrument should not exhibit significantly different WTP values between the two measurements. The reverse holds if any of the factors affecting WTP have changed over time. Obviously, it is then important to consider these factors, to establish whether the survey instrument is temporally reliable[v]. Thus, the first full-scale survey can still only be regarded as a pilot survey in a temporal context, since the temporal reliability of the survey instrument can only be assessed after the lapse of one or a few years. After repeating the survey, revisions of the survey instrument may prove necessary.

5. Conclusions

In this paper, we have developed a model for environmental accounting that can be applied in contingent valuation in a policy relevant manner.

The theoretical framework for our environmentally partially adjusted NDP indicates that we can interpret the measure derived as the sustainable future income that an economy can enjoy along the optimal path. This result is shown without the restrictive assumption of a constant discount rate. The key to this is that we adopt the Ramsey device of writing the objective function, or the integrand, as the deviation from “Bliss”, or sustainability. For an empirical analysis, sustainability is determined by national environmental goals.

It is shown that the CVM framework can be formulated as an equivalent variation WTP measure to avoid deviations from Bliss. This “environmental budget” can then be subdivided to different environmental objects, using a two-stage budgeting process. By obtaining information regarding different levels of environmental change, marginal WTP may be estimated. Such a “virtual price” could, in turn, be used for green accounting purposes.

The next step would then be an integration of the model presented here into a state-of the-art CVM application. This would account for issues such as question format, preference uncertainty, behavioral models, and respondent experience. Most importantly, it would involve a temporally reliable survey instrument. Pilot work on such applications is currently carried out by researchers at the National Institute of Economic Research and the Swedish University of Agricultural Sciences.

The values derived through the suggested survey instrument are, as always, contingent on the scenario. It should therefore always be borne in mind that the use of these data out of context is ultimately an arbitrary procedure. In particular, we believe that the resulting CVM data should be used to calculate a separate adjusted NDP measure, and not be mixed with e.g. results derived by using other valuation methods. This is logical, as we apply CVM because we question whether other techniques adequately reflect the full economic value of the resources of interest.

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Notes

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[i] However, without strong separability, environmental goods could be substitutes, complements or independent in valuation. For qualitative and empirical results regarding the substitution between environmental goods, see e.g. Hoehn and Loomis (1993); Carson, Flores and Hanemann (1998); Brown *et al*. (1995); Neill (1995). Based on these studies, some conclusions can be drawn regarding a type of scope effect that is referred to as the embedding effect by Kahneman and Knetsch (1992), i.e. that WTP for a good may vary considerably depending on whether the good is valued on its own or as a part of a package:
- If all public goods in a package are context independent, the sum of *ceteris paribus* independent valuations of these goods should *equal* the sum of the valuations when all goods are valued sequentially in a package.
- If all public goods are Hicksian substitutes, the sum of *ceteris paribus* independent valuations of these goods should *exceed* the sum of the valuations when all goods are valued sequentially in a package.
- If there are only two public goods, both of which are Hicksian complements, the sum of *ceteris paribus* independent valuations of these goods should *fall short of* the sum of the valuations of these two goods when they are valued sequentially in a package.
- If there are more than two public goods, all of which are Hicksian complements, the sum of *ceteris paribus* independent valuations of these goods could *exceed or fall short of* the sum of the valuations when all goods are valued sequentially in a package.
This underscores the importance not only of finding a policy relevant valuation package, but also of identifying the policy relevant valuation sequence.

[ii] However, for different accounting years, income changes (in terms of changes in lump-sum income, profit changes, and tax changes) should be added to the WTP measure to obtain social profitability (Johansson, 1993).

[iii] Sweden's 15 environmental goals are: clean air, high quality groundwater, sustainable lakes and watercourses, flourishing wetlands, a balanced marine environment and sustainable coastal areas and archipelagos, no eutrophication, natural acidification only, sustainable forests, a varied agricultural landscape, a magnificent mountain environment, a good urban environment, a non-toxic environment, a safe radiation environment, a protective ozone layer, and limited influence on climate change.

[iv] It should be noted that this difference is by no means restricted to WTP questions. O'Conor, Johanesson and Johansson (1999) observe a corresponding pattern, when asking respondents to perform the comparatively simple task of estimating how many kilometers they expect to travel by car during the next 12-month period. Green *et al.* (1998) arrive at similar results when asking respondents to estimate the height of the tallest redwood in California and the monthly gasoline consumption by an average US car owner.

[v] Several CVM studies have shown temporal reliability of WTP estimates over time periods ranging from two weeks to five years, e.g., Carson *et al.*, 1997; Berrens *et al.*, 2000; Hasund, 1996; Stevens, More and Glass, 1994; Reiling *et al.* 1990. In contrast, Whitehead and Hoban (1999) make a comparison when there is time for significant change in factors affecting demand. Between 1990 and 1995, the attitudes toward the environment and governmental policy had become less favourable in the surveyed population and WTP estimates also decreased.

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