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Wieland, Bernhard

Economic and Ecological Sustainability - The Identity of Opposites?

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Economic and Ecological Sustainability – The Identity of Opposites?

Bernhard Wieland

Abstract

It is often contended that there is a sharp conflict between the economist's and the ecologist's approach to the question of sustainability. This paper takes the opposite view. The paper attempts to show that both views can be formulated in a common analytical framework and that carried to its logical consequences the ecologic approach is a special case of the economic approach.

1 Introduction

There is a widespread belief that economists and ecologists are in sharp conflict with respect to the question of sustainable growth. In this paper I want to show that this conflict is largely illusory.[1] I contend that taken to its logical consequences the ecological approach to sustainable growth becomes a special case of the economic approach.

In order to substantiate this contention I shall first try to state the so called neoclassical approach to sustainable growth as clearly as possible. It will be seen that the neoclassical approach largely amounts to finding a growth path for the world economy that maximizes an intergenerational social welfare function subject to a system of environmental and geophysical constraints. From an economist's point of view the politically decisive question therefore is which value-judgments one wants to incorporate in the analytical form of the social welfare function. It will be shown that the notion of an intergenerational social welfare function is sufficiently flexible to represent a wide range of differing conceptions of intergenerational justice. It will be argued that the ecologist's notion of sustainability simply amounts to assuming a special form of social welfare function and to adding a special additional condition for the optimal growth-path to the set of constraints.

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[1] In doing so I borrow heavily from Nordhaus, 1993.

The remainder of the paper is organized as follows. Section 2 introduces the notion of an intergenerational social welfare function. Section 3 explains that social welfare functions can be viewed from two different perspectives: the positive and the normative viewpoint. A social welfare function can be used to describe the value judgments a society *should* have with respect to intergenerational equity. But it is also possible to use a social welfare function to describe the attitude of a society towards intergenerational equity as it *actually is* (not as it should be). It is important to keep these two interpretations apart. Sections 4-6 demonstrate how differing value judgments can be mathematically incorporated in a social welfare function, whereas section 7 shows how the framework developed so far has been used in empirical work by William Nordhaus. After a brief discussion of whether it is appropriate to discount the needs of future generations in the social welfare function or not (section 8) I move to formulating the ecologist's position within the framework developed so far (section 9). In doing so (and following Nordhaus (1993)) I make use of the so-called "Non-Declining–Path-Interpretation" of sustainable growth (Pierce et al.1990) which, in my view, describes the essence of the ecologist's position rather well. It is argued that this interpretation can easily be reformulated to fit into the standard neoclassical model. The paper ends with some brief remarks concerning the role of uncertainty (section 10) and a few conclusions.

Having said what the paper does contain I should also briefly mention what it does *not* contain: There is no calculation of a concrete sustainable growth path and there are no specific policy recommendations (in particular, there are no policy recommendations with respect to "sustainable mobility"). The discussion in this paper is on a more general level. It aims at a better understanding of what we mean by a "sustainable growth path".

2 A General Framework for Defining Sustainable Growth

Almost every paper on sustainability starts from the definition of sustainable growth brought forward by the Brundtland commission. The commission defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

It has become a favorite pastime to pour irony over this definition's vagueness. It is far more difficult to try to clarify its meaning. In the following I shall discuss several possible interpretations based on the framework of (neoclassical) economics. The discussion will be far from complete. In the literature more than twenty definitions of sustainability have been counted. According to one author even more than sixty definitions exist (see Lerch/Nutzinger, 2000). I restrict myself to those definitions that have gained most prominence in the economics literature.

In order to fix ideas let us consider a sequence of generations G_1, G_2, ….., G_n. (The sequence is finite because, as far as we know today, life on earth will be limited by the life cycle of the sun.) Let "consumption" of a typical generation G_i, i = 1, ….., n, be denoted by $c(i)$. "Consumption" here does not only mean consumption of material goods. $c(i)$ refers to a broad concept that also includes non-market items such as leisure, cultural goods and aesthetic enjoyment of the environment. Using this notation a vector $\left(c(1),.....,c(n)\right)$ describes one possible intergenerational distribution of consumption possibilities. Let us assume for the moment, that today's policy makers can only choose among a finite set of growth paths, indexed by j = 1, ….., m. Each growth path leads to an intergenerational distribution of consumption possibilities $GP_j = \left(c_j(1), c_j(2),.....,c_j(n)\right)$. It is assumed that every generation has a preference function

$$u_i\left(c_j(1),.....,c_j(n)\right) \rightarrow \mathrm{a} \in \mathrm{R}, \tag{1}$$

or

$$u_i(GP_j) \rightarrow \mathrm{a} \in \mathrm{R}, \qquad \mathrm{i} = 1,2,.....\mathrm{n}. \tag{2}$$

In this formulation it is assumed that each generation values not only its own consumption but also the consumption of future generations. If this sounds too altruistic, set

$$u_i\left(c_j(1),.....,c_j(n)\right) = u_i\left(c_j(i)\right). \tag{3}$$

Of course, the u_i of the various generations may be in conflict. Generation G_n may prefer a lower consumption level for generation G_{n+j} than generation G_{n+j} itself would like to enjoy. Somehow this conflict must and will be resolved because even taking no conscious decision with respect to a desirable growth path (or "business as usual") will result in some kind of intergenerational distribution. In reality politicians will solve this conflict by proposing some kind of environmental policy (e.g. some type of climate policy) which will be voted upon by citizens.

Formally such an environmental policy may be described by employing the notion of a social welfare function (SWF) known from economic welfare theory. In our context a social welfare function is a function

$$\text{SWF} \; : \quad \text{G}P_j \; \rightarrow \; F\left(u_1(GP_j),\ldots.., \; u_n(GP_j)\right) \in \; \text{R}\,, \qquad (4)$$

with the property that

$$\frac{\partial F}{\partial u_j} > 0, \quad j = 1,\ldots..,n.$$

This means that, depending on the specific form of *F*, the u_j are "weighted" and aggregated into a real number. Each SWF therefore amounts to a value judgement about the "importance" of the preferences of each generation.

3 Normative vs. Positive View of the SWF

The social welfare function developed in the last section can be viewed from two different perspectives. We shall alternate between these two views frequently in this paper. Therefore it may be useful to make the difference explicit.

The first view, of course, is the normative view. We can ask ourselves which ethical principles a society *should* follow when designing policies. In the next few sections we shall present several forms of SWFs, each corresponding to different ethical approaches to intergenerational justice. It is perfectly legitimate, of course, to discuss which of these SWFs a society *should* have. (I avoid here the question of paternalism, which is intimately connected with SWFs, or existence questions like the Arrow-Paradox [see Boadway/Bruce, 1984]).

The second view of SWFs is the positive view. We can observe society's choices empirically and infer from these observations the parameters of a SWF. For example, observing the real interest rate for long-term investments will give the analyst certain indications of a society's attitude towards the future. Many economists argue policies concerning optimal growth should be based on society's values as they *are*, not as they *should* be.

In the following both perspectives come into play. In most cases it will be clear from the context which perspective is dealt with. I must ask the reader, nevertheless, to be aware of the ambiguity.

4 SWFs and the Brundtland Definition

It should have become obvious from the foregoing discussion that the Brundtland report's definition of sustainable growth largely amounts to assuming a special "desirable" form of SWF. This statement may not seem plausible, because at first glance "sustainable growth" seems to be a purely geophysical or biological condition, resulting in certain consumption or investment rules. Following these rules will (hopefully) keep the geophysical system going at its present level. It seems natural therefore to postulate that these rules should be followed.

But as we have seen this view amounts to suggesting one special type of SWF, which (in a form that needs to be specified) postulates that future generations' needs should count exactly as much for our present policies as our own needs. It seems therefore that the notion of an SWF should be a useful instrument to clarify our thoughts about sustainable growth in general and the Brundtland definition in particular.

To start with, let us look once more at the above condition

$$\frac{\partial F}{\partial u_j} > 0, \quad j = 1,.....,n.$$

This condition entails the so-called (strong) Pareto-principle. This principle holds that a state *A* of society is better than a state *B* if at least one individual in the society is better off in state *A* and nobody is worse off in state *A*.

In the context of sustainability the choice is not among various states of society but rather between various growth paths. We can say, that a growth path GP_i is Pareto-better than a growth path GP_j if at least one generation is better off on GP_i than on GP_j and if no generation is worse off on GP_j. A Pareto-optimal growth path would then be a growth path in which no generation can be made better off without making another generation worse off.

This sounds surprisingly close to the Brundtland definition! Why don't we therefore use this definition as a clarification of the Brundtland definition? The problem is that as a guiding principle of politics this definition is practically worthless. In reality every change in policy makes somebody worse off. Therefore the Pareto-ordering of social states does not offer much help. Most social states (or growth paths in our context) are Pareto-incomparable. This, in turn, means that we must be more specific in defining a SWF if we want to use it for practical policy.

5 Sustainable Growth with a Rawlsian SWF

In principle, the SWF could assume many forms: as many as there are value judgements about the intergenerational distribution of consumption possibilities. In the literature, however, two functional forms have gained particular prominence, the Rawlsian SWF and the utilitarian SWF.

The Rawlsian SWF is given by:

$$\text{SWF}(GP_j) = \min\left\{u_1(GP_j),.....,u_n(GP_j)\right\}. \qquad (5)$$

For the moment I neglect the question that the u_i refer to different points in time and should be made comparable by discounting them with an appropriate rate of time preference. I shall take up this question below. It should also be noted that in using this SWF it is implicitly assumed that the utilities of the n generations are interpersonally comparable on an ordinal scale.[2]

This SWF contains the value judgement that only the preferences of the worst off generation should count in judging the desirability of a certain growth path GP_j. Accordingly, a growth path GP_i is Rawls-better than an alternative growth path GP_j if the worst off generation on GP_i is nevertheless still better off on this growth path than the worst off generation on growth path GP_j:

$$\min\left\{u_1(GP_i),.....,u_n(GP_i)\right\} > \min\left\{u_1(GP_j),.....,u_n(GP_j)\right\}. \qquad (6)$$

[2] Assume that there is a group of utility functions $u_i(x)$, $i = 1,....,n$. We say that the u_i are interpersonally comparable on an ordinal scale when the u_i may be transformed by a strictly increasing monotone function $v(.)$ which, however, must be the same for all i.

A sustainable growth path according to Rawls is one, which is Rawls-better than any other growth path, subject to the condition that this growth path is economically and ecologically feasible. Feasibility here means that it must be possible to produce the corresponding outputs with the given amount of resources and the given state of technology. This does not necessarily mean that the natural resources are not allowed to be depleted over time. As Solow (1986) has noted: "The current generation does not especially owe to its successors a share of this or that particular resource. If it owes anything, it owes generalized productive capacity or, even more generally, access to a certain standard of living or level of consumption. Whether productive capacity should be transmitted across generations in the form of mineral deposits or capital equipment or technological knowledge is more a matter of efficiency than of equity. (The preservation of natural beauty is a different matter since that is more a question of direct consumption than of instrumental productive capacity.)"

To illustrate the practical consequences of the Rawlsian definition let us put $u_i\left(c_j(1),.....,c_j(n)\right) = c_j(i)$. This means that generation i is only interested in its own consumption level. The Rawlsian SWF in this case is:

$$\mathrm{SWF}(GP_j) = \min\left\{c_j(1),.....,c_j(n)\right\}. \qquad (7)$$

Assume that all $c_j\,(j = 1,.....,m)$ may take any value between an upper bound $\bar{c}$ and a lower bound $\underline{c}$. (This means we are assuming that each growth path between the two bounds is feasible.) It is easily verified that under these assumptions there is only one sustainable growth path, namely the one where all generations have an identical level of consumption. For assume that there were an optimal growth path $\left(c_j(1),.....,c_j(n)\right)$ and set $c_j(i)$ = *min*{ $c_j(1),.....,c_j(n)$ }. Assume that $c_j(k) \neq c_j(i)$ for at least one $i \neq k$. Hence $c_j(i) < c_j(k)$. But this means that it is possible to increase $c_j(i)$ somewhat by reducing $c_j(k)$ somewhat. Thus $\left(c_j(1),.....,c_j(n)\right)$ cannot have been Rawls-optimal. In other words: "If consumption per head were higher for a later than for an earlier generation, then social welfare would be increased if the early generation were to save and invest less, or to consume capital, so as to increase its own consumption at the expense of the later generation. If consumption per head were higher for an earlier than for a later generation, then social welfare would be increased if the early generation were to consume less and, correspondingly, save and invest more, so as to permit higher consumption in the future. Thus … consumption per head should be the same for all generations" (Solow, 1978).

It may be the case that such a growth path with an identical consumption level for all generations may result in a very low consumption level for each generation, perhaps at the level of pure subsistence, though this must not necessarily be the case.[3] Considerations like this make it very unlikely that the Rawlsian SWF will ever be chosen as the basis of a realistic growth policy. What we need is obviously a more flexible form of the SWF that allows us to vary *the degree* to which the needs of future generations are taken into account. This is possible by employing the so-called utilitarian SWF discussed in the next section. Before proceeding to this section let us, however, make the following remark:

The Rawlsian SWF is, of course, derived from John Rawls' famous Theory of Justice (1971). In this theory the founders of an imaginary society gather in front of a "veil of ignorance" in order to choose the basic principles of a constitution. Invoking the "veil of ignorance" means that nobody knows in which position in society and in what circumstances of life he will find himself after the veil has been lifted. Thus everybody must envisage the possibility that he will occupy the worst position in society. Accordingly, he will only consent to a constitution that cares for the worst off individual. Such a constitution therefore must contain something like the following principle: A change of policy is only acceptable if it improves the situation of the worst off individual(s) in society.

This idea can easily be applied to intergenerational justice: Before the "veil of ignorance" is lifted an individual does not know in which generation he will have to live. Therefore he will accept a change from growth path GP_j to GP_i only if the worst off generation on GP_i is made better off on GP_i than on GP_j.

[3] For a precise analysis of Rawlsian growth paths in the standard neoclassical growth model under differing assumptions about population growth and technical progress see Solow, 1978.

6 Sustainable Growth with a Utilitarian SWF

The utilitarian SWF has the form:

$$\text{SWF}(GP_j) = \sum_{i=1}^{n} u_i(GP_j)\,. \tag{8}$$

Again I suppress discounting for the moment. Furthermore it must be remarked that this kind of SWF presupposes interpersonal comparability in the sense that the u_i are cardinally measurable.[4]

According to this SWF growth path GP_j is better than another growth path GP_i if the sum of the utilities over all generations is greater on GP_j than on GP_i. Obviously , this SWF does not incorporate any considerations of intergenerational equity. Even if GP_j is better than GP_i some generations could have very low levels of welfare on GP_j. It is, however, possible to generalize the utilitarian SWF in such a way that it contains distributional concerns.

It can be shown that both the Rawlsian and the utilitarian SWF are special cases of the following SWF:

$$\text{SWF}(GP_j) = \frac{\sum_{i=1}^{n} a_i u_i(GP_j)^{1-\alpha}}{1-\alpha}\,. \tag{9}$$

In this expression the u_i are weighted with coefficients a_i. If $a_i = 1$ and $\alpha = 0$ this SWF reduces to the utilitarian case; if $a_i = 1$ and $\alpha \to \infty$ this SWF reduces to the Rawlsian case.[5] This shows that by appropriate choice of α value judgements of intergenerational justice can be taken into account. It can be shown that α is a measure of society's aversion towards the inequality of consumption among generations. The higher α, the higher this aversion.

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[4] Assume that the units of measurement have been chosen and that $u(x)$ is the corresponding utility function. Then cardinal measurability means that all utility functions of the form $v(x)=a + bu(x),\ b > 0$ contain the same information. In other words, cardinal measurability allows one the freedom to change both the origin of the measuring scale and the units of measurement (e.g. degrees Fahrenheit or Celsius).

[5] Multiplying by $1 - \alpha$ and taking the $(1 - \alpha)$th root transforms the SWF into the CES functional form. For the CES function, however, the results just stated are well known (see Varian, 1992, p. 20).

This generalized form of SWF seems quite realistic. According to this SWF, the present generation is willing to redistribute "some" of its consumption possibilities to future generations but (perhaps) not "too much". The precise definition of "some" and "too much" is given by the parameter α.[6]

It may seem unethical at first view that the present generation is only prepared to give up "some" of its present consumption to future generations. Given, however, that technical progress could increase future generations' consumption possibilities drastically (or reduce environmental problems) this is, perhaps, not as unethical as it may appear at first. After all there is not only the problem of the justice of present generations towards future generations. There is also the problem of justice of future generations towards the preceding generations. If future generations are richer due to economic growth resulting from technical progress than it seems appropriate that they carry a larger burden of preserving the environment than the current generation.

7 An Example for the Neoclassical Approach: Nordhaus' Analysis of Climate Policies

Among economists one of the most respected studies concerning the policy aspects of the greenhouse effect is the one by William Nordhaus contained in his book "Managing the Global Commons" (1994). In order to illustrate the perhaps somewhat abstract considerations above it may, perhaps, be useful to give a rough sketch of Nordhaus' approach as an example of "best (neoclassical) practice".

Nordhaus conducts his empirical analysis of the greenhouse effect by reinterpreting the above SWF as a function of discrete time intervals of 10 years. This can easily (though, perhaps, somewhat artificially) be done by identifying each generation with one time interval.

[6] In the framework of a Ramsey growth model it can be shown that $r = \alpha g + \rho$, where *g* is the rate of economic growth, *r* is the real interest rate and ρ the rate of time preference. Therefore estimates of α and ρ can obtained from observations on *r* and *g*.

We thus get

$$\mathrm{SWF}(GP_j) = \sum_{t=1}^{T} \frac{c_j(t)^{1-\alpha}}{1-\alpha}\,.^{7} \tag{10}$$

A further simplification consists in replacing the assumption that there is only a finite number of growth paths with the assumption of a continuum of growth paths. This leads to

$$\mathrm{SWF}(GP) = \sum_{t=1}^{T} \frac{c(t)^{1-\alpha}}{1-\alpha}\,. \tag{11}$$

This is the functional form employed in Nordhaus' DICE model. How do we define an optimal growth path in this framework? An optimal growth path is a growth path that maximizes the SWF over all feasible growth paths, that is a growth path that solves

$$\max_{\mathrm{GP}} \mathrm{SWF}(GP)$$

subject to the condition that the growth path $GP = c(t)_{t=1,\ldots,T}$ can be realized with the given resources and the given state of technology.

In order to reflect the environmental aspects of economic growth the DICE model consists not only of the SWF to be maximized but also incorporates a set of geophysical "climate-emissions-damage-equations". These equations describe relationships between economic activity, emissions and climate change. They have nothing to do with economics but are derived from climate models of the natural sciences. They also do not set maximum levels of environmental damage, which the optimal growth path is not allowed to exceed. They are just geophysical relationships describing how the economy and the environment

[7] For technical reasons Nordhaus uses in fact the SWF

$$\mathrm{SWF}(\mathrm{GP_j}) = \sum_{\mathrm{t}=1}^{\mathrm{T}} \frac{\mathrm{c_j(t)}^{1-\alpha} - 1}{1-\alpha}\,\mathrm{L(t)}$$

where c_j is consumption per head and $L(t)$ is the number of individuals in generation t. Growth in this model is generated by growing population $L(t)$ and by technical progress.

interact. It is up to society (whose values towards sustainability are contained in the SWF) whether it wants to respect the maximum levels of environmental damage or not.

Speaking in terms of economic theory the DICE model is a Ramsey-type optimal growth model of the world economy. It is designed to maximize the discounted value of utility of consumption subject to a number of economic and geophysical constraints. From this model an optimal growth path can be calculated, which gives an optimal path for consumption and reduction of greenhouse gas emission. (Emissions reductions here play the role of investment in the traditional Ramsey model.) The model can also be used to simulate various climate policies (e.g. the reduction of emissions by an exogenously given percentage.) In this way the cost (in form of lost output) and benefits of a certain climate policy can be estimated.

I have used the DICE model only as an example in order to illustrate the basic methodology of the neoclassical approach. There are many other models of course. Moreover, this type of model is not restricted to the analysis of the greenhouse effect. It can be put into many environmentally relevant contexts (see Radke, 1999).

Can we say that the optimal growth path derived in a Nordhaus-type model is a "sustainable" growth path? I hope that by now it has become clear that this question is the wrong question. For policy purposes it is the SWF that counts not just the purely geophysical postulate of sustainability. Mankind can consciously decide to run down its resources if its SWF and its judgement concerning the probability of future technical progress tells mankind to do so. In fact, in a highly stylized toy model Nordhaus (1993) has given an example where such a declining path of consumption may be perfectly reasonable (i.e. maximizing the SWF).

It is interesting that during the siege of Leningrad in World War II the authorities followed a declining path in the consumption of food, instead of starting at the lowest possible level compatible with subsistence and then keeping this level as long as possible. (The role of "technical progress" in this case was played by a small probability of rescue by the freezing of Lake Ladoga, which would have made it possible to supply the city with food, which in fact occurred when only a two-day supply of food was left.)

I do not want to be misunderstood: Neoclassical economists do not advocate a policy of no concern for the future or of running down natural resources (though economists are often accused of doing so). The neoclassical approach only makes explicit that choosing a growth path (whether "sustainable" or not) always contains a value judgement.

8 To Discount or not to Discount?

The utilitarian SWF is a sum of utility terms, which refer to different points in time. In general, however, a certain level of utility u enjoyed at time t is not the same thing as the same level of utility enjoyed at time $t+n$. The standard procedure to make two levels of utility enjoyed at different times comparable is to discount them with a rate of time preference ρ. The SWF above would then become

$$\mathrm{SWF}(GP_j) = \sum_{t=1}^{T}\left[\frac{c_j(t)^{1-\alpha}}{1-\alpha}\cdot\frac{1}{(1+\rho)^{t-1}}\right]. \qquad (12)$$

It can be seen from this expression that discounting consumption or utility flows in this way amounts to a devaluation of future generations' needs. Several economists have argued therefore that out of ethical considerations ρ should be set to zero. On the other hand it cannot be denied that in reality people discount the future and that therefore a positive rate of time preference exists. But this means that it may be questionable to base policy decisions on the assumption that $\rho = 0$.

Obviously the question of discounting is a complex question of its own. In order not to overburden this paper a few remarks will have to suffice. To begin with we should note that we have several types of discounting in the above utilitarian SWF, not just time discounting with the rate of time preferences ρ. There is also a type of discounting that is connected with the parameter α. We have already stated that α reflects the degree to which society is willing to redistribute consumption possibilities among generations (i.e. from richer to poorer generations). α measures the degree of aversion towards inequality among generations (as seen from the standpoint of the present generation). Therefore society does not put the same value on an increment of consumption of a richer future generation as on an increment of consumption of the present generation. Society discounts the consumption increase of the future generation by the factor α.

This makes it obvious that setting $\rho = 0$ will not eliminate all discounting from this model.[8] One could object that this just means that in addition to $\rho = 0$ α should take on very high values. But this raises the question whether one should base far-reaching policy decisions on *desired* values of ρ and α rather than on values that can be observed from the factual choices of society. It can be shown that ρ is closely connected with the market rate of interest and with the savings rate. Judging from real world data ρ is not equal to zero but rather around 3 %. This means that by setting $\rho = 0$ we are not reflecting the preferences of society and accordingly are misallocating resources.

9 The Ecological Approach[9]

So far I have spent considerable space and effort in stating the neoclassical economist's view on sustainable growth. I have done so because this view is very often misrepresented. It is often contended that economists do not take non-market goods into account, in particular, that they neglect the possibility that certain environmental goods might have an own intrinsic value. In addition it is frequently asserted that economic analyses of sustainable growth are devoid of any ethical considerations. I hope to have shown that the opposite is true. Economists take great pains to incorporate non-material goods and ethical concerns in their models.

I now try to describe the essence of the (mainstream) ecological point of view of sustainable growth. It is not easy to subsume the various schools of thought under one common approach but I think that the following interpretation of sustainable growth, known as "Non Declining Path Interpretation" describes the basic philosophy rather well.

Let $D = (D_1, \ldots, D_n)$ be a vector of desirable social goals. These goals may include purely economic goals like per capita income but also immaterial goods like health, education, "mobility", civil rights, or a just income distribution. D may also include the enjoyment of certain environmental goods. It may be difficult (or at least controversial) to define such a vector of social goods in practice but for our discussion we can disregard the practical

[8] To be more precise one would have to introduce the distinction between utility discounting and goods discounting. See Nordhaus, 1994, p. 122 passim.

[9] This section again follows closely Nordhaus, 1993.

difficulties for the moment. Given that society has agreed on a certain specification of D an obvious definition of sustainable growth is the following: a growth path GP_j is called sustainable when D declines in no component D_i, $i = 1, \ldots, n$. The advantages of this definition are obvious. First, it is concrete. The D_i can be named and observed. Second, it allows explicitly for the conservation of certain environmental goods at their present level. Third, it is very close to the definition of sustainability in the Brundtland report.

At second sight, however, it is not so clear whether this definition is really different from the economist's definition developed above. The first question that arises is whether we can realistically assume that the various components of D are sacrosanct. In reality we probably must admit a certain degree of substitutability among the D_i. Society may be willing to trade in, say, a certain degree of mobility for a larger amount of health or vice versa. Again, society may be prepared to trade in a certain amount of the enjoyment of environmental goods for more per capita income. (Think of the underdeveloped countries!)

Probably society would only be prepared to conduct these trades at a diminishing rate. That is, the more of, say, mobility it has already acquired the higher would be the price of an additional "unit" of mobility in terms of, say, health. In addition, society would certainly prefer a vector D' to D, if $D_i' \geq D_i$, for all $i = 1, \ldots, n$. All of this sounds very much as if society will establish a continuous and transitive preference ordering over the space of all possible vectors D. However, under certain regularity conditions such a continuous and transitive preference ordering can be translated into a preference function u very much like the one used in the preceding sections of this paper.

Having obtained such a preference function u the Non-Declining-Path-Interpretation tells us to select a growth path GP such that $u_i(GP) \leq u_{i+1}(GP)$, for all $i = 1, \ldots, n$. This postulate certainly amounts to maximizing the sum of the u_i subject to the condition that $u_i(GP) \leq u_{i+1}(GP)$. But this again is nothing but a special case of the neoclassical approach stated above. For instance, setting $\rho = 0$ and $\alpha = \infty$ in SWF (12) in section 8 reflects a maximal aversion to intergenerational inequality. We know from section 6 that under these parameter values the SWF reduces to the Rawlsian SWF. But it was shown in section 5 that the Rawlsian SWF amounts to a growth path where all generations have an identical level of consumption. Therefore the Rawlsian SWF is one SWF that produces the ecologists desired growth path.

I conclude therefore that taken to its logical consequences the ecological approach is not very different from the economic approach. Why then do we seem to observe such a wide gap and so much controversy between the political prescriptions of economists and ecologists? In order to answer this question let us take a look once more at the neoclassical maximization problem, stated above, or incorporated in the DICE model. Obviously the difference between economists and ecologists cannot result from the equations describing the interaction between the economy and the environment. These equations are purely geophysical relationships. It may be true that in geophysics too there are differing models and differing schools of thought in modeling these interactions. But basically these models are a common input for the economist's as well as for the ecologist's policy prescriptions. The same holds true for the question of how the production technology of the economy is to be modeled, in particular the widely discussed question in how far man-made capital can substitute for natural capital. Again this is largely a question of fact.

It seems then that the true difference between economists and ecologists consists in their views about the "right" form of the SWF.

Superficially ecologists seem to be occupied mainly with the aim to keep the natural system going. At first glance "sustainable growth" appears as a purely biotechnical or physico-technical matter, resulting, for instance, in certain "harvesting" or investment rules.[10] Following these rules will keep the system going at its present level. Therefore the ecologist's prescription is to follow these rules, that is, to realize a sustainable growth path. But as we have seen this amounts to suggesting one special type or class of SWF. This is a purely ethical choice, however much one may sympathize with it. It reflects a very high degree of aversion to intergenerational inequality in the sense discussed above. As soon, however, as one admits a lesser degree of aversion to intergenerational inequality the optimal growth path may differ (perhaps even dramatically) from the ecologist's ideal. It is clear, for instance, that a consumption path like the one chosen during the siege of Leningrad is incompatible with the ecologist’s view. For an economist, on the other hand, such a path may be perfectly rational.

Choosing a sustainable growth path is therefore indeed a matter of a generation's (explicit or implicit) ethical views. In this I perfectly agree with many other writers (see for instance

[10] See e.g. Lerch/Nutzinger, 2000, or Radke, 1999.

Faber, 2000, with further references). Probably it is precisely this ethical element, which explains the level of emotion in the sustainability discussion.

10 Uncertainty

Some ecologists will object, however, that there is one more decisive difference between ecologists and economists. This difference consists in their views on uncertainty. I have neglected this topic largely up to now. In fact, uncertainty comes in at two points in the above discussion. First, we are certainly not able to maximize a deterministic SWF, just for the reason that we are not able to predict a future generation's welfare level with certainty. Second, we do not know for sure whether our theories about the workings of the natural environment and of the interactions between the economy and the environment are true. They may be true only with a certain degree of probability.

Uncertainty, of course, can be incorporated in economic models. Take the DICE model once more as an example. A large part of Nordhaus' study is devoted to performing simulations of the model in order to gain an impression of the model's sensitivity to parameter changes. Simulations of this kind combined with the apparatus of the modern theory of decision under uncertainty make it possible to design policies, which avoid catastrophic consequences with a high degree of probability.

However, such an analysis would probably not satisfy an ecologist. He would probably retort that assigning probabilities is not the right reaction to the problem of uncertainty. He would argue that the uncertainty we are facing here is so radical that it might well be possible that all our theories of the geophysical processes involved and of the interactions between economy and ecology are totally false. In such a situation, so the ecologist's claim, the only reliable knowledge that we have is the current state of affairs.

But do we know the current state of affairs? The philosophy of science tells us that we necessarily always observe reality under the guidance of some theory. Even when we are deciding to preserve the status quo (or turn back the clock, for that matter) we are assuming that by and large the current scientific theories about environmental processes are roughly true. Again it would seem therefore as if we are committed (or condemned, if you wish) to the economist's approach.

11 Conclusion

The purpose of this paper was largely expository. It was attempted, first, to show that if carefully thought through the apparent sharp conflict between economists and ecologists seems to vanish. The ecologists' view of sustainability turns out to be a special case of the economists' approach i.e. it amounts to assuming a special form of SWF.

The second thought that the paper intended to convey, and, which is closely connected to the first point, is that for developing a consistent environmental policy the notion of sustainability per se is not of much value. What society is seeking is an optimal growth path which takes into account two aspects: (a) the value judgements of society towards intergenerational justice and (b) the geophysical relationships that govern the interplay between ecology and economy. Neoclassical growth models make it possible to derive such a growth path in a logically consistent way.

It certainly has to be admitted that the neoclassical approach is open to serious criticisms. There are many theoretical efforts to amend the neoclassical approach or to substitute it altogether by competing paradigms especially with the aim of creating a totally new field of "ecological economics" (see Radke, 1999, and Lerch/Nutzinger, 2000, for references). However, up to now these new schools of thought lack the theoretical consistency of the neoclassical approach. Unsatisfying as it may be the neoclassical approach, with all its shortcomings may still be the best available alternative.

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