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Research Paper no.16/02

What Happened to Sustainable Savings?

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Abstract

This paper argues that the dismissal of the capital theoretic (weak) sustainability framework in any aspect of sustainability analysis is unwarranted. It is justified in questions of the preservation of important ecological balances, but not in questions of preserving economic assets for future generations. It is argued that any national sustainability strategy has to incorporate capital adaptation as well as conversion of consumption and production patterns. The paper outlines some criteria for when a strategy of conversion of production and consumption patterns is feasible and when a strategy of capital adaptation is. The feasibility of conversion strategies as well as capital adaptation strategies is discussed.

The paper also analyses the global patterns of accumulation of capital net of natural capital consumption in the last three decades. The analysis shows that the ratio of net accumulation in the middle-income countries did recover from the crisis in the early 80es to the level corresponding to that of the high-income countries. The same is, however, not true for the low-income countries. A number of the poorest countries in fact seem to have had negative net accumulation over extended periods of time. This is a pattern predicting increasing income gaps between rich and poor countries in the future. This pattern is not sustainable development.

Keywords: Sustainable development, adjusted net savings, Hartwick Rule, sustainability strategy

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Introduction

Economists have had quite great expectations to the so called *Hartwick Rule* of investing the resource rent. The available analyses and national strategies for sustainable development prepared or drafted for the Rio+10 summit do, however, not quite come up to the expectations. Most of them take no notice of the Hartwick Rule or touch only very briefly the importance of investment and saving in very general terms.

The practically applicable tools of analysis have included the analysis of *sustainable savings* including the consumption of natural capital in the analysis of accumulation of the total capital stock (Pearce and Atkinson, 1995). The World Bank (1992a, 1998) elaborated on the concept by including environmental expenditure as a measure of increase in human capital. The central indicator of the overall change in reproducible, natural and human capital was called *genuine savings*. Another important contribution from the World Bank is the development and maintenance of a comprehensive database of all the necessary data for this kind of analysis. We shall benefit from this in our empirical analysis of global net accumulation of capital below.

The use of these tools in the preparation of national sustainability strategies is, however, quite sparse. The draft for USA's national sustainability strategy (President's Council for Sustainable Development, 1999) holds nothing about relating aggregate savings to the consumption of real capital, much less nature capital. As for economic sustainability, it merely has a recommendation for households to increase their savings, with the argument that it has decreased. Neither does the national sustainability strategy of the UK (Department of the Environment, Transport and the Regions, 1999). Finland's sustainability programme (Finnish Ministry of the Environment, 1998) barely mentions the relationship. Admittedly, the Finnish programme elucidates the investment quote (of GDP), yet unrelated to the consumption of nature capital. The documents rather consider what to invest in than the aggregate level of investment.

OECD (1999) describes the idea of "genuine" saving as a promising analytic tool, yet does not include it in its set of key indicators. Reference is made to the moot questions concerning future prices, handling of new finds, valuation of environmental resources, and more generally, the substitution problems associated with "weak" sustainability criteria.

In Denmark, among major environmental policy agents (e.g. the Danish Ministry for Energy and the Environment, 1999b) there is a pronounced scepticism towards the "weak" sustainability indicator proposed by The Danish Economic Council (1998b).

Norway appears to be an exception, since part of the resource rent is set aside on a special account in the central bank (the "Petroleum Fund"). The funds are invested in foreign assets. Growth in the fund reflects the surplus on the national budget generated by revenues from oil and gas enterprises. In due course especially expenditure for old age pensions and other demographically conditioned costs will grow, while incomes from oil and gas will decline. The proceeds from the Petroleum Fund will ensure that public spending can be upheld, at least up until 2050. (The Norwegian Finance and Fiscal Dept. 1997). In this case, the objective is tied up with the ability to uphold public spending at a certain level, rather than maintaining a specific national income. The resource rent is merely seen as a source of revenue for the public sector, and not as the object of a more general weighting of the consumption possibilities of present and future generations. Thus, this policy does not include natural resources in general, but only oil and gas incomes.

In the academic discourse on economic sustainability indicators and criteria it has been refused as a useful tool. Faucheux et al (1998; 73) conclude that the neoclassic nature capital theory cannot be used "validly" for studies of sustainability. Its value is merely instructional. Stern (1997; 166) concludes that the capital theorist approach does not at all agree with the sustainability concept defined in the Brundtland Report.

The question is why the Hartwick Rule has so blatantly failed to make an operational element of the national sustainability strategies. In the following, I shall deal with first the theoretical arguments for dismissing the approach and, second, argue for the necessity of using this approach alongside with “strong sustainability” approaches in any national sustainability strategy. Finally I shall provide some figures indicating the importance of this approach for sustainable development in developed and developing countries.

From Growth with Exhaustible Resources to the Hartwick Rule

A considerable portion of the environmental and growth debate of the 1970s was concerned with the issue: could the present standard of living be upheld, even if the resources utilized in production would at some point of time be depleted. Meadows et al. (1972) claimed this to be impossible, since geological mineral reserves have a finite volume, while their consumption is increasing along with the global production, which all expect to undergo heavy growth in the 21st century. Moreover, they considered it highly unlikely that continuing technological advances would be able to keep pace with the increasing scarcity of fossil fuels, because the growth rate of consumption exceeds the growth rates we can reasonably expect in utilisation efficiency, based on their utilisation in production.

The issue was taken up by economists in a series of groundbreaking papers at a 1974 symposium. Dasgupta and Heal (1974), Stiglitz (1974) and Solow (1974) presented a number of papers addressing these questions.

Dasgupta and Heal (1974) demonstrated that if an economy with a single renewable resource followed an optimal growth trajectory, consumption would not necessarily decrease, even if the resource was depleted. Under certain assumptions this would, however, happen. These assumptions are that the economy is stationary, and that substitution possibilities are limited, or that the rate of return on capital will be less than the discount rate. The latter condition was discussed in the previous chapter.

Solow (1974) demonstrated that it was *possible*, in an economy with non-renewable resources, to maintain a constant level of consumption in an infinite future even if the non-renewable resources were essential, the resource stock was depleted *and* even in the complete absence of technological advance. This, however, would require savings to take place according to criteria other than optimisation with a constant discount rate or a constant savings ratio, which is often presupposed. Solow used a Rawlsian maximin criterion, which in the present context means finding the maximum per capita consumption, which can be maintained constantly forever.

Stiglitz (1974) examined, among other things, the conditions to be met in order for a consumption level to be maintained permanently by means of *technological development*. Technological advance must be sufficiently forceful to outweigh the pressure from population growth.

The decisive contribution towards making this descriptive analytical work operational was delivered by Hartwick (1977), who introduced his paper in the following words: "Invest all profits or rents from exhaustible resources in reproducible capital such as machines. This injunction seems to solve the ethical problem of the current generation short-changing future generations by "over consuming" current product, partly ascribable to current use of exhaustible resources." (p. 972).

Hartwick (1978) extended its application to all non-renewable resources. Dixit et al. (1980), Hartwick (1990) and others have extended it to also cover renewable resources and environmental resources.

The generalised formulation in Dixit et al. (1980) also demonstrates that maintaining a constant level of welfare implies that the aggregate value of all changes of stock within an economy is zero.

This policy prescription has later become known as *Hartwick' rule*. It has been greatly recommended by Solow (1986, 1992), among others. It has been linked up with Weitzman's (1976) formulation of the net national product as the present value of future consumption flows, and with efforts to develop "green national accounting".

As has appeared from the literature cited above, Hartwick has not invented the Hartwick rule all by himself, and he has also repeatedly stressed that he doesn't deserve all the credit for it. Other suggested labels such as the Solow-Hicks-Hartwick-Rule or the like appears, however, much less elegant. Thus, we stick to the "Hartwick Rule".

The Criticism

Limitless Substitutability of Essential Inputs

The debate on the Hartwick rule as a sustainability criterion has centred mainly on three questions. First, the assumption of limitless substitution of essential, but exhaustible resource inputs. Second, the assumption of future prices in exhaustible resource markets. And third, the assumption of substitution of environmental resources by man-made capital at all. We will go through these discussions in turn.

The investigations of theoretical models in the neoclassical literature cited above assume that reproducible capital can replace natural resources in a broad sense. If this is not the case, any talk of the Hartwick Rule is, of cause, meaningless. Economics has, of cause, no answers to questions about whether an input is substitutable or not. This is purely a technological-scientific matter. But economics can formulate what substitutability means in a very precise way.

In a CES function, (Constant Elasticity of Substitution) the *substitution possibilities* can be described using the constant elasticity of substitution. The per capita output of the below CES function is the result of capital inputs per person employed, *k*, and resource inputs per person employed, *z*.

$$(1) \quad f(k, z) = \{\beta k^{(\sigma-1)/\sigma} + (1-\beta) z^{(\sigma-1)/\sigma}\}^{\sigma/(\sigma-1)}$$

in which $0>\beta>1$ and $0>\sigma>\infty, \sigma \neq 1$.

The elasticity of substitution is σ. If *e* is greater than 1, then maintaining the present production holds no major problems. In that case the resource can be substituted with capital inputs at the point when – driven by increasing resource scarcity – the resource cost exceeds the cost of acquiring the same utility using another technology. If σ is less than 1, there is a minimum positive input requirement below which production will cease. Since a resource that is both non-renewable and essential will necessarily drop below such positive resource input at some point of time, production will eventually stop. If σ precisely equals 1, the function is a so-called Cobb Douglass (CD) production function, the resource input of which is essential, yet is able to maintain a production of ever diminishing quantities, provided that it is substituted by ever more reproducible capital.

Most of the economic models assume a CD production function. They do so not necessarily because it is the most realistic assumption, but because this is the interesting case from an economic point of view (see Solow 1974). If σ is less than 1, we can as well plan how to use everything up in the rest of the time humanity has left. If σ is larger than 1, we have no economic problem. We just shift to some other input when it is appropriate.

The lesson from the theoretical model exercises is not about how economic development proceed and much less how it will proceed. The results are about the substitutability that must be present if natural resources are essential and exhaustible at the same time. *Essential* is seriously meant: If there is not a certain minimum available, production in society and human life on earth will stop.

The question for interdisciplinary research is therefore if some inputs are both essential and exhaustible at the same time.

It is a physical fact that there is a limited amount of metals and mineral fuels in the earth crust. They are exhaustible within some limited time horizon. At the end of the millennium, Rogner (1997) tallied the total fossil resources available for the next century, including the utilisation and improvements of known technologies, at approx. 5000 Gtoe. Based on an annual energy consumption of around 10 Gtoe there would be enough fuel for the 21st century, even at a considerable rate of economic growth.

Whether they are essential is even more a question of time because conversion to alternative inputs takes time. In a sufficiently long perspective any input can be replaced by another input. Thus, a more precise formulation of the above question is how long this perspective has to be and thus how changes in economic structures can shorten it.

Energy Scarcity

Most of the substitutability debate is concerned with energy resources. Are they really essential and how scarce are they?

There is no doubt that the use of energy sources is indispensable in production processes today. It is hardly possible to feed a World population of 6 billions on muscle energy alone. In this sense energy is essential. Energy is, however, not the same as the individual energy fuels. Electrical and heat energy can be necessary and indispensable, while we can replace fossil fuels by renewable energy sources.

All this has been documented by the research and our practical experience since the early 70s. A substitution pace corresponding to "factor four" was in the Limits to Growth Report considered highly unrealistic. Nevertheless it takes place today for a number of polluting materials in European countries. There is, however, two types of scarcity that only indirectly are linked to the resource scarcity due to exhaustibility.

First, the scarcity related to sink for pollutants related to fossil fuel combustion is now considered very restrictive. Thus energy policy today in many European countries and other countries is dominated by the consideration for the environment.

Second, the fossil fuel reserves are not evenly distributed over the countries of the world. One of the solutions to the oil crises in the 70s was to expand oil production from marginal oil fields such as those in the North Sea. However, just because they are marginal, they will also be exhausted long before the large oil reserves around the Persian Gulf and Aspic Sea. Thus, in a few decades – maybe as early as in the 30s – the oil market can again be characterised by a degree of market power similar to that of the 70s (See IEA, 1998b). In this perspective, supply security is increasingly an important objective for energy policy in oil importing countries as it appears in the recent energy policy programme from the European Commission (European Commission, 2002).

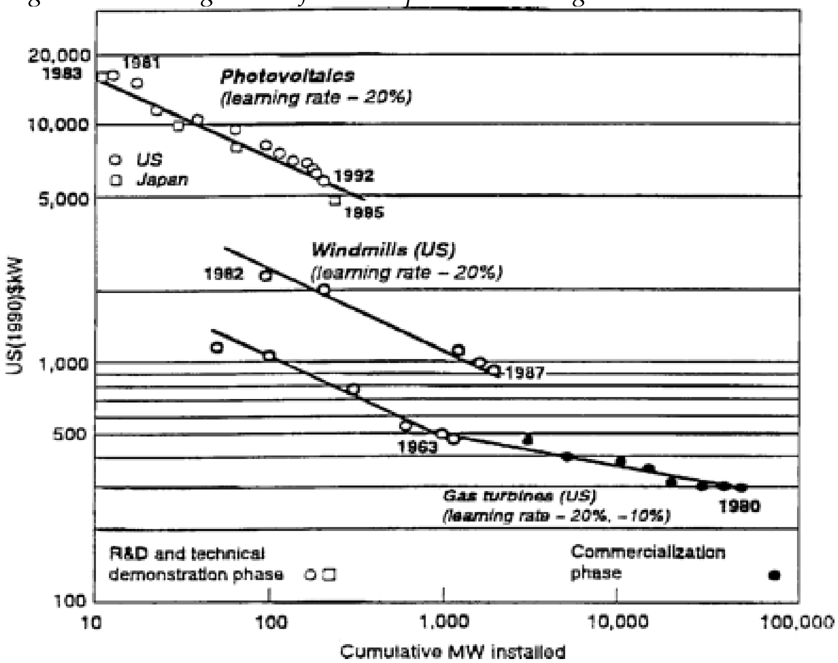
Future and Present Prices

These two kinds of scarcity are not covered in the original theoretical models. The price dynamics in the original analysis followed the Hotelling framework of marginal resource rents increasing with the rate of interest. Asheim (1994) used an example to demonstrate that we can imagine a development process in which following Hartwick's Rule does not result in sustainability because of the price changes. This may even occur in an economy characterized by perfect intertemporal competition. In such an economy the relative prices at a given time will always be determined by the future balanced growth trajectory of the economy. If the economy pursues the goal of providing a high standard of living for those living in the near future (e.g. the next generation), then the price relation between capital and resources will grow, while the production capacity is being built up. Thus, it would be affordable to follow Hartwick's Rule. However, once this build-up is over, the price relation will change, and the return on the compensating capital will not necessarily be sufficient to cover the loss of income from resource extraction. This can have considerable adverse consequences for generations in a slightly further future, even if earlier generations actually invested more than prescribed by Hartwick's Rule.

Another source of price dynamics that was not covered by the original neoclassical framework was the response of technological development to past and future demand. The experience with development of renewable resources shows a pattern of strong feedback mechanisms from accumulated experience – and thus demand – to the costs of the alternative inputs.

The costs associated with power and heat production based on renewable energy sources have fallen considerably over the latest decades. This is a result of R&D and dynamic economies of scale. Dynamic economies of scale can be observed as cost reductions resulting from previous production, which thus leads to an accumulation of experience on the most appropriate technology use.

Figure 8. Learning curves for select power technologies



Source: Grübler og Vincent 1999.

The figure illustrates the relationship between the cumulative production of power plants and their costs. The reduced costs can be ascribed to several factors: The accumulation of technical experience, the organisational set-up, economies of scale, and overall technological progress. These factors are often assumed to be of particular significance to new technologies and they represent a form of price dynamics that is different than assumed in the original neoclassical models.

Although power is more expensive when produced by solar cells and wind power, instead of gas turbines, a continuation of the trends in the figure will cause the production costs of these technologies to converge. IEA (1998a) projects that the next generation of technology in geothermics, biomass power, wind power, and solar heat will cut back the costs to 5-7 USc/kWh, which is below the level of costs for small waterpower plants. Solar cells and marine energy systems are still projected to be twice as costly, yet with a falling level of costs.

It is difficult to find similar data for the liquid fuels sector, which is the most critical one, since uniquely suited to propel means of transportation. Research and development work in the field comprises, inter alia, extraction of liquid fuel from coal/gas and unconventional fossil resources. Moreover, engines powered by ethanol, methanol or possibly hydrogen-based power, are in the pipeline.

This line of reasoning has led to reformulating the question of whether substitution of scarce production inputs is *possible* to a question of within which *time frame* substitution is possible and most economic. The conclusion is that the future value of the resource rent depends on the present policies rather than being given as assumed in the original neoclassical framework. However, this insight doesn't disqualify the Hartwick Rule as such, but calls for sensitivity analysis with alternative assumptions of future marginal resource rents and substitution costs.

If national sustainability strategies are in line with this recognition of the substitutability of fossil fuels and the sink and market power scarcity, which is much more binding than the source scarcity, then they will have no problem with accepting the assumption behind the Hartwick Rule or another principle of capital adaptation in the sustainability strategy.

Directly Consumed Environmental Goods

The controversial assumption of substitution appears when the framework developed here for production inputs is applied to environmental goods that are directly consumed. The ecological balances in our natural environment support life and health and thus bio diversity. These goods are not necessarily substitutable, and any model that squarely assumes that they are is deemed to mistrust.

Stern (1997) and Faucheux et al. (1997) point out that the value of environmental quality is not reflected in observable market prices. Stern (1997; 154) describes these values as "unknown and unknowable", referring to their non-linearity – in the sense that discontinuous changes in environmental properties occur, such as critical threshold values and irreversibilities, e.g. on species eradication. In most cases, we do not have sufficient knowledge to ascertain where such discontinuous changes occur, and much less what would be the value of such lost environmental assets beyond these, and are therefore unable to calculate their socio-economic shadow prices.

This criticism is supported by numerous authors and it is indeed the central source of disagreement between neoclassical environmental economics and other disciplines involved in the analysis of sustainable development. The assumption of unlimited substitutability in the case of environmental values is not consistent with what we know about life supporting functions and the different value systems we use to assert economic and environmental values.

Intergenerational Distribution of Resource Rents

The concern for future generations if certain production inputs are essential as well as exhaustible would challenge national sustainability strategies with the question of how long the available reserves should be stretched before the lights ultimately are turned off. If we accept the substitutability assumption for production inputs, the question instead becomes how we distribute the rents from the economic use of a mineral deposit to future generations. Metals and oil have to be extracted at one point of time if they are to have any value at all. If the rents from this extraction should not be consumed by the extracting generation alone, but shared with future generations, it must be passed on to the future in the form of other economic assets. In this sense, a national sustainability strategy cannot solve the question of a fair intergenerational distribution without securing a certain balance of economic assets transfer to the future. In other words: Some principle of overall adaptation of capital stocks is an indispensable element of a national sustainability strategy.

A strategy for conversion of production and consumption patterns to environmentally sustainable ones is, of cause, an indispensable element too. If the conversion processes today are primarily motivated by sink scarcity, conversion processes in the future can be motivated by source scarcity. One way or another they must take place at some point of time. But process of conversion to an environmentally sustainable economy doesn't excuse the present from sharing the resource rents with future generations or using it to securing its own economic future, which is much the same.

The Hartwick Rule is probably too cruel a principle to be applied directly in the national sustainability strategies. In many poor countries a constant level of capital - even if it was per capita – cannot be considered sustainable development. A more ambitious pace of capital accumulation is in many countries necessary to bring the country or parts of its population out of poverty. In richer countries, a larger stock of productive capital can be necessary too as a basis for environmentally sustainable production and consumption. Hansen (1999) contains a more detailed discussion of these matters as well as a more precise definition of the conditions that a natural resource must meet to be considered substitutable in the sense that is relevant for capital adaptation.

Integrating weak and strong sustainability positions

Concluding on the Debate

The criticism above does not justify blank dismissal of the capital theoretic approach. It does, however, identify some central assumptions about something that lies outside the realm of economics. These are

* minerals (including fossil fuels) are not essential inputs, energy is
* In the future and probably within a few decades, fossil fuel prices (exclusive of environmental taxes) will be higher than today. Sink scarcity will make the social shadow prices even higher.
* mineral extraction represents resource rents that some way or another should be shared with future generations
* the rate of discount and the desired rate of growth reflect an acceptable weighing of future and present consumption
* the natural resources that are included in the concept of natural capital are only those, the rent of which contributes to the national product.

Based on these assumptions, a measure of net capital accumulation can say nothing about ecological sustainability but give some very important information about macroeconomic sustainability. It can measure the size of the national net investments in future productive capacity. This is extremely important in countries where the productive capacity is too small to sustain progress in environmental or decent living conditions. When a more appropriate database become available, these investments can be extended to cover the investments in human capital.

The Limitations of Capital Adaptation According to Proponents of Weak Sustainability

Weak and strong sustainability is often presented as two mutually excluding principles for sustainability strategies. In practice, the proponents of either view are not that square-minded. Most of the economists and other contributors to the debate that defend the weak sustainability position do not dismiss that in some situations capital adaptation is not the appropriate principle.

Turner (1983) and others have classified the capital theorist approach as a weak approach to sustainability, as opposed to a strong approach, which prescribes the preservation of natural resources as they are, regardless of their economic value. Taken as absolutes, this is a somewhat futile juxtaposition. The notion of 'Strong' or 'weak' sustainability used for the use of natural resources as such is a little too categorical view of the symbiosis between economy and its resource basis.

Several economists who use the paradigm of neoclassic capital theory have indeed noted that in using those very general principles we need to take heed of their practical limitations. Some resources must be subject to strong sustainability criteria and others to weak ones.

As Heal (1998) put it: "Imagine all trees replaced by buildings of equivalent value. This maintains the total value of capital stocks intact, yet it is clear that this is not what we mean by sustainable development!" (p. 9)

Solow (1992) maintains that "the claim that a feature of the environment is irreplaceable, that is, not open to substitution by something equivalent but different, can be contested in any particular case, but no doubt it is sometimes true" (p. 21).

This view is amplified by Solow (1986): "The current generation does not especially owe to its successors a share of this or that particular resource. If it owes anything, it owes generalised productive capacity or, even more generally, access to a certain standard of living or level of consumption. Whether productive capacity should be transmitted across generations in the form of mineral deposits or capital equipment or technological knowledge is more a matter of efficiency than of equity." (p. 142).

However, his obviously "weak sustainability" statement is immediately modified: "The preservation of natural beauty is a different matter since that is more a question of direct consumption than of instrumental productive capacity." (p. 142).

Similar ideas are treated in Pearce and Atkinson (1995), and in Atkinson et al. (1997), who advocate the idea of dissociating *critical capital* from substitutable forms of natural resources. *Critical capital* is defined as natural capital that is indispensable for human survival (Atkinson et al. (1997), p. 16), and is therefore to be preserved, while following Hartwick's rule for the remaining natural resources. The Danish Economic Council (1998b; 173) equally points to the importance of identifying critical natural capital.

It could be disputed whether it is appropriate to label such non-renewable natural resources as "capital", when they are not valuated. The definition proposed by Atkinson et al. does not appear to be very well researched, since not comprising e.g. species preservation.

However, as indicated, these ideas are stated in very vague terms. None of them attempts to draw the line between critical and substitutable resources. Most often, they are accompanied by references to the effect that these are scientific issues that cannot be solved within economy.

In fact, I haven't really come across any contribution to this literature that has claimed that everything can be reduced to a questions of capital adaptation. On the other hand, economists are usually not very informative about when capital adaptation is preferable to conversion.

Therefore, the following should be seen as a contribution to the identification of natural resources that are substitutable in this respect. That is, natural resources spent by present generations, thus inflicting a welfare-loss upon future generations that can be compensated by adapting the present stocks of produced capital.

Two Economic-Ecological Strategies

A national sustainability strategy transforms the principles of environmental preservation and restoration, caring for the living conditions of future generations and poverty eradication to a set of operational targets and instruments. The environmental targets set in European countries often aim at preserving environmental qualities and stocks of renewables at the present level or restoring them to a better level. This is not possible for exhaustibles. Any target must be stock that is lower than the present. Thus, a compensating adaptation of other assets is necessary to secure the living conditions of future generations.

Note that even in the cases where reduced stocks of natural resources are inevitable, conversion strategies can be necessary too. This is the case if the strategic target for a stock is higher than what would result of economic growth with unchanged patterns of resource use.

Note also that even in cases where environmental preservation and conservation dictates a conversion strategy, some capital adaptation can be necessary too. For instance, in the case of climate change, the already caused environmental damage in the future can be costly to societies in tropical and subtropical regions.

When it comes to practical planning, weak and strong approaches are not mutually exclusive, but on the contrary mutually dependent. As Hansen (1999) points out, the capital adaptation strategy is applicable on resources that are substitutable in production as well as in consumption. Additionally, they must share appropriability features with the national stock of produced capital.

Capital Adaptation in the Global Economy

Measuring capital adaptation

Extractable reserves of fossil fuel have two significant macroeconomic functions. In part, they represent a capital that compares to a country's financial assets and real capital apparatus. In part, energy supply is an essential input to any economic activity. Therefore, some degree of self-sufficiency is often made part of a strategic goal for security of supply.

Per their *capital* properties, oil and gas are directly substitutable with less foreign debts, more foreign assets, or larger stocks of machinery, building, or infrastructure capital. Per their *supply source* properties, they can be substituted by oil and gas imports, or by other sources of energy. Per their *national energy source* properties, they can only be substituted with renewable energy sources (provided that nuclear power remains out of the question in Denmark).

Thus, it is their *capital* properties that let us use the net capital accumulation to determine if the other parts of our national capital are adapted sufficiently to make up for our consumption of natural capital and real capital.

A positive net capital accumulation implies that the national capital will grow – also when we set off the consumption of oil and gas reserves. If we wish to secure the living conditions of future generations, it would be appropriate to do so by providing them with a capital basis at least as good as the present one.

Thus, the size of our net capital accumulation can be used as an indicator showing if the consumption level is economically sustainable. If negative, it indicates *over consumption*, meaning that the level of consumption cannot be upheld in the future, unless technology and other factors are able to make up for a smaller national capital.

In the 1980s and 1990s, a number of pilot studies on natural capital consumption were carried out in selected countries. (For an overview, comp. e.g. Pearce and Atkinson 1995). However, the applied methods were rather different, thus making direct comparison difficult. But now comprehensive statistical material, prepared by The World Bank (1998), is available, showing the consumption of reproducible *and* natural capital in 140 countries. The natural capital consumption comprises available statistics on the value of extraction of oil and a great number of other mineral resources, and the net consumption of timber reserves. Natural capital consumption is defined as the aggregate resource rent (and is thus a high-end estimate, comp. Hansen (2000a):

Resource rent = world market price – extraction costs – other on-site costs – transport to port – normal capital returns (Hamilton and Clemens 1998).

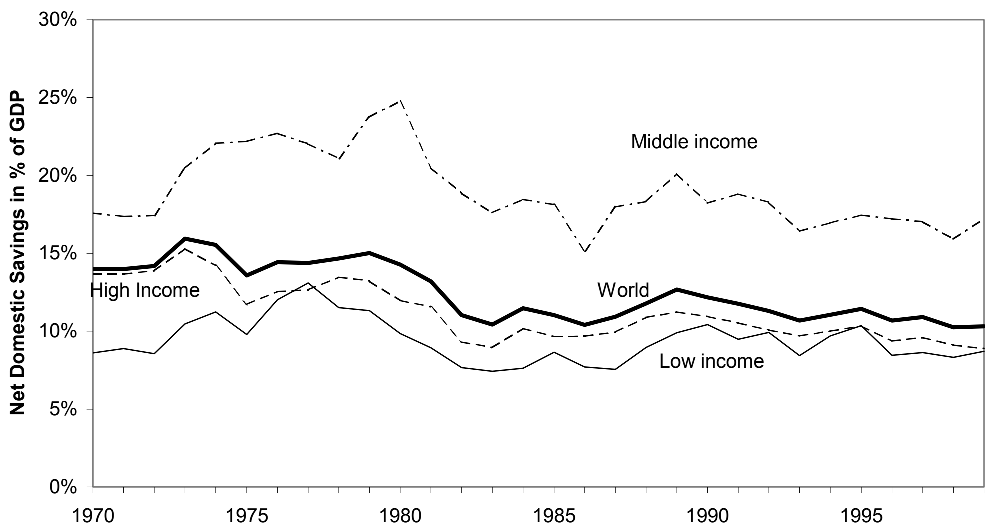
Net capital accumulation will thus be defined as net domestic savings minus the natural capital consumption. To extent the capital concept to comprise human capital as well, the World Bank (1978) also calculates a genuine savings rate, which is the net capital accumulation plus the education expenditures in the country. We have abstained from using these figures since education expenditures are bad indicators of investments in human capital. These investments are primarily made up of the time invested by students, apprentices, and pupils.

What Difference Does it Make?

How much difference does natural resources make to the performance of individual economies? We can get an idea of this by comparing the development of net savings ratios in the world with the development of the net capital accumulation ratios as defined above.

The figure below shows how the ratio of net savings to GDP has developed through three decades for the world as a whole as well as for the high income, middle income, and low income economies (according to the World Bank classification).

Figure 1. Ratios of Savings Net of Consumption of Reproducible Capital in the World



Source: The Genuine Savings Database of The World Bank and own calculations.

Figure one shows the somewhat reassuring pattern of middle-income economies having a savings ratio considerably higher than the high-income countries. Provided that the ratio of production to capital is fairly the same in rich and poor countries, this means that the middle-income countries eventually will catch up with the high-income countries if the productivity and population growth in the long run is similar in the two groups of countries. The low income countries on the other hand has a net savings rate not far from the high income countries, meaning that the patterns of savings will maintain status quo in income disparities between high- and low-income countries.

The table below shows the capital-output ratio in groups of countries according to the World Bank Wealth Database. They are calculated in two ways: The ratio of the sum of capital to the sum of production over countries and the average of individual capital-output ratios from each 92 countries in the database. Two concepts of capital are used. Produced capital is the conventional capital as it is defined in national accounts. Natural capital is the present value of expected future resource rent.

Table 1. Capital-Output Ratio in 1994.

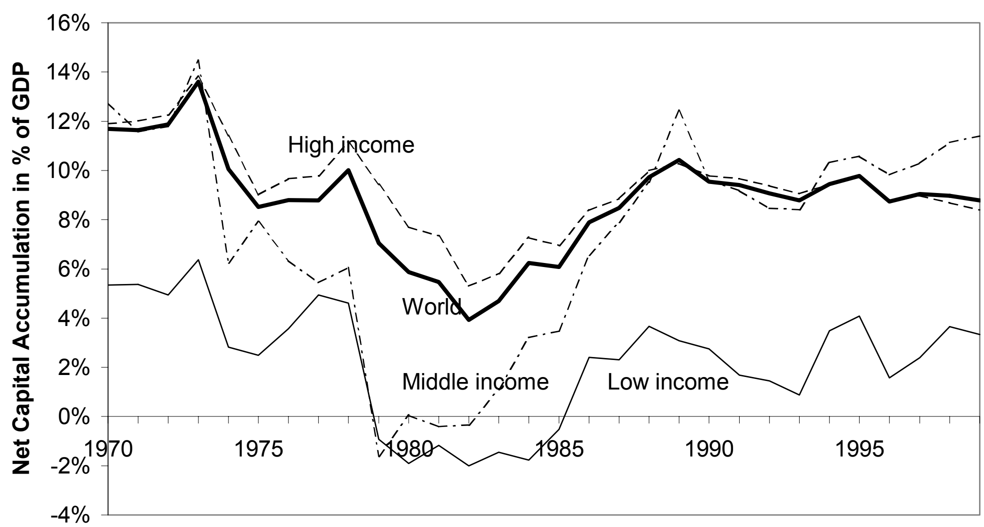
	Ratio of total sums		Average of country ratios	
Country group \ Capital	Produced+ Natural	Produced	Produced+ Natural	Produced
High-income	3,7	3,2	4,2	3,5
Upper Middle-income	5,1	2,8	5,7	2,9
Lower Middle-income	7,2	3,0	6,5	3,1
Low-income	11,5	3,4	17,7	3,9

Source: The World Bank Wealth Database and own calculations.

The pattern of ratios of produced capital to output shows that they are quite similar in different groups of countries. The pattern in total (produced + natural) capital to output ratios is that it is higher the lower income level in the country.

What happens if we also take the consumption of natural capital into account? In the figure below we show the same type of curves as in figure 1, but now we have subtracted the consumption of natural capital as well.

Figure 2. Ratios of Savings Net of Consumption of Reproducible and Natural Capital in the World



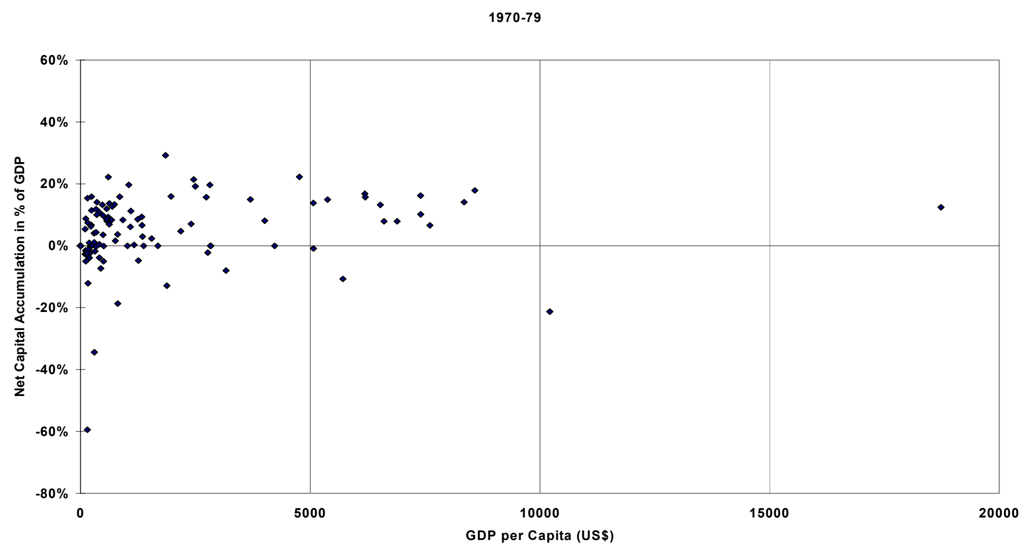
Source: The Genuine Savings Database of The World Bank and own calculations.

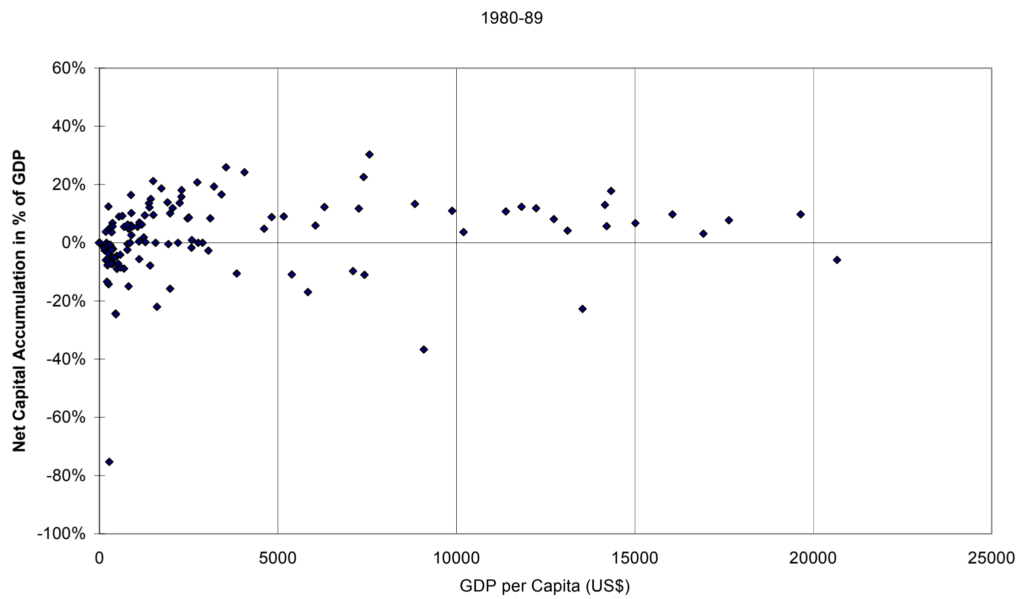
When accounting for the consumption of natural capital, we still note a positive net accumulation of capital for the World as a whole. The low- and middle-income countries display, however, a much different pattern than the high-income countries. First, much of the high rates of net savings in the middle income disappear when corrected for consumption of natural capital. This consumption of natural capital is mistakenly interpreted as income and production. Without correction for the consumption of natural capital, figure 1 shows that the middle-income countries are rapidly about to catch up with the high-income countries because of a high savings rate.

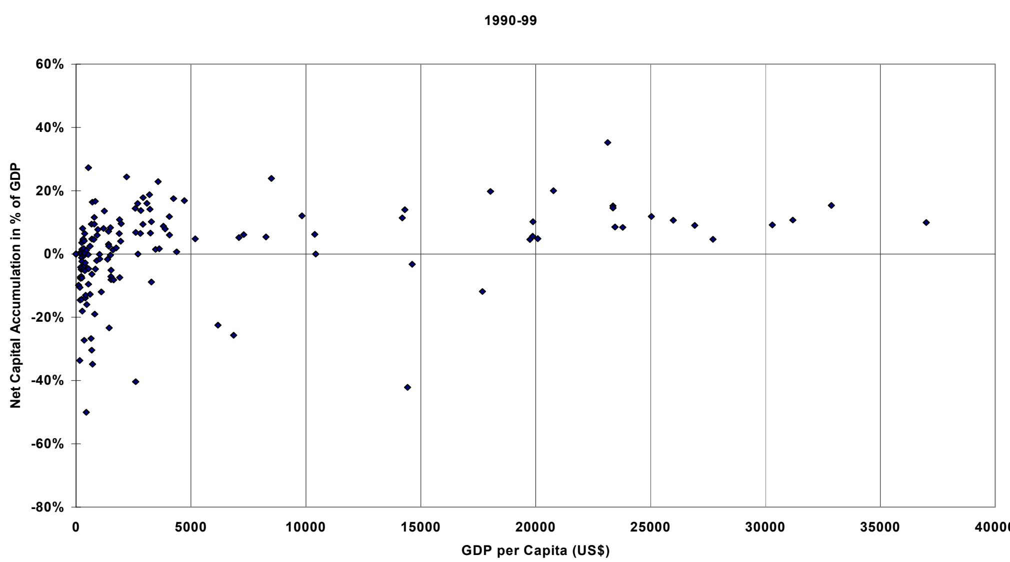
Note that a given rate of net accumulation in GDP results in a lower rate of growth of the capital stock the higher capital-output ratio. Thus, we can conclude from figure 2 that the differences in wealth between high income and low-income countries are increasing.

When trying to identify patterns of capital adaptation it is relevant to compare average net capital accumulation rate with average income (i.e. average over the decade and per capita). This has been done in the below figure, for each of the 140 countries in the database of The World Bank, and separately for the 1970s, the 1980s, and the 1990s

Figure 3. Average net capital accumulation rate according to average incomes in 130 countries, in the 1970s, 1980s, and 1990s.







Source: The Genuine Savings Database of The World Bank and own calculations.

In high-income countries – which for all three decades typically included western industrial nations (OECD countries), some oil countries, and Israel – per capita average incomes were at nearly USD 10,000 in the 1990s. In the 1980s, the limit was at around USD 6,000 and in the 1970s some below USD 3,000.

The figures show a rather consistent pattern in the development of the world's national capital in high-income countries and low-income countries respectively. Generally, the rich countries have no problems with their net capital accumulation. Figures are positive for each of the three decades, and thus the national capitals of the rich countries are climbing steadily over time. They did *not* have an over consumption in the sense that they have been spending at the cost of future consumption possibilities.

With a few exceptions, namely Saudi Arabia, Kuwait, Oman, The United Emirates, and Israel such over consumption is – paradoxically – only seen in the poorest countries. Some of the poorest countries in the world have an over consumption, and not the rich.

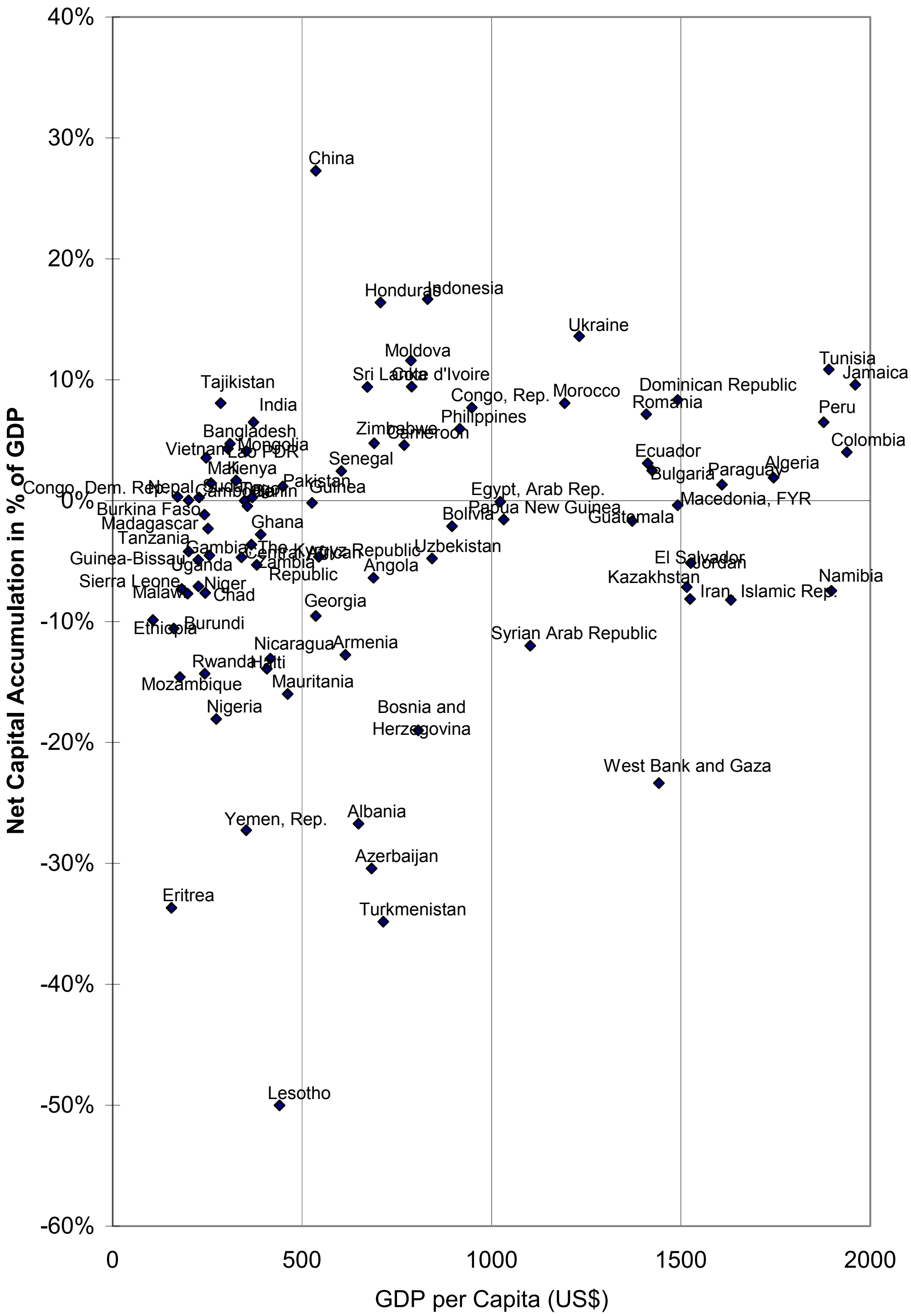
However, this paradox arises from the mere fact that the term *over consumption* can be used interchangeably with *under investment* depending on the preanalytic vision of a policy recommendation. In the case of the poor countries where people generally consume too little, under investment is definitely the more appropriate term. We can, however, easily characterise the temporary negative savings in Denmark in 1980-82 as over consumption.

Figure 2 shows that the low rate of net capital accumulation is concentrated on a few countries that over entire decades fail to maintain their base of produced and natural resource assets. Moreover, except a few countries all of the countries that have negative net capital accumulation in one of the decades according to figure 3 also had in one or two of the other decades. In other words, there is number of countries that systematically are eroding the capital basis of future living conditions.

This pattern of rich countries with a steadily rising national capital and poor countries with a shrinking national capital can hardly be considered sustainable. Still the pattern appears to be ominously stable, and nothing seems to indicate that development aid over the three decades was able to break the pattern.

The following figure is a close-up of the pattern of the 1990s, showing the countries with the lowest average incomes.

Figure 4. Net capital accumulation rates and average incomes in the 1990s for the world's poorest countries.



Note: The incomes scale corresponds to the one used in Figure 2. In order to improve comparability average incomes can be adjusted using the atlas method of The World Bank. However, the resulting pattern does not differ significantly.

Source: The Genuine Savings Database of The World Bank and own calculations.

It is hard to glimpse a general feature explaining why precisely these countries had negative net capital accumulation. In many of them it is the fact, that a large part of their "income" is not really income but revenue from sale of assets. In other cases, it would be obvious pointing to protracted civil wars as the cause, in others to the collapse of economic and political institutions, and in still others to downright economic mismanagement. The only general conclusion to be drawn is that low per capita income and great economic dependency on resource extraction appear to be a risky combination.

These patterns in savings and net capital accumulation let us conclude that the problem of natural capital consumption with respect to the welfare of future generations is more than anything a serious problem facing low-income countries. The problems of rich countries in terms of sustainable development do not lie with the extent of their savings. Of course keeping an eye on the savings rate is also important to the richer countries, but still they are not facing a threat of declining consumption possibilities due to low savings. Instead, for many countries, the problem lies with the declining labour force in proportion to the population.

For developing countries, the problem of lacking savings is a real one. Implications are that once oil and other mineral reserves are depleted, the population's average standard of living will go down from a level that is already too low, unless technological advances can outweigh the pressure of both population growth and a shrinking resource basis.

The fact that there is a concurrent degradation or direct eradication of irreplaceable environmental assets does nothing to change the fact that the impact of resource consumption on the future standard of living is a separate problem that a national strategy for a sustainable development must take heed of. In that context, analyses of net capital accumulation could provide an invaluable basis of information.

In many countries the national capital would also have shrunk, even leaving out the consumption of natural capital. As a result, several of the poorest countries have accumulated foreign debts they will never be able to repay. Against that background, the international organizations The World Bank and The International Monetary Fund are now working on a debt relief scheme.

In that context integrating natural capital consumption into ordinary national accounting concepts, as mentioned above, could prove to hold great promise. In part because the debt burden of some countries could be underestimated, since no allowance has been made for the fact that the country's mineral or timber reserves have been greatly reduced in order to limit foreign debts. In part because the reinforcement of export efforts, to which those countries typically have to commit themselves in order to be granted debt relief, could prove to be a very short-term solution if overly reliant on the export of those reserves.

Finally, it should be noted that the database for the analysis could be improved in a number of ways.

First, the relevant aggregate to compare savings with is not GDP, but GNP. The difference is, however, in most cases negligible.

Second, investments in intangible assets such as education, organisation, and intellectual property can be as important as investments in produced capital. The value of a company like IBM is more than ten times the value of its produced

capital. However, adding that kind of investments to the account would probably tip the global pattern of accumulation even more in the direction of the high-income countries. The World Bank uses the education expenditures as a proxy for investments in that human capital but that is for theoretical reasons not a satisfactory proxy.
Third, population growth matters because what must be important to the countries is the living conditions indicated by, e.g., per capita consumption. Again, correcting for population growth would only make sharpen the pattern of growing disparities between rich and poor countries.
Fourth, there is also one aspect that tends to overestimate the resource rent. The rent used in this paper follows the so-called "total rent" approach that implicitly assumes a zero rate of discount. A more theoretically satisfying concept would be a user cost with a declining rate of discount (see Hansen 2000a, 2000c).

Conclusions

The conflict between the capital theoretic approach and the environmental conservation approach to the analysis of sustainable development cannot be resolved as long as all environmental qualities and natural resources are mixed together in one homogenous ecological porridge.
Thus, we have to distinguish between the ecological balances that are essential to specific forms of life that we want to preserve and mineral deposits that only can be exploited for use as material production inputs. In particular the former case, consumption of "natural capital" means irreversible losses of immeasurable values while in the latter case, it means consumption of a factor of production, that can be replaced by another factor of production.
Adaptation of these other factors of production to compensate for the loss of the mineral reserve makes sense, while capital adaptation doesn't make sense in the former case. Moreover, minerals have to be mined or pumped up in order to have any value to somebody at all. *Capital adaptation is necessary for sharing this value with future generations.*
We must also distinguish between abundant resources and resources that have been shaved down to levels that we definitely should preserve. Forests in the medieval Europe could be examples of the former while forests in today's Europe (and primeval forest generally) typically belong to the latter category. Turning virgin forest into agriculture would probably be part of our recommendation for sustainable development in medieval Europe, but not to extend this economic strategy until all forests were gone.
In a strictly economic sense, the compensation of the consumption of economic resources by adaptation of other economic resources is unavoidable if we want to share the economic value of nature with our descendants. The Hartwick rule is, however, too modest to most poor countries. Without a considerable capital accumulation, it is hard to see any sustainable development in these countries. As repeatedly stressed in the Brundtland Report, the Rio Declaration, and Agenda 21, economic growth is a prerequisite for sustainable development in poor countries. In that perspective, maintaining the sum of capital stocks is not enough. Development requires accumulation of the sum of capital stocks and sustainable development that the additional capital is invested in the right sectors etc.
On the global scale, capital accumulation is not remotely sufficient to provide a better over all standard of living and eradication of poverty. It is a matter of where the additional capital is invested.

The analysis above showed that the world as a whole accumulates much more man-made capital than it consumes. The problem is that this is so in the developed economies and in some of the developing economies and economies in transition. In some of the poorest economies, however, more capital is consumed than reinvested. Moreover, this pattern seems to persist over decades. And it is questionable how much the debt relief programs currently undertaken will change this pattern.

A world development where the rich countries grow richer while some of the poor countries get poorer cannot by any standard be characterised as sustainable.

But capital accumulation has nothing to do with the life support of the ecological balances that cannot be replaced by capital, labour, energy, or knowledge. In that sense to preserve these ecological functions and forms of life, it is obviously necessary to transform consumption and production patterns to patterns that allow for a decent standard of living without eroding these environmental qualities.

Moreover, at some point of time the finiteness of natural resources and environmental qualities means that sustainable development can only be possible with *zero consumption* of these. *Thus, any national strategy for sustainable development must contain a capital adaptation strategy as well as a conversion strategy.*

Summing up, compliance with the Hartwick rule is not a sign of sustainable development. It is too vague to provide a criterion for economic development and poverty eradication. It has nothing to do with ecological sustainability. Nevertheless, non-compliance is a very good test of macroeconomic un-sustainability. This paper has shown that macroeconomic unsustainability persists in the global pattern of capital accumulation.

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