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# An environmental-economic measure of sustainable development

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ABSTRACT

A central issue in the study of sustainable development is the interplay of growth and sacrifice in a dynamic economy. This paper investigates the relationship among current consumption, sacrifice and sustainability improvement in a general context and in two canonical, stylized economies. We argue that the maximin value of utility measures what is sustainable and provides the limit to growth. Maximin value is interpreted as a dynamic environmental-economic carrying capacity and current utility as an environmental-economic footprint. The time derivative of maximin value is interpreted as net investment in sustainability improvement. It is called durable savings to distinguish it from genuine savings, usually computed with discounted-utilitarian prices.



## 1. Introduction

The term *sustainable development* describes growth toward a developed state that can be sustained for what Solow (1993) calls the very long run.

The maximum level of utility that can be sustained from a given, current economic state is the so-called maximin level (Solow, 1974; Cairns and Long, 2006). This reference level depends on the economic endowments and the technology. The development paths that sustain this level are given by the solution of a maximin optimization problem.

An important criticism of applying maximin as a social objective in a poor economy is that future generations may be mired in a “poverty trap.” Poverty may be sustained. This criticism implies that the sustainable (maximin) level of utility is considered to be so low that economic development is called for. The path followed by the economy must be within environmental and technological constraints. Development, or growth, entails the diversion of resources from consumption by the current generation to investment that will increase productivity in the future. For sustainable growth to occur the standard of living of the present must be reduced to an *even lower* level than that of the poverty trap.

The issue is how to grow out of poverty while improving what can be sustained. The concept of *sustainability*, which has been defined as requiring that utility be no greater than the maximal sustainable utility, is not sufficient to tackle this issue. It characterizes the sustainability of current utility, but provides no information on how current decisions impact future sustainability and the development prospect.

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The present paper formalizes the relationship among current consumption, sacrifice and *sustainability improvement*. The concept of sustainability improvement is used to characterize sustainable development paths.

We examine the conditions for a sacrifice by present generations to increase the sustainable level of utility (the maximin value). We find that, except for a non-regular case, if the current level of utility is greater than the maximin value the current maximin value decreases. Conversely, if the level of utility is lower than the maximin value, *sustainable development* is possible, with the sustainable level of utility of the economy increasing through time. Once utility catches up with the (dynamic) maximin value, utility can be sustained at (but not above) the maximin level then prevailing.

Our results are illustrated in two canonical models that have been prominent in the study of sustainability, the simple fishery and the *Dasgupta–Heal–Solow* (DHS) model (Dasgupta and Heal, 1974; Solow, 1974). Each addresses a fundamental issue in environmental economics. Each implies that growth is subject to environmental constraints. The fishery model shows that open access can lead to a tragedy of the commons. The DHS model shows that sustaining an economy may not involve a steady state. Each of open access and growth can lead to unsustainability and to a poverty trap.

Our contributions to the analysis of sustainable development stress two current indicators that, as conveyed by the words "sustainable" and "development," look to the ability to sustain economic well-being in the very long run. In particular, we use

1. the current maximin value as the indicator of sustainability; and
2. the rate of change of the current maximin value as the indicator of sustainability improvement or decline.

The maximin value is a well known indicator in a maximin program. In the present paper, we extend it outside a maximin program to apply to any trajectory, optimal or not, efficient or not. The maximin value characterizes the dynamic limit to growth. It generalizes the concept of ecological footprint. The evolution of the maximin value over time is measured by current net investment at maximin accounting prices. This investment indicator, which we call *durable savings*, can be used to measure sustainable development, providing an alternative to genuine savings, which is usually computed with discounted-utilitarian prices.

## 2. Maximin value and sustainability

For a vector of available capital stocks $X \in \mathbb{R}^n_+$ (including natural resources, levels of technological knowledge and other forms of comprehensive capital) and a vector of decisions within the set of feasible controls, $c \in C(X) \subseteq \mathbb{R}^p$, let utility at time $t$ be represented by $U(X(t), c(t))$. The transition equations for the stocks are

$$\dot{X}_i(t) = F_i(X(t), c(t)), \quad i = 1, \ldots, n. \tag{1}$$

Formally, the maximin value of a given economic state $X$ is defined as

$$\begin{aligned} m(X) \equiv \max_{c(\cdot)} \min_{s \geq t} \quad & U(X(s), c(s)) \\ \text{s.t.} \quad & X(t) = X, \\ & \dot{X}_i(s) = F_i(X(s), c(s)), \ \ i = 1, \ldots, n, \ \ \forall s \geq t. \end{aligned} \tag{2}$$

This is the highest level of utility that can be sustained over all feasible paths starting from state $X$. By Bellman's principle the maximin value $m(X)$ depends only on the current state $X$ and not on the vector of current decisions $c$.

We restrict the analysis to models for which a maximin value function is well-defined, in the sense that maximin paths actually achieve the maximin value at any time.[1]

The maximin value is sometimes identified as intertemporal social welfare, but such an identification is not essential for a study of the properties of sustainability and sustainable development. We do not assume that the economy follows a maximin path or any other optimal or efficient path. The maximin value is defined for all states and it can be computed at any time for the current economic state. We study the effects of choices made for a given vector of states from among the feasible vector of decisions.

Following a standard definition in the literature (e.g., Pezzey, 1997) *sustainability* is defined as requiring that utility be no greater than the maximal sustainable utility.

**Definition 1** (*Sustainability*). Utility at time $t$ is sustainable if it is no greater than the maximin level of utility at time $t$:

$$U(X(t), c(t)) \leq m(X(t)). \tag{3}$$

The sustainability condition (3) establishes whether the current level of utility can be sustained by comparing it to the maximin value. The maximin value is used as a reference point, and not an objective.

[1] Assuming that the maximin value can be achieved allows us to consider a "max min" problem instead of a "sup inf" problem. Mitra et al. (2013) provide conditions on the technology for the existence of a maximin solution in the Dasgupta–Heal–Solow model.