Valuation and Evaluation: Measuring the Quality of Life and Evaluating Policy

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Summary

This paper is about measuring social well-being and evaluating policy. Section 1 concerns the links between the two, while Sections 2 and 3, respectively, are devoted to the development of appropriate methods for measuring and evaluating.

In Section 2 I identify a minimal set of indices for spanning a general conception of social well-being. The analysis is motivated by the frequent need to make welfare comparisons across time and communities. A distinction is drawn between current well-being and sustainable well-being. Measuring current well-being is the subject of discussion in Sections 2.2-2.3. It is argued that a set of five indices, consisting of private consumption per head, life expectancy at birth, literacy, and indices of civil and political liberties, taken together, are a reasonable approximation for the purpose at hand.

Indices of the quality of life currently in use, such as the United Nations Development Programme's (UNDP) Human Development Index, are cardinal measures. Since indices of civil and political liberties are only ordinal, aggregate measures of social well-being should be ordinal. In this connection, the Borda index suggests itself. In Section 2.3 the Borda index is used on data from 46 of the poorest countries in the early 1980s. Interestingly, of the component indices, the ranking of the sample countries in terms of life expectancy at birth is the most highly correlated with the countries' Borda ranking. Even more interestingly, the ranking of countries in terms of gross national product (GNP) per head is almost as highly correlated. There can be little doubt that this finding is an empirical happenstance. But it may not be an uncommon happenstance. If so, GNP per head could reasonably continue to be used as a summary measure of social well-being, even though it has no theoretical claims to be one.

It is widely thought that net national product (NNP) per head measures the economic component of sustainable well-being. Section 2.4 and the Appendix show that this belief is false. NNP, suitably defined, can be used to evaluate economic policies, but it should not be used to make intertemporal and cross-country comparisons of the standard of living. In particular, comparisons of sustainable welfare should involve comparisons of wealth. For the purposes of

comparing social well-being in an economy over time, often, one would analyze whether net investment is positive, negative, or nil. Writings on the welfare economics of NNP have mostly addressed economies pursuing optimal policies, and are thus of limited use. The analysis in Section 2.4 and the Appendix generalizes this substantially by studying environments where governments are capable of engaging only in policy reforms, in economies characterized by substantial non-convexities. The analysis pertinent for optimizing governments and convex economies are special limiting cases of the one reported here.

In Sections 3.1-3.3 I explain that policy-evaluation techniques developed in the 1970s, while formally correct, neglected to consider (1) resource allocation in the wide variety of non-market institutions throughout the world, and (2) the role the environmental-resource base plays in society. It is argued that the evaluation of policy changes can be done effectively only if there is a fair understanding of the way socioeconomic and ecological systems would respond to the changes. The observation is no doubt banal, but all too often decisionmakers have neglected to model the combined socioeconomic and ecological system before embarking upon new policies or keeping faith in prevailing ones. Examples are provided to show that such neglect has probably meant even greater hardship for groups of people commonly regarded as particularly deserving of consideration. The examples are also designed to demonstrate how recent advances in the understanding of general resource allocation mechanisms and of environmental and resource economics can be incorporated in a systematic way into what are currently the best-practice policy evaluation techniques.

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1. Reasons for Valuing and Evaluating

1.1 Means and Ends

In common parlance the term "valuation" is used when comparing objects and "evaluation" when comparing the relative merits of actions. Of course, the objects need not be concrete; they can be abstract (e.g., ideas). Also, evaluation is not restricted to a narrowly construed notion of action. For example, one evaluates "strategies," which are conditional actions that can be personal or collective ("do this if that happens," "do that if he does this," and so forth). One also evaluates "policies," which too can be personal or collective. In this sense valuation is passive, while evaluation signifies more of an active engagement. One frequently values in order to be able to evaluate, but not always. Sometimes one values simply to understand a state of affairs.

This paper is about measuring the quality of life and evaluating policies. When discussing the latter, I will refer to *public* policies, the sort of policies governments are expected to ponder over. They involve such matters as the character of public investment, the structure of taxes and transfers, environmental legislation, and so forth. To clarify, in speaking of the evaluation of public policies, I mean the evaluation of *changes* in public policies. Both valuation and evaluation involve *comparisons*. For example, when one asks if the standard of living in some country is currently higher than in another, one is asking for a comparison. When evaluating a public policy, it must be compared to some other policy, which typically is the status quo (that is,

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the outcome that would prevail if existing policies are kept in place. Evaluation involves the consideration of counter-factuals.

The qualification "public" means two, often-related things. First, it refers to a choice of one public policy over another, which implies one background environment rather than another, within which the various parties in society can act. The existence of a choice influences the constraints to which the various parties are subject. Thus, when evaluating a public policy, the likely responses of the economic system to the policy should be assessed. Second, the evaluation must be conducted on behalf of a large, possibly disparate group of people who possess different preferences, values, and needs. This calls for an acceptable procedure for aggregating the often-conflicting claims of members of a polity. It also requires that the identification of specific features of the consequences of a policy that will be used to conduct the evaluation. In short, to evaluate public policies measures of the quality of life are needed.

But as I have already noted, the need for a quality-of-life index arises not only because policies have to be evaluated. There are many other reasons. For example, one often wishes to know if a group (e.g., women in a country) is doing as well today as they were in the past, or if one group (e.g., a country) enjoys a higher standard of living than another. One of my aims is to develop suitable indices for answering these kinds of questions. I also develop indices based on quality-of-life measures that would be appropriate for evaluating public policies. As explained later, the most suitable criteria for policy evaluation are not necessarily quality-of-life indices, even though, of course, the criteria are based on such indices.

The construction of quality-of-life indices has received considerable attention in recent years in such publications as UNDP’s annual *Human Development Report*. But assessing the likely response of the economic system to policy choice is inherently the harder task. So even though this paper is about quality-of-life indices and policy-evaluation techniques, later(Section 3.3) I touch upon "institutional" responses to policy choice to highlight the fact that such responses affect the way policy evaluation should be conducted. In fact, it can be argued that, at the level of international discourse on development policies, disagreements stem largely from a common lack of understanding of the ways socioeconomic and ecological systems respond to policy changes. International discourse stems less from disagreements over what one might call "ethical values," in particular and from disagreements over what ought to be the ingredients of quality-of-life indices.

This last observation may appear odd. Economists continue to stress that judgement differs on what are appropriate rates of trade-off among competing social goals. Political

differences are traced to this, or so the assertion goes.[1] My own understanding is otherwise. Differences in opinions about how the world works have assumed importance in political debates long before differences in ethical views manifested. I have yet to meet someone who does not wish to see unemployment or destitution reduced or current rates of rain forest depletion stemmed. I have also heard many disagreements about the most effective means of bringing such policies about. As the philosopher Hilary Putnam has said (Putnam 1989, p. 7): "It is all well and good to describe hypothetical cases in which two people 'agree on the facts and disagree about values,' but ... (w)hen and where did a Nazi and an anti-Nazi, a communist and a social democrat, a fundamentalist and a liberal ... agree on the facts?"

It can also be argued that if development policies espoused by international bodies have not infrequently failed, they have failed because of vastly imperfect knowledge and understanding of the way economic systems respond to policies. By this I mean the way *people* respond to policies and the way *ecosystems* respond to the treatment meted out to them. I have not heard of much evidence that shows the failures are due to a wrong view of what constitutes economic progress. In short, even though policymakers are generally in agreement about collective ends, they typically disagree about the right means to further those ends. In Sections 3.2-3.3, I provide examples of this. Nevertheless, even if there is widespread agreement on what counts as social well-being, what this agreement amounts to must be accounted for. In the remaining parts of Section 1 and in Section 2, I provide an account.

1.2 Whose Well-Being?

In the following, I use the terms "well-being," "welfare," "standard of living," and "quality of life" interchangeably. I am interested here in measures of *social* well-being. I assume it is understood that the measure will be built from the ground up. Since the locus of sensation, perception, and feeling is at the individual level, it is appropriate to start there and then build up. It is the individual who matters. I am setting aside arguments that have been offered for treating all animals equally (Singer 1976). The acceptance of animals would have far-reaching implications for many institutions, so I am limiting myself to measures of human well-being.

[1] Among the most prominent expositions of this view are Robbins (1932), Samuelson (1947), Graaff (1962), and Joan Robinson (1964).

An often stated criticism of founding measures of social well-being on individual well-being is based on the thought that "the whole is greater than the sum of its parts." Taken literally, this viewpoint acknowledges that the processes that shape the way individual values and opportunities get translated into social outcomes are non-linear, with positive feedback. Usually, though, the thought is not taken literally, but is regarded more as a metaphor for the "body collective." Now those who espouse collectivist goals (e.g., national prestige) ought to be required to offer reasons why such goals are desirable. I don't know of any convincing reason that cannot be reduced to a concern over the individual members of the body collective (e.g., securing pride among members of the collective, thus enabling them to flourish cooperatively).

Disagreements between religious and secular people (and among religious people themselves) would also appear, ultimately, to be over facts (vis à vis over the existence, character, and the will of God). Ethical differences stem from such disagreements. Religious tolerance encourages people to live their lives in light of their own religious sensibilities, so long as they do not infringe on the liberties of others. These are subtle and complex matters that have been much discussed over the centuries.[2] Their wide recognition today, which is perhaps the most far-reaching influence of the Enlightenment, is a reason why quality-of-life indices must include civil and political liberties.

These brief observations have influenced the notion of social well-being, which I explain in Section 2. But the notion has also been informed by the overarching conception of *citizenship*, which covers three arenas: the civil, political, and socioeconomic.[3] Recall that civil society is the sphere of autonomous institutions, protected by the rule of law, in which people may conduct their businesses freely and independently of the state. The civil element of citizenship consists of the right to justice.

Recall too that by the political element one means the right of a person to participate in the exercise of political power, as a member of a body invested with political authority or as an elector of the members of such a body. Finally, recall that the socioeconomic element is a range

[2] Russell (1946) is a concise reference.

[3] See T. H. Marshall (1964, pp. 71-72). Marshall's classic statement on the nature of social democracies is further advanced in a later text (Marshall 1981). Rawls' two principles of justice (Rawls 1972) pertain to the production and distribution of three basic types of freedom: civil, political, and socioeconomic. Rawlsian justice concerns the fair distribution of what he calls "social primary goods," namely, liberty and opportunity, income and wealth, and the bases of self-respect (see especially, Rawls 1972, p. 303).

that encompasses the right to have a certain share of resources, to share social heritage fully, and to live a civilized life, commensurate with the standards prevailing in the society in question.

Quality-of-life indices in use today are based exclusively on the socioeconomic sphere of citizenship (e.g., UNDP's (1998) Human Development Index). Because of this limitation, they could be misleading. However, in Section 2.3, I study data pertaining to the world's poorest countries and show that an exclusive concern with the socioeconomic sphere is not wildly misleading in the study of contemporary societies. This suggests that the three elements of citizenship do not pull against one another, but rather, that strengthening one helps strengthen the others in general. If this is found to be more widely true, it would be an encouraging finding.

Thus, although I will think in aggregate terms when developing measures of social well-being, I stress that the aggregate I consider is composed of aspects of individual lives. To the extent people differ in their access to opportunities due to differences in ethnic or religious backgrounds, certain consequences seem to follow, such as the prevalence of communal strife. Since communal strife (in the extreme, civil war) is frequently both a cause and consequence of authoritarianism and corruption at the level of government, social inequalities are manifested in a restriction of civil and political liberties. In other words, indices of civil and political liberties reflect inequities along ethnic or religious lines.

There is an explicit weighting system in any reasoned measure of social well-being. To the extent people differ in their access to basic goods and services owing to systematic inequalities in the socioeconomic sphere (e.g., ownership of land), I wish to place greater weight on those who lack ready access to them. In recent years much has been written on weighting systems. One example is the Gini coefficient, which consists of measures of inequality (e.g., Sen 1992; UNDP 1998; World Bank 1998). In what follows, I build on existing literature. I will concentrate on the objects that should be studied when assessing an *individual's* living standard. Aggregate well-being for a given cohort of people will then be regarded as the *average* well-being of the cohort. I will use the thought experiment written about extensively by Harsanyi (1955), in which the standard of living in a society is the *expected* living standard of one who has equal probability of finding oneself in the place of each member of society.[4] This is, of course, what practical measures frequently amount to (e.g., national income per head and UNDP's

[4] It will be recalled that Rawls' thought experiment was so constructed that the average living standard was replaced by a maximum-minimum living standard (Rawls 1971). The indices I work with below do not capture this thought experiment exactly, but it does so with reasonably good approximation.

(1991) Human Development Index). Inequality among a given cohort (e.g., between men and women, and between the poor and non-poor) can then be studied separately and additionally.

1.3 Why Measure Well-Being?

Measures of social well-being are necessary for at least five purposes. First, there is need for an aggregate index of economic activity, which would help one to summarize a macroeconomy. GNP has been useful in this role. Secondly, one may wish to compare the states of affairs in different places (e.g., countries), or between different groups of people (e.g., the poor versus the rich, or men versus women), at a given point in time.

It is the case that in international publications the indices that are typically used for the second purpose reflect only the *current* living standard. For example, the World Bank, in its annual *World Development Report* (e.g., World Bank 1995), compares life expectancy at birth, infant survival rate, and public and private consumption per head across countries in a given year. One of the points of the exercise is to compare the current quality of life across countries (see the Appendix, Proposition 3). However, in the same publication, countries are ranked in accordance with their GNP per head. Why? It may be that the intention is to include a country's future prospects in a summary measure. Being the sum of aggregate consumption and investment, GNP may appear adequate for the task. The problem is that, as it does not include the depreciation of capital assets, GNP is incapable of reflecting future prospects (see Section 3.2). GNP is *not* the flow equivalent of wealth (see Appendix, Propositions 4-5). So it is not accurate to regard a country as poor on the grounds that it’s GNP per head is low. GNP is a measure of current economic activity and the prospects such activity brings with it, nothing more.

The third reason quality-of-life indices are needed is that one might wish to make welfare comparisons over time of people in the same place (e.g., the same country) or members of a particular group (e.g., the poor or rich, or women). For example, one may ask if a country is doing better today than it did a decade ago, and so forth. The World Bank analyzes this as well in its annual *World Development Report* by estimating changes over time through indicators such as life expectancy at birth, infant survival rate, and public and private consumption per head (e.g., World Bank 1995). The idea is to compare the *current* standard of living of a group of people at different dates (see Appendix, Proposition 3).

The previous two reasons for the need for welfare indices focused on measures that reflect the current living standard. In contrast, the fourth reason stems from a desire to estimate

the economic component of the standard of living an economy is capable of *sustaining* along alternative programs. Early definitions of national income (Lindahl 1934; Hicks 1940; Samuelson 1961; Weitzman 1976) were designed to address this latter problem, and the bulk of recent theoretical explorations in green net national product (green NNP) have returned to it.[5] It has been the claim of this literature that NNP per head (that is, GNP per head minus the per capita accounting value of the depreciation of all capital assets) is the measure that is sought (see the references in Footnote 5). In the Appendix (Proposition 2 and the remarks following it), I show that the claim is mistaken: NNP per head is inadequate for the task. I also show that per capita *wealth*, suitably defined, is the appropriate index. More particularly, it is demonstrated in the Appendix (Proposition 4) that if net investment per head is positive, the sustainable living standard increases, and vice versa. It may not be a coincidence that Adam Smith's classic was an inquiry about the wealth of nations, not the income of nations.

The thought then arises that per capita wealth could also be used in making cross-country comparisons of sustainable living standards. In the Appendix (Proposition 6) I show that this is true, but only under what should be regarded as very strong assumptions. If the assumptions don't hold, there is no simple index adequate for the task. In Section 2.4 I present a non-technical account of these findings.

Finally, the fifth reason a quality-of-life index is necessary is that there should exist ways to evaluate alternative economic policies. Criterion functions for social cost-benefit analysis of investment projects, such as the present discounted value of the flow of accounting profits (e.g., Dasgupta, Marglin, and Sen 1972; Little and Mirrlees 1974; Squire and Van der Taak 1975) are examples of such indicators (see Section 3.1).

Since economic activity, the current quality of life, evaluation criteria for policy choice, and sustainable living standards do not refer to the same entity, their numerical measures are not necessarily the same. For example, in a market economy, obviously the wage bill for labor should be included if the required index measures aggregate economic activity, as in GNP. But it is by no means obvious that the item ought to be included if the index is to measure social well-being (Nordhaus and Tobin 1972; Dasgupta and Mäler 1999; see the Appendix). The conclusion

[5] See, for example, Solow (1986, 1992), Hartwick (1990, 1994), Asheim (1994, 1997), Aronsson Johansson, and Löfgren (1997), Aronsson and Löfgren (1998), and Weitzman (1998).

is banal: the way an index ought to be defined, let alone estimated, is not independent of the purpose to which it is put.

But before all else, the purpose of the evaluation should remain clear before undertaking it and evaluations should be conducted as dispassionately as possible. Making good points with bad arguments may disguise the fact that there exist good arguments that would have served the purpose. Here is an example of the kind of mistake one makes when attempting an over-kill:

In drawing attention to the enormous inequality in today's world, UNDP (1998, p. 30) writes: "New estimates show that the world's 225 richest people have a combined wealth of over 1 trillion U.S. dollars, equal to the annual income of the poorest 47% of the world's people (2.5 billion)."

It should be known that wealth is a stock and income a flow. Consequently, one should be converted into the other before the figures can be compared. The standard practice would be to convert wealth into a figure for permanent income by using a 5% annual interest rate, that is, to divide wealth by a factor of 20. When this conversion is performed on the data, my calculations, albeit crude, tell me that the world's richest 225 people, having a combined annual income of over 50 billion U.S. dollars, earn more than the combined annual incomes of people in the world's 12 poorest countries, or about 7% of the world's population (385 million). This is still a sobering statistic.

It could be argued that if a welfare indicator is necessary, well-being should be measured directly, and not given a different name, such as present discounted value of the flow of accounting profits, net national product (NNP), or wealth. This is a valid point. On the other hand, as there are several reasons for seeking a welfare measure, for many purposes the most convenient index could be something other than the thing itself. For example, one could be interested in some object X, but X may prove especially hard to measure (e.g., because it involves estimating non-linear functions of observable quantities). Suppose now that for some purposes X correlates perfectly with Y and that Y is easier to measure than X (e.g., because Y is a linear function of observable quantities). Then one would wish to rely on Y for those purposes. As is well known, wealth is linear in quantities, with the weights being at least in part revealed by observable market prices. This is the case also with the present discounted value of the flow of accounting profits.

2. Measuring Well-Being

2.1 Constituents and Determinants of Social Well-Being

The preceding observation suggests that there are two ways of measuring social well-being. One is to study the constituents of well-being (e.g., health, happiness, freedom, or more broadly, basic liberties); the other is to value the commodity determinants of well-being (goods and services that are inputs in the production of well-being; for example, food, clothing, potable water, shelter, and resources devoted to national security). The former procedure measures "output," such as indices of health and civil and political liberties, whereas the latter values and then aggregates the required "inputs," for example, expenditure on health and resources deployed for the protection and promotion of civil and political liberties.[6] If undertaken with sufficient precision and care, either on its own would do the job (Dasgupta 1993, Ch. 7*): changes in a suitable aggregate measure of either the constituents or the determinants can be made to serve as a measure of changes in the quality of life in a society. Along the former route one would measure the constituents directly and aggregate them in a suitable way, using social weights to reflect the relative worth of the various constituents (Dasgupta, Marglin, and Sen 1972). Along the latter route one would need to estimate accounting prices (see the Appendix, Proposition 4) of the determinants of well-being in order to arrive at a suitable index for the purpose at hand (i.e., wealth. As already observed, wealth is a linear function of the stocks of goods and services. This is why social well-being is frequently measured indirectly in terms of its determinants, rather than measured directly in terms of its constituents.

In practice, neither the constituents nor the determinants, on their own, reflect what I wish to see captured in any reasoned conception of the quality of life. The problem is that there would be far too many person-specific accounting prices to contend with (e.g., those based on income distributional weights) if an overarching measure using only the determinants of social welfare is estimated. At the same time, a person's disposable income (as is customarily measured), does reflect aspects of welfare and the extent of certain patterns of freedom (vis à vis the freedom to choose over commodity bundles)—matters which are hard to come to grips with directly. For this reason, governments and international agencies pursue both avenues at once,

[6] To be sure, there are goods, such as education and skills, that perform both functions: they are at once constituents and determinants of well-being. They do not pose problems if we are able to track the two functions and their contributions to well-being.

and it is today commonplace to assess the quality of life by studying a heterodox collection of socioeconomic indicators (e.g., World Bank 1996; UNDP 1998). Earlier, I noted several weaknesses in the indices currently in use. In the following section, I develop an index that overcomes some of their limitations.

Well-being isn't the same as happiness. One could be in a happy frame of mind under the influence of drugs and yet be in a state that could only be regarded as reflecting a low quality of life. This and other such examples have been discussed frequently in moral philosophy (e.g., Sidgwick 1907). Moreover, it is especially hard to get a quantitative feel for the experiential state associated with the sense of well-being. The point is that states of mind are involved. Admittedly, other minds are not as inscrutable to one as they are commonly made out to be; one's own experiences provide the right source of information. Placing ourselves sympathetically in various possible situations is a way of obtaining the necessary information.

One could, of course, study such objective indices as a country's divorce or suicide rate, so as to measure experiential states. This too has been suggested. But such indicators are seriously deficient. Divorce rates in a society may be low not because marriages are happy, but because the cost of divorce is prohibitively high, as is the case with some women in certain countries. Similarly, suicide rates suggest features of the lower tail of the distribution of mental states. However, one would wish to know something about the entire distribution. A related approach would be to ask people if, on some specified scale (say, from 1 to 10), they were happy (e.g., Frey and Stutzer 1999). States of mind cannot be measured. In any event, whether indices of the state of mind should be included when evaluating a person's well-being depends on the point of the exercise. For example, contractarian theories of the state (e.g., Rawls 1972; Nozick 1974) typically would not allow the state to be concerned with whether citizens are happy. Such theories would restrict the state to making sure that basic liberties are enjoyed.

This said, happiness is far too important a component of well-being to be bypassed. So it is a puzzle that the contemporary literature on social well-being simply ignores it. A prior question would be to ask what, in a normal state of mind, is conducive to happiness? Interestingly, at reasonably high levels of income, income would appear not to contribute much to happiness. Surveys in a number of western countries have revealed that substantial growth in per capita income has not translated into any significant increase in reported happiness (Easterlin 1974; Scitovsky 1976; Oswald 1997). A natural conclusion to draw from this would be that, at relatively high levels of income, personal happiness depends on one's income or expenditure relative to the mean income or expenditure of some reference group (e.g., per capita national income, as discussed in Easterlin (1974)). But I know of no comparable finding among the poor

in poor countries and would be surprised if such findings exist. It is hard to believe that at really low levels of income happiness is not associated with income.

Studies suggest that health contributes significantly to happiness: other things being the same, healthy people are happier than those who suffer from ill health (e.g., Frey and Stutzer 1999). Studies in Europe also suggest that unemployment contributes significantly to unhappiness. Interestingly, in their study of a large sample from various cantons of Switzerland, Frey and Stutzer (1999) find that associational life plays a role too: people who are more engaged in civic activities are happier. Assuming that these findings are robust, indices of health, and civic and political liberties could serve as surrogates for happiness. In poor countries, consumption too would be considered a surrogate. So if these indices are included in measures of well-being, measures of happiness do not need to be introduced directly. This is the route I follow in the next section.

2.2 Measuring Current Well-Being

The problem, then, is to identify a minimal set of indices that would span one's conception of social well-being, whether it is current or sustainable. I have noted already that it is important to avoid double counting. For example, statistics on the proportions in populations of those without access to potable water are in frequent use when depicting the quality of life, as are statistics on infant mortality rates. Thus, the two are expected to be highly correlated; indeed one is an important cause of the other. If one has the former piece of information, one does not need the latter in constructing a quality-of-life index.

It has become customary to make cross-country and intertemporal comparisons of the quality of life in terms of current well-being. In this section I look at the issues that are involved in making such comparisons.

Begin with a person. In choosing a standard-of-living index, a balance must be made between the claims of completeness and costs. Leaving aside for the moment the extent of civil and political liberties one enjoys, it seems there are at least three broad kinds of indices one can use in constructing a measure of current well-being: disposable income, health status, and educational attainments.[7] Now, these are different categories of goods. Health and education

[7] For a detailed discussion, see Dasgupta (1993, chs. 2-5).

seem to embody aspects of what are called "positive freedoms" (moreover, they are both ends and means), whereas disposable income contributes to the enjoyment of freedoms. So then why are they often mixed up?

The reason is that someone's real disposable income measures the extent to which consumption goods like food, clothing, shelter, legal aid, and general amenities are obtainable in the market. But primary health care and education do not fall in the same category. As improvements in primary health care and primary education give rise to wide-ranging "externalities" when they are privately supplied, private markets don't provide an ideal resource allocation mechanism for their supply. Markets for these goods should be supported by the state, in a manner that assures citizens of their supply.

Government involvement in the provision of primary health care and education varies enormously across poor countries. For this reason it is possible for people in one country on average to enjoy a higher disposable income than those in another country, yet suffer from worse health care and education facilities than that same country. Stating matters in the reverse way, it is possible for people in one country on average to be better educated and to enjoy better health than in another even while their access to other material goods is more restricted (see Table 1). Disposable income, health, and education indices reflect in their various ways the current socioeconomic status of a person.

The move from the individual to the aggregate is fraught with well-known difficulties. As I am focusing on (current) well-being, averaged over a population, I bypass inequality measures here.[8] A problem frequently overlooked concerns the legitimacy of moving from one person's disposable income, in thinking of a person's well-being, to a country's aggregate output per head, when reflecting upon social well-being. Thus, GNP per head continues to be regarded as the quintessential indicator of a country's living standard. The gigantic literature on the determinants of economic growth testifies to this, as do annual publications from international organizations. Even the UNDP's *Human Development Index* considers GNP per head a quality of life component.[9]

[8] The literature on distributional issues is vast (e.g., Sen 1992). Their consideration can be included in what follows by imputing person-specific weights to individual well-beings.

[9] The others are life expectancy at birth and literacy (e.g., UNDP 1998). The Human Development Index has been finessed over the years to be, for example, sensitive to gender inequalities.

Table 1. Living Standards' Indicators in 1980

	(Y)	C	E	L	R_1	R_2
Bangladesh	(540)	491	48	26	4	4
Benin	(534)	427	47	28	7	7
Bolivia	(1529)	1147	50	63	3	5
Botswana	(1477)	827	55	35	3	2
Burundi	(333)	393	46	25	6	7
C.A.R.	(487)	536	47	33	7	7
Chad	(353)	339	42	15	6	6
China	(1619)	955	67	69	6	6
Ecuador	(2607)	1642	63	81	3	5
Egypt	(995)	657	58	44	5	5
Ethiopia	(325)	260	44	15	7	7
Haiti	(696)	633	52	23	6	7
Honduras	(1075)	720	60	60	3	6
India	(614)	423	54	36	3	2
Indonesia	(1063)	606	53	62	5	5
Jordan	(1885)	1372	62	70	6	6
Kenya	(662)	430	55	47	5	5
Korea	(2369)	1486	67	93	5	5
Lesotho	(694)	1106	52	52	4	5
Liberia	(680)	374	52	25	4	6
Madagascar	(589)	437	51	50	5	5
Malawi	(417)	334	44	25	6	6
Mali	(356)	288	44	10	7	7
Mauritania	(576)	271	43	17	6	6
Mauritius	(1484)	1042	65	85	2	4
Morocco	(1200)	803	57	28	4	3
Nepal	(490)	456	45	19	6	5
Niger	(441)	309	42	10	6	7
Nigeria	(824)	511	48	34	3	5
Pakistan	(990)	821	49	24	5	6
Paraguay	(1979)	1464	66	84	5	5
Philippines	(1551)	1039	61	75	5	5
Rwanda	(379)	322	45	50	5	6
Senegal	(744)	655	45	10	3	4

Sierra Leone	(512)	394	38	15	5	6
Somalia	(415)	324	44	60	7	7
Sri Lanka	(1200)	509	68	85	3	2
Sudan	(652)	554	46	32	5	5
Swaziland	(1079)	550	51	65	6	5
Tanzania	(353)	275	50	79	6	6
Thailand	(1694)	1117	62	86	4	6
Tunisia	(1845)	1107	60	62	6	5
Uganda	(257)	252	46	52	7	7
Zaire	(224)	168	49	55	6	7
Zambia	(716)	387	50	44	5	5
Zimbabwe	(930)	586	55	69	5	5

Key: Y - per capita GNP (international dollars)
C - per capita private consumption (international dollars)
E - life expectancy at birth (years)
L - adult literacy rate (%)
R_1- index of political rights
R_2- index of civil rights

Abbreviations: C.A.R. (Central African Republic)
Source: World Bank (1982) and Dasgupta and Weale (1992)

Personal income is the return on a person's wealth. But GNP is not the return on a nation's wealth. This will make for complications when, in Section 2.4, I develop the concept of a sustainable living standard (see also the Appendix). As I am now interested in developing an index of the current standard of living, I have to ignore saving for the future. This leaves me with aggregate consumption, which consists of private and government consumption. But note that the latter is composed mainly of expenditures on health, education, and defense. I will measure the quality of health and education directly (by life expectancy at birth and literacy). This means that I count health and education twice if government expenditure is included in the summary index. So I ignore such components of government expenditure.

I will now discuss defense, a central responsibility of government. In poor countries, which is what I am mainly concerned with here, the machinery for warfare is too frequently used by governments against their own citizens. Moreover, what is important for citizens is their freedom to be and do, a freedom that is generally compromised if national security is threatened. As civil and political liberties are prime components of the quality of life, they must be included

explicitly. But this in turn means that defense expenditure can be ignored when constructing an index of the socioeconomic component of social well-being.

Let me summarize: a minimal set of indices that would span one's conception of average well-being in a society would include private consumption per head, life expectancy at birth, literacy, and civil and political liberties.[10]

The question of aggregating the five indices still remains. Here is an interesting problem, one that has been greatly neglected in the literature on living standards. Indices that reflect the economic component of well-being are *strongly cardinal*, that is, they are scale invariant. For example, whether one measures private consumption in dollars or cents does not matter, so long as one remembers that the latter is one-hundredth of the former. This enables one to say, for example, that someone's consumption rate is twice that of another person, or that someone today consumes three times as much as he did ten years ago, and so forth. But indices of civil and political liberties aren't like that, and cannot be like that. They are ordinal. It would make sense to say that the average citizen of one country enjoys greater civil liberties than the average citizen of another country, or that civil liberties have increased in a country, but it makes no sense to say that civil liberties in one country are four times those in another, and so on. An ordinal aggregator is needed.

Of the many that could be devised, the one best known and most studied is the Borda Rule. This rule provides a method of rank-order scoring, in which each alternative (say, a country) is awarded a point equal to its rank in each criterion of ranking (the criteria being (i) per capita private consumption, (ii) life expectancy at birth, (iii) literacy, (iv) political liberties, and (v) civil liberties). All of each alternative's scores are added to obtain its aggregate score, and then alternatives are ranked on the basis of their aggregate scores.

To illustrate, suppose a country has the ranks i, j, k, l, and m, respectively, for the five criteria. Then its Borda score is i + j + k + l + m. The rule invariably yields a complete ordering of alternatives. It can be viewed as a "social welfare function," since the criteria can be thought of as "voters." Of Arrow's classic axioms on social choice, the Borda Rule violates the one concerning the independence of irrelevant alternatives (Arrow 1963). Goodman and Markowitz (1952) and Fine and Fine (1974) have investigated the strengths and limitations of the Borda Rule. There is now a good intuitive understanding of it. So I use it for illustrating how one could

[10] For a more thorough justification of the choice of these indices, see Dasgupta (1993, chs. 2-5).

make cross-country comparisons of the current quality of life if the use of ordinal indices is restricted, as it ought to be.[11]

2.3 Estimating Current Well-Being in Poor Countries

This study consists of countries that were among the world's poorest in terms of income per head in the early 1970s. My hope is to gain a preliminary understanding of the way various components of well-being are related in today's world. Given the context in which such discussions have recently been undertaken, the restriction to the world's poorest countries is both deliberate and right.

I consider countries where GNP per head in 1970 was less than $1,500 at 1980 international dollars.[12] The idea is to look at a snapshot of the quality of life in each country. The year in question is 1979-1980. I was able to obtain data on all five components of social well-being for only 46 out of the more than 55 countries that should be on the list. Table 1 summarizes the data. Since GNP per head is probably the most familiar international statistic, figures for this are provided in the first column of figures (but in parentheses, so as to remind ourselves that the country ranking on the basis of GNP per head is not being used in the construction of the Borda index).

The second column in Table 1 consists of estimates of private consumption per head in 1980. The third and fourth columns of figures present life expectancy at birth and literacy, respectively, again, for the year 1980.

The fifth and sixth columns of figures in Table 1 represent indices of political and civil liberties in my sample for the year 1979. They are taken from the valuable compendium of Taylor and Jodice (1983). Rights to political liberty are seen as a citizen’s right to play a part in determining who governs the country, and what the laws are and will be. Countries are coded

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[11] Of course, we could create a cardinal aggregator for the socioeconomic indices (private consumption per head, life expectancy at birth, and literacy) and then construct the Borda ranking out of the three resulting rankings, namely, the rankings based on civil and political liberties and the socioeconomic aggregate. In what follows in the text, I avoid creating complications by working directly with the five rankings.

[12] As the exercise that follows is purely illustrative, I have relied on data collated in Dasgupta and Weale (1992) and Dasgupta (1993), in which per capita GNP is one of the socioeconomic components of the quality of life. As I have just argued in the Sections 2.1-2.2, this is a mistake. So I have recalculated the data by replacing per capita GNP with private consumption per head. This makes for some difference in the ranking of poor nations.

with scores ranging from 1 (highest degree of liberty) to 7 (lowest degree of liberty). Values for this index are given in the fifth column of figures in Table 1.

Civil rights are different. They are rights the individual has vis-à-vis the state. Particularly important in the construction of the index in Taylor and Jodice (1983) are freedom of the press and other media concerned with the dissemination of information, and the independence of the judiciary. The index measures the extent to which people, because an independent judiciary protects them, are openly able to express their opinions without fear of reprisals. Countries are coded with scores ranging from 1 (highest degree of liberty) to 7 (lowest degree of liberty). Values of the index are given in the sixth column of figures.

Even a glance at the last two columns shows that for the most part political and civil liberties were scarce goods in poor countries in the late 1970s. Citizens of 32 countries in my sample of 46 suffered from systems that score 5 or more for political rights, and those of no fewer than 39 countries from systems that score 5 or more for civil rights. This suggests that civil rights can be, and are frequently, curtailed in countries where elections are held. The scores reflect severe deprivation of basic liberties. There were exceptions of course, most notably Botswana, India, Mauritius, and Sri Lanka. But for the most part the columns make for dismal reading. And when they are combined with the columns that reflect the socioeconomic sphere of life, the picture that emerges is chilling. There was nothing to commend the state of affairs in a large number of the countries in my sample.

The first column in Table 2 presents the Borda ranking of nations, based on the rankings in the five columns that follow. Countries are listed in accordance with their Borda ranks. The ranking is from the worst (score of 1; Mali and Ethiopia being the joint losers) to the best (score of 46; Mauritius being the winner). For completeness, country rankings on the basis of GNP per head are provided in the final column in parentheses.

It is a useful exercise first to look at the best- and worst-off sets of countries. From the first column of figures, I note that in ascending order of aggregate well-being, the ten lowest-ranked countries in 1980 were Mali, Ethiopia, Niger, Mauritania, Chad, Malawi, Uganda, Burundi, Somalia, and Benin. How does this list compare with the ranking of nations based exclusively on GNP per head? To see this, I note from the final column that, in ascending order, the ten poorest countries in terms of GNP per head were: Zaire, Uganda, Ethiopia, Burundi, Tanzania, Chad, Mali, Rwanda, Somalia, and Malawi. The lists aren't the same, but they are strikingly similar. All countries are in sub-Saharan Africa, and the lists contain seven countries in common.

Table 2. Rankings of Living Standards Data for 1980

	BORDA RANK	C	E	L	R_1	R_2	(Y)
Mali	1	6	5	1	1	1	7
Ethiopia	1	3	5	4	1	1	3
Niger	3	7	2	1	7	1	11
Mauritania	4	4	4	7	7	11	17
Chad	5	11	2	4	7	11	6
Malawi	6	10	5	10	7	11	10
Uganda	6	2	12	27	1	1	2
Burundi	8	14	12	11	7	1	4
Somalia	9	9	5	30	1	1	9
Benin	10	17	15	15	1	1	15
Sierra Leone	11	15	1	4	20	11	14
Zaire	12	1	19	29	7	1	1
C.A.R.	13	24	15	18	1	1	12
Nepal	14	20	9	18	7	23	13
Haiti	15	29	26	9	7	1	24
Rwanda	16	8	9	25	20	11	8
Tanzania	17	5	21	40	7	11	5
Liberia	18	12	26	11	33	11	22
Pakistan	19	34	19	10	20	22	29
Sudan	20	26	12	17	20	23	20
Zambia	21	13	21	22	20	23	25
Madagascar	22	19	24	25	20	23	18
Swaziland	23	25	24	35	7	23	33
Kenya	24	18	31	24	20	23	21
Senegal	25	30	9	1	38	40	26
Nigeria	26	23	17	19	38	23	27
Bangladesh	27	21	17	14	33	40	16
Egypt	28	31	35	22	20	23	30
Indonesia	29	28	29	32	20	23	31
China	30	36	44	36	7	11	40
Zimbabwe	31	27	31	36	20	23	28
Jordan	32	43	39	38	7	11	43
Tunisia	32	40	36	32	7	23	42
Honduras	34	32	36	30	38	11	32
India	35	16	29	21	38	44	19
Lesotho	35	39	26	27	33	23	23
Philippines	37	37	38	39	20	23	39
Bolivia	38	42	21	34	38	23	38
Morocco	38	33	34	15	33	43	35
Botswana	40	35	31	20	38	44	36
Thailand	41	41	39	45	33	11	41
Paraguay	42	44	43	42	20	23	43
Korea	43	45	44	46	20	23	45
Ecuador	44	46	41	41	38	23	46
Sri Lanka	45	22	46	43	38	44	34
Mauritius	46	38	42	43	46	40	36

Key: BORDA RANK - ranking using Borda Rule
C - per capita private consumption (international dollars)
E - life expectancy at birth (years)
L - adult literacy rate (%)

R_1- index of political rights
R_2- index of civil rights
Y - per capita GNP (international dollars)

Abbreviation: C.A.R. (Central African Republic)

Turning next to the ten highest-ranked countries in terms of social well-being, I note first that they are, in descending order: Mauritius, Sri Lanka, Ecuador, Korea, Paraguay, Thailand, Botswana, Bolivia and Morocco (tied), and the Philippines.

The relative positions of China on the Borda ranking (coming in at 17 from the top) and India (coming in five places ahead, at 12) deserves a brief comment. For a long while China and India have provided commentators with a classic tension: achievements in the economic sphere against those in the arena of political and civil liberties. As can be seen from Table 1, China beat India handsomely in each of the three socioeconomic indices on my list (for example, private consumption per head in China in 1980 was more than twice that in India), while India beat China in political and civil liberties. All this is consistent with general knowledge. However, the fact that the two finish so close in a ranking of 46 countries means that the ordinal distance between them in political and civil liberties is large relative to their distance in terms of the socioeconomic indicators. Other things remaining the same, had more countries managed to squeeze themselves in between China and India in the socioeconomic indicators, the overall ranking of these two countries would have been reversed (recall that the Borda Rule violates the "independence of irrelevant alternatives" axiom in Arrow 1963). On the other hand, had more countries squeezed themselves in between China and India in the sphere of political and civil liberties, the Borda gap between the two countries would have been greater. Clearly then, the relative placing of China and India are sensitive to the aggregator being used. To me this is instructive.[13]

How does the list of the ten top countries compare with the list of the ten least poor countries? As it happens, they are very similar. The ten least poor countries in my sample were, in descending order: Ecuador, Korea, Paraguay, Jordan, Tunisia, Thailand, China, the

[13] In texts by Dasgupta and Weale (1992) and Dasgupta (1993), in which such computations were first undertaken, the socioeconomic indices included were GNP per head, life expectancy at birth, infant survival rate, and literacy. Since life expectancy at birth is strongly influenced by infant survival, this amounted to counting similar health indices twice. It explains why, using what was essentially the same data set as Table 1, the two earlier studies found China to have a higher Borda score than India, the reverse of the present finding.

Philippines, Bolivia, and Mauritius. There are seven countries in common. I conclude tentatively that, among the poorest nations, rankings in terms of my index of aggregate well-being are not too different from rankings based on income per head.

But this is a qualitative claim, and it will be informative to get a quantitative feel for the relationship between the Borda ranking and each of the rankings based on the five components of social well-being. Statistically, how close then is the Borda ranking to the other five? In order to examine this I will look at rank correlations.

Table 3 provides the (Spearman) correlation coefficient for each pair of rankings from the seven rankings of nations in Table 2. It shows that the correlation coefficient between the Borda ranking and the others are 0.84 with private consumption per head; 0.88 with life expectancy at birth; 0.72 with literacy; 0.76 with political rights; and 0.75 with civil rights. I had not expected that life expectancy at birth would be the closest to my measure of the quality of life.

Table 3. (Spearman) Correlation Matrix of Living Standard Rankings

C	0.84					
E	0.88	0.75				
L	0.72	0.54	0.79			
R_1	0.76	0.51	0.48	0.28		
R_2	0.75	0.50	0.50	0.30	0.76	
Y	0.87	0.91	0.83	0.61	0.55	0.57
	Borda	C	E	L	R_1	R_2

At the same time, it is interesting that the Borda ranking of countries is highly correlated (0.87) with the ranking of countries based on GNP per head. The present findings imply that if one had to choose a single, ordinal indicator of aggregate well-being, either life expectancy at birth or GNP per head would do! There must be a moral to this.

In this paper I have argued that GNP per head should not be considered a component of social well-being, rather, that private consumption per head should be. Not surprisingly though, the link between GNP and private consumption is close: in my sample, the correlation coefficient is 0.91. It is customary in studies of economic development to regress GNP per head against

other socioeconomic indicators to see how closely they are related. The last row of figures in Table 3 presents Spearman rank correlation coefficients between GNP per head and each of the chosen five components of well-being. Ignoring private consumption per head, the highest correlation (0.83) is with life expectancy at birth. Again, I did not expect this. I also had no prior notion that correlation with literacy (0.61) would be considerably less.

Richer countries seem enjoy greater political and civil liberties. But the correlation is not significantly high (the correlation coefficient between private consumption per head and political rights is 0.51 and with civil rights is 0.50). But neither private consumption per head nor political nor civil liberties should be thought of as being exogenously given. Any such link between them, as observed in international data, should only be seen as a link, nothing more. No causal relationship can be presumed from the data. However, correlation coefficients of 0.51 and 0.50 do suggest that claims that poverty-inducing circumstances are the same as circumstances that necessitate a government's denial of citizens' civil and political liberties are simply false. There are countries in the sample that are very poor in terms of private consumption but enjoy relatively high civil and political liberties.

Literacy is a rogue index: it stands somewhat apart from the other socioeconomic indices. The correlation coefficient between literacy and political and civil liberties are 0.28 and 0.30 respectively. These are relatively low figures, far and away the lowest figures in Table 3.

2.4 Wealth as Sustainable Well-Being

One may wonder where (if anywhere) NNP, suitably defined with all relevant accounting prices, comes in. Recall that GNP is an index of economic activity, including "gross" capital formation, not "net." NNP is superior precisely for this reason (Section 1.3). It reflects not only one of the economic components of current well-being (vis à vis consumption), it is sensitive also to the provisions currently made for the economic component of future well-being.

In the previous two sections indices of current well-being were studied. Here I study sustainable well-being (a formal definition is provided in the Appendix, Sections A.5-A.6). This requires of one to peer into future possibilities. For tractibility, I restrict discussion to the socioeconomic component of well-being, the implicit hypothesis being that civil and political liberties are a given. This is not a great hypothesis, but not much can be done to improve it. An adequate overarching theory that relates "economics" to "political science" is still lacking. In particular, there is no workable model in which both future production possibilities and civil and political liberties are endogenous. So with hands tied behind the proverbial back, I consider

intertemporal output and consumption possibilities, but not civil and political liberties. In the Appendix a canonical model of production and accumulation involving labor, physical, knowledge, and environmental capital is presented. It enables number of conclusions to be drawn. The discussion here is based on findings discussed in the Appendix.

What *does* NNP reflect? Following Weitzman (1976), NNP at any given date is widely thought to measure the *sustainable standard of living* made possible by an economy's assets at that date. Why might one be interested in such a result? One would be interested if it enabled NNP comparisons to be made, say between two dates, to infer how sustainable living standards compare between those same two dates. For example, if the Weitzman result is correct, I would conclude that sustainable living standard in a country has grown over a period if I observe that its NNP per head has grown over that same period.

In the Appendix, I show that this cannot be done: unless an economy is in a steady state, NNP per head does not measure the sustainable standard of living (Proposition 2) in the sense that comparisons of NNP per head across time and communities do not amount to comparisons of the standard of living across time and communities (Propositions 4-7). This in turn means that NNP per head should not be used in making intertemporal or cross-country comparisons of well-being. I show that in order to make intertemporal comparisons of a community's sustainable living standard, the appropriate index is wealth (Propositions 4 and 6), which is another way of saying that, in making intertemporal comparisons of a community's sustainable welfare, one should estimate if net investment has been positive, negative, or nil.[14] Unfortunately, I am unable to conduct the kind of numerical investigation I was able to offer in Section 2.6: Presently, there are only a few reliable country-estimates of the value of changes in natural capital over time. Nevertheless, there are reasons for thinking that many sub-Saharan African countries have seen their assets decline during the past four decades or so. The development of international statistics on changes in the wealth of nations should now be a matter of urgency.[15]

The findings derived in the Appendix reflect the fact that *NNP is not the flow equivalent of wealth*. However, NNP, properly defined, *can* be used to evaluate short-term changes in economic policy. This is proved in Proposition 1 in the Appendix. To be sure, if NNP is to be

[14] Pearce, Hamilton, and Atkinson (1996) have also suggested the use of wealth as the basis for welfare comparisons.

[15] Serageldin (1995) has reported empirical work conducted at the World Bank on measuring changes in wealth (see also World Bank 1996).

used for the purposes of policy evaluation, accounting prices should be used. Recall that the accounting price of a resource is the increase in social well-being if an additional unit of the resource is made available without additional cost. Assume for simplicity that labor is supplied inelastically (I drop this assumption in the Appendix). In this case, NNP in a closed economy, when correctly measured, reads as

> NNP = *Consumption + net investment in physical capital + the value of the net change in the stock of natural capital - the value of current environmental damages.*[16]

Notice that the value of net changes in human capital and knowledge is included implicitly in the first two terms in the formula for NNP. It is useful also to note that the convention of regarding expenditures on public health and education as part of final demand implicitly equates the cost of their provision with the contribution they make to social well-being. This in all probability results in an underestimate in poor countries. If education is a constituent of the standard of living, and not merely a determinant because it raises productivity, then its accounting price would be that much higher. I should note as well that current defensive expenditures against damages to the flow of environmental amenities ought to be included in the estimation of final demand. Similarly, investment in the stock of environmental defensive capital should be included in NNP. These and a number of other rules for constructing national accounts are proved in the Appendix. In the remainder of this essay I explore methods appropriate for evaluating policy change.

3. Evaluating Policy

3.1 Valuing Goods and Evaluating Projects

Policy changes are perturbations to a prevailing state of affairs. Investment projects can therefore be interpreted as policy changes. A project consisting of a dam would be a perturbation to an economy without the dam. The economic forecast without the project can be thought of as

[16] In an open economy the value of net exports ought to be deducted from the equation. See Sefton and Weale (1996).

the status quo. I could, of course, analyze the consequences of a policy change in terms of their impacts on the constituents of social well-being. But as I argued earlier, there are advantages to analyzing them in terms of their impacts on social well-being determinants. The linear indices I have been alluding to, such as the present discounted value of the flow of accounting profits from a project, work most effectively if the perturbation being evaluated is "small."[17] What constitutes "smallness" is a delicate matter and the project evaluator should be sensitive to it. An investment project can be small in terms of a country's NNP and yet have a big impact on the lives of some very poor people; in which case it wouldn't be small for them. The way to proceed would be to estimate the net benefits the people in question would experience if the project is undertaken. The net benefits would typically be non-linear functions of quantities.

In evaluating an investment project, the need for labor, intermediate products, and raw materials is estimated, and the project's output and its impact on the ecological system are predicted, quantitatively, for each period. Most often, though, one does not have sufficient knowledge to make precise estimates of the consequences. One therefore needs quantitative estimates of the uncertainties, preferably in terms of probabilities. This means that, in general, one has to model the integrated ecological and economic system.[18] The evaluation procedure involves estimating the impact of projects on human well-being —now and in the future. In order to arrive at an estimate, each and every commodity of the project has to be valued in terms of some numeraire (e.g., consumption, as in the formula for NNP in Section 2.4). The accounting price of a commodity or service is measured by its social opportunity cost in terms of the numeraire. These steps are common to all methods of evaluation.

If one wishes to assess the impact of a brief policy change on social well-being (e.g., a short-term investment project), then, as noted in Section 2.4, the effect of the change on NNP (suitably defined) could be used for evaluating whether the change is worthwhile (Appendix, Proposition 1). For long-lasting projects the most useful criterion is the present discounted value of the flow of accounting profits. To estimate this, one first computes the net social profit of a project in each period of its life. The net social profit, in turn, is obtained by multiplying the project's inputs and outputs in the period in question by its corresponding accounting prices, and adding them (outputs are taken to be positive, inputs are taken to be negative). Using a suitable

[17] Formally, we are then able to limit ourselves to the first-order approximations of the perturbations.

[18] See Daily et al. (1999) for an elaboration of this step.

discount rate, often called the "social rate of discount," the per-period net social profits yielded by a project are added.[19] Projects that yield a positive present discounted value of net social profits are then recommended and those that yield a negative present discounted value of net social profits are rejected.

Procedures for estimating the accounting prices of goods and services were much discussed at the World Bank in the 1970s (e.g., Squire and Van der Taak 1975). The theory of accounting prices at that time assumed in effect that the economy in which social cost-benefit analysis is conducted has an optimal economic policy in place, perhaps a second-best policy, but an optimal policy nonetheless. This was assumed explicitly in Little and Mirrlees (1974).

In contrast, Dasgupta, Marglin, and Sen (1972) developed prescriptions for project evaluation in economies where projects could be thought of as *policy reforms*, that is, perturbations to economic forecasts that may be riddled with inefficiencies and inequities. However, they offered no formal theory to justify their prescriptions for an economy moving through time.[20] Dasgupta and Mäler (1999) have since developed theoretical foundations of social cost-benefit analysis when investment projects are policy reforms. The theory is presented in the Appendix below. It is important to stress that the theory does not presume economies to possess a convex structure; production non-convexities arising from economies of scale and scope and from ecological thresholds can be accommodated. This is a significant improvement on earlier theories, which relied heavily on the assumption that economies possess a convex structure.

How would those valuation techniques developed in the 1970s and extended recently instruct society if they are put to work on current concerns? In a recent lecture, the president of the World Bank correctly observed that, "... the success of most projects is dependent on many assumptions extraneous to the project itself. Building new schools is of no use without roads to get the children to the schools and without trained teachers, books, and equipment... Initiatives to make progress creating equal opportunities for women make no sense if women have to spend many hours each day carrying clean water, or finding and gathering fuel for cooking. Seeking universal primary education without prenatal and postnatal health care means that children get to

[19] The social rate of discount in any period is the percentage rate of decrease over that period and the next in the accounting price of the numeraire.

[20] Projects as policy reform have been studied also by Meade (1955), Mäler (1975), Starrett (1988), Ahmad and Stern (1990), and Dreze and Stern (1990). But their analysis has been limited to essentially timeless economies.

school mentally and physically damaged. Establishing a health system but doing nothing about clean water and sewerage diminishes enormously the impact of any effort." (Wolfensohn 1999, p. 8.)

The author is pointing at the need to understand an economic system's response to project selection. His examples are about complementarities. Just as a shoe for the left foot is useless without the corresponding shoe for the right foot, establishing a health system, but doing nothing about clean water, would not amount to much. The accounting price of an object whose complements are unavailable is low, in the extreme it is nil. Projects that produce one without its complements would register a negative present discounted value of social profits. In short, an integrated project could pass the test even when its components, each on its own, would not.

3.2 The Environmental-Resource Base[21]

A significant weakness of the several manuals on social cost-benefit analysis written during the 1970s was their total neglect of the natural world. The environment was simply not taken into account.[22] Since market failure abounds in dealings with the environment, markets cannot be relied upon to provide prices that would even approximately signal the social scarcities of environmental resources. A great deal of work in environmental and resource economics since the 1970s has been directed at discovering methods for estimating the accounting prices of various types of environmental resources. But in considerable measure, practical methods have been developed for estimating the accounting prices of "amenities" (e.g., Mitchell and Carson 1989; Freeman 1992), much less so for the multitude of ecosystem services which constitute society’s life-support system, such as pollination, recycling of biomass, nitrogen fixation, and water purification. A systematic body of work is also lacking, one on valuation techniques appropriate for the many non-market institutional settings in which environmental resources are transacted.

However, the following is now abundantly clear: Indicators of social well-being in frequent use (e.g., GNP per head, life expectancy at birth, and infant survival rates) do not reflect the impact of economic activities on the environment and the latter's response to the treatment meted out to it. Since such indices as GNP per head pertain to commodity production, they don't

[21] Some of the material of this section is taken from Dasgupta (1993) and Dasgupta, Levin, and Lubchenco (1999).

[22] Dasgupta (1982) attempted to correct this.

fully take into account the use of natural capital in the production process. So, statistics on past movements of GNP reveal nothing about the resource stocks that remain. It is not clear, for example, whether increases in GNP per head are being realized by means of a depletion of the resource base (for example, if increases in agricultural production are not being achieved by means that adversely affect the services ecosystems are capable of providing us).

Over the years environmental and resource economists have shown how national accounting systems should be revised to include the value of changes in the environmental resource-base that occur each year due to human activities (e.g., Mäler 1974; Dasgupta and Heal 1979; Dasgupta and Mäler 1999). Economists should be in a position to determine whether resource degradation will reach the stage in which current economic activities will be unsustainable. But the practice of national-income accounting has lagged so far behind its theory that society has little idea of what the facts have been. It is entirely possible that time trends in such commonly used socioeconomic indicators as GNP per head, life expectancy at birth, and infant survival rates depict a singularly misleading picture of movements of the true standard of living over time.

To state the matter in another way, current-day estimates of socioeconomic indicators are biased because the accounting value of changes in the stocks of natural capital are not taken into account. Because their accounting prices are not available, environmental resources are frequently regarded as having no value. This amounts to regarding the depreciation of natural capital as of no consequence. But as these resources are scarce goods, their accounting prices are positive. If they depreciate, there is a social loss. This means profits attributed to projects that degrade the environment are frequently greater than the social profits they generate. Estimates of their rates of return are higher than their social rates of return. Wrong sets of investment projects therefore get selected, in both the private and public sectors; resource-intensive projects look better than they actually are. It should be no surprise, therefore, that installed technologies are often unfriendly towards the environment. This is likely to be especially true in many poor countries, where environmental legislation usually is neither strong nor effectively enforced.

The extent of such bias in investment activities will obviously vary from case to case and from country to country. But it can be substantial. In their work on the depreciation of natural resources in Costa Rica, Solorzano et al. (1991) estimated that in 1989 the depreciation of three resources—forests, soil, and fisheries—amounted to about 10% of GDP and over a third of gross capital accumulation.

One can go further: the bias extends to the prior stage of research and development. When environmental resources are underpriced (in the extreme, when they are not priced at all), there is little incentive on anyone's part to develop technologies that would economize their use. So the direction of technological research and technological change is systematically directed against the environment. Consequently, environmental "cures" are sought once it is perceived that past choices have been damaging to the environment, although "prevention," or input reduction, would have been the better choice.

To give an example, Chichilnisky and Heal (1998) compare the costs of restoring the Catskill Watershed ecosystem in New York State to the costs of replacing the natural water purification and filtration services the ecosystem has provided in the past by building a water-purification plant costing 8 billion U.S. dollars. They show the overwhelming economic advantages of preservation over construction. Independent of the other services the Catskill watershed provides, and ignoring the annual running costs of 300 million U.S. dollars for a filtration plant, the capital costs alone showed a more than six-fold advantage for investing in the natural-capital base.

But bad habits are hard to overcome. Even today the environment has not entered the common lexicon of economic discourse. Accounting for the environment, if it comes into the calculations at all, is an after-thought to the real business of "doing economics." For example, in a recent issue of *The Economist* (25 September 1999), a 38-page survey of the world economy does not mention the environmental-resource base in the authors' assessment of what lies ahead. An individual’s habits are so ingrained that I rather doubt many readers noticed this fact.

It is worth emphasizing that the purpose of estimating environmental accounting prices is not to value the entire environment; rather, it is to evaluate the benefits and costs associated with human-induced changes to the environment. Prices, whether actual or accounting, have significance only when there are potential exchanges from which choices have to be made (for example, when one has to choose among alternative investment projects). Thus, the statement that a particular act of investment is expected to degrade the environment by, say 1 million dollars annually, has meaning because it suggests that if the investment is not undertaken, humanity would enjoy an additional 1 million dollars of benefits in the form of environmental services. The statement also has operational significance: the estimate could (and should) be used for calculating the present discounted value of the flow of social profits attributable to the investment in question.

Contrast an estimate such as the value of an incremental change in the environmental-resource base with one that says the flow of environmental services is currently worth, in total, 33 trillion U.S. dollars annually world wide (Costanza et al., 1997). The former is meaningful because it presumes that humanity will survive the incremental change and will experience and assess the change. The latter should cause one to balk because if environmental services cease, life would not exist. Who would receive the 33 trillion U.S. dollars of annual benefits? This is a case where, paradoxically, the value of something has no meaning and therefore, is of no use, even though the value of incremental changes to that thing not only has meaning, it also has use.

An approach similar to Costanza et al. (1997) appears in *The Economist* (26 June 1999). In observing the disturbing tendency of compound interest to make large figures in the distant future look very small today, the article states (p. 128): "Suppose a long-term discount rate of 7 percent (after inflation) is used ... Suppose also that the project's benefits arrive 200 years from now ... If global GDP grows by 3 percent a year during those two centuries, the value of the world's output in 2200 will be 8 quadrillion U.S. dollars (a 16-figure number). But in present-value terms, that stupendous sum would be worth just 10 billion U.S. dollars. In other words, it would not make sense for the world to spend any more than 10 billion U.S. dollars (under 2 U.S. dollars a person) today on a measure that would prevent the loss of the planet's entire output 200 years from now."

One problem has already been seen with this reasoning. Another is its presumption that social rates of discount are independent of the income forecast whose perturbation is being discounted. The underlying assumption in the passage is a massive perturbation (zero world output in year 2200). This would involve a secular decline in output, at least from some point in the future. But social discount rates associated with declining consumption streams are expected to be negative.[23] When viewed from the present, negative discount rates amplify incomes in the distant future; they don't shrink them. Discounting future incomes produces paradoxes only when it isn't recognized that, since they are accounting prices, discount rates should be endogenous to the analyses. The rates cannot be plucked out of the air.

[23] See Dasgupta and Mäler (1995, pp. 2,400-1) for why this would be so.

3.3 Institutional Responses to Policy Change

It is easy enough to define policy change (for example, an investment project) as a perturbation to an economic forecast. It is altogether a more difficult matter to identify what the perturbation actually consists of. Any system, human or otherwise, is expected to respond when subjected to a perturbation. In an economy that is not pursuing an optimum policy, a policy change can create all sorts of effects that ripple through without being noticed by the public offices, because there may be no public "signals" accompanying them. Tracing the ripples requires an understanding of the way markets and non-market institutions interact.

Many transactions take place in non-market institutions. Prime examples are transactions involving environmental services. In poor countries further examples abound. In recent years long-term relationships have been studied by economists and political scientists with the same care and rigor that they used to invest in the study of markets and the state. There is now a large and illuminating theoretical and empirical literature on the wide variety of ways that people cope with resource scarcity when there are no formal markets for exchanging goods and services across time, space, and circumstances.[24] The literature offers a lever with which to predict, in broad terms, the way people, both individually and communally, would respond to policy changes. Unfortunately, the literature hasn't filtered through sufficiently to decisionmakers. I want to illustrate what I mean by providing two examples: one a local miniature, the other altogether grander and near global.

For many years now, political scientist Elinor Ostrom has been studying the management of common-property resources in various parts of the world. In her work on collectively-managed irrigation systems in Nepal (Ostrom 1996), she has accounted for differences in rights and responsibilities among users (who gets how much water and when, who is responsible for which maintenance task of the canal system, and so forth) in terms of particular factors. One example is the fact that some farmers are head-enders, while others are tail-enders. Head-enders have a built-in advantage, in that they can prevent tail-enders from receiving water. On the other hand, head-enders need the tail-enders' labor for repair and maintenance of traditional canal systems, which are composed of temporary headworks, made of stone, trees, and mud. This means that both sets of parties can in principle gain from cooperation. However, in the absence

[24] For further detail regarding this literature, see Dasgupta (1999).

of cooperation their fortunes would differ greatly. So, cooperative arrangements would be expected to display asymmetries, and they do.[25]

Ostrom (1996) reports that donors gave well-meaning aid to a number of communities in her sample: canals were improved by the construction of permanent headworks. But those improved canal systems were frequently in worse condition and delivered less water to tail-enders than previously. Ostrom also reports that water allocation was more equitable in traditional farm-management systems than in modern systems managed by external agencies, such as government and foreign donors. She estimates from her sample that agricultural productivity is higher in traditional systems.

Ostrom has an explanation for this. She argues that unless it is accompanied by counter-measures, the construction of permanent headworks alters the relative bargaining positions of the head- and tail-enders. Head-enders now do not need the labor of tail-enders to maintain the canal system. So the new sharing scheme involves even less water for tail-enders. Head-enders gain from the permanent structures, but tail-enders lose disproportionately. This is an example of how well-meaning aid can go wrong if the donor does not understand the institution receiving the aid.

Resource allocation rules practiced at the local level are not infrequently overturned by central fiat. A number of states in Africa's Sahel imposed rules that in effect destroyed communitarian management practices in the forests. Villages ceased to have authority to enforce sanctions on violators of locally instituted rules of use. State authority turned the local commons into free-access resources.

My second example is altogether grander and fiercely debated. It relates to the experience people in poor countries have had with structural adjustment programs, which involved reductions in the plethora of economic distortions that have been introduced by governments over decades.

Many have criticized the way structural adjustment programs have been carried out. They have pointed to the additional hardship many of the poor have experienced in their wake. Some proponents argue that structural adjustments are necessary since they facilitate the growth of markets. What I want to suggest is that both proponents and opponents of the programs may be

[25] In fact, a general finding from studies on the management of common property systems is that entitlements to products of the commons is, and was, almost always based on private holdings. See McKean (1992) and Ostrom and Gardner (1993).

right. Growth of markets benefits many, but they can simultaneously make vulnerable people face additional economic hardship and thereby increase the incidence and intensity of poverty and destitution in an economy.

How and why might this happen? There are a number of pathways. Here I will sketch one that I have developed in previous writings (e.g., Dasgupta 1993, 1999).

Long-term relationships in rural communities in poor countries are typically sustained by the practice of social norms, for example, norms of reciprocity. This isn't the place to elaborate upon the way social norms should technically be viewed (as self-enforcing behavioral strategies). The point about social norms that bears stressing, however, is that they can be practiced only among people who expect to encounter one another repeatedly in similar situations.

Consider then a group of "far-sighted" people who know one another and prepare to interact indefinitely with one another. By a far-sighted person I mean someone who applies a low rate to discount future costs and benefits of alternative courses of action. Assume as well that the parties in question are not separately mobile (although they could be collectively mobile, as in the case of nomadic societies); otherwise the chance of future encounters with one another would be low and people (being far-sighted!) would discount heavily the future benefits of current cooperation.

The basic idea is this: if people are far-sighted and are not separately mobile, they could threaten to impose sufficiently stiff sanctions on anyone who broke an agreement, thereby deterring everyone from breaking it. But the threat of sanctions would cease to have potency if opportunistic behavior becomes personally more enticing. This can happen during a process in which formal markets grow nearby and uncorrelated migration accompanies the process. As opportunities outside the village improve, those with lesser ties (e.g., some young men in certain countries) are more likely to take advantage of them and break from those customary obligations that are enshrined in prevailing social norms. Those with greater attachments would perceive this and infer that the expected benefits from complying with agreements are now lower. Either way, norms of reciprocity could break down, making certain groups of people (e.g., women, the old, and the very young) worse off. This is a case where improved institutional performance elsewhere (e.g., growth of markets in the economy at large) has an adverse effect on the functioning of a local, non-market institution.

To the extent local common-property natural resources are made vulnerable by the breakdown of communitarian control mechanisms, structural adjustment programs can be unfriendly also to the environment and, therefore, to those who are directly dependent on it for

their livelihood. This is because when the market value of a resource-base increases, there is especial additional pressure on the base if people have relatively free access to it.[26] Structural adjustment programs devoid of safety nets for those who are vulnerable to the erosion of communitarian practices are defective. They can also be damaging to the environment unless the structure of property rights, be they private or communitarian, is simultaneously made more secure. Matters should not be expected to be otherwise.[27]

3.4 Conclusions

This paper has focused on measuring social well-being and evaluating policy. Section 1 was concerned with the links between the two, while Sections 2 and 3 were devoted, respectively, to the development of appropriate methods of measuring and evaluating.

In Sections 2.2-2.4 I identified a minimal set of indices for spanning a general conception of social well-being. The analysis was motivated by the need to make welfare comparisons across time and communities. A distinction was drawn between current well-being and sustainable well-being. Measuring current well-being was the subject of discussion in Sections 2.1-2.3. It was argued that a set of five indices, consisting of private consumption per head, life expectancy at birth, literacy, and indices of civil and political liberties, taken together, are a reasonable approximation for the purpose at hand.

Indices of the quality of life currently in use, such as UNDP's *Human Development Index*, are cardinal measures. Since indices of civil and political liberties are only ordinal, aggregate measures of social well-being should be required to be ordinal. In this connection, the Borda index suggested itself. In Section 2.3 the Borda index was used on data on 46 of the poorest countries in about 1980. Interestingly, of the component indices, the ranking of countries in the sample in terms of life expectancy at birth was found to be highly correlated with the countries' Borda ranking. Even more interestingly, the ranking of countries in terms of their GNP per head was found to be almost as highly correlated. There can be little doubt that this finding is

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[26] See Dasgupta (1990) for a theoretical analysis; and Reed (1992) for an empirical investigation in three poor countries of some effects of structural adjustment programs on resource bases.

[27] As I am wholly inexpert on the matter, I am not offering even a sketch of the kinds of arguments that can be advanced to show that the reforms urged upon Russia in the early 1990s suffered from a lack of acknowledgement of the role that governance plays in the operation of markets. In an illuminating body of work, Richard Rose (e.g., Rose 1999) has been investigating the way social networks there have entered spheres of activity they would not have if citizens enjoyed reliable governance.

an empirical happenstance. But it may not be an uncommon happenstance. If this is so, GNP per head could reasonably continue to be used as a summary measure of social well-being even though it has no theoretical claims to be one.

It is widely thought that NNP per head measures the economic component of sustainable well-being. In Section 2.4 I argued that this belief is false. (In the Appendix the argument is substantiated.) It was shown that NNP, suitably defined, could be used to evaluate economic policies, but that it should not be used in making intertemporal and cross-country comparisons of sustainable well-being. In particular, comparisons of sustainable welfare should involve comparisons of wealth. In other words, when comparing social well-being in an economy over time, one must check if net investment is positive, negative, or nil. Writings on the welfare economics of NNP have mostly addressed economies pursuing optimal policies, and are thus of limited use. The analysis in Section 2.4 (and the Appendix) generalizes this substantially by referring to environments where governments are capable of policy reforms only in economies characterized by substantial non-convexities. The analysis pertinent for optimizing governments and convex economies are special limiting cases of the one reported here.

Part 3 was about policy evaluation. Policy evaluation techniques developed in the 1970s, while formally correct, neglected to consider (1) resource allocation in the wide variety of non-market institutions that prevail throughout the world, and (2) the role the environmental-resource base plays in society. It was argued that policy changes could be effectively evaluated only if there is a fair understanding of the way the socioeconomic and ecological systems would respond to the changes. The observation is no doubt banal, but all too often decisionmakers have neglected to model the combined socioeconomic and ecological system before embarking upon new policies or keeping faith in prevailing ones. Such neglect has probably meant even greater hardship for precisely those groups of people commonly regarded as particularly deserving of consideration. However, recent advances in understanding of general resource allocation mechanisms and of environmental and resource economics can be incorporated in a systematic way into current best-practice policy evaluation techniques.

Appendix[28]

A.1 The Model

Consider a model economy where the production of goods and services requires labor, manufactured capital, and natural resources. The economy is deterministic. Time is continuous and is denoted by t (≥ 0). Assume that there is an all-purpose, non-deteriorating durable good, whose stock at t is K_t (≥ 0). The good can be consumed, spent in increasing the stock of natural resources, or reinvested for its own accumulation. For reasons to be identified in Section A.9, I assume that both population size and the stock of human capital are constant, which means that they may be ignored. The all-purpose good can be produced with its own stock (K), labor (L) and the flow of natural resources (R) as inputs. I write the production function as F(K, L, R). Production of the all-purpose durable good at date t is then $F(K_t, L_t, R_t)$. I take it that F is an increasing and continuously differentiable function of each of its variables. But I do not assume F to be concave. It transpires that I do not need to, given that my interest is in the welfare economics of policy reform.

Let C_t (≥ 0) denote aggregate consumption at t, and E_t (≥ 0) the expenditure on increasing the natural-resource base. Net accumulation of physical capital satisfies the condition:

$$dK_t/dt = F(K_t, L_t, R_t) - C_t - E_t. \qquad (1)$$

It helps to interpret natural resources in broad terms because it enables one to consider a number of issues. Certainly, in the natural-resource base, the multitude of capital assets that provide the many and varied ecosystem services upon which life is based should be included. But minerals and fossil fuels should be added. Note too that environmental pollution can be viewed as the reverse side of environmental resources. In some cases the emission of pollutants amounts directly to a degradation of ecosystems (e.g., loss of biomass); in others it amounts to a reduction in environmental quality (e.g., deterioration of air and water quality), which also amounts to degradation of ecosystems. This means that for analytical purposes there is no reason to distinguish resource economics from environmental economics, nor resource management problems from pollution management problems (Dasgupta 1982). To put it crudely, "resources"

[28] This Appendix is based very closely on Dasgupta and Mäler (1999).

are a "good," while "pollution" (the degrader of resources) is a "bad." So I work with an aggregate stock of natural resources, whose size at t is denoted by S_t (≥ 0). For simplicity of exposition I assume that resource extraction is costless.

Let the natural rate of regeneration of the resource base be $M(S_t)$, where $M(S)$ is a continuously differentiable function.[29] I suppose that the base can also be augmented by expenditure E_t (exploration costs in the case of minerals and fossil fuels, clean-up costs in the case of polluted water, and so forth). Define

$$Z_t \int_{-\infty}^{t} E_\tau d\tau.^{30} \qquad (2)$$

In certain applications of the model, Z_t would be a measure of the stock of knowledge at t. This interpretation enables my model to be connected to one in which there is endogenous technical progress. Let me now re-express equation (2) in the more useable form

$$dZ_t/dt = E_t. \qquad (3)$$

There are a number of ways in which one can model the process by which the resource base is deliberately augmented. Let $N(E_t, Z_t, S_t)$ denote the rate at which this augmentation occurs, where N is taken to be a continuously differentiable function. It is natural to assume that N is non-decreasing in both E and Z. I therefore assume it to be so.

The dynamics of the resource base can be expressed as:

$$dS_t/dt = M(S_t) - R_t + N(E_t, Z_t, S_t). \qquad (4)$$

The idea of social welfare is formulated in a conventional manner and many matters that arise when households are heterogeneous are ignored to keep the notation tidy. Following the classic articles of Koopmans (1960, 1972), assume that social well-being at t (≥ 0) is of the "utilitarian" form, $\int_t^\infty U(C_\tau, L_\tau)e^{-\delta(\tau-t)}d\tau$, where U is strictly concave, increasing in C, decreasing in L (at least at large enough values of L), and continuously differentiable in both C and L. δ (> 0), a constant, is the "utility" discount rate. My analysis does not require that U be concave. I assume it nonetheless to be concave for ethical reasons.

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[29] If the resource in question is a mineral or fossil fuel, S_t would denote known reserves at t and we would have $M(S) = 0$ for all S.

[30] Z_0 is part of the data of the economy. Like K_0 and S_0, it is an "initial condition."

A.2 The Analytics of Policy Reform

Let $(C_t, L_t, R_t, E_t, K_t, Z_t, S_t)_0^\infty$ denote an *economic program*, from the present (t = 0) to the indefinite future. A theory of economic policy capable of speaking only to optimizing governments would be of very limited interest. For it to be of practical use, a theory should be able to cover economies where governments not only do not optimize, but perhaps cannot even ensure that economic programs resulting from its policies are intertemporally efficient. Consider then such an economy. To have a problem to discuss, imagine that even though the government does not optimize, it can bring about small changes to the economy by altering its existing, sub-optimal policies in minor ways. The perturbation in question may, for example, consist of small adjustments to the prevailing structure of taxes, or it could be minor alterations to the existing set of property rights, or it could be a public investment, and so forth. I call any such perturbation a *policy reform* and proceed to develop the mathematics of policy reforms.

For concreteness, consider an economy facing the technological constraints in equations (1), (3), and (4). In addition, it faces institutional constraints (sometimes called transaction and information constraints) which I will formalize presently. The initial capital stocks (K_0, Z_0, S_0) are given and known. By the institutional structure of the economy I mean market structures, the structure of property-rights, tax rates, and so forth. I assume that the institutional structure is given and known. If in addition the behavioral characteristics of the various agencies in the economy (i.e., those of households, firms, the government, and so on) is known, it would be possible to make a forecast of the economy, or a forecast of the economic program $(C_t, L_t, R_t, E_t, K_t, Z_t, S_t)_0^\infty$ that would be expected to unfold. This relationship is called a *resource allocation mechanism*. So, a resource allocation mechanism is a mapping from initial capital stocks (K_0, Z_0, S_0) *into* the set of economic programs $(C_t, L_t, R_t, E_t, K_t, Z_t, S_t)_0^\infty$ satisfying equations (1), (3)-(4).

I now formalize this. Write

$$\Omega_t \equiv (K_t, Z_t, S_t), \text{ and} \tag{5}$$

$$(\xi_\tau)_t^\infty \equiv (C_\tau, L_\tau, R_\tau, E_\tau, K_\tau, Z_\tau, S_\tau)_t^\infty, \text{ for } t \geq 0. \tag{6}$$

Next let $\{t, \Omega_t\}$ denote the set of possible t and Ω_t pairs, and $\{(\xi_\tau)_t^\infty\}$ the set of economic programs from t to the indefinite future. A resource allocation mechanism, α, can then be expressed as a mapping

$$\alpha: \{t, \Omega_t\} \rightarrow \{(\xi_\tau)_t^\infty\}. \tag{7}$$

α would depend on calendar time if knowledge, population, or terms of trade changes autonomously over time.[31] If they do not display any exogenous shift, α would be independent of t. For reasons to be discussed in Section A.8, I will pay particular attention to the case where α is autonomous. So assume that α does not depend on calendar time (i.e., it is time-consistent).

It bears re-emphasis that I do *not* assume α to sustain an optimum economic program, nor even do I assume that it sustains an efficient program. The following analysis is valid even if α is riddled with economic distortions and inequities.

To make the dependence of the economic forecast on α explicit, let $(C_t(\alpha), L_t(\alpha), R_t(\alpha), E_t(\alpha), K_t(\alpha), Z_t(\alpha), S_t(\alpha))_0^{\infty}$ denote the forecast at t = 0. Consider date t (≥ 0). Use (5)-(7) to define

$$V_t(\alpha, \Omega_t) \equiv \int_t^{\infty} e^{-\delta(\tau - t)} U(C_\tau(\alpha), L_\tau(\alpha)) d\tau \qquad (8)$$

The right-hand-side (RHS) of equation (8) is social welfare at t. In the theory of optimum programming V_t is called the *value function* at t (Bellman 1957).[32]

Before putting the concept of resource allocation mechanism to work, I will discuss examples by way of illustration. Imagine first that all capital assets are private property and that there is a complete set of competitive forward markets capable of sustaining a unique equilibrium. In this case α would be defined in terms of this equilibrium. (If equilibrium is not unique, a selection rule among the multiple equilibria should be specified.) Most studies on green accounting (e.g., Heal 1998) are implicitly based on this mechanism.

Of particular interest are situations where some of the assets are not private property. Consider, for example, the class of cases where K and Z are private property, but S is not. It may be that S is a local common-property resource, not open to outsiders. If S is managed efficiently, I am back to the case of a competitive equilibrium allocation, albeit one not entirely supported by market prices, but in part by, for example, social norms.

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[31] There are exceptions to this statement in extreme cases, namely, closed economies where production is subject to constant returns-to-scale, population changes exponentially, technical change is Harrod-neutral, environmental resources no longer exist, and social well-being is based on classical utilitarianism (Mirrlees 1967). In such an economy α would be a mapping from the set of capital assets per efficiency unit of labor into the set of economic programs, where the programs are expressed in efficiency units of labor.

[32] In all this, we take it that V_t is well-defined. The assumption that $\delta > 0$ is crucial for this.

On the other hand, it may be that local institutions are not functioning well (e.g., because social norms are breaking down), in that the marginal private benefits from the use of S exceed the corresponding marginal social benefits. Suppose in addition that decisions bearing on the net accumulation of K and Z are guided by the profit motive. Then these behavioral rules together help determine α. In a similar manner, I could characterize α for the case where S is open-access.

These observations imply that institutional assumptions underlie one's notion of resource allocation mechanisms. Aspects of the concept of "social capital" (Putnam 1993) would appear in my framework as part of the defining characteristics of α, as would ideas relating to "social capability" (Adelman and Morris 1965; Abramovitz 1986), and "social infrastructure" (Hall and Jones 1999); other aspects would be reflected as factors in the production functions F and N.[33]

The crucial assumption is that V_t is differentiable in each of the three components of Ω. I apologize for imposing a technical condition on something endogenous, but space forbids further exploration of the various conditions on an economy's fundamentals (behavioral characteristics of the various agencies and properties of the various production functions and ecological processes; initial set of property rights; and so forth) which would guarantee a differentiable value function.

It is not easy to judge if differentiability of V_t is a strong assumption. What is certainly true is that if α is a differentiable mapping, then V_t is differentiable. I should therefore ask if α is differentiable. This is not easy to answer. An economy's underlying institutional structure is incorporated in α, and there are no obvious limits to the kinds of institutions one can envision. So one looks at what might be termed "canonical" institutions. Analytically, the most well-understood are those that support *optimum* economic programs. What is known of the mathematical properties of the corresponding α?

If the production functions are concave and differentiable everywhere, then for optimum economic programs V_t is differentiable in each of the components of Ω. Interest therefore lies in cases where the production functions are *not* concave. Now, even if such production functions are differentiable, not only could optimum economic programs be discontinuous in each of the components of Ω, so could V_t be discontinuous (Skiba 1978). But at points where V_t is

[33] Dasgupta (1999) explores the analytics underlying the idea of social capital.

discontinuous, social cost-benefit analysis of policy reforms cannot be conducted solely with the aid of accounting prices: the relevant "consumer surpluses" need to be estimated.[34]

Having noted this, it should be stressed that such discontinuities I allude to are non-generic. So, unless the optimizing economy is by fluke at one of the points of discontinuity (they are called "bifurcation points"), V_t would be differentiable within a sufficiently small neighborhood of the initial capital stocks. The same could be expected to be true for other "canonical" institutions, such as market economies subject to fixed distortions. It would seem, therefore, that the demand that V_t is differentiable would not rule out much of practical significance. The theory offered here about the role of NNP in social cost-benefit analysis of policy reforms is valid for a considerably more general set of environments than is usual in writings on NNP.

A.3 Local Accounting Prices and their Dynamics

Define,

$$P_t(\alpha) \equiv \partial V_t(\alpha, \Omega_t)/\partial K_t;\ q_t(\alpha) \equiv \partial V_t(\alpha, \Omega_t)/\partial Z_t;\ \text{and } r_t(\alpha) \equiv \partial V_t(\alpha, \Omega_t)/\partial S_t. \qquad (9)$$

I refer to them as *local accounting prices*. They measure social scarcities of the economy's capital assets along the economic forecast.

How might local accounting prices be estimated? If households are not rationed in any market and externalities are negligible, market prices would be the reasonable estimates. However, when households are rationed or externalities are rampant, estimating local accounting prices involves more complicated work. For example, in the presence of environmental externalities market prices need to be augmented by the external effects (see, for example, Freeman (1992) for an excellent account of current evaluation techniques). If households are rationed, one has to estimate "willingness-to-pay." And so on. I will presently show that NNP, computed on the basis of local accounting prices, can be used to evaluate short-term policy reform.

What are the dynamics of local accounting prices? To study this, note that the current-value Hamiltonian associated with α can be expressed as

[34] The analysis that follows can be extended to cover cases where V_t possesses right- and left-derivatives everywhere, but is not differentiable everywhere.

$$H_t = U(C_t, L_t) + p_t(F(K_t, L_t, R_t) - C_t - E_t) + q_t E_t + r_t(M(S_t) - R_t + N(E_t, Z_t, S_t)). \quad (10)$$

Recall equation (8), which is re-written here as

$$V_t(\alpha, \Omega_t) \equiv \int_t^{\infty} e^{-\delta(\tau - t)} U(C_\tau, L_\tau) d\tau. \quad (11)$$

V_t is social well-being at t. Differentiating V_t with respect to t obtains

$$d V_t / d t = \delta V_t - U (C_t, L_t). \quad (12)$$

But $V_t = V_t(\alpha, \Omega_t)$. Using (9), conclude also that

$$d V_t / d t = p_t d K_t / d t + q_t d Z_t / d t + r_t d S_t / d t + \partial V_t / \partial t. \quad (13)$$

Now combine equations (10), (12)-(13) to obtain

$$H_t = \delta V_t - \partial V_t / \partial t. \quad (14)$$

Use equations (9) and (14) to conclude that

$$dp_t/dt = - \partial H_t/\partial K_t + \delta p_t; \; dq_t/dt = - \partial Ht/\partial Z_t + \delta q_t; \text{ and } dr_t/dt = - \partial Ht/\partial St + \delta r_t. \quad (15)$$

The equations embodied in (15) define the dynamics of local accounting prices. It will be noticed that they are formally the same as the Pontryagin conditions for the evolution of accounting prices in an optimizing economy. Note also that all future effects of changes in the structure of assets on the economy are reflected in local accounting prices. That is why they are useful objects.

As α has been assumed not to depend on calendar time, V_t does not depend on it either. So equation (14) reduces to

$$H_t = \delta V_t. \quad (16)$$

Equation (16) is fundamental in intertemporal welfare economics. It says that the Hamiltonian equals the return on social well-being even in a non-optimizing economy.

A.4 Using NNP to Evaluate Short-Term Policy Reforms

Recall that α is being assumed not to depend on calendar time. Let me now think of a short-term policy reform as a perturbation to α over the *short* interval $[0, \tau]$. The perturbation is expressed as $\Delta\alpha$. During $[0, \tau]$ the resource allocation mechanism is denoted as $(\alpha + \Delta\alpha)$. From τ onward the economy is assumed to be governed by α again. Note now that if the reform is

undertaken, the economic variables during $[0, \tau]$ would be slightly perturbed ($(C_t + \triangle C_t)$ rather than C_t, and so forth). Note too that at τ, stocks of capital assets would be slightly different from what they would have been had the reform not been undertaken.[35]

Let the stocks at τ be $(\Omega_\tau + \triangle\Omega_\tau)$ as a consequence of the short-term reform. The change in V_0 arising from the reform can then be expressed as

$$\begin{aligned}\triangle V_0 &= V_0(\alpha+\triangle\alpha, \Omega_0) - V_0(\alpha, \Omega_0)\\ &= 0\int_0^\tau e^{-\delta t}[U(C(\alpha+_\triangle\alpha), L(\alpha+_\triangle\alpha)) - U(C(\alpha), L(\alpha))]dt\\ &\quad + e^{-\delta\tau}[V_\tau(\alpha, \Omega_\tau +_\triangle\Omega_\tau) - V_\tau(\alpha, \Omega_\tau)]\end{aligned} \tag{17}$$

On using equation (9) and the accumulation equations (1), (3), and (4), equation (17) can be expressed as:

$$\triangle V_0 = \tau e^{-\delta\tau}(U_C\triangle C + U_L\triangle L) + e^{-\delta\tau}(V_K\triangle K_\tau + V_Z\triangle Z_\tau + V_S\triangle S_\tau) + \varepsilon(\tau), \tag{18}$$

where $\varepsilon(\tau)$ is an error term with the property that $[\varepsilon(\tau)/\tau] \to 0$ as $\tau \to 0$.[36]

Equation (18) is simple to interpret. A policy reform undertaken during $[0, \tau]$ has two effects on V_0. First, the reform affects consumption and leisure during the period of the reform. Second, it affects the asset structure of the economy at τ, when the reform ends. The RHS of equation (18) measures the combined effect of the two sets of changes on V_0.

Consider now the perturbation to the asset structure at τ as a consequence of the short-term reform. Observe that

$$\Delta K_\tau = \int_0^\tau \Delta(dK_t/dt)dt = \tau\Delta(dK_t/dt)_{t=0} + \gamma(\tau),$$

where $\gamma(\tau)$ is an error term with the property that $[\gamma(\tau)/\tau] \to 0$ as $\tau \to 0$. Perturbations to Z_τ and S_τ can be estimated in a similar manner. Therefore, equation (18) can be re-written as

[35] Here I invoke the assumption that α is a differentiable mapping. Seierstad and Sydsaeter (1987) offer a rigorous account of the reasoning involved here.

$$\Delta V_0 / \tau = e^{-\delta\tau}(U_C\Delta C + U_L\Delta L + p_0\Delta(dK_t/dt)_{t=0} + q_0\Delta(dZ_t/dt)_{t=0}$$

$$+ r_0\Delta(dS_t/dt)_{t=0}) + \Theta(\tau), \qquad (19)$$

where $\Theta(\tau)$ is an error term with the property that $\Theta(\tau) \to 0$ as $\tau \to 0$. The left-hand-side (LHS) of (19) is the change in social well-being per unit of time during $[0, \tau]$. As I am interested in small perturbations, let $\tau \to 0$. The LHS of equation (19) then becomes the change in social welfare occasioned by the short-term reform, and the RHS tends in the limit to:

$$U_C\Delta C_0 + U_L\Delta L_0 + p_0\Delta(dK_t/dt)_{t=0} + q_0\Delta(dZ_t/dt)_{t=0} + r_0\Delta(dS_t/dt)_{t=0}. \qquad (20)$$

Choose consumption as numeraire and write

$n_0 = -U_L / U_C$; $m_0 = p_0 / U_C$; $u_0 = q_0 / U_C$; and $v_0 = r_0 / U_C$.[37]

Dividing expression (20) by U_C, obtains

$$\Delta C_0 - n_0\Delta L_0 + m_0\Delta(dK_t/dt)_{t=0} + u_0\Delta(dZ_t/dt)_{t=0} + v_0\Delta(dS_t/dt)_{t=0}. \qquad (21)$$

Now use equations (1), (3), and (4) to convert expression (21) into:

$$\Delta C_0 - n_0\Delta L_0 + m_0\Delta(F(K_t,L_t,R_t)-C_t-E_t)_{t=0} + u_0\Delta(E_t)_{t=0}$$

$$+ v_0\Delta(M(S_t)-R_t + N(E_t,Z_t,S_t))_{t=0}. \qquad (22)$$

If expression (21), or equivalently (22), is positive, the short-term reform increases social welfare, so it is desirable; if it is negative, the reform decreases social welfare, so it is undesirable. Define

$$\hat{\rho}_t \equiv U_C C_t + U_L L_t + p_t dK_t/dt + q_t dZ_t/dt + r_t dS_t/dt, \qquad (23a)$$

and thereby

$$\rho_t \equiv C_t - n_t L_t + m_t dK_t/dt + u_t dZ_t/dt + v_t dS_t/dt. \qquad (23b)$$

If the RHSs of equations (23a,b) have a familiar ring to them, it is because they represent NNP at t (in utility and consumption numeraires, respectively), measured in local accounting prices.

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[36] U_C and U_L are evaluated at t=0. V_K is the partial derivative of V with respect to K at t=0, and so forth. I have now dropped writing the dependence of the economic forecast on α. This saves on notation.

[37] Since the economic program sustained by α is not a first-best, m_0 is typically not equal to 1.

Observe now that expression (21) is the change in NNP at t = 0 occasioned by the short-term policy reform at t = 0. So I have

> **Proposition 1:** A short-term policy reform increases social well-being if and only if it registers an increase in NNP measured in local accounting prices.

Note that NNP as defined here is not NNP as it is usually defined. Conventional NNP is the sum of aggregate consumption and net investment in physical capital, both measured at market prices. Expressions (23a,b) show that all components of NNP should be valued at the local accounting prices given in equation (9), and that the accounting value of net investment in the stocks of all durable capital goods (manufactured, natural, human, and knowledge capital) should be included in NNP. The NNP studied here is "green NNP."[38]

Note that autonomous changes in α would not affect the result. Being exogenous, such changes would be unaffected by elementary policy reforms, so they are irrelevant for social cost-benefit analysis of policy reform.

The policy reforms envisaged here are confined to a short interval. But what if a reform is small but irreversible (e.g., a small permanent change in fuel tax)?

Section A.9 (Proposition 8) shows how accounting prices can be used to construct indices with which one may evaluate the desirability of such a reform. The indices developed there are linear in quantities. If those indices are not put to use (Johansson and Löfgren 1996), future changes in consumer surpluses must be estimated for the purposes of social cost-benefit analysis. This is because a permanent reform, no matter how small, would have cumulative effects on the size of capital stocks.

How are short-term policy reforms related to optimum planning? Consider an indefinite sequence of such reforms at every t, each of which increases NNP at t, where NNP is computed at the prevailing local accounting prices. I take it that the entire sequence is conducted in a counter-factual manner; that is, as a tatônnement. Such an adjustment process is called a "gradient process" (it is also called the "hill-climbing method"). So far I have not needed to assume convexity of the production possibility set. But now I do. In a well-known paper, Arrow and Hurwicz (1958) prove in the context of a finite-dimensional economy that, provided the set

[38] Dasgupta and Mäler (1991), Mäler (1991), and Dasgupta, Kriström, and Mäler (1999) give more detailed accounts of the various components of NNP.

of production possibilities has a sufficiently convex structure, the gradient process converges to the optimum. A corresponding result for the model economy would be harder to prove, given that I am considering infinite-dimensional consumption streams. Despite this, my conjecture is that a sequence of short-term policy reforms in the form of a suitably-defined gradient process would converge to the optimum economic program if the economy has a strong convex structure.

A.5 The Hamiltonian as Constant-Equivalent Utility

In the previous section I showed that NNP could be used as an index for conducting social cost-benefit analysis of short-term policy reforms. But the theoretical literature on green NNP has been directed toward a quite different end (Weitzman 1998). It has been argued that NNP measures "constant-equivalent consumption." In order to look into this interpretation, assume that V_t is differentiable everywhere.

Continue to assume that $\partial V_t / \partial t = 0$. Since $\delta[\int_t^\infty e^{-\delta(\tau-t)}d\tau]=1$, equation (15) can be written as

$$H_t = H_t\{\delta[\int_t^\infty e^{-\delta(\tau-t)}d\tau]\} = \delta[\int_t^\infty e^{-\delta(\tau-t)}H_t d\tau] = \delta V_t$$

from which obtains

$$H_t[\int_t^\infty e^{-\delta(\tau-t)}d\tau] = \int_t^\infty e^{-\delta(\tau-t)}H_t d\tau = V_t \equiv \int_t^\infty e^{-\delta(\tau-t)}U(C_\tau,L_\tau)d\tau. \qquad (24)$$

Equation (24) can be summarized as

> **Proposition 2:** Along any economic program the Hamiltonian at each date equals the constant-equivalent flow of utility starting from that date.

This result was proved for optimum economic programs by Weitzman (1976), who restricted his analysis to linear utility functions (specifically that U(C,L) = C). Since in this case the Hamiltonian *is* NNP, Weitzman interpreted NNP as the constant-equivalent consumption. The interpretation is today in wide usage.

A.6 Social Well-Being and the Concept of Sustainability

The World Commission (1987) defines "sustainable development" as an economic program in which, loosely speaking, the well-being of future generations is not jeopardized. There are a number of possible interpretations of this.[39] Consider the following:

(a) An economic development is sustainable if $dU_t/dt \geq 0$, where $U_0 \geq \lim U_t$ as $t \rightarrow -0$.

(b) An economic development is sustainable if $dU_t/dt \geq 0$.

(c) An economic development is sustainable if $dV_t/dt \geq 0$,

where $V_t(\alpha, \Omega_t) \equiv \int_t^{\infty} e^{-\delta(\tau - t)} U(C_\tau, L_\tau) d\tau$.

It is clear that (a) lacks ethical foundation. For example, it may be desirable to reduce U in the short run in order to accumulate assets so that the flow of U is still higher in the future. In this sense (b) offers greater flexibility in ethical reasoning: it permits initial sacrifices in the current standard of living, U (a burden assumed by the generation engaged in the reasoning), but requires that no future generation should have to experience a decline in their standard of living.

Consider the resource allocation mechanism α. The mechanism allows one to make an economic forecast. Suppose (b) is adopted as the definition of sustainable development. Now

$$dU_t / dt = U_C dC_t / dt + U_L dL_t / dt. \qquad (25)$$

From equation (25) one may conclude with:

> **Proposition 3:** If sustainable development is taken to mean that, starting from now, utility must never decline, then an economic program corresponds to sustainable development if, and only if, the value of changes in the flow of consumption services is always non-negative.

A.7 Comparisons of Social Welfare Across Time

In contrast to (b), the focus of (c) as a notion of sustainable development is social well-being, V. The criterion permits the first generation to make initial sacrifices in V (relative to the past), but requires that social well-being should never decline in the future. Note that, while (b)

[39] See Pezzey (1992) for a thorough treatment. It should be noted that asking if economic development is sustainable is different from asking if a given level of consumption is sustainable. See the following text.

implies (c), (c) does not imply (b).[40] In short, (c) is more general. In what follows, I adopt (c) as my notion of sustainable development and develop criteria for judging if a given economic program represents sustainable development.

Continue to assume that $\partial V_t/\partial t = 0$. Differentiating both sides of equation (15) with respect to time, obtains

$$dH_t/dt = \delta\, dV_t/dt. \tag{26}$$

Use (23b) to define

$$I_t^K \equiv p_t dK_t/dt;\ I_t^Z \equiv q_t dZ_t/dt;\ \text{and}\ I_t^S \equiv r_t dS_t/dt, \tag{27}$$

which are net investments in the three types of capital assets, respectively, expressed in utility numeraire. Aggregate net investment can then be defined as

$$I_t = I_t^K + I_t^Z + I_t^S.\ ^{41} \tag{28}$$

It follows from equations (10), (13), and (26)-(28) that

$$U_C dC/dt + U_L dL/dt + dI_t/dt = \delta I_t. \tag{29}$$

From Equation (29), two alternative indicators of sustainable development can be obtained. The first can be obtained from the RHS of equation (29). For it implies

> **Proposition 4:** An economic program increases social well-being over time if, and only if, along the program net investment in the economy's capital assets is always positive.[42]

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[40] For an arbitrary α this is a trivial matter to confirm. Interestingly, Asheim (1994) has identified cases where even an optimum economic program may satisfy (c), while violating (b).

[41] Note that the summation in equation (28) does *not* imply any assumptions regarding substitution possibilities among the three kinds of capital assets. Whatever substitution possibilities there may be would be reflected in the local accounting prices.

[42] This result, shown to be a property of optimum economic programs, was developed by Solow (1974, 1992) and Hartwick (1977), who determined the investment rule that would sustain the maximum constant utility stream. Dasgupta and Heal (1979, ch. 10) showed that, in the context of a model economy consisting of manufactured capital and an exhaustible resource, social well-being is an increasing function of time if $\delta = 0$ along an optimum economic program. This requires net savings to be positive. Pearce, Hamilton, and Atkinson (1996) suggested using the rule obtained in the text for practical purposes, but offered no proof that the suggestion is valid. Serageldin (1995) has reported empirical work done at the World Bank on the use of the rule. See also World Bank (1996).

The result has intuitive appeal. It says that social welfare is higher today than it was yesterday if the economy is wealthier today. Here, an economy's "wealth" is interpreted as the accounting value of all its capital assets, and wealth comparisons are made at constant prices. In a famous article Samuelson (1961) argued in connection with national income accounting that welfare comparisons should deal with "wealth-like" entities. Proposition 4 formalizes that insight.

Note, however, that what I have obtained is an equivalence result: Proposition 4 cannot on its own explain if sustainable development is feasible. Whether the economy is capable of growing wealthier indefinitely depends, among other things, on the extent to which different assets are substitutable in production.[43]

An equivalent way of characterizing sustainable development is to use the LHS of equation (29). I state the result as:

> **Proposition 5:** Social welfare increases (decreases) over a short interval of time if, and only if, during the interval the value of net changes in the flow of consumption services plus the change in the value of net aggregate investment is positive (negative).

For making intertemporal welfare comparisons it is customary to compare NNP over time at constant prices. Proposition 5 says that this is not a correct procedure unless the economy is stationary (i.e., $dp_t/dt = dq_t/dt = dr_t/dt = 0$). In conclusion, intertemporal NNP comparisons are far less informative about changes in social welfare over time than is commonly believed. Indeed, they would be highly misleading indicators if relative prices were changing significantly. Note that this is consistent with Proposition 1, which says that NNP provides a valid measure of the impact on social well-being of short-term policy reforms.

A.8 Comparisons of Social Welfare Across Space

In both popular and academic writings, cross-country comparisons of GNP per head are today a commonplace method for comparing well-being across countries. The analysis in the previous section suggests not only that this practice is wrong, but also that replacing GNP by

[43] For an account of this, see Dasgupta and Heal (1979, ch. 7). The problem is deeper than was recognized in that work, since substitutability involves substitutability not merely in production, but also in consumption (Dasgupta, Levin, Lubchenco, and Mäler 1999).

NNP would not rescue matters. So the question is what index should be used instead? I attempt to explain this in the following paragraphs.

It is simplest to consider a continuum of closed economies, parameterized by x (a scalar).[44] One may interpret differences among economies in terms of differences in initial endowments, behavioral characteristics, or the resource allocation mechanisms guiding them. But in order to make meaningful comparisons of social well-being, the same value-function should be ascribed to all countries, that is, the same utility function U(.) and the same δ.

Consider a date when the cross-country comparisons are to be made. To keep the notation simple, I drop the time subscript. Let H_x be the Hamiltonian in country x, and V_x the value function. Recall equation (15). In the present case it reads as $H_x = \delta V_x$. An argument identical to the one establishing equation (29) then yields

$$\delta[p_x dK_x/dx + q_x dZ_x/dx + r_x dS_x/dx + \partial V_x/\partial x] = U_C dC_x/dx + U_L dL_x/dx + dI_x/dx + \partial H_x/\partial x, \quad (30)$$

where I_x is net aggregate investment in country x.

For tractability, the interesting special case to consider is $\partial V_x/\partial x = \partial H_x/\partial x = 0$.[45] From the LHS of equation (30) conclude that

> **Proposition 6:** Social well-being in a country is higher (lower) than in any of its immediate neighbors if in the aggregate it is wealthier (less wealthy).

Proposition 6 formalizes Samuelson's (1961) assertion that in making welfare comparisons across countries, one should compare their wealth. It corresponds to Proposition 4.

An equivalent indicator for making welfare comparisons can be obtained from the RHS of equation (30):

> **Proposition 7:** Social well-being in a country is higher (lower) than in any of its immediate neighbors if the value of the difference in the flow of consumption

[44] I assume a continuum of economies in order to make use of the calculus. It simplifies the computations. The analysis that follows can be easily adapted to the case where there is a discrete number of economies.

[45] The condition requires that the same resource allocation mechanism prevails in all countries. The condition is strong.

services between them plus the difference in the value of aggregate net investment between them is positive (negative).

Notice that the recommendation in Proposition 7 (which corresponds to Proposition 5) would not amount to NNP comparisons across countries unless local accounting prices were the same (i.e., $dp_x/dx = dq_x/dx = dr_x/dx = 0$). I conclude that cross-country comparisons of NNP reveal nothing about differences in social well-being excepting under empirically uninteresting circumstances.

Equation (30) is exact, but the pair of (linear) indicators I obtained in Propositions 6 and 7 serve their purpose accurately only when $\partial V_x/\partial x = 0$. I believe this to be a strong condition. If, as I suspect is the case, $\partial V_x/\partial x$ is not even approximately zero, there are no linear indices for making cross-country welfare comparisons.

A.9 Evaluation of Permanent Policy Change

The technique I have developed for making cross-country comparisons of social well-being can also be used for evaluating the desirability of a permanent policy reform, or of a permanent change in some parameter of the economy. In keeping with the notation introduced in Section 2.1, let α be this parameter (e.g., the given resource allocation mechanism). Then, retracing the arguments there, equation (16) can be written as

$$H_t(\alpha) = \delta V_t(\alpha). \qquad (31)$$

Using equations (27)-(29) obtains

$$\delta dV_t(\alpha)/d\alpha = dH_t(\alpha)/d\alpha = U_C dC_t(\alpha)/d\alpha + U_L dL_t(\alpha)/d\alpha + dI_t(\alpha)/d\alpha. \qquad (32)$$

From equation (32) I deduce

> **Proposition 8:** If the value of the changes in consumption services plus the change in the value of net investment occasioned by a permanent change in a parameter characterizing an economy is positive (negative), social well-being increases (decreases).

A.10 Technological Change and Growth Accounting

How should NNP be computed in the presence of technical change? Note first that resource augmentation, N, in equation (4) could itself be regarded as a form of technical progress. This said, it must also be granted that the growth and decay of knowledge involve

wider considerations. For example, it has been customary in the economics literature to regard technical progress as shifts in production functions. In what follows I explore this route by introducing technical progress in the production of the final good in the model of Section A.3.

The notation must be extended. Denote by E_{1t} and E_{2t} expenditures on resource augmentation and on generalized research and development (R & D), respectively. Now define Z_{1t} and Z_{2t} by the equations

$$dZ_{1t}/dt = E_{1t}, \text{ and} \tag{33}$$

$$dZ_{2t}/dt = E_{2t}. \tag{34}$$

Z_1 and Z_2 can be thought of as two types of knowledge. Denote the resource augmentation function as $N(E_1, Z_1, S)$ and imagine that output of the produced consumption good at t can be expressed as

$$Y_t = e^{\lambda t}Q(Z_{2t})F(K_t, L_t, R_t), \tag{35}$$

where $\lambda \geq 0$ and $Q'(Z_2) \geq 0$. Technical progress in the production of the final good appears here as the term $e^{\lambda t}Q(Z_{2t})$. It combines exogenous factors (λ) with endogenous ones (Z_2).

Let consumption be the numeraire, u_1 and u_2 the local accounting prices of Z_1 and Z_2, respectively, and let the remaining local accounting prices be denoted as in Section A.5. Retracing the arguments leading to (23b), it is a simple matter to conclude that NNP reads as

$$\rho_t = C_t - n_tL_t + m_tdK_t/dt + u_{1t}dZ_{1t}/dt + u_{2t}dZ_{2t}/dt + v_tdS_t/dt. \tag{36}$$

Similarly one can confirm that the discussion in Section A.5 on the evaluation of short-term policy reform remains unchanged in the presence of technical change.

The question remains: what factors contribute to changes in GNP over time? To see what the answer could be, consider that GNP in the model economy is given by (35). Differentiating both sides of equation (35) with respect to t, re-arranging terms, and dropping the time subscript from variables for the sake of notational simplicity, I obtain the growth accounting identity as

$$(dY/dt)/Y \equiv \lambda + (Q'(Z_2)dZ_2/dt)/Q(Z_2) + (F_KdK/dt)/F + (F_LdL/dt)/F + (F_RdR/dt)]/F. \tag{37}$$

The sum of the first two terms on the RHS of equation (37) measures the percentage rate of change in "total factor productivity," while the remaining terms together represent the contributions of changes in the "factors of production" to the percentage rate of change in GNP. Since λ is an exogenous factor, it is unexplained within the model. For this reason it is called the "residual." When it is not zero, λ could well be the most important determinant of $\partial V_t/\partial t$.

In a famous article, Solow (1957) uses a reduced form of the production function in (35) to estimate the contribution of changes in the factors of production to growth of non-farm GNP per "man-hour" in the U.S. economy over the period 1909-1949. He discovered that it was a mere 12% of the average annual rate of growth.[46] In other words, 88% of the growth was attributable to the residual. (Solow's estimate of λ was 1.5% per year.) A significant empirical literature since then has shown that when K is better measured (e.g., by accounting for changes in the utilization of capacity and changes in what is embodied in capital; see footnote 28) and when account is taken of human-capital formation, the residual is small for the non-farm sector in the U.S. economy.[47]

This is congenial to intuition. I should doubt if it is prudent to postulate everlasting increases in total factor productivity, let alone in *per capita* output. To do so would be to place an enormous burden of proof on an experience that is not much more than a few hundred years old. Extrapolation into the past is a sobering exercise: over the long haul of time (say, a few thousand years), the residual has not been much more than zero.

It is in any case hard to believe that serendipity, unbacked by R&D effort and investment in physical capital (learning by doing), can be a continual source of productivity growth. A positive value of λ would imply that the economy is guaranteed a "free lunch" forever. To be sure, such an assumption would guarantee that growth in aggregate consumption is sustainable. In fact, that would be its attraction: it would enable one to assume away problems of environmental and resource scarcities. But there are no theoretical or empirical grounds for presuming that it is a reasonable assumption. At this point in one's understanding of the process by which discoveries are made, it makes greater sense to set $\lambda = 0$ in (35), (which would imply that $\partial V_t/\partial t = 0$).[48] This thought is reinforced by the observation that most environmental

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[46] Solow assumed in particular that $Q'(Z_2) = 0$.

[47] Jorgenson (1995) writes a masterly account of this complex literature.

[48] Lau (1996) reports on a series of studies that have specified the aggregate production function to be of the form $Y_t = F(A_t K_t^{a} H_t^{(1-a)}, L_t)$, where K is physical capital, H is human capital, A is the augmentation factor of the composite capital, L is the number of labor-hours, and $0 < a < 1$. The studies have uncovered that, since the end of World –War II, the contribution of technical progress (i.e., the percentage rate of change in A_t) to growth in Y_t in today's newly industrialized countries has been negligible. He also reports that, if new knowledge is embodied in new capital-equipment, the contribution of growth in the value of A_t to growth in Y_t among western industrialized economies has been a mere 10%, that of growth in physical capital some 75% , while the contributions of growth in human capital and labor-hours have each been some 7%. Lau also notes that the studies are silent on whether technical progress in Western industrialized economies has been exogenous or the fruit of expenditures on research and development.

resources go unrecorded in growth accounting. The implication is obvious: When growth in GNP is regressed on growth in inputs that exclude the use of environmental resources, too high an estimate of λ is obtained if in fact the use of such resources has been growing. In adopting this position, I am not suggesting that there is no such thing as technical change; what I *am* suggesting is that, of the first two terms on the RHS of equation (37), it is the second term that is significant. It denotes the contribution of technical change to productivity growth.

Productivity growth in equation (37) is productivity growth in GNP. It has often been suggested that one should instead be interested in productivity growth in NNP, as defined in equation (36). For example, in their important early work on Indonesia, Repetto et al. (1989) showed that if one includes deforestation, soil erosion, and the depreciation of oil reserves in the country's national accounts, Indonesia's rate of growth in NNP during the 1980s would be half the estimated growth rate of its GNP. And there are other environmental and natural resources that Repetto et al. did not consider.

In Section A.6 it was shown that NNP comparisons across time reveal nothing about changes in social well-being unless an economy is in a steady state. It was also shown that one should ask instead if, in the aggregate, net investment is positive. It is possible for an economy's GNP (per head) to increase over a period of time even while, in the aggregate, net investment (per head) is negative. I know of no evidence that in recent years this has not been experienced in a number of countries.[49]

A.11 Commentary

Green NNP has widely been interpreted as constant-equivalent consumption. In Section A.5 it was shown that, excepting for the uninteresting case where U is linear in consumption (or else homogeneous of degree less than one), this interpretation is simply false. What is true is that the Hamiltonian equals constant-equivalent utility (Proposition 2). However, since the Hamiltonian is typically a non-linear function of consumption and leisure, it is of little practical use.

[49] Serageldin (1995) contains a report on the beginnings of this research program.

In developing the concept of NNP I have made use of a series of models of increasing generality. However, of necessity even the most general of the models had important features missing. I comment on a few of them. Readers can easily fill in the details.

(1) Problems associated with intragenerational distribution have been ignored. However, it is theoretically a simple matter to include them. One could enlarge the set of commodities to distinguish a good consumed or supplied by one person from that same good consumed or supplied by another person. This means, for example, that a piece of clothing worn by a poor person should be regarded as a different commodity from that same type of clothing worn by a rich person. Such commodities are called "named goods" (Hahn 1971). Accounting prices of named goods would typically depend on the names attached to them. With this re-interpretation of goods and services, the results I have obtained continue to hold.[50]

(2) Environmental externalities can be incorporated by a device identical to (1) above. To describe who is affected, in which manner, and by whose actions involves the use of named goods and services. It follows that accounting prices would be "named" to distinguish private costs from social costs and private benefits from social benefits. Indeed, Pigouvian taxes and subsidies on externalities can be computed on the basis of named accounting prices (Dasgupta and Heal 1979, ch. 3; Mäler 1991; Freeman 1992).

(3) Uncertainty has been avoided here. Assume then that social well-being at date t=0 is the expected value of the present discounted flow of utility. The natural move would be to make use of the idea of contingent goods, and therefore of contingent accounting prices. My analysis would then go through.

(4) The discussion has been restricted to closed economies. However, the analysis can be extended to an economy that trades with the rest of the world. Dasgupta, Kriström, and Mäler (1995) and Sefton and Weale (1996) account for this.

(5) Human capital has been absent from the discussion. Analytically it is not difficult to include it. Human capital can be thought of as another form of capital. So net investment in it would be included in NNP (see Dasgupta, Kriström, and Mäler (1995) for a formulation).

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[50] I am assuming in this example that income or wealth mal-distribution is the cause of concern. Dasgupta, Marglin, and Sen (1972) suggest the use of income distributional weights as a rough-and-ready way to capture such concern. The Bergson social welfare function was designed precisely to incorporate these considerations.

However, unlike physical capital, human capital is non-transferable. So they should be regarded as named goods.

(6) The models studied here have not included demographic change. It is customary in growth accounting to regard changes in population over time as exogenously given. However, in many societies parents regard children as both an end in themselves and a means to other things (e.g., income security). So population needs to be regarded as a stock whose movements over time are, at least in part, endogenously determined. The problem is that the current understanding of the determinants of fertility behavior is weak. Moreover, serious problems arise when one comes to construct intergenerational welfare economics in such a world. There is no received theory. Population ethics is an underdeveloped field of inquiry. For the moment it seems reasonable to conduct such analyses as conducted in this paper, conditional on specified demographic movements. This has been my approach here.[51]

Finally, I reiterate that this Appendix has focused on conceptual matters only. The findings here imply that the estimation of accounting prices should now be a priority. This said, it must be acknowledged that estimating the accounting prices of certain categories of resources will prove to be impossible. So no single index could suffice. But this means that tradeoffs must be made explicitly (e.g., how much biodiversity should be permitted to be destroyed for the sake of so many dollars of aggregate income?). These are hard choices, even tragic choices. But I believe they are unavoidable.

[51] See Dasgupta (1998) for a discussion of some of the more transparent problems that arise when one thinks about the concept of optimum population.

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