The Munich Lectures in Economics 2011

Time and the Generations

by

Partha Dasgupta

University of Cambridge
and
University of Manchester

Lecture 3

"Sustainable Development"

November 17, 2011

Readings:

P. Dasgupta (2001), *Human Well-Being and the Natural Environment* (Oxford: Oxford University Press). 2nd Ed. (2004).

P. Dasgupta (2009), "The Welfare Economics of Green National Accounts," *Environmental and Resource Economics*, 2(1), 3-38.

A formal model:

Time is continuous, t ($\geq$ 0). We consider a deterministic world. Let $\underline{C}(t)$ be an M-vector of consumption services at time t. $C_j(t)$ is the jth consumption service (j = 1,2,...,M). There are N capital assets. $K_i(t)$ is the quantity of the ith asset (i = 1,2,...,N). An *economic forecast* at t is the infinite sequence $\{\underline{C}(s), \underline{K}(s)\}$ for $s \geq t$.

Assume population is constant, of size L (but see below). People are indexed by l (= 1,2,...,L).

Suppose the social evaluator is studying the economy at t. $\boldsymbol{K}(t)$,being an inheritance from the past, is given. Let $s \geq t$. At date t, a forecast of the state of the economy for date s is the pair of vectors $\{\boldsymbol{K}(s),\boldsymbol{C}(s)\}$. Imagine that the social evaluator's horizon for the society is T years into the future. In sustainability analysis T is a large number. The Intergovernmental Panel on Climate Change (IPCC), for example, consider T as large as 300 years when preparing alternative scenarios. Economic theorists are known to take T to be infinity.

Definition 1: A forecast for the future consists of the pair of vectors $\{\boldsymbol{K}(s),\boldsymbol{C}(s)\}$ *for all* $t \leq s \leq T$.

Forecasts should not be simply arbitrary guesses, but should be based on an understanding of the processes shaping the society's future. That involves an understanding of ecological accounting, and social and technological processes. Reasoned forecasts (we are not saying good forecasts!) take into account counter-factuals, such as what trajectory would society take if thing now were different.

Write the pair of vectors $\{\boldsymbol{C}(s),\boldsymbol{K}(s)\}$ as $\boldsymbol{E}(s)$. We define a *societal programme* at t to be the vector $\boldsymbol{E}(s)$ for all $t \geq s \leq T$, and we write it as ${}_t\{\boldsymbol{E}(s)\}^T$. $\underline{K}(t)$ is the "initial condition".

Definition 2: A resource allocation mechanism, ***M****, at t is a many-one mapping*

$$\boldsymbol{M}\colon \{\underline{K}(t),t\} \rightarrow {}_t\{\underline{E}(s)\}^T. \quad (1)$$

It is not being assumed that $\boldsymbol{M}$ maps $\{\underline{K}(t),t\}$ into a socially desirable programme. It may be that $\underline{M}$ is riddled with social ills and inequities. If institutions and the state of the economy were known to co-evolve, that co-evolution would be reflected in $\boldsymbol{M}$. The system of property rights is embedded in $\boldsymbol{M}$ in as much as an understanding of an economy's property rights and their co-evolution with economic changes would enable the social evaluator to construct $\boldsymbol{M}$.

As in Lecture 1, let $V(t)$ denote social well-being at t. $V(t)$ is taken to be of the Utilitarian form

$$V(t) = \int_t^{\infty}[U(\underline{C}(s),\underline{K}(s))e^{-\delta(s-t)}]ds, \qquad (2)$$

where δ (> 0) is the rate of time discount. We assume that the integral exists. Expression (2) gives us an ethical calculus with which we address questions (B)-(E).

Sustainable Development:

"... development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland Commission, 1987).

NB: (i) "sustainable development" requires that relative to their populations, each generation should bequeath to its successor at least as large a *productive base* as it had itself inherited.

(ii) The requirement is derived from a relatively weak notion of intergenerational equity. Sustainable development demands that future generations have no less of the means to meet their needs than we do ourselves. It demands nothing more; it doesn't, for example, demand that development be *optimal* or *just*.

Question: How is a generation to judge whether it is leaving behind an adequate productive base for its successor?

Tracking GDP or the United Nations' Human Development Index (HDI) won't do. Why?

Definition 3: An economic programme $\{\underline{C}(t),\underline{K}(t)\}$ *displays sustainable development at t if*

$$\Delta V(t) \geq 0,$$

(where $\Delta V(t)$ should be read $\mathrm{d}V(t)/\mathrm{d}t$). (3)

NB: $V(t) = V(\boldsymbol{K}(t),t)$. At t, $\underline{K}(t)$ and t are the state variables.

Shadow prices: Let $q_j(t)$ denote the shadow price of consumption good j at t. Then

$$q_j(t) = \partial U(\underline{C}(t),\underline{K}(t))/\partial C_j(t), \quad j = 1,2,...,M. \tag{4}$$

Let $p_i(t)$ be ith capital asset's shadow price. Then, on using (2), we have

$$p_i(t) = \partial V(\underline{K}(t),t)/\partial K_i(t), \qquad i = 1,2,...,N. \tag{5}$$

Time to be a capital asset too, measured in terms of the value of waiting. If institutions improve (alternatively, deteriorate) exogenously, time reflects institutional capabilities (social capital). If $r(t)$ is the shadow price of t,

$$r(t) = \partial V(\underline{K}(t),t)/\partial t. \tag{6}$$

3 pieces of information are required for estimating shadow prices:

(i) A descriptive model of the economy.

(ii) The size and distribution of the economy's capital assets.

(iii) A conception of social well-being.

Requirements (i) and (ii) are the basis for estimating the changes that take place in the allocation of resources if an additional unit of the asset is made available free of charge. Requirement (iii) is the basis for placing a value on that change.

Comments on $p_i(t)$:

(1) It is a function of the stocks of all assets. Moreover, it depends not only on $\underline{K}(t)$, but on all $\underline{K}(s)$, $s > t$.

(2) Future scarcities of natural capital are reflected in $p_i(t)$, implying that the $p_i(t)$'s are functions of the degree to which various assets are substitutable for one another, not only at t, but at all subsequent dates as well.

(3) If δ is large (low), the influence on today's shadow prices of future scarcities would be attenuated (large). Recall Lecture 1.

Definition 3: the economy's comprehensive wealth at t as:

$$W(t) = r(t)t + {}_i\Sigma[p_i(t)K_i(t)]. \tag{7}$$

Why should we be interested in comprehensive wealth? The reason is:

Proposition 1: A small perturbation to an economy increases (resp., decreases) social well-being if, and only if, holding shadow prices constant, it increases (resp., decreases) comprehensive wealth.

Proof: Let Δ denote a small perturbation. Assuming V is differentiable, we have

$$\Delta V(t) = [\partial V/\partial t]\Delta t + {}_{i}\Sigma[\partial V/\partial K_i(t)]\Delta K_i(t). \qquad (8)$$

Now use (5) and (6) to re-express (8) as:

$$\Delta V(t) = r(t)\Delta t + {}_{i}\Sigma p_i(t)\Delta K_i(t).\ \text{QED} \qquad (9)$$

Write $I_i(t) = p_i(t)\Delta K_i(t)$. Then equation (9) can be expressed as

$$\Delta V(t) = r(t)\Delta t + {}_i\Sigma[I_i(t)]. \quad (10)$$

The RHS of equation (9) is the *comprehensive investment* that accompanies the perturbation to the economic programme. This means Proposition 1 can be re-stated as:

Proposition 2: *A small perturbation to an economy increases (resp., decreases) social well-being at t if, and only if, the comprehensive investment at t that accompanies the perturbation is positive (resp. negative)*.

NB: If the perturbation Δ is conducted at a moment in time, its evaluation is called "social cost benefit analysis". In contrast, if the perturbation is the passage of time itself, the evaluation involves testing for "sustainable development". Conclusion: Two seemingly different exercises amount to the same thing.

What does comprehensive investment measure? For simplicity, assume M = 1 and $U = U(C)$. Write $I(t) = {}_{i}\Sigma[I_i(t)$.

Proposition 3: $I(t) = {}_{t}\int^{\infty}[U'(C(\tau))\Delta C(\tau)e^{-\delta(\tau-t)}]d\tau$. (11)

So, comprehensive investment is a measure of the present discounted value of the changes in consumption that are brought about by it. Proposition 3 is the basis of social cost-benefit analysis.

Global Public Goods

What of public goods (e.g., carbon concentration in the atmosphere)? Let $G(t)$ be the stock of a global public good at t. G is an argument in the V-function of every country. Let $\underline{K}_m(t)$ be the vector of assets owned by residents of country m. If V_m is social well-being in m, $\quad V_m(t) = V_m(\underline{K}_m(t), G(t), t)$. $\quad$ (12)

Let $\underline{p}_m(t)$ be the vector of shadow prices of all the assets owned by residents of m, and $g_m(t) = \partial V_m(t)/\partial G(t)$. G may well be an economic "good" for countries in the temperate zone and an economic "bad" in the tropics. If so, tor the former, $g_m > 0$; for the latter, $g_m < 0$.

Let $E_m(t)$ be the net emission rate from country m and $E(t)$, the net aggregate emission. It follows that

$$\Delta G(t) = {}_m\Sigma(E_m(t)) = E(t). \tag{13}$$

Write

$$I_m(t) = {}_i\Sigma p_{mi}(t)\Delta K_{mi}(t). \tag{14}$$

Using (12), (8) becomes,

$$\Delta V(t) = r_m(t)\Delta t + I_m(t) + g_m(t)[{}_m\Sigma(E_m(t))]. \tag{15}$$

Population Growth

Population is a capital asset. Population growth is usually assumed to be exogenous. For simplicity assume that the size of the population, $P(t)$, is the stock of the demographic asset. It may seem intuitive that the way to tease exogenous growth in population out of $\partial V/\partial t$ is to define comprehensive wealth in *per capita* terms and re-express Proposition 1 accordingly. It can be shown that to be a correct move only under very special circumstances.

The Progress of Nations

Country/Region % annual growth rate 1970-2000

	I/Y*	population per capita	TFP"	wealth	GDP	ΔHDI**
Africa	-2.1	2.7	0.1	-2.8	-0.1	+
Bangladesh	7.1	2.2	0.7	-0.8	1.9	+
India	9.5	2.0	0.6	-0.4	3.0	+
Nepal	13.3	2.2	0.5	-0.4	1.9	+
Pakistan	8.8	2.7	0.4	-1.4	2.2	+
China	22.7	1.4	3.6	4.8	7.8	+

* comprehensive investment as share of GDP (average over 1970-2000)
" total factor productivity
** change in HDI between 1970-2000

Adapted from Dasgupta (2000) and Arrow et al. (2004).