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What have economists learned about valuing nature? A review essay

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ABSTRACT

The question of value has occupied the human mind for millennia. With the ascent of neoclassical welfare economics in the twentieth century, "value" was constrained to chrematistics, or exchange value in a market economy. This narrowing of meaning allowed economists to use a precise mathematical framework to highlight the contributions of nature both to local economic activity as well as to economic growth in general. Nevertheless, current controversies in valuing the cost and benefits of long-lived environmental changes like climate change and biodiversity loss have exposed serious flaws in standard welfare economics. Many of these arise from the assumption that social value can be calculated using the revealed or stated preferences of self-regarding, narrowly rational individuals. New findings in behavioral psychology, neuroscience, and social anthropology have shown that human decision-making is also a social, not only an individual, process. This review essay examines the contributions of standard welfare theory, its shortcomings, and the necessity for more realistic valuation models based on truly social preferences.

Contents

1. Introduction: a short history of economic value theory

Contemporary notions of economic value have deep roots in Western belief systems. Specifically, anthropocentric concepts of value are deeply rooted in the Helenic and Judeo-Christian tradition. In 1440, Cusanus (Nicholas of Cusa) reasoned that human will and judgment was God's way of establishing the value of the things he created. God created human preferences as a way of organizing the world as a *system of values.* Without human judgments, created things would be mere material goods, which in and of themselves have no value.

> For although the human intellect does not give being to the value [i.e., does not create the things valued], there would nevertheless be no distinctions in value without it….Without the power of judgment and of comparison, every evaluation

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ceases to exist, and with it value would also cease. Wherewith we see how precious is the mind, for without it, everything in creation would be without value. When God wanted to give value to his work, he had to create, besides the other things, the intellectual nature (Cusanus, quoted in Cassirer 1963, pp. 43–44).

Cusanus' view foreshadowed the idea of the centrality of the individual that came with the enlightenment and even the idea of value creation in a self-regulating market. Thus the germ of the idea of purely self-interested beings assigning value within a self-regulating system seems to predate by centuries contemporary theories of economic value. As Sahlins (1996) observes, the universe was commoditized long before commerce and commodity exchange became the central organizing principle of human society. He traces the definition of economics as the ''allocation of scarce resources among alternative ends'' back to the creation story of Adam and Eve. By disobeying God in the Garden of Eden, man became a slave of his insatiable desires. But, as Sahlins (1996, p. 397) writes:

Still, God was merciful. He gave us Economics. By Adam Smith's time, human misery had been transformed into the positive science of how we make the best of our eternal insufficiencies, the most possible satisfaction from means that are always less than our wants. It was the same miserable condition envisioned in Christian cosmology, only bourgeoisified, an elevation of free will into rational choice, which afforded a more cheerful view of the material opportunities afforded by human suffering. The genesis of Economics was the economics of Genesis.

It is always disconcerting to discover that ideas we think are new and fresh have in fact been in the air for hundreds if not thousands of years. But it is important to recognize that ideas central to the Judeo-Christian world for millennia are encapsulated and reincarnated in economic theory. These ideas continue to influence (and frequently cloud) our understanding of economy, society, and the relationship of humans to the natural world. In the words of Jorge Luis Borges (1962, p. 189) ''It may be that universal history is the history of a handful of metaphors.'' Certainly the history of ''value'' in economics revolves around a few powerful metaphors—equilibrium in a field of forces, optimization via the invisible hand, and rational economic man independent of society (Gowdy et al., in press). These metaphors were enshrined in neoclassical economics and the rapid acceptance of that theory was in due in part to its compatibility with the general themes of Western cosmology.

An age old struggle in developing a coherent theory of value has been to understand the relationship between use and exchange value. As far back as Aristotle philosophers understood that exchange value was somehow derived from use value, but were unable to explain the paradox between these two values, as in the diamond–water paradox. Water, essential to life, has a high use value, but its exchange value is very low. Diamonds are unessential for life and have a low use value but they have a very high exchange value. Galiani (1751) was among the first to suggest that price was derived from utility and scarcity, foreshadowing the concept of marginal utility which solved the paradox (Schumpeter, 1955). Commodities have exchange values when they can be exchanged for money in societies which have markets and commodity production. Commodity production is not a direct way of satisfying needs, but is a means of acquiring money from exchanging a product, which can then be used to obtain other commodities (Hunt, 2002). As neoclassical economics became dominant in the twentieth century, it began to focus exclusively on exchange value and the field of economics became *chrematistics*—the study of market price formation for the purpose of making money (Martinez-Alier, 2005).

During the era of Classical economists, the discipline of ecology did not exist and the notion of ecosystem services did not appear in the literature. However, some Classical economists explicitly recognized the contribution of these services, referring to them as ''natural agents'' or ''natural forces.'' This recognition was only in relation to their use value, as these services were considered free gifts of nature and therefore did not play any role in exchange value (Gómez-Baggethun et al., 2010). ''Natural agents'', as (Ricardo, 1817, quoted in Gómez-Baggethun et al., 2010) noted, ''are serviceable to us, by increasing the abundance of productions, by making men richer, by adding to value in use; but as they perform their work gratuitously, as nothing is paid for the use of air, of heat, and of water, the assistance which they afford us, adds nothing to value in exchange.'' Marx agreed but he also commented on the relationship between nature and use values in his critical response to the *Gotha Program* (a party platform of the German Social Democratic Party): ''Labor is *not the source* of all wealth. *Nature* is just as much the source of use-values (and these, certainly, form the material elements of wealth) as labor, which is itself only the expression of a natural force, human labor-power'' (Marx, 1922, p. 19). By making this distinction between wealth and value, Marx recognized that, although markets establish exchange values based on given resource endowments, the human economy ultimately depends on the natural world (Foster, 2000; Gowdy, 1984).

With the so-called *marginalist revolution* of the 1870s, the economic problem was re-cast as the optimal allocation of scarce resources using the mathematics of classical physics (Jevons, 1871; Menger, 1871; Walras, 1874). Earlier, more nuanced, notions of value were replaced by one compatible with the application of differential calculus, namely marginal utility—the value of one additional unit of a good, keeping the amounts of all other goods constant (for an excellent discussion of the transformation of classical into neoclassical economics see Mirowski, 1989). The marginalist revolution was in part a challenge to Marx's labor theory of value—an answer to the dangerous idea that if labor created all value, labor was entitled to the surplus product of production. John Bates Clark (1938) posited that under perfect competition, each factor of production would receive a return equal to the value of its marginal product; hence, returns could be given to not only labor, but to capital as well. Issues of exploitation and unearned incomes were rendered moot, as all factors of production should be awarded fairly according to their contribution to the product (Landreth and Colander, 2002). The power of the marginalist revolution lay in the mathematization and simplification of the economic process of consumption, production and exchange (for a full discussion see Mirowski, 1989, Chapter 5). Psychology and interpersonal comparison of utility were banished from the discourse. In the history of economic analysis, the exclusive focus on the self-regarding individual as the unit of analysis represented a sharp break with the past in the sense that it removed psychology from economics (Bruni and Sugden, 2007). Pareto was explicit about this: ''It is an empirical fact that the natural sciences have progressed only when they have taken secondary principles as their point of departure, instead of trying to discover the essence of things…Pure political economy has therefore a great interest in relying as little as possible on the domain of psychology'' (quoted in Glimcher et al., 2009). There also exists a vast anthropological literature documenting the very different value systems of other, non-Western, cultures (see the articles in Gowdy). Polanyi (1944, 1977) described the incorporation of nature (land) into markets as tradable commodities as ''commodity fiction'' (Gómez-Baggethun and Ruiz-Pérez, 2011). By relying on an economic model composed of self-regarding, narrowly rational individuals economics came to be reduced to the study of "the mechanics of utility and self-interest" (Jevons, 1871, p. 90). Value became value at the margin resulting from a small change in the commodity basket in a general equilibrium framework. Calculating economic value was cast as a constrained optimization problem in an idealized system assuming rational consumers, perfect competition, and socially efficient prices. Whatever one thinks of the intellectual merits of the marginalist approach to value, an undeniable effect was a narrowing of the scope of economic analysis and the kinds of research questions economists ask.

The concept of *shadow prices* came out of policy analysis within a general equilibrium framework in which all possible choices are evaluated within an entire interacting market. The shadow price approach is used when one or more of the assumptions of the general equilibrium model (including a perfectly competitive market) are violated and thus market values differ from the "ideal" (socially efficient) set of prices. Although shadow prices fall out of a general equilibrium framework, in practice partial equilibrium (considering only a single market) methods are used to calculate them for specific projects, policies, or public goods (Ha et al., 2008). In various practical applications, shadow prices have been estimated as social prices of public goods including environmental goods, the social cost of pollution, or the opportunity cost of public projects (Dietz and Fankhauser, 2010).

In the two good case (X_1 and X_2) assume that prices are given by P_1 and P_2 and that M is the income. The consumer's maximization problem is given by the Lagrangian function:

$$L(X_1,X_2,\lambda)=U(X,X_2)+\lambda(M-P_1X_1-P_2X_2) \tag{1}$$

The shadow price is the value of λ in the constrained maximization problem. Using the first-order conditions and assuming that the second-order conditions are satisfied we obtain

$$\lambda^*=\frac{\frac{\partial u(x_1^*,x_2^*)}{\partial x_1}}{p_1}=\frac{\frac{\partial u(x_1^*,x_2^*)}{\partial x_2}}{p_2} \tag{2}$$

In competitive equilibrium the shadow price λ^* of any good (or bad) is equal to its marginal utility divided by its price. In the absence of externalities, on the efficiency frontier, shadow prices and market prices are the same. This is not the case when external effects are present and calculating the shadow prices of untraded ecosystem services has become a major task of environmental economists.

Since shadow prices of environmental externalities (costs or benefits not transferred through prices) are usually unobservable economists calculate them using a distance function approach (Shephard, 1970). Formally, in the production function case, the shadow price measures the distance that any producer is away from the efficiency frontier. Production is a function of the set of inputs used, **x**, and the level of outputs produced, **y**. This can be expressed as

$$D_o(\mathbf{x},\mathbf{y})=\min\{\theta:\mathbf{y}/\theta\in P(\mathbf{x})\} \tag{3}$$

where $D_o(\mathbf{x},\mathbf{y})$ is the distance from the firm's output set to the frontier, and θ is the corresponding level of efficiency. If the firm is on the frontier (fully efficient), then $D_o(\mathbf{x},\mathbf{y})=\theta=1$. If the firm is inefficient $\theta<1$ and the distance (difference) is a measure of inefficiency or the shadow price of the inefficiency. An "inefficiency", for example, might be the non-market ecosystem cost of destroying a mangrove forest to construct a shrimp farm.

Estimates of the shadow prices of environmental externalities can also be thought of as the socially optimal tax rates or the prices that should prevail in environmental permit markets. Historically, contingent valuation has been the most widely used method to calculate shadow prices using a variety of survey techniques to obtain the "true" social cost of environmental goods and bads (Mitchell and Carson, 1989). More recently, choice experiments have replaced CV as the preferred method of calculating shadow prices. Although the notion of value as shadow price greatly simplified economic analysis and lead to a massive research program yielding many useful insights into the problem of value and exchange, it also came with a cost. As the shadow price approach gained popularity it soon became clear that the underlying assumptions were more restrictive than originally thought. In partial defense of the neoclassical approach, it should be said that it can be used to support strong environmental policies. In the past few years, the debate over the economics of climate change (Stern, 2007) and biodiversity loss (Kumar, 2010) has re-opened the discussion of the welfare theory underlying standard economic valuation and opened the door to new approaches (Gowdy et al., 2010).

2. Progress in valuing nature in neoclassical welfare models

The 1950s saw the beginning of renewable resource economics with the establishment of Resources for the Future and the work on fisheries by Gordon (1954). In the 1960s, spurred by the emerging environmental movement, the sub-discipline of environmental economics emerged, built on the foundations of welfare economics (Pearce and Turner, 1990). A major step in incorporating the environment into neoclassical welfare economics was to introduce the concept of *natural capital*—the extension of the notion of manufactured productive inputs to those provided by the natural world. Natural capital was a recognition that the limited availability of critical resources could eventually act as a constraint on the growth potential of the economy, Dasgupta and Heal (1974), Solow (1974), Stiglitz (1974), and Weitzman (1976) aimed to find optimal solutions for the depletion of these exhaustible resources, addressing the issue that most economic growth models neglected entirely. The standard economic sustainable growth equation was summarized by Pezzey and Toman (2002, p. 5) as

$$\max_{C(t),R(t)}\int_0^\infty U[C(t)]\Phi(t)\,dt \tag{4}$$

where U is the instantaneous utility, C is the consumption flow, R is the rate of resource depletion and Φ is the utility discount factor. Intergenerational sustainability is defined as (Hartwick 1994; Pearce and Atkinson 1993)

$$dW(t)/d(t)\geq 0 \tag{5}$$

This model is dubbed weak sustainability, defined as non-declining intertemporal social welfare. Under this model, natural capital may be depleted if the net present value of transforming and consuming it is greater than the value of leaving it for future generations (Arrow et al., 2004; Gowdy, 2000). In Solow's (1974) growth model any level of consumption can be maintained, even when there is a limited amount of essential natural resources, if the ability to substitute between natural and manufactured capital is high enough. Hartwick (1977) established that if rents from resource depletion are reinvested back into built capital, then intergenerational equity can be maintained, implying that it is possible to achieve a constant path of consumption forever. Given sufficient substitution possibilities, "genuine investment" allows for the productive base of the economy – including ecosystem services – to be maintained. Following Hartwick, Solow showed that this constant consumption forever is equivalent to sustaining an aggregate level of wealth at a constant level over generations. The market can provide a sustainable allocation of resources as long as attention is paid to market inefficiencies and externalities, and as long as the future is not discounted too much (Howarth, 1998; Solow, 1986).

Although the neoclassical welfare model has been widely criticized by ecological economists, it can be used to support very strong environmentalist policies, as in the work of Dasgupta, Mäler, and others associated with the Beijer Institute. In the steady-state model, adjusted for externalities and other market imperfections, Dasgupta and Mäler (2000) showed that the growth rate of per capita income can be considered as the rate of return on all forms of capital, including natural capital. In a dynamic growth context, with a non-growing population and a constant resource base, the growth rate of income is equivalent to the growth rate of total factor productivity (TPF) along a balanced growth path. TFP is the rate of growth of economic output not accounted for by the weighted growth rates of productive input use. This "residual" of unaccounted for growth is assumed to be the result of pure technological change. In the three input case, manufactured capital (MK), human capital (HK), and natural capital (NK)

$$\mathrm{TFP} = \mathrm{Q} - a\mathrm{M}K - b\mathrm{H}K - c\mathrm{N}K, \quad \text{where the weights are cost shares and } a+b+c=1 \tag{6}$$

Environmental economists have long maintained that estimates of TFP overestimate technological change because they do not adequately take into account the draw-down of the stock of natural capital (Dasgupta and Mäler, 2000; Repetto et al., 1989). Vouvaki and Xeapapadeas (2008) found that when the environment is not considered as a factor of production TFP estimates are strongly upward biased. They argue that failing to internalize the cost of an environmental externality is equivalent to using an unpaid factor of production. After including natural capital (considering only the external effects of CO_2 pollution from energy use) they found that TFP estimates for 19 of the 23 countries switched from positive to negative. This result implies that when the negative effects of economic production on the ability of natural world to provide productive inputs are taken into account, the projected growth in true wealth could well be negative, so future generations would be worse off. Moreover, when environmental degradation effects beyond CO_2 accumulation are included, the case for a negative real TFP growth becomes even stronger. This has serious implications for long run economic policies for climate change mitigation and biodiversity loss. Given some reasonable assumptions about pure time preference and the elasticity of consumption, one can make a strong case that TFP growth has been negative due to drawing down the earth's stock of natural capital. This implies a negative social discount rate (the discount rate to use for social as opposed to private investments), leading to the conclusion that the present generation should consume less in order to invest more in restoring the natural capital base we have taken from future generations (Gowdy et al., 2010).

3. Applying welfare theory to environmental valuation: successes and limitations

Valuation exercises are typically part of cost benefit analysis (CBA)—the practical application of neoclassical welfare theory to public policy. In its neoclassical welfare form, CBA is based on identifying changes in consumer and producer surplus resulting from public policies. Justification for applying CBA is based on the Hicks–Kaldor compensation criterion or the *Potential Pareto Improvement*, in which a policy is justified if winners could compensate the losers and still be better off, even if actual compensation does not occur. If it is possible to determine an individual's willingness to pay (WTP) for a service or willingness to accept (WTA) compensation to forgo an environmental service, then it is possible to establish the proper monetary measures of the utility effects (gains or losses) of a change in that service. Indirect methods of environmental valuation – revealed preference approaches – use observed market data on an ordinary commodity in order to infer the monetary level of a comparable environmental service (Perman et al., 2003). In economic jargon, the goal is to find privately-consumed, non-market goods which are *weakly complementary* to the public goods (Bockstael and McConnell, 1993). Indirect economic valuation techniques include avoided cost, replacement cost, factor income, travel cost and hedonic pricing (Turner et al., 2003). It is useful at this point to look at a few empirical studies using traditional economic concepts to value nature. This is not meant to be a comprehensive survey but these studies illustrate both the power of the standard welfare analysis of ecosystem values and its limitations.

3.1. Direct measures of the value of nature

The total value of nature (Costanza et al., 1997) published the results of a comprehensive study in *Nature* estimating the value of annual global ecosystem services at $33 trillion. The publication of the paper and the ensuing discussion proved to be a watershed in environmental and ecological economics. The paper was meant to be a first exercise in valuing the world's ecosystem services. The authors acknowledge sources of error and limitations, such as the possibility of double counting, the exclusion of household labor and the informal economy, the estimation of the supply and demand curves, the lack of consideration of thresholds, discontinuities or irreversibilities in ecosystems, and the inability to fully incorporate important goals such as social fairness and ecological sustainability (Costanza, 1998). The paper spurred much discussion which ranged from basic agreement, to disagreements with the specific methods used, to questioning the wisdom of placing economic values on ecosystem services at all. Herman Daly (1998), while recognizing the crudeness of the estimate, applauded the effort. As exchange values can only be calculated when there is an element of scarcity, he proposes that the value produced in the study be viewed as "the measured scarcity value of natural capital services (33 trillion dollars) as an indirect index of the extent of past sacrifice of natural capital, and thus of the scarcity of remaining natural capital" (Daly, 1998, p. 22). Toman (1998), on the other hand, argued that this type of information is ultimately misleading to decision-makers, as it provides no insights into the changes in ecosystems or ecosystem thresholds, and provides no context to how these services are linked to particular people in a particular place and time. Norgaard et al. (1998, p. 37) questioned the usefulness of such an exercise saying, "…now that we know the exchange value of the earth, we wondered with whom we might exchange it and what we might be able to do with the money, sans earth." Others raised concerns such as the use of marginal values when the total collapse of some services is plausible and the question of whose values the estimates represented in a world with rich and poor, powerful and not. In spite of the shortcomings of the Costanza et al. study, there is no doubt that it achieved its original purpose of stimulating future research and debate.

3.2. Production function estimates of ecosystem services

In the 1980s and 1990s a veritable cottage industry developed around building econometric models of the environment as a productive input (Bockstael and McConnell, 1981; Mäler, 1991). One of the best examples is Barbier's (2000) study of the role of mangrove estuaries in supporting the fishing industry in south Thailand and Campeche, Mexico. Using the traditional economic decomposition of value into use values (direct use, indirect use, and option values) and nonuse values (bequest and existence values), he came up with substantial monetary values for preserving mangroves in both Thailand and Mexico. The logic behind the model used is impeccable. Mangroves provide services essential to the fishing industry including providing habitats for juvenile fish, nutrient cycling and storm protection and their loss has negative economic consequences. But in reading Barbier's paper and the other production function literature on ecosystems one is struck by the mismatch between the sophistication of the econometric models and the actual application of the model to specific ecosystems. Following the welfare theory described above, the model assumes among other things, a Cobb–Douglas production function with its restrictions on the elasticities of substitution among inputs, an optimal harvest fisheries model, and long-run competitive equilibrium. Another round of assumptions are necessary to calculate the relationship between mangroves and fish harvest including (for Compeche) a value for the intrinsic growth rate of shrimp, a constant stock of shrimp in long-run equilibrium, estimates of the carrying capacity of the ecosystem, and a proportional relationship between mangrove area and ecosystem carrying capacity (see the critique of the standard fisheries model by Ludwig et al., 1993). Researchers consistently derive seemingly reasonable numbers using the production function approach, but it is obvious that the theory has gone far beyond the reality of inadequate data availability and basic conceptual problems with biophysical models of ecosystem services.

In another production function type approach, Boyles et al. (2011) used estimates of the value of pest suppression services provided by bats in a cotton-dominated agricultural environment in south-central Texas to calculate the economic importance of bats in agriculture for the entire United States to be roughly $22.9 billion/year. Fisher and Naidoo (2011) responded to the study with great concern for the flaws in calculation. The variables, such as mixture of crops and their yields, production costs, market prices, pests, as well as the distribution, abundance and feeding ecology of bats, vary greatly across the United States. However, these variations are ignored in Boyles et al.'s study, which is "tantamount to calculating the nation's gross national product based on a country-wide extrapolation of steel production in Pittsburgh" (Fisher and Naidoo, 2011, p. 287). The lesson to be drawn is that, in general, natural scientists are too eager to accept estimates made by economists of the value of nature's services. This is understandable but the danger is that poorly designed studies discredit the entire effort to document the economic importance of ecosystem services.

3.3. *Measuring consumer preferences for nature through contingent valuation surveys*

In recent years a commonly used measure of preferences is the contingent valuation method (CVM) which involves directly asking people how much they would be willing to pay for a service or how much they would have to be compensated to accept to accept the loss of a service. CVM falls directly out of neoclassical (Walrasian) welfare economics with its starting assumption that human preferences are the only source of economic value (Mitchell and Carson, 1989; Portney, 1995). Stated preferences can be used to derive the shadow prices of environmental features. The method is specifically used to dealing with "non-use" or "passive-use" values, values people hold for environmental amenities even if they do not come into direct contact with it (Arrow et al., 1993; Bennett, 1996). The validity of CVM came under debate following the Exxon Valdez oil spill in Prince William Sound, Alaska, in 1989. Following the Exxon Valdez spill the National Oceanic and Atmospheric Administration (NOAA) was asked establish rigorous CVM criteria. The NOAA panel cited numerous drawbacks including: inconsistency with the assumptions of rational choice, implausibly large responses of willingness to pay (WTP), the absence of a meaningful budget constraint, a lack of adequate information regarding the policy or program for which the values are being elicited, and questions regard the extent of the market. The panel recommended major reform to the method, established strict guidelines, and concluded that "CV studies can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including lost passive-use values" (Arrow et al., 1993, p. 43). The reference to judicial processes indicates that the NOAA recommendations may be peculiar to the US case where courts may be seen as a vehicle for deliberative social choices. One might speculate, therefore, that the NOAA recommendations are for a hybrid valuation process involving both individual and social choices.

Other issues, however, continue to plague CVM studies. For example, economists distinguish between a person's willingness to accept a loss (WTA) and a person's willingness to pay for a gain (WTP), but in practice willingness to accept (WTA) measures are seldom used, even when it is obvious that the degradation an ecosystem should be measured as a loss and not a gain (Brown and Gregory, 1999). According to welfare theory, these two measures of value will be roughly equal (Willig, 1976). But empirical evidence demonstrates otherwise, revealing that losses matter more to people than do corresponding gains. The causes of the disparity are not limited to issues with economic survey techniques like CVM. The disparity between these values is due both to economic and psychological reasons. The psychological reasons are summarized under four categories as the endowment effect, legitimacy, ambiguity, and responsibility. As WTP estimates are commonly lower and researchers are reluctant to employ WTA measures, the real value of negative environmental impacts is underestimated in economic studies and environmental management decisions can be wrong (Brown and Gregory, 1999). The psychological evidence for these points was first uncovered by Kahneman and Tversky (1979).

Perhaps the most serious shortcoming of CVM is the apparent arbitrariness of the estimation studies. Spash (2008, 2009) has criticized CVM surveys for eliminating "protest bids" which sometimes comprise more than half the responses. Many surveys of the value of specific environmental features are unrealistically high because people perceive specific items (blue whales for example) as proxies for "the environment." Bateman and Mawby (2004) found that reported willingness to pay for an environmental good was substantially higher if the interviewer wore formal clothing. CVM studies have shown that human preferences, unlike the way they are characterized in welfare economics (Stigler and Becker, 1977) are frequently capricious and they differ greatly among individuals. Because of the arbitrariness of CVM results, the technique is beginning to fall out of favor as the preferred method of eliciting the values of ecosystem services.

3.4. *Rethinking cost–benefit analysis*

Disillusionment with CVM has led to an intensive questioning of cost–benefit analysis in general. Critiques of CBA are housed in two categories: those concerned with the theoretical foundations of value theory and those concerned with the legitimacy of the numbers produced and of the methods employed (Gowdy, 2007; Spash et al., 2005). One line of criticism is that economic value alone vastly underestimates the true value of ecosystems, leading to their overuse (de Groot et al., 2006). The economic value of ecosystem services does not necessarily capture values such as ecological sustainability and distributional fairness (Howarth and Farber, 2002; MEA, 2003). Additional criticisms regarding the use of CBA in regard to environmental issues, as outlined by Røpke

(2005), include: (1) many important factors cannot be measured in terms of price (value incommensurability), (2) prices basically reflect historic and existing power structures, (3) the assumption of value monism, (4) the focus on marginal values is arbitrary and can be misleading, (5) marginal values should only be used when valuing reasonably intact and normally functioning ecosystems (Limburg et al., 2002), (6) fundamental moral dilemmas should not be disregarded, and (7) CBA tends to be used for validation of policies and relieves policy makers from responsibility. A more general criticism is that the neoclassical approach is based on utilitarian ethics, but in reality, many individuals follow a deontological or rights-based approach to decision-making (Spash, 1997; Thaler and Sunstein, 2008). In summary, asking individuals about their willingness to pay "assumes that people: hold these values in advance or can easily generate them; have sufficient information and understanding of what they are valuing; can decide (alone) on the values they attribute to ecosystems; behave according to the cost-benefit rule; value consistently; value according to individual rationality" (Kumar, 2010, p. 162).

All these issues pose a problem for the use of standard cost–benefit analysis method in environmental valuation and policy making. From classical economics, the original conception of nature's benefits was in the form of use value; however, this conception has shifted to conceptualization in terms of exchange values in neoclassical economics. While this shift has attracted political support for conservation, it has also imposed a focus on the market to solve environmental problems (Gómez-Baggethun et al., 2010). As Martinez-Alier (2002, 46) summarizes, "Prices should not be mistaken for value. Even in the most capitalist society, the market economy is a small island surrounded by an ocean of unpaid caring and domestic work and free environmental services that are essential for true economic security." As decisions must be made and valuation is inevitable, viable alternatives to standard CBA need to be developed in order to assist decision-makers (Røpke, 2005). While monetary valuation can be valuable to decision makers and is important for internalizing externalities in policies that affect ecosystems, it should be supplemented with the consideration of other types of value, such as ecological, social and cultural (Kumar, 2010; de Groot et al., 2006; Farley, 2012; Kosoy and Corbera, 2010).

4. Unresolved environmental valuation issues

As discussed above, the neoclassical approach to environmental valuation has come a long way toward accounting for the contribution of the natural world to human welfare. Nevertheless, recent debates about the economic valuation of biodiversity loss and climate change have exposed some serious shortcomings of the basic economic model. The basic economic model is essentially a financial investment model for an individual making a purely economic decision at a given point in time (Gowdy, 2004, 2005). This framework is, in general, too narrow to give reliable guidance for environmental policies involving the distant future or large-scale ecosystem changes. Three insurmountable problems inherent in the standard welfare model are (1) the assumption of the self-regarding economic agent, (2) the necessity of choosing a particular rate to discount the welfare of future generations, and (3) the assumption that social welfare is merely the cardinal and additive sum of the welfare of individuals.

4.1. The self-regarding economic agent

Work in theoretical welfare economics over the past six decades has exposed flaws in the basic principle supporting CBA, that is, that preferences can be characterized as independent and exogenous (Bowles and Gintis, 2000; Chipman and Moore, 1978; Suzumura, 1999). This assumption is strongly contained in CBA which assumes that social welfare is a cardinal measure of the sum of the preferences of independent individuals. Furthermore, it has been well-established in the behavioral literature that preferences are other regarding, and that they vary significantly according to cultural conditioning, relative position, and other reference points (Camerer, 2008; Kahneman and Tversky, 1979). The theoretical and behavioral critiques are consistent in calling into question attempts to estimate ecosystem values without explicitly recognizing the social nature of human decision-making. The current turmoil in economics centers around the debate over the relevance of behavioral and neuroscience evidence about actual human decision-making. On one side, in a dismissive paper about neuroeconomics, Gul and Pensdorfer (2008) argue, like Pareto one hundred years earlier, that psychology has no place in economics: "Populating economic models with 'flesh and blood human beings' was never the objective of economists." On the other side, Camerer (2008) writes in response:

> [T]he philosophy GP espouse suggests that knowing a lot about actual human behavior, as established by psychology and neuroscience, is a waste of time in improving economic models of decision making. It is ironic that mindless economists prefer less knowledge to more, since preferring more to less is such a fundamental premise in economics. And sciences which have found new tools have always become more productive by using them.

Current theory and empirical research in economic valuation has moved well beyond the basic expected utility models but these ideas have been relatively slow to influence environmental valuation techniques and policy analysis. The evidence is clear that preferences for environmental goods and services depend on a variety of cultural and psychological characteristics that vary from individual to individual, and from culture to culture (Gowdy et al., 2003; Henrich et al., 2004). To the extent that preferences vary within the same cultural setting, they have an individual as well as social explanation. Kahneman (2011) suggests that people reveal "attitudes" more than "preferences" in economic surveys. A major step needed to move forward in environmental valuation is the recognition of the social nature of preferences, and recognizing the limited cognitive ability of individuals.

4.2. Discounting the future

Discussion of the proper discount rate was central to the controversies surrounding the *Stern Review* (Stern, 2007) on the economics of climate change and The Economics of Ecosystems and Biodiversity (TEEB) report on the economics of biodiversity loss (Kumar, 2010). The upshot of these discussions is that there is no purely economic justification for choosing a particular discount rate. Econometric studies offer little guidance since even with fairly short-lived choices people employ a wide range of discount rates depending on the nature of the product, income, and numerous other factors (Frederick et al., 2002; Gowdy et al., 2010).

In the standard model, future monetary costs and benefits should be discounted at the rate r defined by the so-called Fisher–Ramsey equation

$$r = \rho + \eta g \tag{7}$$

The discount rate r is determined by the rate of pure time preference (ρ), η, and the rate of growth of per capita consumption (g). In intuitive terms, people discount future economic benefits because: (1) they are impatient, and (2) they expect their income and consumption levels to rise so that 1 unit of future consumption will provide less satisfaction than 1 unit of consumption today. This simple equation encompasses many of the key debates about the economic valuation of nature. The term ρ can be interpreted as pure social time preference, that is, how much should the well being of future generations be worth to those living in the present. The difference between the policy recommendations of the *Stern Review* (substantial efforts to curb climate change should be undertaken immediately) and Nordhaus' DICE and RICE models (limited policy response) was driven almost entirely by the choice of ρ in their climate change models. The climate change discussion revealed that the choice of ρ is an ethical one not an economic choice. The term ηg, the marginal utility of consumption times the growth rate of income, represents today's best guess about how well off future generations will be.

Several assumptions are buried in the parameter η as it is usually formulated. It is assumed that η is independent of the level of consumption, that it is independent of the growth rate of consumption, and that social well-being can be characterized by summing individuals' consumption of market goods. These assumptions are arbitrary and adopted mainly for convenience (Pearce et al., 2006). A high value for η (in conjunction with g) would seem to take the moral high ground—a given loss in income has a greater negative impact on a poor person than a rich person. But if we assume, as most economic models do, that per capita consumption g continues to grow in the future, a higher η means a higher value for ηg and the less value economists place on income losses for those in the future. In steady-state equilibrium, the value of g is equal to the growth rate of total factor productivity as shown in Eq. (6) above. Again, when drawdown of natural capital is taken into account, and given the Stern review assumptions that ρ is near zero and $\eta = 1$, it is quite possible that the discount rate is negative.

A major unresolved issue is that what economists usually refer to as "social discounting" is really not social at all except in the framework of the standard general equilibrium model where decisions are confined to the world of perfectly rational self-regarding agents operating under conditions of competitive equilibrium. Dasgupta (2008, 167) admits that "Intergenerational welfare economics raises more questions than it is able to answer satisfactorily."

4.3. The neoclassical social welfare function

Very soon after the neoclassical synthesis solidified welfare theory after WWII, major difficulties with that theory appeared. These include the very stringent conditions required to establish a unique equilibrium (Arrow and Debreu, 1954), various inconsistencies arising from individual choice (the Allais, Boadway, Ellsberg, and Scitovsky paradoxes), the theory of the second best (Lipsey and Lancaster, 1956–1957), and the impossibility of avoiding interpersonal comparisons of utility (Chipman and Moore, 1978; Suzumura, 1999). One of the most devastating theoretical findings undermining standard welfare economics is the Arrow impossibility theorem. Arrow (1950) demonstrated that there is no social welfare function that satisfies the conditions of non-dictatorship, universality, Pareto consistency, monotonicity, and independence. Arrow's impossibility theorem (also known as the paradox of voting) is so important that it is called the Third Fundamental Theorem of welfare economics. Feldman (1987, 894) writes:

> Since the Third Theorem was discovered, a whole literature of modifications and variations has been spawned. But the depressing conclusion has remained more or less inescapable: there is no logically infallible way to aggregate the preferences of diverse individuals. By extension, there is no logically infallible way to solve the problem of distribution.

The Arrow result is particularly threatening to mainstream economists because it calls into question free market outcomes as representing a social optimum even when all externalities are accounted for. Its relevance for valuation is that aggregating individual preferences, as in standard cost benefit analysis, cannot yield a consistent ranking of policy alternatives.

Major unresolved, and largely unresolvable, issues have plagued neoclassical welfare economics since its inception. These issues call into question standard approaches to environmental valuation based on the self-regarding rational actor model. This raises the question as to why so many environmental and ecological economists continue to uncritically employ valuation methods based on the rational actor assumption. One reason is that, as many commentators have lamented, welfare theory is generally neglected in contemporary economics (Atkinson, 2000). Although controversial welfare judgments underlie all economic policy and valuation exercises, these are rarely discussed by economists and their importance is usually unrecognized by natural scientists.

5. Truly social valuation: the next frontier in environmental valuation

There is a growing feeling among many economists that neoclassical welfare economics has reached its limit (Bowles and Gintis, 2000; Gowdy, 2004; Quiggin, 2010). Davis (2006) suggests that, since the 1980s, the dominance of neoclassical economics has been supplanted by competing approaches sharing little in common with each other or with neoclassical economics. Major alternative approaches include behavioral economics, non-linear complexity theory, evolutionary economics, evolutionary game theory, (the return of) institutional economics, post-Keynesian economics, and neuroeconomics. Ecological and environmental economics have been slow to take advantage of new developments in these fields, and now seems like an opportune time to assess the past progress in environmental valuation and to take stock of the future.

On the positive side, it seems that economists have had the most success in local studies documenting the values of specific threatened ecosystems. In spite of theoretical controversies and a paucity of data, these studies have had great policy relevance and have in general been well-received. Economists have shown that ecosystem services have substantial economic value as capital contributing to human well-being. Economists have also shown convincingly that traditional economic measures seriously overestimate economic growth because they do not take into account the destruction of natural capital. On the negative side, traditional economic measures of value have been shown to be flawed because of unrealistic assumptions about human rationality and the ability of market outcomes to reflect the social optimum. The rational actor model makes poor predictions of actual human behavior (Henrich et al., 2004).

If there is one underlying idea behind neoclassical welfare economics it is the self-regarding "rational agent" and the sanctity of individual choice. But one of the most robust findings from behavioral and neuroeconomics is that humans are uniquely social mammals. Evidence from neurobiology, psychology, and behavioral economics has clearly demonstrated that the self-regarding rational actor model is a misleading representation of actual human behavior. Experiments like the ultimatum game, the public goods game and even the one-shot prisoner's dilemma indicate that economic behavior is other-regarding. The behavioral evidence is verified by neuroscience confirming the existence of the "social brain" (Frith and Frith, 2010). There is mounting evidence that the configuration of human brain develops according to cultural conditioning. New findings about the structure of the human brain show that it contains neurons designed for sociality (Allman et al., 2010). This may be the smoking gun that unequivocally refutes the claim that human behavior can be considered only as self-regarding. Evidence from behavioral economics, psychology, neuroscience, and evolutionary biology points to the need for an alternative to the neoclassical model of human behavior based on the fact that human values are social not individual. It should also be recognized that both individual and group decisions depend on "short-cut" heuristics that may not be the "best" decision but rather "good enough." Social valuation is subject to many of the same cognitive constraints as individual valuation.

In our view, the development of techniques to elicit truly social valuation of environmental services and public policy alternatives is the greatest challenge facing ecological and environmental economics. Some progress along this front has been made in the area of deliberative valuation which involves a group of selected persons who explore the values that should guide social decision-making through a process of reasoned discourse (Howarth and Wilson, 2006; O'Hara, 2006). Although the field of deliberative valuation is still in its infancy, deliberative techniques can be an alternative to the self-regarding decision-making process adopted in revealed and stated preference approaches. Through deliberation, people can reach agreement by exploring arguments and developing mutual understanding and trust. The institutional settings range from exploratory workshops, such as focus groups, to decision-oriented designs, such as citizen juries. Deliberative processes can enhance the effectiveness and support for policy decisions by explicitly recognizing the importance of groups and group identity, making the decision process transparent, and allowing a role for collective intelligence in the decision-making process. If properly structured, groups can negotiate distributional outcomes that participants can accept as fair and legitimate. Deliberative valuation can be a viable alternative to neoclassical welfarism with an approach based on establishing deliberative, democratic institutions that can resolve distributional conflicts given a procedural conception of distributional justice (Gowdy and Parks, in press).

It must be said that deliberative valuation approaches do not as yet fully take advantage of the findings from behavioral and neuroscience (Kumar and Kumar, 2008). Still, deliberative decision-making is part of human evolutionary history and it is certainly more consistent with human psychology and neurobiology than traditional stated preference techniques. If done carefully it also offers a way to get out of the trap of valuing ecosystem services only for their commodity values (Gómez-Baggethun and Ruiz-Pérez, 2011). What "carefully" entails is still being worked out in the design of deliberative valuation techniques and in the design of core principles for managing natural resources (Wilson et al., in press).

Among the advantages of deliberative valuation are:

1. The group setting of deliberative valuation exercises can enable participants to develop an understanding of relative income effects and the impact of individual decisions on the whole group. In a further elaboration of group processes, Gómez-Baggethun and Kelemen (2008) used Vatn's concept of "value articulating institutions" to examine the role of institutional change in case studies of resource use management.
2. Deliberative valuation recognizes that welfare involves much more than marginal changes in the utility from accumulating market or pseudo-market goods. Deliberative valuation processes explore important dimensions of value than the standard model allows for.
3. The framing of the question works to help construct responses, implying that preferences are not set in stone, but rather are formed in part during the valuation process. Deliberative valuation explicitly aims to give participants the opportunity to revise their preferences after having explored the problem at hand.
4. Most importantly perhaps, deliberative valuation in groups can lead to more nuanced decisions than those based on individual choice. One of the most exciting areas in behavioral and neuroscience is the nature of collective consciousness. For example, a study of group decision-making found that group cohesion and cooperation was a better predictor of good group performance than average or maximum individual intelligence (Woolley et al., 2010).

Of course, the limitations of group decision processes should also be recognized. The point of deliberative valuation exercises is to improve environmental and ecosystem conservation policies. So group valuation techniques go hand-in-glove with designing efficient institutions for communal resource governance as described by Elinor Ostrom's core design principles (Wilson et al., 2013).

Neuroscience is beginning to inform policy choices (Camerer, 2008) and may help us to understand why it is so difficult to change patterns of human behavior even when behavioral patterns are clearly unsustainable. Our evolutionary history programmed our brains to favor short-term rewards over long-term consequences. We have difficulty perceiving gradual environmental changes, we are risk averse, and we assess possible future outcomes based on reference points that may change rather capriciously. These human attributes further call into question standard economic valuation techniques. The emerging field of social neuroscience is beginning to uncover the ways in which social institutions shape preferences and how these preferences may be modified to encourage, for example, better health-related outcomes (Rilling et al.; 2002; Sanfey, 2007). Another promising line of research attempts to value nature based on a life satisfaction approach (Frey et al., 2010). Reported life satisfaction is taken to be a proxy for individual welfare. Measures of life satisfaction can be correlated with environmental attributes and the estimated coefficients can be used to construct willingness-to-pay estimates for environmental goods.

To summarize, neoclassical welfare economics has made important contributions to understanding the relationships between nature and the economy. But current debates in environmental and ecological economics, particularly those surrounding long-term irreversible effects of human activity, have exposed serious flaws in standard welfare economics. At the same time, exciting new research in behavioral and neuroscience has opened the door to exciting new possibilities for ecosystem valuation. A key implication of current research is that individual based valuation is inadequate to capture the complexities of human decision-making. Recent research has confirmed the reasons for the dissatisfaction with neoclassical economics that spurred the development of the new field of ecological economics some 25 years ago. The door is now open as never before for new approaches to environmental valuation.

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