Reconciling Weak and Strong Sustainability

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Abstract: *A conceptual and analytical approach is presented to reconcile weak and strong sustainability. It involves a reconsideration of the conception of total capital from an ecological economic system perspective. In particular, natural capital is classified into non-renewable resources, renewable resources that are harvested, and those that are not used in production. Strong sustainability is defined in terms of constant environmental quality. Weak sustainability is characterised by non-decreasing value of aggregate income and environmental quality.*

1. Introduction

The idea of sustainability as a management rule and policy principle is by no means new. However, interpretations and management objectives have changed over time. As a fundamental principle of resource management, it has a long tradition in orestry, and has logically been extended to other concerns of natural resource use (Hediger, 1997). In addition, the notion of sustainability has been adapted to the context of various objectives of economy, society and the environment (cf. Tisdell, 1991), including the context of economic growth (OECD, 1960) and nature conservation (IUCN, 1980). As a consequence, the interpretation has become ambiguous and the operational content increasingly unclear. It was the contribution of the “Brundtland Commission” (WCED, 1987) to provide a still vague but nonetheless meaningful definition of sustainable development which involves a shift of the predominant development paradigm (Munasinghe, 1993), and “a subtle but extremely important transformation of the ecologically-based concept of sustainable development, by leading beyond concepts of physical sustainability to the socio-economic context of development” (Adams, 1990, p. 59).

Correspondingly, sustainable development is an important concept of integrating social, economic and ecological dimensions of development and jointly addressing objectives conservation and change. Since these objectives cannot be achieved simultaneously as a rule, trade-offs across the various objectives are inescapable. They must be made explicit to have a clear idea of what is meant by “sustainability” and “sustainable development”, respectively (cf. Barbier, 1987; Tisdell, 1988, 1990; Hediger, 1997). Nonetheless, much of the present literature does neglect these trade-offs, by either concentrating on issues of environmental preservation or economic development. This has culminated in mutually exclusive concepts of “weak” and “strong” sustainability that are either grounded on an ethical premise of keeping the general production capacity of the economy constant, or maintaining essential functions and capacities of the environment intact over time. It is dividing economists and environmentalists, rather than reinforcing and integrating different perspectives, and comprehensively addressing the overall challenge of sustainable development.

An integrated approach is required that goes beyond traditional debates on economic development versus environmental conservation, and monodisciplinary conceptions of sustainability. Hence, an important task is to bridge the gap between the value principle of weak sustainability and the physical principle of strong sustainability. This is the aim of this paper which provides a conceptual and analytical approach to reconciling different concepts of sustainability. In section two, I briefly present basic principles of “weak” and “strong” sustainability, and discuss limitations of either conception. In section three, I reconsider the understanding of total capital this is, an economy's generalised productive capacity and the aggregate of natural capital as a reference base for defining terms of sustainability in a consistent framework. On this background, I elaborate an integrated approach of sustainability in an ecological-economic context of development and long-run preservation of the environment as our life-support system. This problem of integrating the objectives of economic growth and environmental preservation is formally

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analysed in section four, where a “sustainability-based social value function” is proposed. This shall contribute to the elaboration of an integrated framework of sustainable development which is required for the definition of operational and consistent terms of sustainability, and the evaluation of environmental and development policies from a system perspective.

2. Basic Interpretations of Sustainable Development and Sustainability

2.1 Sustainable Development

In correspondence with the WCED (1987), sustainable development is generally defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. It has evolved from different development paradigms, encompasses economic, social and ecological perspectives, and contains within it the key concepts of equity, needs and limitations.

First, the concept of sustainable development is generally motivated by an ethical imperative of intergenerational equity, a concern that must logically be extended to requirements of intragenerational equity. This is not only fundamental to the idea of sustainable development. It also corresponds to the development paradigm of equitable growth that evolved in the 1970s, where distributional objectives were recognised as distinct from and as important as economic efficiency (Munasinghe, 1993). Correspondingly, priority should be given to meet the essential needs of the world's poor; this is, the alleviation of poverty and inequity (WCED, 1987). Yet, this is not sufficient for sustainable development. Rather, the satisfaction of both human needs and aspirations (needs and wants) is seen as the major objective of development: “Sustainable development requires meeting the basic needs of all and extending to all the opportunity to satisfy their aspirations for a better life” (WCED, 1987, p. 44).

Second, the concept of sustainable development implies limitations that need to be imposed on economic development. These are not absolute limits, but rather limitations that are determined by:

- institutional arrangements and technologies that are under control of social and individual decision makers; and
- current capacities of the environment as our global life-support system.

The recognition of such limitations reflects a major paradigm shift that occurred in the 1980s, where environmental protection has become a third major objective of development. This does not imply preservation of every ecosystem everywhere. Rather, it requires that “sustainable development must not endanger the natural systems that support life on Earth” (WCED, 1987, p. 45), and that the adverse impacts on the quality of the environment (air, water, and other natural elements) are minimised such as “to sustain the ecosystem's overall integrity” (WCED, 1987, p. 46). Correspondingly, sustainable development is broader in conception than traditional conservation-versus development problems. It requires that the goals of social and economic development should be defined in terms of sustainability. However, this is not straightforward.

2.2 Sustainability

Divergent interpretations of the objectives and notional definitions of terms of sustainability are source of confusion, rather than contributions that could help to reinforce the root idea of sustainable development. As a consequence, there is disagreement about the conceptual and operational content of the terms.

Among other reasons, this is caused by:

- differences in disciplinary perspectives, including different paradigms and axiomatic foundations of the dynamic models within which the concepts have been explored; and
- differences in the philosophical and ethical interpretation of sustainable development. This has resulted in different paradigms of economic and ecological, or “weak” and “strong” sustainability. These can also be referred to as economic value principles and ecologically-based physical principles, respectively.

First, “weak” sustainability is an economic principle which is founded within the body of neoclassical capital theory. It is a value principle with the necessary condition that some suitably defined value of aggregate capital including human-made capital and the initial endowment of natural resources must be maintained intact over time. However, this definition is subject to different interpretations about the objectives of sustainable development. In narrow terms, it requires that the generalised production capacity of an economy is maintained intact, such as to enable constant consumption per capita through time (Solow, 1974, 1986). This is also referred to as “Solow sustainability” (Common and Perrings, 1992), or “very weak sustainability” (Turner et al., 1994). In broader terms, “weak sustainability” requires that the welfare potential of the overall capital base remains intact (Opschoor, 1996). This is not restricted to sustaining a material standard of living, or consumption, but also includes values that are related to non-consumptive uses (existence and bequest values) and the public good character (amenity and recreational values) of the environment (cf. Freeman, 1986; Siebert, 1987; Munasinghe, 1993).

Second, the conception of “strong” sustainability emerged from the basic paradigm of ecological economics that the economy is an open subsystem of the finite and non-growing global ecosystem, the environment (Costanza et al., 1991; Daly, 1991a, 1991b). It is a physical principle which is founded upon the laws of thermodynamics, and requires that certain properties of the physical environment must be sustained. As a minimum necessary condition, “strong sustainability” requires that the total stock of natural capital remains constant over time (Costanza et al., 1991; Costanza, 1991; Daly, 1991a; Pearce et al., 1994). Apparently, this implies an “ecological value principle” which measures to total “value” of the heterogeneous stock of natural capital from an ecosystem perspective (Hediger, 1998). In contrast, to make it an operational principle, the above criterion of constant natural capital has been translated into principles of “safe, minimum sustainability standards” (Costanza, 1991). These imply a set of ecological criteria which every project should meet (Costanza, 1991; Daly, 1991a, 1991c). This is a stationary-state principle which is also referred to as “very strong sustainability” (Turner et al., 1994).

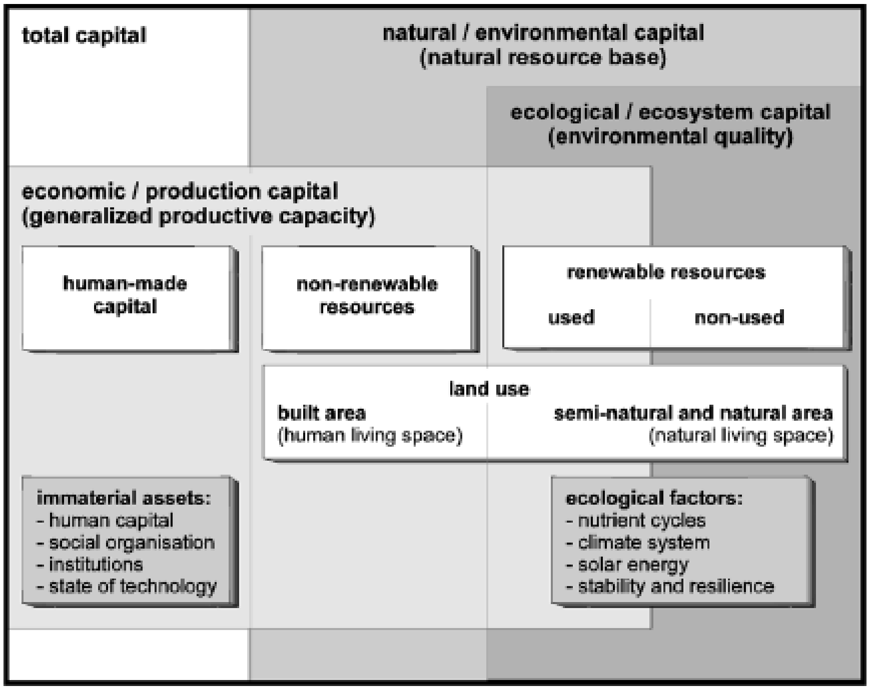
Differences among these concepts are a result of different visions about what a sustainable world can and should look like. This cannot be reduced to differences in the representation of economic transformation processes (production functions), and assumptions about the substitutability of manmade and natural capital. It is also a consequence of notional differences, and particularly involves differences in the way the environment and its functions are integrated and valued. This implies different objectives of what it is that should be sustained, and different conceptions of capital. It is therefore important to investigate these differences.

3. Conceptions of capital and sustainability reconsidered

3.1 Conceptions of capital

Conventionally, total capital is defined as consisting of human-made capital and natural resources. Yet, this is too narrow as a conception for defining operational terms of sustainability. Rather, as illustrated in Figure 1, we may usefully distinguish four main categories of physical assets: human-made capital, non-renewable resources, renewable resources that are used (harvested), and those that are non-used (not harvested) for economic production. These are the key compartments for defining the main aggregates of total capital that can be referred to as economic capital, natural capital, and ecological capital. To provide an overall framework, this must be extended to also include immaterial assets such as human capital, social organisation, institutions, and the state of technology as well as land and other determinants of the ecosystem's carrying capacity.

The generalised productive capacity, or total stock of economic capital (production capital) is an aggregate of human-made, non-renewable, and harvested stocks, as well as the above immaterial assets. Non-used renewable resources are excluded, unless an option value is associated to them for potential future uses. However, there may always be natural areas protected from development, and biological populations that have no instrumental value in present and future production processes. Nonetheless, these “non-used” ecological assets are essential and therefore valuable from a total system perspective. They are essential components of the ecological, or ecosystem capital. The latter can also be referred to as overall quality of the environment, and defined as an increasing function of used and non-used biological resources and the total carrying capacity of the ecosystem which depends upon the space available (this is, the land area of the ecosystem), the flow of nutrients and other factors that are essential for the integrity and productivity of the ecosystem (Hediger, 1998)[1]. Furthermore, we may define natural, or environmental capital as the overall natural resource base; this is, all forms of non-renewable and renewable resources, as well as the total land area (built through natural landscapes), and other ecological factors.



From this perspective, and under consideration of the WCED's overall conception of sustainable development (1987, pp. 43-6), we can judge the various principles of sustainability as follows.

3.2 Strong Sustainability

Strong sustainability is a principle of environmental conservation. It is generally formulated in terms of keeping some aggregate of environmental assets, or natural capital constant over time. However, these aggregates can be variously defined. Therefore, without additional specification, the concept of strong sustainability remains unclear, even from an ecological perspective. In general terms, it can either be referred to as a physical criterion of maintaining the economy's material resource base intact for production through time, or an ecosystem principle of protecting the natural environment as our life-support system, or both.

As a physical principle of production, it implies the strong requirement of balancing the depletion of non-renewable resources with enhancing the stock of renewable resources. In other words, it implies a need for enhancing the ecological capital base (see Figure 1). This is only feasible, if the rate of regeneration of used resources would be increased, or if additional resources would be developed to enlarge the base of resources that can be used in economic transformation processes. This may be questionable from an ecological point of view. Hence, any viable alternative implies an improvement of the generalised productive capacity of the economy without degrading the overall quality of the environment. This will require intensified use of waste materials through recycling processes, investment in technological progress and human capital, and improvement of institutions and social organisations. Correspondingly, sustainability criteria that refer to the physical resource base of an economy should be analysed from an economic capital perspective, and thus integrated in the framework of an economic value principle. Similar caveat applies if the maintenance of the total stock of natural capital is at issue (see Figure 1).

As a consequence, a feasible and viable criterion of strong sustainability is the most suitably defined in terms of maintaining ecological capital intact over time. This is an ecosystem principle which corresponds to the request for protecting our global life-support system (Costanza et al., 1991), and to minimise adverse impacts on the quality of the environment so as to sustain the overall integrity of the ecosystem (WCED, 1987). To this end, the aggregate structure of the ecosystem the life-support system for all species, including humanity needs be taken into account. Critical issues that should be addressed in this context are the stability and resilience of ecosystems, interdependencies of ecological processes, and the non-substitutability of some components of ecological capital (cf. Common and Perrings, 1992; Perrings, 1991, 1996). I shall take up this matter later.

3.3 Very strong sustainability

Very strong sustainability is a stationary-state principle which requires limiting human scale (zero population growth and zero economic growth), enforcing technological progress that is reducing throughput of matter and energy, and compliance with a set of "safe, minimum sustainability standards" (Costanza et al., 1991; Costanza, 1991; Daly, 1991a, 1991b). These criteria may be sufficient for a steady-state economy, but not viable for sustainable development as a process of change. In particular, such stationary-state criteria are not sensitive to essential properties and dynamics of ecosystems, as well as the existence of natural resources, or species, that are not harvested and therefore out of direct control. Correspondingly, the strict application of safe, minimum sustainability standards as a decision rule imposed upon each asset will not in general be sufficient to meet total system requirements, such as the maintenance of natural, or ecological capital (Hediger, 1998). However, it may be useful to selectively integrate stationary-state criteria into an ecosystem principle of strong sustainability.

3.4 Very weak sustainability

The principle of very weak sustainability, or "Solow sustainability", is the economic counterpart to the environmental principle of strong sustainability. It requires an economy's generalised productive capacity ("economic capital", production capital of the economy) be transmitted across generations to maintain a constant level of consumption per capita (cf. Solow, 1986). This is an ethical principle based on an application of Rawls' (1971) maximin principle to a problem of intergenerational equity and intertemporal capital accumulation with non-renewable resources (Solow, 1974). Moreover, it is a value principle which contains within it Hicks' (1939) definition of income as the maximum amount that may be spent on consumption in one period without reducing real consumption expenditures in future periods, and corresponds to the standard welfare interpretation of Net National Product (NNP) as the largest permanently maintainable value of consumption (Weitzman, 1976).

An important feature is that growth in Hicksian income is by definition sustainable, otherwise it could not be counted as income (Daly, 1991a, p. 249). But, this essential property of development is excluded from the Solow model for reasons of intergenerational equity. Rather, Solow sustainability requires an initial stock of total capital big enough to support a decent standard of living, else it perpetuates poverty (Solow, 1974). Correspondingly, Solow sustainability is "less a criterion for sustainable development than a condition for the efficiency of intertemporal resource allocation" (Common and Perrings, 1992, p. 11). It is blind to the dynamic properties of ecosystems, and working in a framework of stationary-state conditions that apart from non-renewable resource depletion and accumulation of reproducible capital provide a rationale for constant consumption per capita through time, given the initial stock of renewable resources (cf. Hartwick, 1978).

Yet, if we would relax Solow's intertemporal maximin criterion, and enable growth in per capita income, then we may obtain a principle of economic development defined in narrow terms of consumption growth that would be sustainable by definition. This would not provide a criterion of sustainability, but rather introduce economic efficiency as an additional criterion for the evaluation of sustainable development boundaries; this is, the benchmarks of a "sustainable development corridor" within which aggregate economic growth would not be in conflict with any sustainability criterion. Correspondingly, the maximin criterion of constant consumption per capita provides a minimum necessary condition for economic development. In this sense, it can be interpreted as "sustainable development frontier" on the economic side of the overall system, rather than a criterion of sustainability.

3.5 Weak Sustainability

Finally, weak sustainability is defined here as an integrative value principle, which requires that the total value of aggregate economic activity and environmental quality should be maintained intact over time. In essence, this is an integrated framework to the ecosystem principle of strong sustainability and the above principle of economic development. It does not need that either stock of ecological capital or economic capital should be maintained intact over time. Rather, weak sustainability requires that some suitably defined value of services of these stocks should be maintained over time.

The rationale of this value principle is that changes in environmental quality can be evaluated and traded-off against changes in aggregate income, and vice versa. This involves the distinction between renewable resources that are harvested and those that are not directly used. This distinction corresponds to the above conception of ecological capital and economic capital, that are integrated into this welfare economic principle.

Correspondingly, we can take into account that, apart from instrumental values in physical transformation processes in an economy (production and consumption), the environment provides non-consumptive services. The latter include:

- functional benefits that are provided through ecological processes, like the regeneration of natural resources and assimilation of waste and pollutants; and
- ecosystem values that are generally associated to the public-good attribute of the environment in providing social benefits to present and future generations, such as recreation and amenity services, or existence and bequest values (cf. Freeman, 1986; Munasinghe, 1993).

Altogether, these non-instrumental values are integrated with the concept of environmental quality which is defined as an increasing function of the totality of environmental assets. They determine the interactions and relationships which are essential for the integrity of an ecosystem ("ecological capital"), and provide public good functions to society (Hediger, 1998). Hence, the concept of weak sustainability integrates the various environmental benefits (value of ecosystem capital) with those of economic development (value of production capacity).

3.6 Integrating Weak and Strong Sustainability

In sum, the principle of weak sustainability is crucial for making sustainable development a meaningful and operational concept. It brings about an evaluation of trade-offs among different system goals. As a minimum criterion, it requires that the total value of aggregate economic activity and environmental quality should be non-decreasing from one generation to its successors. This can be compatible with environmental degradation if suitably compensated by growth in Hicksian income. However, weak sustainability is not sufficient for sustainable development, which also requires that the ecosystem's overall integrity should be sustained (WCED, 1987). This is generally conceptualised as an ecosystem principle of strong sustainability which is consistent with ecosystem resilience, and thus with the maintenance of the overall quality of an ecosystem. This principle of maintaining the physical stock of ecological capital intact over time can also be justified on economic grounds. In the presence of irreversibility and uncertainty, loss aversion felt by many individuals, and the criticality (non-substitutability) of some components of natural capital, strong sustainability applies as valid decision criterion. However, this does not necessarily imply a stationary-state economy, and conservation of every ecosystem and environmental asset. Rather sustainable development requires a process of change that is in harmony with:

- . both ecological and economic minimum conditions, such as ecosystem resilience and basic human needs; and
- . the satisfaction of preferences beyond these limits.

Altogether, this calls for integrating the objectives of weak and strong sustainability, and changing resource allocation over time (Turner et al., 1994) which is usefully formalised in terms of an intertemporal allocation model (cf. Common and Perrings, 1992; Hediger, 1998).

This gives rise to two key questions that are related to the vision of sustainable development. The first question is concerned with the positive dimensions of development. It involves the understanding of the functioning and interdependence of the different subsystems which is fundamental for determining the feasibility and viability of any development path. The second question deals with the normative foundations of sustainable development. It is concerned with the underlying value system and the desirability of optional states and development paths; this is, the integrated objective of sustainable development. This involves further questions about what we want to sustain consumption per capita, environmental quality, or some function of social welfare and the evaluation of trade-offs across different system goals ofsustainability and development. Apparently, this is an issue of formal analysis.

4. Formal Analysis from an Ecological Economic Perspective

4.1 The opportunity space of Weak and Strong Sustainable Development

From an overall ecological-economic system perspective, an important task is to integrate the objectives of weak and strong sustainability with the goals of positive socio-economic development. This paper elaborates an analytical framework of environment-versus-development trade-offs that are implicit to any conception of either weak or strong sustainability, or an integrated principle of both. This framework is based on the above conceptions of capital and sustainability. It allows to formally represent the relative values that are associated to economic and environmental assets. The corresponding analysis inevitably involves the fundamental question about how ecosystems are valued with reference to the economy. Apparently, this is different for different sustainability principles.

If the principle of strong sustainability applies, then environmental quality can be said to be given an astronomical, or asymptotically infinite, value with reference to that of aggregate economic activity. In other words, the environment, or an ecosystem can be said to be considered as sacred capital (Taylor, 1996). In contrast, under the weak sustainability criterion, there exist possible trade-offs between economic activities and the overall quality of the environment. This implies an economic value principle which is based on a total system perspective. It is usefully conceptualised in terms of a social value, or social preference function.

For this analysis, we assume constant population, and that a social preference measure, U, exists which is represented by a strictly concave function of current consumption, or income, Y, and environmental quality, or ecological capital, Q:

$$U = U(Y,Q)$$

$$U_Y\ , U_Q > 0,\ Y_{YY}, U_{QQ} < 0,\ U_{YQ}, U_{QY} > 0,$$

$$\mathit{lim}\ y \longrightarrow 0\ UY\ (Y, Q) = \infty,\ \mathit{lim}\ _Q \longrightarrow 0\ \ U_Q\ (Y, Q) = \infty$$

In principle, this can be thought of reflecting some aggregate of individual preferences, or those of a benevolent dictator. It can be referred to as an individualistic, preference-based aggregate value function. For the formal analysis, this can be introduced into different frameworks. In any case, the value function U provides the normative representation of the analytical framework which constitutes the basis for evaluating trade-offs between economic development and environmental quality.

Preference-based social value function: $U = U\ (Y, Q)$.

. Weak sustainability $U = U_Y\, Y = U_Q\, Q \geq 0$

.Strong sustainability $Q \geq 0$

Integrated weak and strong sustainability

$U = U_Y\, Y + U_Q\, Q \geq 0$ and $Q \geq 0$

Economic growth (“development”)

$$Y \geq 0$$

.Weak sustainable development

$$U \geq 0 \text{ and } Y \geq 0$$

. Strong sustainable development

$$Q \geq 0 \text{ and } Y \geq 0$$

Weak sustainability requires that at least the aggregate value U remains constant over time. This is, the weighted sum of changes in aggregate income and environmental quality should not intertemporally decrease. The weights are determined by the marginal value U_Y and U_Q of aggregate income and environmental quality, respectively. These values are not constant. Rather, they reflect the characteristics of the underlying value function at the current stage of economic development and quality of the environment.

The minimum requirement of strong sustainability is the maintenance of the current stock of ecosystem capital. This is a physical principle that can also be included in a value concept of weak sustainability. The result is an integrated principle of weak and strong sustainability that requires both compliance with non-decreasing aggregate values, and a constant stock of ecological capital. This may be compatible with a decrease in aggregate income, and therefore be in conflict with the requirement of income growth. The latter is an essential means for enabling development, but in itself is a highly imperfect proxy for development (World Bank, 1992). Nonetheless, it is crucial for sustainable development. Indeed, since growth in Hicksian income is sustainable by definition, growth of income per capita should be considered as a minimum requirement for sustainable development. Otherwise, we may refer to a concept of sustainability, rather than development. Correspondingly, an integrated framework is requested which adequately matches elements of weak and strong sustainability with those of economic development.

The above conditions for weak and strong sustainability and economic development are illustrated in Figure 2. For any given situation, or state of development (Y_0;Q_0), the frontiers of weak sustainability, strong sustainability, and economic development are determined by U_0, Q_0, and Y_0, respectively. Apparently, these frontiers are state dependent. They are historically determined. In other words, sustainable development frontiers are the consequence of past development. Together, they determine the boundaries of the opportunity space for sustainable development.

As formally represented above, and graphically illustrated in Figure 2, the opportunity space for sustainable development can be categorised into domains weak and strong sustainable development. The weak form would enable development into areas 1 and 2, whereas strong sustainable development is characterised by an opportunity space that is restricted to area 2 . In contrast, any transition into area 3 would be both consistent with weak and strong sustainability, but not compatible with the requirement of growth in Hicksian income, and thus with a minimum requirement for economic development. Correspondingly, development into area 2 is the sole opportunity of change that is consistent with the conjoint requirements of weak and strong sustainability and economic development.

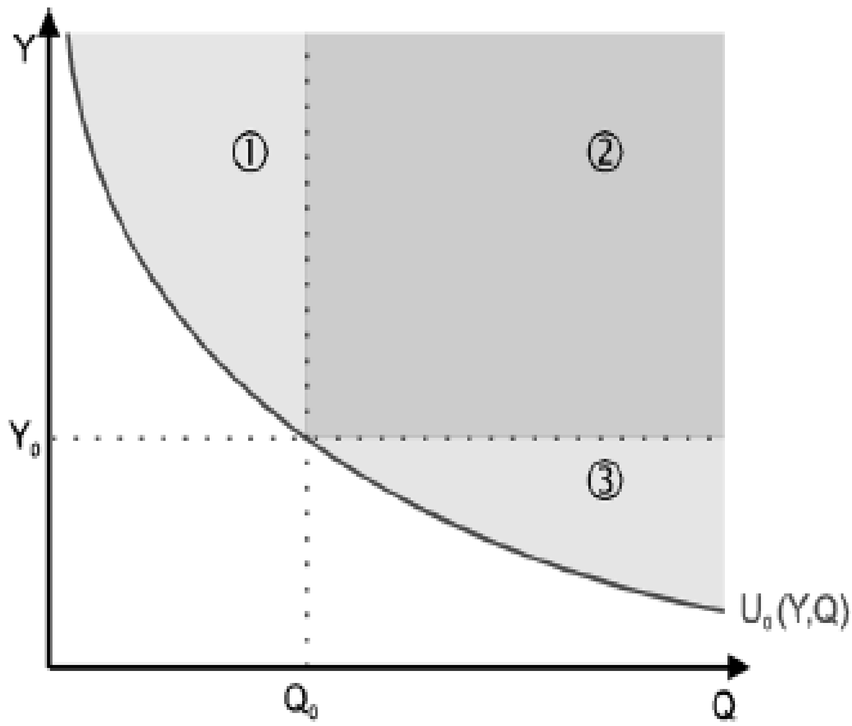
Development into area 2 is not only sufficient for weak sustainable development, but also for strong sustainable development (see equations above). However, it can only be realised:

1. if investments are undertaken into technological progress or change that is sufficient for reducing adverse impacts upon the quality of the environment; or
2. if it would be possible to improve the stock of ecological capital without reducing the level of aggregate human activity.

The first, technology option seems very promising to various groups of people. It involves engineering solutions and induces investments within the economic system. Correspondingly, it has gained much attention in the economic literature. Potential and limitations of this option have been largely discussed in the broad context of economy and the environment (e.g. Faber et al., 1987; Tisdell and Maitra, 1988; Victor, 1991; Giampietro, 1996; Hourcade et al., 1996; Gowdy and O'Hara, 1997). In contrast, the second option is by far less attractive to engineers and economists. It requires investments in environmental assets, such as to improve the ecological capital base. Yet, this is only feasible if beneficiary ecological effects could either result from increasing the assimilative or regenerative capacity of the ecosystem, or from making land use changes reversible (cf. Hediger, 1998). Otherwise, any feasible and viable option of sustainable development must be formulated in terms of a value principle which enables a trading off of environmental assets against economic benefits.

This accentuates a dilemma of sustainable development that on the one side, aggregate income growth will generally go along with a decrease of ecological capital (development into area 1 of Figure 2), and, on the other side, ecosystem improvement would only be possible at the cost (sacrifice) of income (development into area 3). These alternatives bear the risk of alterations of the ecosystem or socio-economic system that may be undesirable from an overall system perspective. To reduce this threat, we need to integrate some minimum requirements of strong sustainability, along with that of weak sustainability and economic development.

Figure 2 : Illustration of Reconciling Week and Strong Sustainability



We can formally define terms of sustainability and sustainable development from an ecological-economic system perspective, and reconcile the above concepts of weak and strong sustainability. The minimum conditions for integrating weak and strong sustainability are:

Ecological-Economic Sustainability (EES):

$$W = W_Y Y + W_Q Q \geq 0$$

$$Y > Y_{\#} \quad \text{and} \quad Q > Q_{\#}$$

. Ecological-Economic Sustainable Development (EESD):

$$\text{EES plus } Y \geq 0$$

This says that, from an ecological-economic system perspective, sustainability requires that the social value, W, should not decrease through time. However, the underlying value function W, and therefore the above condition for ecological- economic sustainability (EES) is only defined for $Y > Y_{\#}$ and $Q > Q_{\#}$; this is, the region of compliance with aggregate economic and ecological minimum standards for sustainable development.

5. Conclusion

Sustainable development is a global challenge, which calls for envisioning both conservation and change. It is a normative concept, which involves conflict across various system goals that may be optimally achieved through an adaptive process of trade-offs. This cannot exclusively be addressed with either an economic value principle of “weak” sustainability, or an ecologically-based physical principle of “strong” sustainability. Rather, an integrated approach is required that is based on an ecological-economic system perspective of development and preservation of the environment as our life-support system. This needs to be suitably extended to the social context of development and the environment, which remains subject to further research. The focus of this contribution is to reconcile the conceptions of weak and strong sustainability in a context of economy-environment interactions.

A major problem of sustainable development analyses is that traditional principles of weak and strong sustainability are based on different conceptions of capital, and different objectives of what it is that should be sustained. As a consequence, they are mutually exclusive, rather than reinforcing the root idea of sustainable development. For this reason, the conceptions of capitaldevelopment. aggregates and sustainability principles have been reconsidered. The illustration in Figure 1 underlines that it would not be sufficient for sustainable development if some suitably defined aggregate of capital, natural or total, would be maintained intact over time. First, the root of the problem is the coexistence of environmental assets that are used in economic processes, and those that are non-used. The former have both an instrumental value in the production of goods and services, and a functional value within the ecosystem. They are part of the economy's generalised productive capacity (economic/production capital), as well as part of the ecosystem's capital base and determinants of environmental quality. The latter includes elements of the natural resource base that have no instrumental use, but may be essential for the functioning of the ecosystem. As a consequence, the economic and ecological capital bases are overlapping. Second, the physical criterion of maintaining the material resource base of the overall system intact through time will not in general be sufficient for sustainable development. Rather, this should be extended to protecting the natural environment (ecosystem capital) as our life-support system. In order to comprehensively address the challenge of sustainable development, the ecosystem principle of strong sustainability may be usefully integrated with the value principle of weak sustainability. The latter requires that the total value of aggregate economic activity and environmental quality should be non-decreasing from one generation to its successors.

Having accepted such integrated framework of weak and strong sustainability, we need to identify the requirements for sustainable development. These can be referred to as minimum conditions of sustainability and development, respectively. First, assuming constant population, a minimum requirement for development is that, if suitably defined, aggregate income should not decrease. This is consistent with the fact that growth in Hicksian income is sustainable by definition. But, it gives rise to a dilemma of sustainable development. The problem is that:

- either technological progress or opportunities of environmental improvement must be sufficient to enable a strong sustainable development; or
- economic development results in continuous degradation of the ecosystem capital as it is not generally possible to realise economic growth without physical expansion of the economy which involves land use and cover change.

Under these circumstances, sustainable development requires stabilisation of ecosystem capital at a level that is compatible with the minimum standard of ecosystem resilience.