ON "GREEN NATIONAL PRODUCT": THEORIES AND A COMPARISON AMONG DIFFERENT APPROACHES

Yun-Peng Chu
Department of Economics and Research Center for Taiwan Economic Development, National Central University, Chung-Li, Taiwan

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Summary

A theoretically "ideal" measure of green Net National Product (green NNP) is derived by finding the Hamiltonian of a dynamic equation which maximizes the utility of a representative consumer. A "sustainable" model of production is derived by limiting production to a level which keeps the quality and quantity of natural resources intact. It is shown that the "ideal" measure is the sum of the NNP under the sustainable mode and the "net benefits" from deviating from that mode. It is also shown that this ideal measure differs from the conventional NNP in that it includes the total post-defense direct service of the environment to consumers, and excludes the economic depreciation of environmental quality, the economic depreciation of renewable resources, and consumers' defensive spending (because it is a cost borne by the consumers in order to have access to the post-defense environmental services). It is further shown that while all previously developed concepts of green accounting reviewed in this chapter have their merits, the "damaged-adjusted net national income" developed by the London Group is closest to our ideal measure, followed by the ENRAP (Environmental and Natural Resources Accounting Project) approach, and further followed by the SEEA (System of Integrated Environmental and Economic Accounting)'s Environmentally adjusted Domestic Product II or EDPII, to which the London Group's "cost-based net national income" is similar.

1. Introduction

Adjustments of conventional national product measures to reflect changes in the value of environmental assets, popularly known as green accounting, have gained considerable attention in recent years. In the United States, intensive work on environmental accounting began in the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce in 1992. Shortly after the first publication of the U.S. Integrated Environmental and Economic Satellite Accounts (IEESA) in 1994, however, Congress directed the Commerce Department to suspend further work in this area and to obtain an external review of environmental accounting. A panel was then organized by the National Research Council and charged to do the work. The findings of the panel were recently released and published as the report *Nature's Numbers*.

There the panel concludes that "extending the U.S. national income and product accounts to include assets and production activities associated with natural resources and the environment is an important goal; and that developing a set of comprehensive non-market economic accounts is a high priority for the nation." The panel explicitly recommends that the "Congress authorize and fund Bureau of Economic Affairs of the Department of Commerce to recommence its work on developing natural-resource and environmental accounts." Elsewhere the work continued without pause in many countries.

Given the growing importance of green accounting, there are unfortunately still doubts around it both theoretically and empirically. This note attempts to clarify some of concepts concerning the treatment of important variables including defensive spending, direct services of the environment, and depreciation, in the process of constructing the green national product. It will do so by comparing the United Nations' SEEA (System of Integrated Environmental and Economic Accounting) and the Philippine ENRAP (Environmental and Natural Resources Accounting Project) framework (closely associated with Professor Henry Peskin) with a theoretically ideal measure of national product, involving an extension of the work by Kirk Hamilton of the World Bank.

The theoretically ideal measure constructed in this chapter uses a dynamic theoretical model based on optimization out into the future. It fits into the neoclassical economic growth tradition, in which produced capital is considered substitutable with natural resources (according to the so-called "weak" or "broad" sustainability criterion). This line of research in the context of national accounting goes back to the 1976 paper of Martin Weitzman, who showed that the present value of future consumption would be maximized by maximizing in each period the "national product" as conventionally defined, if the economy is on the dynamically optimal path *and* all contributing elements to growth are appropriately accounted for. Robert Solow subsequently showed that national product could be conceived of as the interest on total accumulated wealth, followed by Dan Usher who discussed the interpretation of the Hamiltonian in the dynamic optimization specification as the return to wealth, where wealth is defined as the present value of future consumption. John Hartwick and Karl-Goran Mäler both extended Weitzman's model to analyze different aspects of the problem, while Kirk Hamilton synthesized and integrated the analysis in two papers published in the mid 1990s by presenting a series of models that touch upon almost all of the important aspects of concern.

In particular, for our purposes, Hamilton's Models 2 and 5 in his 1996 paper as well as some parts of Model 1 in his 1994 paper will be integrated into one model, which will subsequently be transformed and re-interpreted. The idea is to develop a formulation that is as simple as possible, but powerful enough to address the issues at hand. It will be clear that the model to be presented is enough for the purpose, and possible extensions of the model to include other aspects such as exhaustible resources would be intuitive.

2. The Model

2.1. The Set-Up

In the type of dynamic model widely used in this kind of work, the main components are a technological relationship that describes production possibilities, an objective function that describes the things that provide benefits to members of society (in this case, consumption of material goods and services, denoted C, and the environmental benefits they enjoy, denoted Φ), and a series of constraints on, and relationships between, inputs and resources that act as limits on what can be achieved.

The model presented here is an optimal control model, that solves for optimal values of key variables over (in this case) time. Let us define the following symbols:

U = utility (the instantaneous welfare of the society under consideration)
C = consumption other than consumers' defensive expenditure
K = capital stock (produced assets)
F = production
S = stock of (renewable) resource
R = resource extraction/harvest
f = extraction/harvest cost
X = cumulative amount of pollution emitted
g = net natural growth of resource
B = flow of environmental services
d = dissipation rate of the stock of pollution
e = pollution emissions
a = abatement expenditure by producers
Φ = environmental benefits to households
h = consumers' defensive expenditure
L = available labor
LL = total supply of labor

Thus, the economy has a given technology, transforming inputs (capital, labor and resource flow) into outputs. Specifically, the economy produces according to

$$F = F(L, K, R) \qquad (1)$$

where $F_L > 0$, $F_K > 0$, $F_R > 0$, and $L \leq LL$.

This production process is subject to a series of constraints. For $L \leq LL$, the inequality holds if some labor is not available due to environmentally caused harm:

$$L = LL - \delta(B_0 - B) \tag{2}$$

where $\delta > 0$ is the effect of harm, proportional to the difference between B_0 and B, both of which will be defined immediately below.

The flow of environmental services—a measure of the services received by the population from the natural environment—is governed by

$$B = B_0 - \beta(X - X_0) \tag{3}$$

where B_0 is the level of environmental services that flow from a pristine environment, X (X_0) is the stock (initial stock) of the pollutant, and $\beta > 0$. In turn, the rate of change in X is given by

$$\dot{X} = e - d(X) \tag{4}$$

where e is emission, and d is the rate of natural dissipation, a function of X.

The rate of change in the (renewable) resource stock is governed by

$$\dot{S} = -R + g \tag{5}$$

The extraction or harvest cost of the resource, represented by f, is a function of R:

$$f = f(R) \tag{6}$$

where $f_R > 0$. Emission of pollution is given by

$$e = e(F, a) \tag{7}$$

where $e_F > 0$ and $e_a < 0$. Environmental benefits to households (consumers)—net benefits received by the population from environmental services—are given by

$$\Phi = \Phi(B, h) \tag{8}$$

where $\Phi_B > 0$ and $\Phi_h > 0$.

Having specified the production technology and the appropriate constraints, it remains to specify the objective function: that is, what is it the population would like to do (achieve) in these circumstances? Convention is followed in this treatment, by regarding the population as a single person ("a representative consumer"), for purposes of tractability. Being concerned with sustainability as we are, the "person" (population) is presumed to live forever, so their actions are described out to infinity. As noted above, the population is presumed to care about the consumption benefits they receive plus the environmental benefits they experience.

In formal terms, the dynamic optimization problem is then to maximize the social utility function

$$\int_0^\infty U(C,\Phi)e^{-rt}dt \qquad (9)$$

subject to $\dot{K} = F - C - a - f - h$ and Eqs. (4) and (5).

Mathematically, as stated, this is a problem in optimal control theory, with a constant discount rate assumed. To solve a complex dynamic problem of this nature, a function called the Hamiltonian is used, which, if maximized, supplies conditions that will solve the entire control problem. Essentially, we solve the problem for "one instant in time", with the conditions that solve for a single instant applying to *every* single instant of the problem. Thus it is sufficient to solve as if for "one instant" only.

The relevant Hamiltonian in this problem is

$$H = U + \gamma_1\dot{K} + \gamma_2\dot{X} + \gamma_3\dot{S} \qquad (10)$$

Linearizing U (and Φ) so that $U = U_C C + U_\Phi \Phi = U_C C + U_\Phi \Phi_B B + U_\Phi \Phi_h h$, and dividing both sides of (10) by U_C gives

$$H / U_C = C + \theta_1\dot{K} + \theta_2\dot{X} + \theta_3\dot{S} + \theta_4 B + \theta_5 h \qquad (11)$$

where
$\theta_1 = \gamma_1 / U_C$, $\theta_2 = \gamma_2 / U_C$, $\theta_3 = \gamma_3 / U_C$, $\theta_4 = U_\Phi \Phi_B / U_C$ and $\theta_5 = U_\Phi \Phi_h / U_C$.

It can be shown that the first-order conditions yield

$\gamma_1 = U_C = U_\Phi \Phi_h$, which makes θ_1 and $\theta_5 = 1$, so (11) can be re-written as

$$MEW = C + \dot{K} + \theta_2\dot{X} + \theta_3\dot{S} + \theta_4 B + h \qquad (12)$$

where MEW is what is termed in the literature the "measure of economic welfare." (This is analogous to the measure of economic welfare as developed in pioneering work by William Nordhaus and James Tobin in 1973.) The distinction between measures of "net product" and measures of "economic welfare" is important to appreciate, although in the above analysis they are interchangeable. Net product measures are, principally, measures of an economy's output—measures of what can be *produced*. "Green accounting" measures of net product are generally modified to account for changes in "natural capital" (e.g. reductions in stocks of natural resources) that are not captured in the conventional market-based accounts. Measures of economic welfare are based on consumption, rather than production, possibilities, and typically include pollution flows and other elements that affect consumption and thus welfare, while not necessarily directly affecting production possibilities.

Equation (12) can be rewritten as

$$\mathrm{MEW} = \mathrm{F} - \mathrm{a} - \mathrm{f} - \mathrm{h} + \theta_2 \dot{\mathrm{X}} + \theta_3 \dot{\mathrm{S}} + \theta_4 \mathrm{B} + \mathrm{h}$$

which is similar to an expression derived by Hamilton in his 1996 paper (his equation 12) except for the following:

- His Φ / Φ_h equals the term $\theta_4 \mathrm{B} + \mathrm{h}$ here; since $\theta_4 \mathrm{B} > 0$, this explains why he argues that his result regarding household defensive expenditure is not different from one derived by Mäler. The latter shows that such expenditure should not be subtracted from conventional GNP to get the measurement of welfare.
- His model 5, which gives his Eq. (12), does not include renewable resources but the model presented here does; this is reason for the inclusion of the terms $-\mathrm{f}$ and $\theta_3 \dot{\mathrm{S}}$ in the RHS of Eq. (13) above.
- He defines *GNP* as F and writes *GNP* instead of F in his Eq. (12); here we keep the F term, for reasons to be given below shortly.

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Biographical Sketch

Yun-Peng Chu, currently Distinguished Professor of Economics and Director of the Research Center for Taiwan Economic Development at National Central University, Taiwan. Dr. Chu received his Ph.D. in Economics from the University of Maryland, USA. He served as President of Jin-Wen Institute of Technology, Director of the Institute for Social Sciences and Humanities, Academia Sinica, and Commissioner of the Fair Trade Commission, Executive Yuan, Taiwan. He was a co-author of the books, *Taiwan 2000: Balancing Economic Growth and Environmental Protection* and ***Sustainable*** *Taiwan 2011: Visions and Strategies*. His other publications appeared in such journals as the *American Economic Review*, *Journal of Development Economics*, and *The Developing Economies*.