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Are We Consuming Too Much?

by

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1. Introduction

Is our use of Earth's resources endangering the economic possibilities open to our descendants?

There is wide disagreement on the question.[1] People who worry about "excessive" use of resources -- in particular, natural resources – often point to population growth as the main reason for concern.[2] But such problems are a function of society's demand for goods and services. Population size certainly contributes to that demand, but the average demand per person contributes to it too.[3]

Some people argue that consumption per head in industrialized nations has reached levels that are socially very costly – even irresponsible. Clearly per capita consumption in industrialized nations today is considerably higher than a hundred years ago. It is high enough to have had significant impacts on the environment.[4] If we look at specific resources and services (e.g. fresh water, a wide variety of ecosystem services, and the atmosphere as a carbon repository), there is evidence that continuing growth in the rates at which they are utilized is unsustainable.[5] Such evidence suggests that we are currently living beyond our means.

On the other hand, standard macroeconomic reasoning implies that high consumer expenditure in industrialized nations is essential if prosperity is to be maintained there and if poor countries are to prosper. It can also be argued that, just as earlier generations had invested in capital goods, research, and education to "bequest" current generations with the ability to enjoy high levels of consumption, so will current generations make the investments to assure higher real living standards in the future. In support,

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[1] For a good illustration of the sharpness of the disagreement, see the debate between Norman Myers and the late Julian Simon in Myers and Simon (1994).

[2] For a study of global and local population problems, see Ehrlich and Ehrlich (1990) and Dasgupta (2000), respectively.

[3] Although aggregate demand includes both consumption and investment, it is consumption that is most frequently targeted for comment when environmental and resource scarcities are the subject of discussion.

[4] During the twentieth century, world population grew by a factor of four to more than 6 billion, industrial output increased by a factor of 40, energy use by a factor of 16, methane-producing cattle population grew in pace with human population, fish catch grew by a multiple of 35, and carbon and sulfur dioxide emissions by a factor of 10. The supply of nitrogen to the environment from the use of fertilizers and from burning fossil fuels is now of the same order of magnitude as biological nitrogen fixation. See McNeill (2000) for global statistics on changes in the magnitude of global use of the natural environment during the twentieth century.

[5] See, for example, Vitousek *et al*. (1986, 1997) and Postel, Daily, and Ehrlich (1996).

early growth theories showed that as long as investment in human and manufactured capital is governed by interest rates that stay above the population growth rate, the standard of living will be monotonically increasing over time. More recently, an even rosier picture has been painted by incorporating the increasing returns that are associated with learning by doing and the public-goods aspects of technological knowledge as inputs to production in a world where natural capital is viewed as a fixed factor. Certain trends seem to support this perspective. If we study historical trends in the price of marketed resources, or the recorded growth in the conventionally measured indices of economic progress in industrialized countries, resource scarcities would not appear yet to have bitten.[6] But as continued growth puts more pressure on the fixed factors of our environment, one might expect that the balance would tip the other way eventually.[7]

In this paper we offer an analysis that we hope will go some way toward reconciling the two sets of intuitions and evidence. The analysis is the outgrowth of discussions among a group of ecologists and economists. The paper reflects a belief in the binocular vision that can be obtained from using both ecological and economic insights, by raising questions that might not occur in either viewpoint alone. We discuss criteria for deciding whether consumption is excessive, and we identify factors in the economic and ecological domains that determine whether it is excessive according to those criteria.

Section 2 introduces some key issues relevant to the debate about consumption. Here we mention how both the composition and the overall level of consumption are relevant to well-being, and sketch out the relationship between a nation's consumption and its productive base. This relationship is a central issue that is analyzed subsequently throughout the paper. The question whether consumption is excessive depends, of course, on the criterion for excessiveness. Sections 3 and 4 offer alternative criteria. Section 3 presents the "optimal development" criterion of maximizing the present value of utility from present and future consumption; this contrasts with the "sustainable development" criterion, which is defined in Section 4. In Section 4 we show how, in principle, one can assess whether the sustainable development criterion is satisfied by examining the sign of "genuine investment" or, more generally, the sign of the change in per-capita "genuine wealth." According to the definition emphasized here, a nation consumes too much if it fails to invest enough to increase its per-capita genuine wealth. Sections 5 and 6 consider the evidence for whether consumption is excessive according to the optimal development and sustainable development criteria. Section 5 offers a number of arguments why, in light of prevailing circumstances and institutions, consumption could well exceed the level that would satisfy the optimal development criterion. Section 6 utilizes information from the World Bank to assess whether consumption in various countries satisfies the sustainable development criterion. Section 7 offers conclusions.

[6] See, for example, Barnett and Morse (1963) and Johnson (2000).

[7] For contrasting views on this issue, see Johnson (2001) and Dasgupta (2001a).

2. Preliminaries

2.1 Consumption and the Productive Base

One can view a society's *productive base* as a key determinant of its well-being. This base includes human capital, reproducible capital (manufactured capital goods), and natural capital. It also includes its cultural coordinates and institutions. The latter are sometimes referred to as social capital, although such terminology can mislead. Institutions are distinct from capital assets, in that they guide the allocation of resources, including capital assets. Institutions are probably better seen as resource allocation mechanisms.[8]

The heterogeneity of the productive base poses a problem. No doubt it serves heuristic purposes say that output (including consumption goods) is produced by the various capital assets, but this will not satisfy statisticians, who will ask how all the bits and pieces called capital goods are to be measured and valued. The usual goal is to assign values to capital assets (at any level of disaggregation) according to their contribution to well-being. If capital is valued this way, then maintaining the productive base becomes equivalent to maintaining a capacity for well-being. According to one definition of "too much" (see below), the question "Do we consume too much?" can be translated into the question whether a society is undertaking sufficient saving and investment to maintain its (appropriately valued) productive base. A main focus of this paper is analyze how to determine whether investment meets this criterion, which involves assigning values to differing capital assets.[9]

Thus, the flip side of insufficient investment is excessive consumption. This might suggest that countries with insufficient investment are always consuming too much. However, there is a sense in which some countries can both invest *and* consume too little. This combination of problems seems to afflict some of the poorest nations of the globe: inefficient use of resources means that the productive base yields a low level of output, so that production of both consumption and capital goods is compromised. We address this issue in Section 6 below.

2.2 The Level vs. Composition of Consumption

The question whether consumption is excessive requires attention to both the *overall level* and the

[8] Formally, a resource allocation mechanism is a mapping from dates and capital stocks to intertemporal consumption profiles starting from the dates in question. Competitive market equilibria are examples of resource allocation mechanisms, as are optimum programs of accumulation. See Dasgupta and Mäler (2000). We return to resource allocation mechanisms below.

[9] Economists also note that some of the items on the list (for example, social capital in the form of communal festivities) do not involve sacrifice, but rather, seem more like pleasurable activities. They offer joint products. See Arrow (2000).

composition of consumption. Consumption goods (in their widest sense) include not only such objects as food, drink, clothing, shelter, and leisure activities, but also environmental services, such as the life-sustaining services of clean air or the recreational and benefits stemming from places of scenic beauty or the wild species that inhabit them.[10] How consumption divides across these various specific goods affects future well-being. Consider two individuals with identical incomes and expenditures, who differ in terms of the goods and services they purchase. The person who spends income on goods that require large inputs of resources, or whose production, use, or disposal generates a great deal of pollution, will impose a greater strain on resources, or on the environment, than the person who spends income on "lighter" or "cleaner" goods and services.

The distinction between the level and composition of consumption closely parallels elements of the *I=PAT* equation first formulated by Paul Ehrlich and John Holdren.[11] The equation expresses *I* (the impact on the environment), as the product of three components: *P* (population size), *A* (affluence; that is, aggregate expenditure per person), and *T* (the environmental impact per unit aggregate expenditure). Thus, in the *I=PAT* equation, *A* relates to the level of per-capita expenditure, while *T* reflects its composition.[12] By examining *A* and *T* in this paper, we complement the focus in other studies on population size, *P*. However, in Section 6, where we study cross country data on economic activity, the role of *P* in shaping societal standards of living will display itself in a sharp manner.

2.3 Normative Yardsticks for Excessive Consumption

We begin our analysis by aggregating consumption goods so as to focus on the level of overall consumption. An extensive literature on welfare economics has taught us that if the underlying resource allocation mechanism is intertemporally efficient, higher aggregate consumption today means slower accumulation (or faster depletion) of capital and, thereby, a lower potential for future consumption.

Let $c(t)$ represent a society's aggregate consumption at time t. We may imagine that different values of t are associated with different "generations." Let $U(c(t))$ represent society's *felicity* (or instantaneous utility) at t.[13] Marginal felicity, $dU/dc(t)$, is taken to be positive at all t.

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[10] The concept of Net Economic Welfare (NEW), as defined in Nordhaus and Tobin (1972), included environmental services among the determinants of well-being.

[11] Ehrlich and Holdren (1971).

[12] The rationale for using the symbol *T* is that environmental impact per unit of aggregate consumption is a reflection of *technology*. *T* depends on scientific knowledge and the social, political, and economic arrangements that influence how goods are produced. In our terminology, *T* should be interpreted to be a resource allocation mechanism.

[13] We use "felicity" to denote the utility enjoyed from consumption at a given moment. This contrasts with intertemporal welfare, which is a function of the time path of felicities.

Any given consumption path implies a corresponding path of felicity. One can aggregate these felicity levels, using a utility discount rate, $\delta\ (\geq 0)$.[14] Let time be continuous and population size be a constant. For a given path of consumption, the present value of felicities, as seen from t, is:

$$V(t) \equiv \int_t^{\infty} U(c(t))e^{-\delta(t-t)}dt \qquad (1)$$

V(t) is *intergenerational welfare* at t. Below we discuss two criteria for evaluating time-profiles of consumption, based on their implications for intergenerational welfare.

3. Optimal Development

From the viewpoint of the theory of optimal development, consumption paths are judged according to how closely they approximate the path that maximizes expression (1).[15] A nation's current consumption will be deemed excessive if, by lowering consumption and increasing investment, the nation could generate discounted future felicities that more than compensate for lost current felicities. Which path is optimal depends, among other things, on the value of δ and on the curvature of U, as measured by the elasticity of marginal felicity. The two parameters reflect considerations of intergenerational equity. A higher value for δ, other things equal, would mean that less weight is awarded to future generations' felicities. Similarly if, other things being the same, the elasticity of marginal felicity were chosen to be large, it would mean that a large weight has been awarded to interegenerational equity in the distribution of consumption. What constitutes the "right" value of δ has been a matter of much debate.[16] Curiously, not much has been written about the role played by the elasticity of marginal felicity in reflecting the goal of intergenerational equity in consumption.[17]

An attraction of expression (1) as a measure of intergenerational welfare is that it can be linked, at least in theory, to the outcome of a decentralized market economy. In an idealized, fully competitive

[14] δ is often called the rate of pure time preference.

[15] The classics are Ramsey (1928), Cass (1965), and Koopmans (1965).

[16] Ramsey (1928) suggested that the appropriate value for δ is zero. Most economists favor positive values. Diverse arguments concerning the choice of value for δ are collected in Lind (1982) and Portney and Weyant (1999).

[17] But see Dasgupta and Heal (1979, ch. 10) for exercises in the sensitivity of optimal consumption and resource depletion paths to δ and the elasticity of marginal felicity, respectively. It can be shown that, other things being the same, the larger is the elasticity of marginal felicity, the closer is the present-value criterion to the criterion of intergenerational "max-min felicity."

economy, in which there are no externalities and in which the market interest rate on consumption is the same as the social discount rate on consumption, the time path of consumption will be that which maximizes expression (1). Much contemporary macroeconomics is based on this interpretation of the theory.

4. Sustainable Development

4.1 A Criterion for Sustainable Development

A second yardstick for evaluating time-profiles of consumption is the idea of *sustainable development.* The phrase became commonplace after the publication of a report by the World Commission on Environment and Development (WCED), widely known as the Brundtland Commission Report, where sustainable development was defined as "... development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[18]

Many alternative formalizations of sustainable development are consistent with this phrase.[19] Here we emphasize an approach that concentrates on maintaining intergenerational welfare, as defined in (1) above. Under this approach, the condition for sustainable development is that intergenerational welfare must not decrease from the current period to the next. Formally, we say that a consumption path yields a sustainable development program at t (≥ 0) if and only if

$$dV(t)/dt \geq 0. \qquad (2)$$

We will confirm that the requirement entails that a society's productive base, in a suitable sense, should at least be maintained at t. Notice that if (2) is feasible for an economy, the condition can be met by any number of development programs. Sustainability does not specify a unique program. On the other hand, it can be that a given economy is incapable of satisfying the condition at t (see below).

Several features of this notion of sustainability deserve mention. First, note that, in contrast with the optimal development criterion, the sustainability criterion concentrates on the change in V, not its level. Second, this notion does not assure that *felicity* in each future period will be as high as its current level. It only refers to V, a given aggregation (discounted value) of felicities. Moreover, it does not assure that V could be sustained at the current level for all future periods. It only refers to the change of V

[18] World Commission (1987: 43).

[19] The most thorough, as well as the earliest, exploration is Pezzey (1992). See also Asheim (1994), Asheim *et al.* (2001), Jansson *et al.* (1994), Heal (1998), and Dasgupta and Mäler (2000).

from the current period to the next one.[20]

In the next section we shall show that condition (2) entails maintaining a certain index of the productive base. At present it is worth noting that condition (2) does not stipulate that a particular set of resources should be conserved at *t*. Condition (2) could in principle be satisfied even if particular assets, such as stocks of mineral resources, were to be drawn down at t. Ecologists express concern that such a criterion as (2) may not offer adequate protection to particular forms of natural capital, most especially, critical ecosystems. In fact, the criterion does offer protection to such resources. The point is that natural resources contribute to human well-being either directly, as in the case where humanity derive pleasure from recognizing their existence, or indirectly, as in the case where the assets generate flows of goods and services that contribute to human well-being (e.g., various ecosystem services).[21] If a natural resource (or, more generally, a capital asset) is essential to well-being, in the sense that no other asset can substitute for it in an adequate way, its preservation will be crucial to meeting condition (2) if the condition is to be satisfied over a period of time. On the other hand, if increases in other forms of capital (e.g., other species; or new ideas to economise on the use of resources) could compensate people for the loss of a particular resource, then meeting the sustainability criterion would not require the preservation of that particular resource.

This discussion points to an important empirical issue, namely, the extent to which various forms of capital can be substituted for one another in providing (directly or through their flows of goods and services) well-being to humanity. Ecologists express concern that the limited sustitutability and associated essentiality of certain natural resources are not sufficiently recognized in many economic analyses. To arrive at useful measures of sustainability requires good information on the extent of substitution options, both locally and globally. A major goal of ecological economics is to advance our understanding of these issues by identifying crucial contributions made by various forms of natural capital, and by indicating the extent to which these forms of capital allow for substitutes.[22] We return to this issue below.

4.2 Genuine Investment and Sustainable Well-Being

Condition (2) refers to felicities at each point in time in the future. These felicities directly reflect the *constituents* of well-being, such as food, shelter, enjoyment of beauty, and basic liberties. In what

[20] For a penetrating analysis of these issues, see Asheim (1994).

[21] The ecosystem services that flow from renewable stocks of natural (or ecosystem) capital include water purification, flood control, climate stabilization, pollination of crops, control of agricultural pests, and the generation and maintenance of soil fertility (see Daily, 1997).

[22] See, for example, Dasgupta and Heal (1979: ch. 7), Daily (1997), Daily *et al*. (2000), Dhand and Howlett (2000), Ehrlich and Ehrlich (1990), Levin (1999), and Heal *et al*. (2001).

follows, we define "consumption" broadly to embrace all the relevant constituents. The productive base, in contrast, can be regarded as a *determinant* of well-being – as a level of resources that implies a given capacity for well-being. It is a means, rather than an end. In this section we discuss the connection between the productive base and intergenerational welfare. We concentrate on one component of an economy's productive base: its array of capital assets.[23]

Assume that the state of the linked economic-ecological system can be represented by a vector of capital stocks, *K*. As mentioned earlier, *K* is a comprehensive list of capital assets, including not only manufactured capital goods, human capital, and knowledge, but also natural capital.

Let *t* represent the initial period, so that *K(t)* is the vector of initial capital stocks. Consider a deterministic world and assume for the moment that population is constant. In particular, assume a *resource allocation mechanism* that determines how the capital stock at any point in time is allocated toward consumption and investment. Hence *K(t)* and the resource allocation mechanism together yield vectors of consumption, investment, and capital at all subsequent points in time. Thus:

$$c(t) = f(t - t; K(t)) \tag{3}$$

$$K(t) = g(t - t; K(t)) \tag{4}$$

We make no assumptions concerning the merit of the decisions in the resource allocation mechanism. These decisions need not be optimizing from anyone's perspective. However, we do assume that the functions *f* and *g* immediately above, as well as the *U* functions in (1), are autonomous in the sense that they do not depend on calendar time (although they do depend on the time interval $t - t$). While the state of the economy changes over time, it does so as a result of changes in capital stocks and consumption; it is not directly a function of time (or unidentified factors that change with time).

If (3) is recursively substituted into (1), *V(t)* is seen to depend only on *K(t)*, the capital vector at *t*. Let this functional dependence be denoted as *W*. Hence *V(t) = W(K(t))*. A crucial assumption we make now is that *W* is differentiable. If it is, we have:

$$dV(t)/dt = \sum_i (\partial W/\partial K_i) dK_i dt = \sum_i P_i (dK_i/dt), \tag{5}$$

where *i* is the index of the *i*th capital asset and $P_i \equiv \partial W/\partial K_i$. P_i is the accounting price of *i* (at the given time *t*). It is the marginal contribution to intergenerational welfare of an incremental unit of capital good *i*.[24]

[23] Section 2 indicated that institutions can also be considered an element of the productive base.

[24] Skiba (1978) and Brock and Starrett (2000) have studied the character of optimum consumption time-profiles for certain types of non-convex *f*'s in equation (3). They have shown that *W* is differentiable in all but a countable number of points on the space of capital stocks. Dasgupta and Mäler (2001) has an example of a non-optimizing,

The far-right-hand side of (5) is a measure of the change in the productive base. We refer to this as *genuine investment*. Equation (5) reflects a temporally local relationship. It says that intergenerational welfare is higher today than it was yesterday if genuine investment was positive yesterday.

Let us call the accounting value of an economy's capital assets the economy's *wealth*. Another way to interpret equation (5) would then be to say that intergenerational welfare is higher today than it was yesterday if the economy is wealthier today. Instantaneous wealth comparisons are made at constant prices (i.e., capital goods are not revalued even when the economy is not on a stationary economic program).[25]

Several additional points deserve mention. First, the derivation of equation (5) does not require the assumption that the economy in question is following an optimal program. The framework being discussed here is applicable to an arbitrary resource allocation mechanism. Second, genuine investment, as defined in (5), does not directly indicate whether felicity, U, is non-declining at t: V could be increasing at t even though U declines.[26]

Third, equation (5) does not on its own say whether positive genuine investment is possible. If, relative to the size of the human population, the natural environment is overly depleted, it may not be possible to increase wealth. Whether the economy is capable of growing wealthier depends on the extent to which different assets are substitutable in production. Accounting prices reflect substitution possibilities in production and consumption, among other things. To illustrate, imagine, for example, that substitution possibilities are limited and the allocation mechanism, as reflected in $C(.)$, is profligate in the use of natural resources. Under these circumstances intergenerational welfare will not be sustainable for more than a limited period. At some date in the future accounting prices will assume such values as to make it impossible for genuine investment to be positive.

Fourth, the estimation of accounting prices is no simple matter. The prices are based on marginal rates of indifferent substitution among the capital assets. In non-optimizing economies, they bear no obvious connection to marginal rates of "transformation," as reflected in market prices. Fifth, if a capital good is not a "good," but is instead a "bad" (sulfur deposit in the atmosphere), its accounting price is negative. But even if a good is a "good" its accounting price could be negative if the economy's

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convex economy for which W is differentiable everywhere. An important problem for applied welfare economics is to determine the robustness of the assumption that W is differentiable.

[25] Estimation problems are harder if the welfare comparisons to be made are discrete. Consider the comparison of intergenerational welfare between two arbitrary dates *0* and *T*. Write wealth as $Q(t) = \sum_i [P_i(t)K_i(t)]$. Integrating (5) yields $V(t) - V(0) = [Q(T) - Q(0)] - \int_0^T [\sum_i \{(dP_i(t)/dt)K_i(t)\}]dt$, for $T>0$.

[26] Asheim (1994) has shown that U may be unsustainable (in the sense that some future utility must be below the current level) even when V is currently rising.

institutions are bad: offering an extra unit of the good to someone could be a bad thing. Examples include common-property resources suffering from the tragedy of the commons. Consider that carbon is emitted into the atmosphere when fossil fuels are burned. The use of fossil fuels by motorists yields private benefits to them, but they lead to collective losses (enhanced greenhouse effect). If emissions are untaxed, private benefits would be impervious to the collective damage caused by the combustion of fossil fuels. Imagine now that the collective damage arising from a small increase in the use of fossil fuels exceeds private benefits. An additional unit of fossil fuels awarded to a motorist will then lower intergenerational welfare. The accounting price of fossil fuels in a motorist's vehicle would in this case be negative.

Sixth, in empirical work natural capital is frequently partitioned in a coarse way (see Section 6). At a high level of aggregation, however, one can miss critical bottlenecks, or limits on substitutability. For specific forms of natural capital (e.g., topsoil, water, oceanic currents, and genetic resources used in agriculture), there may be few or no effective substitutes (e.g., Postel, 1999). The appropriate accounting price on the specific form of capital could be very high, and the "drag" on genuine investment associated with loss of this capital would then be significant. Estimates of genuine investment that employ a high level of aggregation might well overstate genuine investment because they tend to ignore the limited substitution possibilities that arise at a more disaggregated level.

4.3 Addressing Population Change

We now relax the assumption that the size of the population is constant. How should intergenerational welfare be construed when population is not constant, and how does this affect the connection between the productive base and intergenerational welfare?

Let $N(t)$ be population size at t.[27] Let $y(t)$ denote *per capita* consumption at t and $U(y(t))$ the felicity of the representative person at t. Two alternative formulations of intergenerational welfare suggest themselves: total felicity of all who will ever exist and average felicity of all who will ever exist. Let $n(t)$ be the percentage rate of change of $N(t)$. For notational simplicity, we ignore intragenerational inequality and changes in the age composition of the population. The two alternative formulations yield:

$$V(t) = \int_t^{\infty} N(t)U(y(t))e^{-d(t-t)}dt \qquad (6a)$$

and

$$V(t) = \int_t^{\infty} N(t)U(y(t))e^{-d(t-t)}dt \; / \; [\int_t^{\infty} N(t)e^{-d(t-t)}dt \,] \qquad (6b)$$

respectively.[28]

[27] It would be reasonable to suppose that $N(t)$ is a logistic function.

[28] If V(t) is to be well-defined, it must be that $d > [\int_0^t n(t)dt \,]/t$ for large enough t. For a justification of the first

The two formulations would, of course, be equivalent if we sought to locate an optimum consumption policy, that is, one that maximizes $V(t)$. But they differ as criteria for sustainable development. Arrow, Dasgupta, and Mäler (2001) argue that average felicity of all who will ever exist – expression (6b) -- is the appropriate criterion to use for judging sustainability. It can also be shown that if population remains constant in the neighborhood of t and the production functions embodying economic transformation possibilities are subject to constant returns to scale, then intergenerational welfare (in the sense of average felicity of all who will ever exist) increases at t if and only if the productive base *per head* (evaluated using constant shadow prices P_i) is increasing at t. We will often refer to the productive base as *genuine wealth*. Hence our expanded criterion for sustainability is that genuine wealth be non-decreasing.

A caveat: constant returns to scale is a bad assumption for characterising ecological processes; such processes frequently reflect complex dynamics (Levin, 1999, 2001). Thus, to rely on changes in the genuine wealth per head for assessing whether development is sustainable is to rely on an approximation. As of now, we do not know if the approximation would be way off mark when applied to aggregate data.

5. Prospects for Excessive Consumption I: Classical Arguments

The preceding analysis indicates two main ways of addressing the question as to whether consumption is excessive. We can ask whether genuine investment (per capita) is below the optimal level, that is, the level that maximizes V. Alternatively, we can ask whether genuine investment is positive (or, with changing population, whether genuine wealth per capita is rising). The first applies the optimality criterion; the second, the sustainability criterion. We will apply each criterion in turn.

5.1 Factors Promoting Excessive Consumption

The prevailing viewpoint among economists is that policy failures and institutional failures tend to encourage consumption levels above that which would maximize V: consumption is excessive according to the optimality criterion. The arguments that support this view tend to be qualitative: they suggest excessive consumption but do not indicate the extent of excessiveness. There is a strong need for empirical work on these issues. Key factors leading to excessive consumption are:

1. A divergence between the market interest rate and the social discount rate on consumption. This implies private saving rates that fall short of the optimal rates.

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formulation, see Meade (1955) and Arrow and Kurz (1970); for a justification of the latter, see Harsanyi (1955) and Vickrey (1960). For further discussion of the distinction between the two formulations, see Dasgupta (2001b).

2. Taxes on labor and capital income. Taxes on labor income affect the choice between consumption and leisure, and thus will have effects on total consumption. Taxes on the return to capital discourage private savings by reducing the after-tax return to such savings. Widely-accepted analyses indicate that a positive tax rate on capital implies inefficiently low savings.[29]

3. Externalities associated with production or use of consumer goods. In circumstances involving *negative* externalities in production and consumption, social costs of production exceed private costs of production.[30] Examples of such externalities include the various damages stemming from the use of fossil fuels (acid precipitation, climate-change); water quality damages resulting from pesticide and fertilizer run-off from agricultural areas; and flooding and erosion damages resulting from deforestation. In the absence of government intervention, there will be excessive use of these fuels relative to other commodities whose market prices are closer to accounting prices. Such imperfect pricing would lead to excessive overall consumption if the market price of consumer goods are less than their accounting prices and the market prices of investment goods are closer to their accounting prices.

4. Interdependence in consumption. A small but growing body of empirical work suggests that a person's sense of well-being is based not only on her own level (and composition) of consumption but also on the level (and composition) of her consumption relative to the level (and composition) of her "reference group."[31] A given individual may suffer a loss of well being when others' consumption rises, since that person's relative consumption now falls. This can be viewed as another example of an externality. Such interdependence in consumption can compel individuals to work harder and consume more in order to keep up with the neighbors. This is individually rational, but collectively sub-optimal. Under these circumstances, public policies to discourage consumption (including a general consumption tax) could raise individual well-being.[32]

5. Absence of well defined and secure property rights. Aquifers, fisheries, and forests often lack secure and well defined property rights. This too can cause market prices to fall short of accounting prices. This situation leads resource owners to produce more in the near term, in order to avoid expropriation or losses

[29] See, for example, Judd (1985).

[30] This argument dates back at least to Pigou (1920).

[31] See, for example, Frank (1985a,b), Ng (1987), Howarth (1996), and Schor (1998). This research is in the spirit of Veblen (1899) and Duesenberry (1949).

[32] A formal "growth model" incorporating these ideas is developed in Cooper, Garcia-Pealosa, and Funk (2001).

to other producers who claim the same property: the private rate of return on conservation falls below the social rate of return.[33]

5.2 Factors Promoting Insufficient Investment

The other side of the coin of consumption is investment. Under current accounting practices, recorded investment could be positive, even large, while genuine investment is negative. Underpriced environmental natural resources contribute to this phenomenon. Ecosystem services usually are available free to those who use them (fisheries in the open seas; our use of the atmosphere as a sink for pollutants; most services offered by mangrove forests, coral reefs, and watersheds; and so forth). In general, the depletion of environmental assets is not counted properly in economic calculations, and consequently investment projects that are judged to be commercially profitable are not infrequently socially unprofitable. They are unprofitable because they are rapacious in their use of natural resources, and they are rapacious because the resources are underpriced. Such underpricing not only affects investment decisions but also may bias the direction of technological change against the natural environment. This conclusion squares with the claim often made that industrial technology is unfriendly toward the environment.

When property rights are poorly defined or non-existent, people, both individually and communally, suffer damage from others' actions but remain uncompensated. This problem often is a reflection of a weak or corrupt State. We return to this issue in our discussion below of environmental problems in poor countries.

6. Prospects for Excessive Consumption II: Empirical Assessments of Genuine Investment[34]

The previous section offered a number of reasons why consumption might be excessive relative to the level that maximizes discounted felicities. In the present section we consider whether consumption meets the sustainability criterion, focusing on empirical studies. A growing body of research now aims to measure genuine investment in various countries. Some important first steps have been taken by researchers at the World Bank. For example, Hamilton and Clemens (1999) have provided summaries of

[33] The literature on this is huge.

[34] Serageldin (1995) provides an outline of empirical work on genuine investment that was in consequence initiated in his Vice Presidency. For estimates of the depreciation of natural capital on a regional basis, see Pearce, Hamilton, and Atkinson (1996) and World Bank (1997).

World Bank estimates of genuine investment in a number of countries. Genuine investment was calculated by adding net investment in human and natural capital to estimates of investment in manufactured capital goods. A further adjustment is to account for disinvestment in environmental capital. In the Hamilton-Clemens study, such disinvestment is calculated simply as the estimated damage associated with annual emissions of carbon dioxide.[35]

Although these studies have led the way in attempts to estimate genuine investment, they have several important limitations. Data limitations significantly constrain the measurement of genuine investment (as Hamilton and Clemens readily acknowledge). For example, among the resources making up natural capital, only commercial forests, oil and minerals, and the atmosphere as a sink for carbon dioxide were included (not included were water resources, forests as agents of carbon sequestration, fisheries, air and water pollutants, soil, and biodiversity). So there is an undercount, possibly a serious one. Second, these studies consider only very broad categories of capital. At a high level of aggregation, one can miss critical bottlenecks or limits on substitutability. Genuine investment calculations that employ a high level of aggregation might well overstate genuine investment because they tend to ignore the limited substitution possibilities that arise at a more disaggregated level. Third, these studies employ market prices as proxies for shadow prices in indicating the potential trade-offs among different forms of capital. Because natural capital is typically underpriced, the use of market prices could bias upward the estimate of genuine investment. Other problems arise in the methods deployed for estimating prices.[36]

A fourth important problem is the neglect of uncertainty. The World Bank work provides only point estimates of genuine investment. Point estimates can suggest an unwarranted degree of certainty and, in cases where the estimate is positive, invite unwarranted complacency. Readers may regard a positive point estimate of genuine investment as indicating that the well-being of future generations is not at risk. Given the vast uncertainties associated with these measures, even when central estimates are positive there may remain a significant possibility that genuine investment is negative. To the extent that societies are risk averse, they will want to give extra weight to the possibilities of negative genuine investment.

As a related point, because of significant nonlinearities, ignoring the uncertainties may lead to mis-estimates of the expected value of genuine investment. The biophysical impacts associated with the loss of natural capital can be highly nonlinear: these impacts may be small over a considerable range, and then become immense once a critical threshold is reached. Crossing the threshold leads to a

[35]Hamilton and Clemens assume each ton of carbon dioxide emissions leads to a loss of $20 dollars of environmental capital. Damages from carbon dioxide emissions should also reduce the value of investments in manufactured capital, to the extent that such capital is expected to yield increased carbon dioxide emissions and subsequent damages. Hamilton and Clemens do not adjust such investments to account for this effect.

[36]For a more thorough discussion of ways in which genuine investment could be better estimated, see Arrow, Dasgupta, and Mäler (2001).

"bifurcation" where the characteristics of the natural system change fundamentally. For example, shallow lakes have been known to flip from clear to turbid water as a consequence of excessive runoff of phosphorus from agriculture. Such flips can occur over as short a period as a month.[37] The possible reversal of the Gulf stream current that now warms northern Europe represents another potential bifurcation.[38] Existing estimates of genuine investment effectively assess the cost of a loss of natural capital based on the impact under the most likely scenario. This "central" impact may be fairly low, implying a small drag on the genuine investment calculation. If instead one considered the distribution of possible outcomes by integrating the cost over all scenarios, the expected cost (in a highly nonlinear system) would be much higher, and the estimate of genuine investment would be considerably lower.

Despite these limitations, it is instructive to use the World Bank figures to assess the character of recent economic development in different parts of the world. Table 1 does that, consolidating information from various World Bank sources. The table covers sub-Saharan Africa, the Indian sub-continent, and China, from among the poor world; and the USA and the UK from among industrialized countries.

The first column of figures contains the World Bank's estimates of genuine investment, as a proportion of GNP, during the period 1973-93. Notice that Bangladesh and Nepal have disinvested: their capital base declined during the period in question. In contrast, genuine investment has been positive in China, India, Pakistan, sub-Saharan Africa, USA and the UK. Thus the figures could suggest that the latter countries were wealthier at the end of the period than at the beginning.

The picture changes, however, when population growth is taken into account. The second column of figures contains the annual percentage rate of growth of population over the period 1965-96. Among poor countries, all but China experienced rates of growth in excess of 2 percent per year, sub-Saharan Africa and Pakistan having grown in numbers at nearly 3 percent per year. We next estimate the average annual change in wealth per capita during 1970-93. The third column of the table contains our estimates of an upper bound of the annual percentage rate of change in per capita wealth. The procedure we have followed in arriving at the figures was to multiply genuine investment as a proportion of GNP by the output-capital ratio, and to subtract the population growth rate from that product.[39] This is a crude

[37]See Scheffer (1997), and Carpenter, Ludwig, and Brock (1999). When the density of phosphorus is low, there will be very little algae in the water and sunlight can support green plants on the bottom. However, if more and more phosphorus is added to the lake through sewage or runoff from agricultural land, sunlight reaching the bottom will be reduced and the green plants will disappear. As a consequence, the bottom sediments (which contain phosphorus from dead algae) will be less stable and phosphorous will be released from the bottom. Thus, more discharge of phosphorus from outside will trigger even more phosphorus from the bottom. This positive feedback will eventually force the lake to flip (or "bifurcate") from a clear state to a eutrophic state.

[38]Climate models indicate that such a reversal can occur if the rates and magnitude of greenhouse gases increase sufficiently, although the threshold point is not known. It is clear from paleoclimatic history that such events were common. Mastrandrea and Schneider (2001) employ a linked climate-economy model to investigate the future possibilities of climate thresholds of this type, and assess the implications for climate policy.

[39]Since a wide variety of "manufactured" capital assets (e.g., human capital) are unaccounted for in national

way to adjust for population change, but more accurate adjustments would involve greater computation.

6.1 The Poor World

Turning first to the poor world, the striking message of the third column is that all but China have *decumulated* their capital base during the past 30 years or so. This may not be a surprise in the case of sub-Saharan Africa, which is widely known to have regressed in terms of most socio-economic indicators. But the figures for Bangladesh, India, Nepal, and Pakistan should cause surprise. Even China, so greatly vaunted for its progressive economic policies, has just about managed to maintain the ratio of genuine investment to "manufactured" capital ahead of population growth. For a poor country, a figure of 0.8 for the difference between the ratio of genuine investment to manufactured capital and the population growth rate isn't something about which one gets too excited. In any event, a more accurate figure for the output-capital ratio would almost surely be considerably lower than 0.25. Moreover, the estimates of genuine investment don't include soil erosion or urban pollution, both of which are thought to be especially problematic in China.[40]

How do changes in wealth per head compare with changes in conventional measures of the quality of life? The fourth column of the table contains estimates of the rate of change of GNP per head during 1965-96; and the fifth column records whether the change in UNDP's Human Development Index (HDI) over the period 1987-1997 was positive or negative.

First, consider the results for GNP per head. Our assessment of long-term economic development in the Indian sub-continent would be hugely off the mark if we were to look at growth rates in GNP per head. Pakistan, for example, would be seen as a country where GNP per head grew at a healthy 2.7 percent per year, implying that the index *doubled* in value between 1965 and 1993. In contrast, the per-capita genuine investment figures imply that the average Pakistani became poorer by a nearly a factor of two during that same period. Bangladesh too has disinvested in its capital base. The country is recorded as having grown in terms of GNP per head at a rate of 1 percent per year during 1965-1996. The figures imply that at the end of the period the average Bangladeshi was *less than half* as wealthy as they were at the beginning.

The case of sub-Saharan Africa is especially sad. At an annual rate of decline of 2.3 percent in

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accounts, there is a bias in published estimates of output-wealth ratios, which traditionally have been taken to be something like 0.30. In what follows, we use 0.25 as a check against the bias in traditional estimates for poor countries, and 0.20 for industrialized countries. The figures of 0.25 and 0.20 per year are averages of output-wealth ratios over the period 1970-93.

[40]Hussain, Stern, and Stiglitz (2000) contains an analysis of why China has been the economic success it is widely judged to have been in recent years. However, there is no mention of what may have been happening to China's natural-resource base in the process of the country's economic development. Judith Shapiro's study of ill-conceived economic programmes in Maoist China (Shapiro, 2001) is a convincing account of how suppression of civil and political liberties can contribute to the destruction of a country's natural-resource base.

wealth per head, the average person in the region becomes poorer by a factor of two every 30 years. The problems facing citizens of sub-Saharan Africa are routine reading in today's newspapers and magazines. But the ills are not depicted in terms of a decline in wealth. Table 1 reveals that sub-Saharan Africa has experienced an enormous decline in its capital base over the past three decades.

India can be said to have avoided a steep decline in its capital base. But the country has been at the thin edge of economic development, having managed not quite to maintain its capital base relative to its population size. If the figures are taken literally, the average Indian was slightly poorer in 1993 than in 1970.

What of HDI? In fact it contrasts from wealth per head even more than does GNP per head. As the third and fifth columns show, HDI offers a picture that is the precise opposite of the one we would obtain from wealth per head in poor countries. For sub-Saharan Africa HDI *grew* during the 1990s. Bangladesh and Nepal have been exemplary in terms of HDI. However, both countries have decumulated their assets at a high rate.

The figures in Table 1 are very rough and ready; our conclusions must be tentative. But the figures show how accounting for natural capital can make for substantial differences in our conception of the development process.[41] The implication should be depressing: the Indian sub-continent and sub-Saharan Africa, two of the poorest regions of the world, comprising something like a third of the world's population, have over the past decades become even poorer. In fact, some of the countries in these regions have become a good deal poorer.

6.2 The Rich World

The final two rows of Table 1 display these statistics for the U.S. and U.K. Both the U.S. and the U.K. appear to have grown wealthier in per-capita terms, although the U.S., growth rate is smaller. The estimates of growth rates of per-capita GDP and the HDI are also positive. Thus, for these countries, the differences across the different indices are less dramatic.

One might infer from Table 1 that poor countries are "consuming too much." But such a description does not fully convey the situation in these nations. In many poor nations, production of both capital (investment) goods *and* consumption goods is highly inefficient. These countries simultaneously suffer from low levels of investment *and* consumption, and in the most important sense of the term, these nations do not overconsume. One cannot assure a satisfactory quality of life in these nations simply by devoting a larger share of productive factors toward the production of capital goods. Production of both

[41]Conventional growth measures might also overstate growth in total factor productivity. National accounts mostly still do not include the changes in non-marketed natural resources. Suppose that over a period of time the economy makes increasing use of the natural resource base. The additional output made possible from such use would be attributed as a residual, that is, regarded as a change in total factor productivity. What appears as a positive development is actually a reduction in the economy's productive base.

capital (investment) goods *and* consumption goods falls well short of what could be produced with better use of current resources.

It is also worth noting that Table 1's figures for changes in per-capita wealth of various nations are not entirely independent. In particular, the "success" of rich countries may in part be due to the "failure" of poorer nations. As we noted earlier, owing to ineffectual systems of property rights, natural capital is very frequently underpriced in the market: in extreme cases such capital is free. In calling a system of property rights ineffectual, we mean that those inflicting damage (e.g., destroying mangroves in order to create shrimp farms; logging in the uplands of watersheds) are not required to compensate those who suffer the damage (e.g., local fishermen dependent on the mangroves; farmers and fishermen in the downlands of the watersheds). Even where property rights are reasonably well-defined, they are often unenforced. This suggests the possibility that countries that are exporting resource-based products (they are often among the poorest) may be subsiding the consumption of those countries that are importing these products (they are often among the richest).[42] Such hidden subsidies would help promote positive growth rates in per-capita wealth in rich countries, while working toward negative growth rates in the poorer nations that export resource-based products. High levels of consumption in rich countries may promote excessive resource degradation in poor countries, which imperils well-being in the poorer countries. To the extent that people from rich nations care about the well-being of people from poorer nations, this is a negative by-product of rich nations' consumption. This external effect is not captured in existing measures of changes in per-capita wealth: hence Table 1's figures for the growth in per-capita wealth may be biased upward.

7. Conclusions

We have analyzed the determinants of consumption and the criteria for deciding whether or not levels are excessive according to two criteria: the discounted present value of future well being (optimality) and the maintenance or improvement of well being over time (sustainability). We indicate why consumption might be excessive according to these criteria and explain why this could be so even when more standard measures of economic performance (such as GNP) are simultaneously rising. The issue at hand is ultimately an empirical one. The available evidence, though incomplete, is sufficient to generate significant concerns about the ability of societies to maintain current consumption under existing policies.

[42] The example is taken from Dasgupta (1990) and Chichilnisky (1994).

Recent studies have attempted to apply the sustainability criterion by ascertaining whether nations undertake sufficient investment to increase (genuine) wealth per capita. Although these studies suffer from data limitations and methodological problems, they nevertheless strongly indicate that many of the poorer nations of the globe fail to satisfy the sustainability criterion. In nations in the Indian sub-continent and sub-Saharan Africa, the prospects for the future appear much dimmer when viewed in terms of the sustainability criterion than when examined according to changes in GNP or the Human Development Index.

The World Bank's estimates indicate that consumption in richer nations is *not* excessive according to the sustainability criterion: these nations appear to undertake sufficient investments to increase per-capita (genuine) wealth.[43] However, we find that these estimates may be biased upward for several reasons. Important forms of natural capital, whose depletion lowers the estimate of the change in wealth, are disregarded. Market prices are employed as proxies for shadow prices: the use of more accurate shadow prices would likely give greater weight to negative entries (such as depletion of natural capital) in the equation for the change in wealth. Moreover, these estimates disregard uncertainties. Natural systems often exhibit significant nonlinearities or thresholds. As a result, the downside risks associated with the loss of certain forms of natural capital can be substantial. In the face of such nonlinearities, estimates of genuine investment based on most likely scenarios may well be biased upward. Societies that are risk-averse will wish to give extra weight to the possible negative scenarios – scenarios that might require larger investments in human and reproducible capital to yield a positive measure of genuine investment. Finally, we point out that the statistics for the changes in genuine wealth of various countries are not independent. The increases in per-capita wealth of richer nations are due in part to the inability of poorer nations to price their resources and resource-intensive exports at social cost. In light of these interdependencies, richer nations have less reason to feel complacent about the measured levels of genuine investment.

Even if the overall "excessiveness" of consumption in richer nations cannot be determined with certainty, the need for new and vigorous public policies to support sustainable consumption is unambiguous. Various forms of natural capital, and the numerous environmental and ecosystem services that they produce, are often priced well below their social cost. Through regulation, taxes, or the establishment of clearer or more secure property rights, public policy has an important role in helping to prevent such excessive use and thereby promoting higher genuine investment. These policies are justified on efficiency grounds whether or not genuine investment is positive.[44]

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[43]In this paper we provide data for these two industrialized nations. It may be noted that the World Bank's estimates indicate that nearly all industrialized nations succeed in undertaking sufficient investment to increase per-capita genuine wealth. The exceptions are Australia and Israel. See Hamilton (2000).

[44]The rationale for many public policies remains strong irrespective of whether genuine investment is positive or negative. From this one might conclude that quantifying genuine investment is not very useful. Measuring genuine

In addition to policy action, there is a need for further research to identify the areas where consumption poses a threat to sustainability. First and foremost, we need to develop better data quantifying the losses of natural capital we currently are experiencing, and the potential for substitution between various forms of capital. This would facilitate the measurement of genuine investment on a more disaggregated basis. Further, to complement the rather simple analytical calculations genuine investment, we need to make more use of disaggregated numerical growth models. Such models can contain considerable detail in the interaction of various forms of capital and the services they generate. They can be used to project growth paths of economies under various conditions and can aid us in getting the crucial accounting prices right. Additional information of this kind will help reduce uncertainties about genuine investment and clarify the extent to which current consumption levels imperil the quality of life of future generations.

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investment still has significant value. By providing an overall "scorecard" as to whether a nation is investing enough to sustain the welfare of future generations, it can offer an important summary assessment that can help mobilize the general public and politicians.

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Table 1

Genuine Investment and Changes in Per-Capita Wealth in Selected Regions: 1970-93

Country	Genuine Investment as Proportion of GNP	Annual Percentage Growth Rate of ...			
		Population	Per-Capita Wealth	Per-Capita GNP	Human Development Index (HDI)
	I/Y [a]	*g(L)* [b]	*g(W/L)*	*g(Y/L)* [c]	*g(HDI)* [d]
Bangladesh	-0.013	2.3	-2.60	1.0	positive
India	0.080	2.1	-0.10	2.3	positive
Nepal	-0.024	2.4	-3.00	1.0	positive
Pakistan	0.040	2.9	-1.90	2.7	positive
Sub-Saharan Africa	0.014	2.7	-2.30	-0.2	positive
China	0.100	1.7	0.80	6.7	negative
U.S.	0.08	1.0	0.60	1.4	positive
U.K.	0.08	0.3	1.30	1.9	positive

[a] Source: Hamilton and Clemens (1999, Table 3).

[b] Average annual percentage rate of growth of population, 1965-96. (Source: World Development Indicators, World Bank, 1998, Table 1.4).

[c] Average annual percentage rate of change in per capita GNP, 1965-96. (Source: World Development Indicators, World Bank, 1998, Table 1.4).

[d] Average annual percentage rate of change in UNDP's Human Development Index, 1987-97. (Source: Human Development Report, UNDP, 1990, 1999).

Assumed output-capital ratios: 0.25 for poor countries, 0.20 for rich countries.