Sustainability as a Resource Distribution Constraint

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Abstract: The aim of this article is to provide a deeper analysis on the concept of sustainability. In this respect, we make use of the large body of scientific work developed hitherto on the subject. The main focus of the article is the problem of sustainable development under limited resouce constraints. The implications of our research are that sustainability cannot be a function maximization issue (regardless of what quantity would be maximized), due to the fact that sustainability is a functional dependent on three functions, all of which are heavily reliant on capital. Given the fact that capital is limited, one cannot maximize one of the functions, without minimizing another. We conclude, thusly, that sustainability is a constraint on development, at the root of which lies the problem of limited capital.

Keywords: Sustainability; capital; sustainable development; development constraints.

JEL Classification: Q00; Q01; Q32.

1. Introduction

Sustainability has become one of the leading problems to face humankind in the XXI century, stemming from an already complicated situation, passed on from the last century. Despite this, the goal of sustainable development, asserted in order to achieve sustainability for the human global community is a poorly defined one. Indeed, some scholars have even challenged the very core of the notion (Beckerman 1992, 1994). Past these methodological issues, largely confined to the academic medium, one might be entitled to ask: what exactly does sustainability comprise? If we adopt a standard, albeit vague definition, one might say that a sustainable society is one in which no generation has to undergo stages of diminishing welfare (see Solow 1974a, 1974b, 1986, 1993a, 1993b). But if we set this as a starting point, why not go beyond it, and say: a sustainable society is one in which welfare is maximized for any given generation? This idea seems highly appealing, since it paints the brightest picture of our future; but is it feasible?

The concept of non-diminishing welfare, proposed by Robert Solow is a good starting point for any discussion on sustainability; however, from this expression one can logically deduce that an extended period of increasing welfare crawl also

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fits the criterion. Nobody would find that desirable, although, in a technical sense, it would be sustainable. At this point, a common sense approach would tell us that the optimum sustainability scenario would be one that combines the concept of non-diminishing welfare with that of maximizing the utility or welfare gained by each generation. But is such a scenario possible? John Pezzey wrote the following: "*[…] sustainability may be viewed as a constraint on the conventional optimality criterion of maximizing discounted utility […]*" (Pezzey, 1992. p. xi). There is no further explanation for this assertion, and the word *may*, from the given quotation is clearly a guarding term. In this article, we will explain why sustainability is a resource distribution constraint and briefly discuss some of the implications of this result.

2. The Model

Sustainable development depends very much on the interpretation of the future that each individual has. The logical implication of this situation is that, if individual preferences are not fixed, then sustainable development policies cannot be fixed, lest we risk having unwanted policies. Assume the following example:

Let there be a community of X number of people, at a given time Y. At this moment, let us assume that all the individuals in the said community value lowering the income inequalities, as a sustainability goal for the future. Given the fact that any sustainability criterion is implicitly assuming a designated time period of 20 years or more, we conclude that at time Y (initial time), the leaders of the community establish a plan for sustainable development, with reducing income inequalities as the main objective.

Now let there be a time Y+10 years. In this period, due to various reasons (one of which might be the coming of age of another generation, which has different priorities), the community shifts its focus from income inequalities to environmental preservation. This is not due to the fact that the problem of income inequalities has been eradicated. Indeed, the problem might have been barely addressed. Yet now, at Y+10 years, society views the problem of sustainability with a different lens. Regardless of the reasons behind this situation (and there can be many such reasons, including manipulation), the individual preferences have changed, and this has impacted on the way our fictional society views its sustainability. The fact that individual preferences change over time need not necessarily be a bad thing; however, if we agree that sustainable development is a concept overlooking a long to very long time period (20 years or more), while individual preferences can easily change from year to year, it is clear that there is a difference in perspective, and this can undermine any such forward looking plans.

There is, of course, an underlying structural problem in the previous paragraph:

individual preferences cannot be cumulated in a mathematical sense, in order to determine a societal aggregate preference, unless every person has exactly the same view towards sustainability. This can only occur if one the following 3 cases are present:

- all the humans have turned into robots, and have, thus, the same goals;
- the governing system is liberty-restricting in such an acute manner that it is able to impose its goal as universal, regardless of what each individual wants;
- the problem at hand is so pressing that there is a general, circumstantially imposed consensus that, unless the given sustainability problem is fixed, the consequences for the human community will be disastrous[1].

The implications of our previous rationale are that individual preferences should be considered when determining a policy for the welfare of future generations, and that there is a temporal discrepancy between sustainability policies and individual preferences. More-so, issues like temporal discounting can severely affect any consensus on a given policy. But what could that consensus be about? The current Economics literature is concerned with three domains, regarding sustainability: economical/ecological/social sustainability[2]. Although clearly many more issues could be found, let us assume that, indeed, any policy on sustainability needs to address these three key issues. The sustainability can then be expressed as a functional of the following form:

$$S = f(E_c, E_g, S_o),$$

where E_c represents economical sustainability, E_g represents ecological sustainability and S_o represents social sustainability. S is the aggregate sustainability criterion, which would, in theory, have to be maximized, in order to achieve the best results.

The three component functions can be defined thusly:

$$E_c = f\left(\overset{+}{Q}, \overset{+}{C}, \overset{+}{I}, \overset{+}{S_a}\right),$$

where Q is production, C is consumption, I is investment, and S_a are the savings. The symbols above the variables denote their probable impact on the sustainability

[1] Even so, there might be people who will oppose, either out of stubborness, ignorance, or a failure to truly comprehend the implications of the situation. It is, therefore, acknowledged that only the first two cases are viable, although neither seems to be of any particular appeal.

[2] Splitting the problem of sustainability into three parts like this means that there is a need for an interdisciplinary approach. For other subtleties that stem from this division, see Costanza & Folke (1997) and Costanza (2000).

criterion. Clearly, more variables could be loaded, like the comercial balance, interest rate and so on. Also, we could delve deeper and analyse each of the component functions, with regards to their dependent variables. However, neither of these complications would return any benefit for the purpose of this article.

$$E_g = f\left(\overset{-}{P}, \overset{-}{H_l}, \overset{+}{S_n}, \overset{+}{S_d}\right),$$

where P is pollution, H_l is human appropriation of land, S_n represents the number of species and S_d would be a species diversity indicator[1].

$$S_o = f\left(\overset{-}{I_I}, \overset{-}{P_o}\right),$$

where I_I would measure income inequality and P_o would measure the rate of poverty.

The previous formulas are just unsofisticated premises for the reasoning that will shortly be exposed. In no way should it be understood that social sustainability, for example depends on just two factors. In the same manner, it might well be that some of the variables do not behave in a monotonous manner.

For example, it might well be that past a certain threshold, more consumption simply does not make our economy any more sustainable (for some remarks in this manner, see, for example, Costanza & Daly 1992; Daly 1992, 2005). There is more to be said on this particular aspect, though. Some of the function components show positive correlations between them. For example, consumption and production have been known to increase pollution, at least to a certain point[2]. Similarly, the impact of invesments on income inequality is uncertain. *Ergo*, even though raising investments might be beneficial for raising the economic sustainability of the community, it might impact negatively on the social sustainability, by raising the income inequality. We can therefore hypothesise that each variable has a threshold, past which, even though it is still positively impacting its function, the effects spillover and lower the other sustainability criteria. This can clearly cause problems when deciding on sustainability policies, since not only do we not fully know how the variables within a sustainability function interact with each other, or with the variables of the other functions, but we also do not have a complete picture of what any of the three forms of sustainability are dependent on. This is also contingent on

[1] There is a growing literature in Ecology, which asserts that environmental sustainability is correlated with the diversity of the inhabiting fauna and flora. This means both in number and in functional role within the given ecosystem (*e.g.* Tilman & Downing, 1994; Tilman *et al*., 1996; Tilman *et al*., 1997; Tilman *et al*., 2006; Naeem *et al*. 1994)

[2] This is the case when the distribution follows a standard environmental Kuznets curve. For a different, more pessimistic hypothesis, see Max-Neef (1995).

the fact that, as asserted in previous pages, individual preferences can change in a short time interval[1].

2.1. The Substitution Hypothesis

There is a debate in the field of economics, with regards to sustainability, and, in particular, to the degree to which human-made capital can substitute for natural capital. This stemmed from a growing fear of exhausting natural resources, in the second half of the XX[th] century. This fear matured and invaded the academic circles with the publication of the *Limits to growth* report (Meadows *et al.* 1972). Prompt answer was given to this transgression, with the works of Solow (1974a), Dasgupta & Heal (1974) and Stiglitz (1974). Essentially, the answer was simple: technological progress, obtained via economic growth would allow humans to substitute the exhausting natural capital with human-made alternatives. This point was not easily accepted and, although it remains the "official" perspective in mainstream economics, a new approach to sustainability was devised in order to "properly" address the issue. In time, the rift between the two sides grew, and it is of this reason that we now speak of two sustainability paradigms: *weak sustainability* (Solow 1974a, 1974b, 1986, 1993a, 1993b; Hartwick 1977, 1978a, 1978b, 1990, 1991; Dasgupta & Heal 1974; Nordhaus 1973, 1991; Stiglitz 1974), and *strong sustainability* (Daly 1992, 1994, 1996, 1997a, 1997b, 2005, 2008; Daly & Costanza 1992; Daly & Cobb 1989; Pearce 1998; Pearce *et al.* 1989; Turner & Pearce 1992; Hueting 1980; Hueting & Reijnders 1998; Spash 1993; Ekins 2003)[2].

As mentioned before, one of the key points of dissent between these two paradigms is represented by the substitutability hypothesis: depleting natural capital will, in the long run, be substituted by human-made capital, brought on by technological progress. This view is asserted by weak sustainability adepts and can be viewed, thusly, as the point of view of mainstream economics. If we accept this bold idea, then some of the variables within our limited model undergo changes. One example would be the relation between Q and P, in that, if we allow for a complete substitution to take place, then it is reasonable to assert that, even though production will increase, the effects of pollution will be mitigated by human-made substitutes for the faltering forms of natural capital. Although highly unlikely at this moment, one could imagine, for example, that discrepancies in the global nitrogen cycle, due to increased usage of fertilizers, could be alleviated by human intervention. The implications are extraordinary, and so is the strain put on technological progress[3]. Although interesting in itself, the topic of extolling technological progress cannot be further investigated in this paper. What we are

[1] This is especially pertinent in the case of social sustainability.
[2] For a discussion on the two opposing paradigms, see Neumayer (2010).
[3] Once you assert the posibility of a substitution between all forms of natural capital and human-made capital, it becomes clear that the only vector by which you can do this is technological progress. This places a high amount of trust on a variable that is inherently chaotic and unpredictable in nature.

interested in, though, are the implications of this principle of substitution.

Impact on our Model

If we accept the principle of substitution, then it becomes clear that capital plays a key role. Capital spurs on technological progress, but it is also vital because it *de facto* supports the process of substitution. Lowering the poverty rate requires financial resources; installation and maintenance of solar plants also requires capital. All activities which can be circumscribed to the sphere of sustainability policies require capital. Graphically, this is represented in Figure 1. Seemingly, there is nothing out of the ordinary to this assertion. Essentially, every aspect of a modern economy depends on capital. Therefore, the logical inference that any policy involving the three pillars of sustainability is based on capital is really unassuming.. The implications are, however, less dreary. For if all three sustainability criteria are based on a common and limited resource pool (capital), then it stands to reason that one must carefully balance the flow of resources, in order to fullfil all the economical, ecological and social objectives. Mathematically speaking, this means that one cannot simply maximize all the three sustainability functions, and implicitly, the aggregate *S* function, due to the fact that maximizing any one of these functions uses up the available capital. *Ergo*, in a hypothetical case in which one would desire to maximize the economical sustainability criterion, both the ecological and the social pillars would be left without resources to be operative. In other words, the sustainability problem, as understood today, with its three criteria, is not a function maximization issue, but rather an optimum distribution of resources constraint.

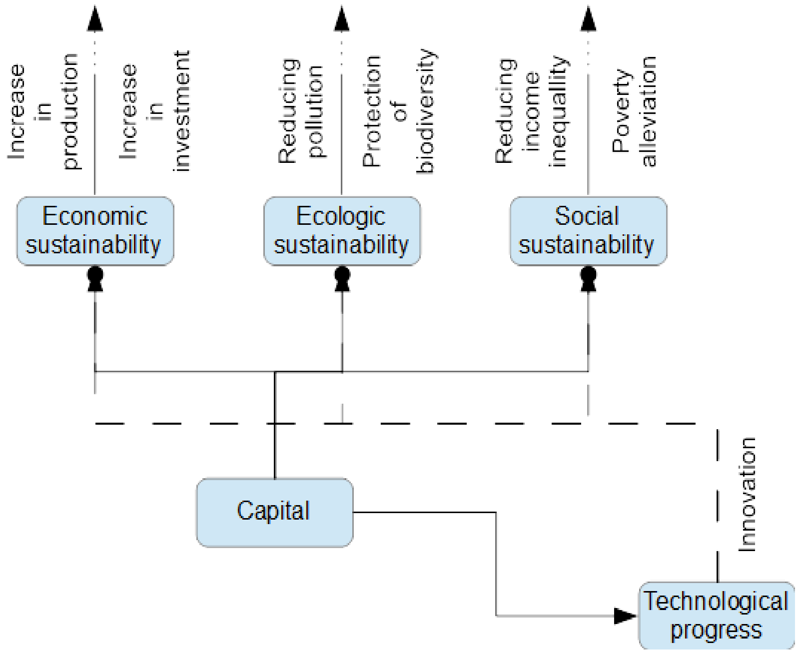

Figure 1. Capital as the basis both for technological progress and economic, ecologic and social sustainability

Source: own work

There would probably be little or no oposition to the statement that capital is limited. The whole discipline of economics is founded on the notions of scarcity, and capital, as any good, is subject to the same law of scarcity. Whether this scarcity is caused by the laws of Thermodynamics, as asserted in the works of Georgescu-Roegen (1971, 1972, 1975, 1986), or by other factors is beyond the discussion of this article. Although there are some voices which see the future of economics painted in different colors (Nordhaus 1973), it is clear that at the present time our capital resources are limited.

But what would an optimum distribution of resources actually mean? On paper, we are able to elaborate static models, in which we can safely modify variables and quickly decide which distribution would be optimal. In reality an optimum distribution of resources is rarely achieved, and even in such occasions, it is not long lasting. A rational way of going about the distribution of limited resources would be this: assuming the three pillars of sustainability E_c, E_g and S_o, logic would dictate that the best course of action would be to invest one aditional unit of capital in the pillar which returns the greatest benefit. This is certaintly easy to do on paper, but some of the component variables defined in the previous pages of the article show a time lag characteristic which prevents rapid analysis. For example, one dollar spent on reducing air pollution might show improvement in the actual quality of the air in a few years time, and not immediately. In order to solve this issue, one could use a system of weights, in order to prioritize policies. An example could be:

Define capital investment in any sustainability criteria as an improvement:

$$\frac{\dot{E}_c}{K} > 0; \frac{\dot{E}_g}{K} > 0; \frac{\dot{S}_o}{K} > 0,$$

where the numerators represent first order derivatives with respect to the denominator, capital (K).

Define the ecological sustainability criterion as the bringing the most benefits:

$$\left(\frac{\dot{E}_g}{K} > \frac{\dot{E}_c}{K}\right) \wedge \left(\frac{\dot{E}_g}{K} > \frac{\dot{S}_o}{K}\right)$$

At this point, a rational decision would be to invest in ecological sustainability. If we define weights, though, the formula might look like this[1]:

$$\left(\alpha \cdot \frac{\dot{E}_g}{K} > \beta \cdot \frac{\dot{E}_c}{K}\right) \wedge \left(\alpha \cdot \frac{\dot{E}_g}{K} > \gamma \cdot \frac{\dot{S}_o}{K}\right),$$

where α, β, γ are all weight coeficients varrying in value from 0 to ∞. These coefficients could encompass the effect of time lag; for our previous example on reducing air pollution, α would be bellow 1, meaning that the overall effects would be lessened. These weights should encompass other factors, such as the time preference of the community (time discounting), spatial discounting, community preference[2], *etc*. This could mean defining the weights as vectors, in a form similar to this:

[1] This assumes that the weights have no impact on the previous inequations. As we can see, whatever the value of the weights, our inequations have not changed. In reality, it is highly likely that weights could severely impact on the sustainability policies adopted.

[2] For a brief discussion on notions such as time lag, temporal discounting and spatial discounting, see Daily & Ehrlich (1992).

$$\alpha = \{\alpha_1; \alpha_2; \alpha_3; ...\}; \beta = \{\beta_1; \beta_2; \beta_3; ...\}; \gamma = \{\gamma_1; \gamma_2; \gamma_3; ...\}$$

In this form, each of the vector components could be associated with one of the auxiliary effects, such as time lag, spatial discounting, *etc*. The weights are unique to every pillar of sustainability, due to the fact that some of these vector components would be themselves unique to that pillar. For example, if we define the discounting of time as one of the vector components of each weight, we might find that for *α*, it has a high value, which means that with regards to their environment, people heavily discount the future; all the while, with regards to social issues, people might have a very low discount rate, due to the fact that the community would perceive lowering the poverty rate as a crucial objective. In this respect, the environment could be seen as a more distant issue, while alleviating the situation of the poor could be seen as a more pressing matter. If other vector components vary as in this example, the result is that the weights are different for each pillar, which accurately describes reality. Time lag in showing the results of sustainability policy is similar, although for different reasons, in the sense that, as we have seen, it can be high in environmental issues, while in economical and social issues, it can be significanly lower.

In a sense, the first order derivatives would show the return on capital investment, while *α*, *β*, and *γ* weights would show both how readily the given effect would reveal itself, but also how the community would view the effect. We have no desire to go into further detail regarding these weights, as this crude analytical model serves only the role of conveying the difficult nature of determing a optimum distribution of resources. The logical implication of the forementioned analysis is that decisions regarding sustainability will not only be made by seeking the best returns on capital investment (which would mean computing the first order derivatives), but also the plethora of auxiliary effects (which would mean computing the weights).

3. Implications for Human Sustainability

In the narrowest sense, our analysis is meant to show that in the short run, economical sustainability is subject to more variables than those restricted to the discipline of Economics. In the broadest sense, and taking a longer perspective on time, we show that sustainability cannot equal maximization of consumption (or any other index of economic prosperity). Indeed, building upon previous work, we could place sustainability in between survivability and optimum economic growth[1]

[1] We have only focused on sustainability in this article, but for the following paragraphs to make sense, we need to mathematically define the concepts of *optimum economic activity* and *survivability*. *Ergo*, we define the optimum as the maximizing function of human welfare, at present value; in other

(see Pezzey 1992, p. 12). While this article has not even mentioned survivability hitherto, we could graphically depict the forementioned situation in the following figure:

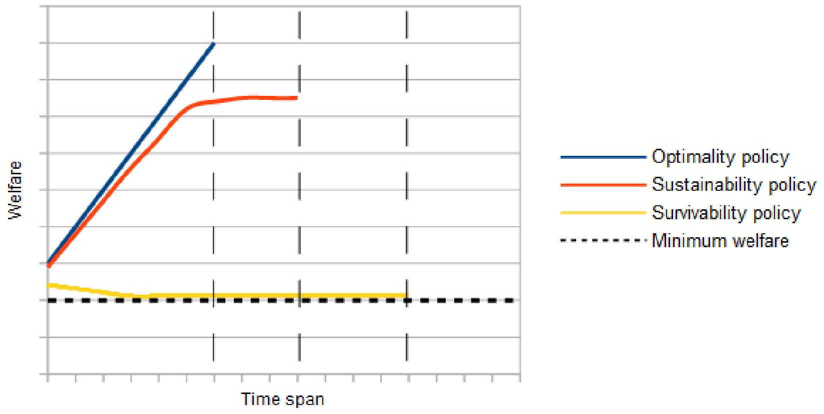

Figure 2. Sustainability scenario, plotted against the two other alternatives

Source: own work

The interpretation is that, taking into account the rarity of resources, the time span of the human society is maximized in the survivability scenario, due to the fact that the least resources are used then. This obviously is not a welfare maximization case, and the level of welfare would most surely be below the general satisfactory threshold. At any rate, the difference between our optimum economical welfare and our sustainability case is clear: while the optimum case maximizes welfare at a present value, the future is heavily discounted in such a manner that the scarceness of resources dictates a limited horizon for the human enterprise. The sustainability scenario, on the other hand, is concerned with limited welfare but with a longer time period for the society.

What the crude graphical representation above tells us is that we should never expect optimality, however defined, to stem from a sustainability policy. This is so because sustainability is concerned with tracing a fine balance between economic welfare and the lifetime of the human society. Given the fact that our resources are

words, $\max \int_0^\infty U(t) \cdot e^{-\delta t} dt$, where U is utility gained (welfare), t is the time span, and δ is the social discount rate. Survivability means simply that $U(t) \to U_{\min}(t)$, where $U_{min}(t)$ represents the minimum amount of welfare that a given community needs at time t. For a broader discussion focusing on all these three concepts, the reader is invited to see Pezzey (1992).

limited, we should never expect, in the long run, for sustainability to equate to optimality.

4. Conclusions

Following our analysis, we can summarise the results in the next paragraph: technological progress and capital resources are both required in order to develop and implement policies on sustainability. Given the fact that our resources are limited, and all sustainability criteria depend on a common pool of resources, it follows that sustainability cannot be an issue of function maximization. Maximizing any of the three pillars of sustainability would deplete resources for the other two. Therefore, the issue at hand is one of optimum distribution of resources between the three factors. But even this task is not forthcoming, since developing policies on sustainability depends on both a calculus of cost/benefit analysis, but also a host of other factors (deemed auxiliary effects). Among these are exogenous factors, like the time lag between policy implementation and actual result (most obviously found in ecological issues), but also endogenous factors, like time preference, spatial discounting, *etc*. These factors can severely impact on the common cost/benefit analysis, and should be taken into account when sustainability policies are elaborated. All these conclusions are contingent on the assumption that that a full substitution between natural capital and human-made capital is possible.

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