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Sustainability accounting and green accounting

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ABSTRACT Theoretical issues arising in maximin and utilitarian programs are considered in order to shed light on the merits of various concepts of income and types of environmental accounting as guides for environmental policy. The accounting prices for sustaining an economy obey Hartwick's rule but are inconsistent with the principles of national accounting. Moreover, they would be formidably difficult to calculate. Green net national product is an approximate index of welfare in a utilitarian economy which maximises future discounted utility flows. These conclusions hold even if underlying conditions are non-autonomous.

JEL Codes: Q3, E2

KEY WORDS: green accounting, sustainability, Hartwick's rule, stationary equivalent consumption, Hicksian Income, Fisherian Income

Two current preoccupations in environmental economics are green accounting and sustainability. Green accounting is the incorporation in the national accounts of an explicit recognition of the contribution of the environment to human well being. Sustainability entails maintaining welfare constant through time by trading off environmental and non-environmental services. Sustainability *accounting* would provide the prices which would be indispensable for implementing a sustainable economy. Some economists and policy analysts perceive green accounting as a guide for a policy of sustainability. However, green and sustainability accounting arise in qualitatively different economic models with different objectives.

Nordhaus (1995) discusses two venerable income concepts for dealing with these issues. *Hicksian income* is what can be consumed while leaving total value or wealth, generalised to include resources, intact. He documents that many ecological economists focus on this concept. *Fisherian income* is the maximum sustainable level of consumption.

Mathematically, a sustainable path may not even exist (Solow, 1974). For the sake of argument, let us assume that a path of constant, positive consumption (Fisherian income) for all time is feasible. Let the economy utilise stocks, $(S_1, \ldots, S_n) = S$, of various types of produced or human capital and environmental resources and let the growth or decline of each stock be

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governed by a differential equation incorporating the decisions made by society. If the goal of the economy is to maximise the *sustainable* consumption $\bar{C}$ then, by a simple extension of a model of Burmeister and Hammond (1978), the path of the stocks lies along a hypersurface $C(S, t) = \bar{C}$.

The wealth of the economy (its objective) is $\bar{C}$, the maximal, sustainable flow of consumption. In this so-called maximin program, Hicksian and Fisherian incomes are equal. Let us assume that $C(S, t)$ is differentiable with respect to all of its arguments. Then

$$\sum_{k=1}^{n} \frac{\partial C}{\partial S_k} \dot{S}_k + \frac{\partial C}{\partial t} = \frac{dC(S, t)}{dt} = \frac{d\bar{C}}{dt} = 0. \tag{1}$$

The sum on the left in equation (1) is the change in wealth, evaluated at the prices of the sustainability accounts, $\partial C/\partial S_k$ and $\partial C/\partial t$.

In an *autonomous* problem ($\partial C/\partial t \equiv 0$), the vector $\dot{S}$ is in the direction of the tangent hyperplane to the hypersurface. In this case equation (1), Hartwick's (1977) rule, is an example of the condition that the gradient of a hypersurface is orthogonal to and lies in the direction of increases of the hypersurface. If there are one resource R and one capital good K, the graph in (R, K) space is (under regularity conditions) a curve convex to the origin, with the gradient pointing to the northeast.

Equation (1) generalises Hartwick's rule to problems with exogenous changes in conditions through time. It allows a perception of Hartwick's rule in two ways. One can treat time t as one of the state variables of the system. In the sustainability accounts, time would have to be given a price, $\partial C/\partial t$. Or one can write $\sum \dot{S}_k \partial C/\partial S_k = -\partial C/\partial t$: net depreciation exactly offsets any exogenous change in underlying economic conditions. Again, time would have to be priced.

Maximising sustainable consumption is not a utilitarian problem in which the discounted flow of social well being is maximised. By forcing the sustainability problem into a utilitarian framework, Asheim (1994: 261) shows that a competitive economy can support constant consumption only if the utility discount rate happens to vary along a specific path. But there are an uncountably infinite number of plausible paths for the rate of utility discount. Trying to impose sustainable consumption on to a utilitarian path is inconsistent.[1]

Indeed, Hartwick's rule (1) does not generate a natural expression for green NNP. The net investments $\dot{S}_k \partial C/\partial S_k$, having as their dimension (the flow of) consumption divided by time, are incommensurable with (the flow of) consumption. Accounting prices used to measure *net national expenditure (NNE)* as the value of (the flow of) consumption plus net investment would not be the shadow values $\partial C/\partial S_k$ but would be derived from the production-possibility surface.

In sum, if the planner's objective is to maximise sustainable consumption, then a simple generalisation of Hartwick's rule is a robust, elegant policy rule even if the system is non-autonomous. But sustainability

[1] Some have claimed that sustaining consumption requires that Hartwick's rule hold at all times, not just at a particular time. If $C(S,t)$ exists and Hartwick's rule (1) is followed at time t, then consumption at t is the sustainable consumption.

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accounts, using shadow prices not equal to market prices, would be a total break from the national accounts. The planner would have to derive shadow prices by solving the formidable maximin problem. Implementing the prices would undoubtedly be controversial and subject to pressures from special interests.

A natural expression for green NNP does arise in a utilitarian maximisation. Suppose that a planner seeks to maximise the present value of the utility of consumption, $\int_0^\infty e^{-rt}U\,[C(t)]dt$. Consumption C and gross investment I are produced according to a neoclassical production function $F(K,q)$ using capital K and the flow $q = -\dot{R}$ from the stock R of a non-renewable resource. In particular, $C = F(K,q) - \phi(I)$, where $\phi(I)$ is the investment-cost schedule and $\phi'(I) > 0$. The net change in the capital stock is $\dot{\mathbf{K}} = I - \delta K$, where $\delta \geqslant 0$ is the rate of physical deterioration. For simplicity we assume $I > 0$. The current-value Hamiltonian is

$$H = U(F - \phi) - uq + v(I - \delta K),$$

and the first-order conditions are

$$u = F_q U'; \tag{2}$$

$$v = \phi' U'. \tag{3}$$

By the principle of optimality, the value of the program, V, can be expressed as a function of the state variables at any time t

$$V(R, K) \mid_t = \int_t^\infty U(C)e^{-r(s-t)}ds. \tag{4}$$

Let us assume that $V(R, K)$ is differentiable with respect to R and K. Then $\partial V/\partial R \mid_t = u(t)$ and $\partial V/\partial K \mid_t = v(t)$. Differentiating equation (4) with respect to time, in two ways, yields

$$rV - U(C) = \dot{V} = \frac{\partial V}{\partial R}\dot{R} + \frac{\partial V}{\partial K}\dot{K} = -uq + v(I - \delta K), \text{ or}$$

$$rV = U(C) - uq + v\,(I - \delta K) = H.$$

Weitzman (1976) calls $H \mid_t$ the stationary equivalent because a hypothetical, constant flow of utility equal to $H \mid_t$ has present value $H \mid_t / r$ equal to the program value $V \mid_t$.

We identify $-\dot{V}$, (negative) the rate of change of the program value, as total net depreciation *of the program*, in utility terms. Let

$$D(t) = -v(t)[I(t) - \delta K(t)]$$

be the (net) *depreciation of capital*, an amount that recognises the net decline in value (in utility terms) of the capital used in production. Analogously, let

$$\Delta(t) = u(t)q(t)$$

be the *depletion* of the resource.[2] The net decline of the program value is equal to the sum of depletion and depreciation

[2] Depreciation is a *financial* concept, the decline in *value* of a capital asset. We adhere to the convention that depletion is also a financial concept, as opposed to a physical degradation.

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$$-\dot{V} = uq - v(I - \delta K) = \Delta + D.$$

As is well known, competitive market prices can support the optimal program. Let $p(t)$ be the price of the consumption good. Utility $U(C)$ can be scaled such that $p(t) = U'(C) \mid_t$. (If C were a vector indexed by i then $p_i(t) = (\partial U/\partial C_i) \mid_t$.) National accountants would record consumption as $p(t)C(t) = C(t)\,(\partial U/\partial C) \mid_t$. This is an approximation of $U(C)$ *at the margin*, neglecting aggregate consumers' surplus. Depreciation and depletion *at market prices* ($[p\phi'] \mid_t$ and $[pF_q] \mid_t$) are

$$D(t) = -[p\phi'] \mid_t [I(t) - \delta K(t)];$$

$$\Delta(t) = [pF_q] \mid_t q(t).$$

Green NNE at market prices is equal to the *linearised Hamiltonian*

$$Y(t) = [pC - (pF_q)\,q + (p\phi')\,(I - \delta K)] \mid_t = [CU'(C) - uq + v\,(I - \delta K)] \mid_t.$$

Figure 1, preparation of which was encouraged by Jeff Vincent, depicts the types of income for the linear ($U(C) = C$), two-period case. Maximal discounted welfare $\hat{V}$ is attained at M, and maximal constant consumption (Fisherian income) C_F, at F. Stationary equivalent income C_E is such that $C_E\,[1 + 1/(1 + r)] = \hat{V}$. NNP is equal to $C_E > C_F$. Consuming Hicksian income leaves the same present value after as before period 1. Thus, $C_1 + C_2/(1 + r) = V = C_2$, or $C_2 = C_1\,(1 + 1/r)$, at H. If the slope of the transformation function *happens to be* $-(1 + r)$ at F, then M, F and E, but not H, coincide (Asheim, 1994). The diagram also applies to utility of consumption, in (U_1,

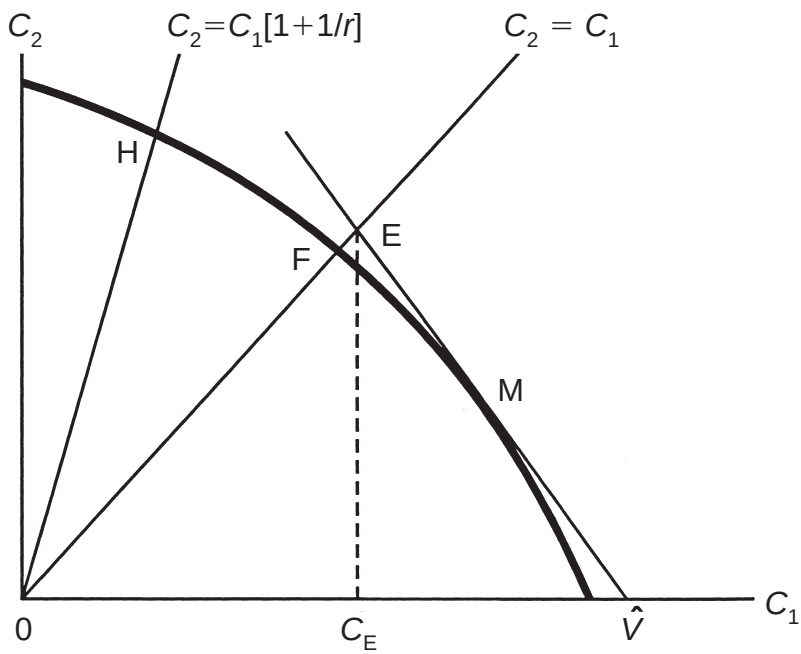


Figure 1

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U_2) space and with $U(C)$ written in place of C, except that NNP, $C_E U'(C_E)$, cannot be depicted. The concavity of $U(C)$ makes the frontier in (U_1, U_2) space more curved; hence, C_E is closer to C_F than $U(C_E)$ is to $U(C_F)$ (Asheim, 1997).

As figure 1 suggests, there is little to recommend the Hicksian concept. Suppose, nevertheless, that a mortal regulator imposes Hicksian utility at time t. Let $V_\theta[R(t),K(t),t] = \max \int_t^\infty U[C(s)]\, e^{-r(s-t)}\, ds$, such that V_θ is constant on the interval $[t, \theta]$. For $\tau \in (t, \theta)$, wealth $V_\theta \big|_\tau$ depends on τ and θ as well as the stocks because of the set of constraints. Still, $rV_\theta - U(C_\theta) = \dot{V}_\theta = 0$. Hence, $U(C_\theta) = rV_\theta$ and $\dot{C}_\theta = r\dot{V}_\theta/U' = 0$; consumption is constant, and utility is the stationary equivalent *for the new program*.[3] If V_θ is differentiable, the shadow values can be obtained by differentiation. Generalised net investment is

$$v_\theta (I_\theta - \delta K_\theta) - u_\theta q_\theta + \partial V_\theta/\partial t = \dot{V}_\theta = 0 \tag{5}$$

Equation (5) is a mirage of Hartwick's rule (1); the economy is not consuming its Fisherian income (if it exists). Let us assume that the solution to this problem, with a continuum of integral constraints, is analogous to that for a problem with a finite number of such constraints. In the conditions corresponding to (2) and (3), a multiplier $1 + \psi_\theta \neq 1$ is applied to U'; the constraints act like a trade quota, opening a (proportional) distortion between market prices of the factors, u_θ and v_θ, and the values of their marginal products, $U'(C_\theta)F_q(q_\theta, K_\theta)$ and $U'(C_\theta)\phi'(I_\theta)$.

A non-autonomous model can admit exogenous changes in technology (through F and ϕ) and evolution of the utility function or the utility discount *factor* (corresponding to e^{-rt}). Let that factor be $\beta(t)$. With other obvious changes in notation

$$W(R,K,t) = \int_t^\infty \tilde{U}(C, s)\, [\beta(s) / \beta(t)]\, ds.$$

Differentiating in two ways and solving as before yield

$$\begin{aligned}(-\dot{\beta}/\beta)\, W = \tilde{U} - uq + v(I - \delta K) + \partial W/\partial t = \\ \tilde{H} + \partial W/\partial t \approx \tilde{Y}(t) + \partial W/\partial t,\end{aligned} \tag{6}$$

where $\partial W/\partial t$ combines all purely temporal effects. Generalised net investment is $\dot{W} = -uq + v(I - \delta K) + \partial W/\partial t$. Stationary-equivalent utility is $[\beta^2(t) / (-\dot{\beta} \int_t^\infty \beta(s)\, ds)]\, [\tilde{H} + \partial W/\partial t] \approx [\beta^2(t) / (-\dot{\beta} \int_t^\infty \beta(s)\, ds)]\, [\tilde{Y}(t) + \partial W/\partial t.]$.

Equation (6) expresses the *welfare interpretation of NNP*: net earnings on generalised wealth are approximated at the margin by a generalisation of NNE at market prices. A source of error is the drift $\partial W/\partial t$. But if all purely

[3] It is equivalent to impose constant consumption on $[t, \theta]$. In the limit as $\theta \to \infty$, these programs become equivalent to the sustainable program, if it is feasible. Hicksian utility is, then, equal to Fisherian utility in these limiting problems (but not in a general utilitarian problem with an infinite horizon). The limiting problems are incongruous, however, with a planner pursuing forever an implicit goal which is at variance with the explicit goal.

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temporal effects act slowly, then $\partial W/\partial t \approx 0$ and green NNE provides an index of human welfare.

The conceptual problems of the national accounts are well known. If there are important divergences from competition, market prices are not shadow values. Furthermore, green accounting's welfare interpretation relies on discounting the utility of future generations, an unappealing feature to some.

On the other hand, to the extent possible, green accounting uses observable, market prices. Where there is no market price, the shadow value can be determined using cost–benefit analysis. The potential for abuse of cost–benefit techniques is well understood, and any actual abuse is comparatively transparent. Successful development, defined as increasing green NNP, should lead to *improving*, not just sustaining, environmental quality if the last is a normal good.

The role of environmental accounting is as a practical guide for environmental policy. At issue is whether the negative features of green accounting are as undesirable as the computational difficulties, and the consequent opportunities for rent seeking, of sustainability accounting.

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