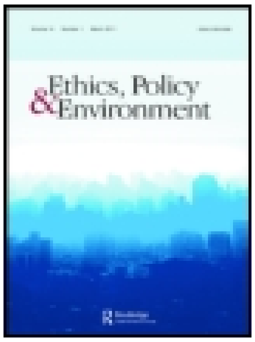

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Some Truths Don't Matter: The Case of Strong Sustainability

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ABSTRACT
The proponents of strong sustainability have advanced four main arguments for the non-substitutability of natural capital: the existence argument, the Aristotelian argument, the motivation argument, and the argument from *critical* natural capital. This paper argues that the first three arguments fail while the fourth cannot be properly assessed without clarifying the notion of critical natural capital. To that end, this paper develops a specific account of critical natural capital as ecological conditions required for the continued existence of economic agents. This improved argument establishes that strong sustainability is probably true, but it also reveals that it may not matter for the purpose of public policy.

1. Introduction

Social scientific models of sustainable development show that, for the goal of sustainability, the aggregate level of capital must remain intact. With respect to these models, there is no greater point of disagreement than the putative substitutability of natural capital. Neo-classical economists often assume that natural capital is substitutable and thus, any depletion in this stock can be offset by the accumulation of manufactured capital. This position, commonly called 'weak sustainability', is traditionally associated with the work of Robert Solow (1986, 1993)), among others. On the other hand, ecological economists, such as Robert Costanza and Herman Daly (1992), have long argued that there are at least some instances of natural capital that have no substitutes. This canonical position has been labeled 'strong sustainability'. Strong sustainability is true if and only if natural capital, or a subclass of natural capital, has no substitutes.

The proponents of strong sustainability have offered at least four arguments to support their claim that natural capital is non-substitutable: the existence argument, the Aristotelian argument, the motivation argument, and the argument from *critical* natural capital. This paper argues that, while the first three fail to establish the non-substitutability of natural capital, the fourth cannot be properly assessed without first clarifying the concept of critical natural capital. To that end, this paper develops a specific account critical natural as ecological conditions required for the continued existence of economic agents. Such 'basic ecological

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conditions' are distinct from ordinary goods in standard consumer choice theory since the former are objective conditions that must be met for an agent to exist while the latter merely yield subjective utility to agents that already exist. It will be shown that the central reason why basic ecological conditions are required for the continued existence of agents is because they possess objective causal properties that are essential for this purpose.

This improved argument from critical natural capital establishes that strong sustainability is probably true. Be that as it may, it will also be argued that strong sustainability is superfluous for the purpose of public policy. Why? On the assumption that economic agents are committed to sustainable development, the basic ecological conditions denoted by the concept of critical natural capital will also be essential for sustained economic production and the agent welfare that depends on it. And, since the proponents of weak sustainability would never endorse a policy that reduces either of these variables, weak and strong sustainability collapse into the same position.

The paper is structured as follows. The next section briefly considers the social scientific approach to sustainable development; section three evaluates the four main arguments for the non-substitutability of natural capital. Sections four and five improve the argument from critical natural capital by giving a specific account of the ecological conditions required for the continued existence of economic agents. Section six then argues that while the revised version of this argument establishes strong sustainability, the policy consequences are negligible. Section seven concludes.

2. The Social Scientific Approach to Sustainable Development

Sustainability is an interdisciplinary topic that has not only attracted the attention of philosophers and natural scientists but social scientists as well. Political philosophers have generally taken sustainability to be a matter of intergenerational justice, while giving special attention to the problem of anthropogenic climate change.[1] Natural scientists working on the topic of sustainability – 'sustainability scientists' – describe their relatively new field as one that is concerned with the interactions between natural and social systems, and how these interactions affect the challenge of sustainability: meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems (Heinrichs, Martens, Michelsen, & Wiek, 2016; Kates, 2011). This paper sets aside these two approaches to the sustainability and focuses on the economist's approach to sustainability or what will be termed the 'social scientific approach to sustainability'.[2]

The social scientific approach to sustainable development was originally motivated by *Our Common Future* and was pioneered by the earlier work of Solow (1986, 1993), among others. This approach involves sustaining the productive capacity of an economy over time whereby 'productive capacity' is represented by the aggregate level of capital in an economy. Sustaining capital over time requires following 'Hartwick's Rule' whereby total net investment in capital remains above or equal to zero (Hartwick, 1977, 1978). Otherwise, if net investment were to fall below this threshold, then capital would be depleted and since the stock of capital represents the productive capacity of an economy, present and future human welfare would also decline.

Ken Arrow et al.'s (2004, 2010) most recent instantiation of such models shows that a sustainable economy will remain capable of providing the current standard of living across generations as long as each generation bequeaths to its successor at least as large a quantity of an economy's 'productive base', which is composed of three distinct capital assets: human, natural, and manufactured capital. Manufactured capital includes the traditional produced means of production, such as machines, factories, and tools; human capital includes items such as knowledge, technology, and institutions; and the stock of natural capital consists of traditional renewable and non-renewable resources, but it also denotes various non-market phenomena, including ecosystems.

With respect to such models, two main positions have been advanced: weak and strong sustainability.[3] The source of this division rests on the disputed substitutability of natural capital, a topic that has filled the pages of several journals.[4] Weak sustainability requires that the *total* stock of capital is held constant across time or between generations. Under this view, agents can always deplete natural capital provided that it is replaced by a sufficient quantity or level of manufactured capital. What matters is not that any particular stock of capital is depleted over time but that the *overall* stock of capital remains intact. By contrast, strong sustainability maintains that since natural capital and manufactured are complements rather than substitutes, sustainable development requires that *each* stock of capital should be held constant, independently. While the proponents of this latter view sometimes recognize exceptions to this rule – that there are instances of manufactured capital that might serve as a substitute for natural capital – the extent to which this holds true is a matter of disagreement.

3. Arguments for the Non-Substitutability of Natural Capital

The proponents of strong sustainability have deployed several arguments to support their claim that natural capital is non-substitutable: the existence argument, the Aristotelian argument, the motivation argument, and the argument from critical natural capital. It will be argued that while the first three arguments fail, the fourth cannot be properly assessed without first clarifying the concept of critical natural capital, a project that will be undertaken in sections four and five.[5]

The existence argument contends that manufactured capital invariably depends on the existence of natural capital but that the existence of natural capital does not depend on the stock of manufactured capital. If there was no natural capital, then there would be no manufactured capital. Without manufactured capital, then welfare-enhancing economic production would grind to a halt. Therefore, in order to sustain production, natural capital needs to be sustained independently. For this reason, natural capital and manufactured capital are better viewed as complements rather than substitutes.

The problem with this argument is that, aside from establishing a one-way dependency relation between natural and manufactured capital, we could still accept the existence argument while accepting the claim that substitutability between manufactured capital and natural capital remains the general rule. Moreover, even if the existence argument is true, it is conceivable that the entire stock of manufactured capital could be produced with a very small quantity of natural capital (Jamieson, 1998). The point being made here is that improved techniques alone might well enable future production processes to employ far less natural capital than they do today.[6]

One might respond to this argument by insisting that improved techniques alone will not enable future production processes to employ less natural capital, but this claim is simply not supported by the empirical evidence, which suggests that technology does in fact (frequently) reduce the amount of raw material used in production.[7] Of course, this claim does not entail that *every* instance of natural capital is necessarily substitutable. As we will see below, this is precisely the claim that is being denied by those who accept the argument from critical natural capital.

The Aristotelian argument was made famous by Herman Daly (1990) who concludes that 'materials transformed and tools of transformation are complements, not substitutes.'[8] In this case, the materials transformed are instances of natural capital and the tools of transformation, to be used by intentional human agents, represent instances of manufactured capital. To properly grasp this argument, it is useful to first distinguish between Aristotle's four causes: material, efficient, formal, and final, and then apply it to an example (*Metaphysics*, I. 3–6).[9] Consider a bronze statue. In this case, the material cause is the bronze, the material that actually constitutes the statue; the efficient cause is the artist's tool that she uses to fashion the statue out of the bronze; the formal cause is the idea, plan, or design that exists in the mind of the artist; and, the final cause is the purpose or goal for which the artist fashions the statue, whether it is to create a beautiful piece of art or some other purpose. In such a case, it would be erroneous to identify the material cause with the efficient cause. The material transformed – the bronze – is not identical to the agent of transformation: the artist and her tools, which give shape to the raw material. And, since both kinds of causes are essential to making the bronze statue, neither can be supplanted by the other. Therefore, in all such cases, the materials transformed and tools of transformation better viewed as complements rather than substitutes.

There appears to be at least two problems with this argument. First, invoking Aristotle's distinction between material cause and efficient cause may establish complementarity between natural capital and manufactured capital over some domains of production, but it may not establish this relation over every domain. If one accepts the claim that natural capital denotes a set of phenomena that is relatively detached from intentional human agency, then economic production might take place without any natural capital, as is the case when instances of manufactured capital, such as machines, are used to produce more manufactured capital. One might respond to this objection by claiming that all physical instances of manufactured capital are in fact constituted by natural capital *qua* energy, and thus, the production process just described would still require natural capital as an input. But if natural capital is identified with energy, something that cannot be destroyed, then there would be no reason to worry about its depletion. No proponent of strong sustainability wants to reach this conclusion.

Second, as Mark Sagoff (2004, 165) has noted, even if the Aristotelian argument is true, it appears to fall on deaf ears since the conclusion is compatible with the main principle adhered to by those wedded to weak sustainability: formal causes (design, plan, innovation, etc.) will invariably overcome reasonable shortages in natural capital.[10] For this reason, the Aristotelian argument – on its own – flounders in response to the technological optimist.[11]

The third argument for the non-substitutability of natural capital is the motivation argument. This ingenious argument proceeds as follows. If manufactured capital were perfectly substitutable, then people would have never of had the incentive to produce and accumulate it in the first place. Since people *have* taken pains to produce and accumulate manufactured capital, then we can conclude that manufactured capital and natural capital must be complements, not substitutes.

The fundamental error with this argument is perhaps one that pervades all of the arguments for the non-substitutability of natural capital: it wrongly presupposes that natural capital is either substitutable or non-substitutable (Jamieson, 1998). As Wilfred Beckerman (1995) argued long ago, the same item can be treated as a substitute in one context and as a complement in another. Thus, unless such contextual factors are taken into account, then this argument for the non-substitutability of natural capital fails.

One might respond to this argument by insisting that this characteristic is precisely what makes natural capital special in the first place: there *are* some instances of natural capital that are non-substitutable – no matter what the context. While there appears to be some truth to this claim – the next two sections attempt to account for such contextual factors, including time, place and available technology – one would still need to establish the criterion (or criteria) that distinguish between instances of natural capital that are non-substitutable from those that are substitutable. In fact, the fourth argument from critical natural capital is meant to deliver this specific result.

The final argument – from critical natural capital – allows for some substitution between manufactured and natural capital, but the proponents of this argument insist that there is still a subclass of natural capital, critical natural capital, for which there are no substitutes.[12] This concept is commonly used to denote the set of ecological conditions that is required for the continued existence of economic agents.[13] If the argument from critical natural capital is true, then every sustainable outcome requires maintaining the stock of critical natural capital. It follows that, if we are committed to sustainable development, then we ought to sustain this special subclass of natural capital to achieve this goal.

The problem with this argument is that no one has precisely explained *what* the ecological conditions denoted by the concept of critical natural capital are and *why* they are essential for the continued existence of economic agents.[14] As it stands, the concept of critical natural capital merely serves as a placeholder for such conditions. While it may be true that there are instances of critical natural capital, the meaning of terms commonly associated with the concept, such as 'non-substitutable', 'near-impossible to substitute', and 'essential' require a clearer formulation then they tend to receive. Any satisfactory account of the ecological conditions essential for the continued existence of economic agents should explain what makes them distinctive – why the members of this subclass have no substitutes. Only after such an account is developed will it be feasible to evaluate the argument from critical natural capital.

The following two sections specify an account of critical natural capital that explains why the members of this subclass have no substitutes and what, *in principle*, would be required for an item to serve as a substitute for such conditions. Section six then reconsiders the argument from critical natural capital, arguing that strong sustainability, though probably true, collapses into weak sustainability.

4. Clarifying Critical Natural Capital

If we accept that the concept of critical natural capital is to denote ecological conditions essential to the continued existence of an economic agent, then it should be clear that the relation of interest will be between a particular economic agent and these special ecological conditions. For the remainder of this paper, I will refer to such conditions as 'basic ecological conditions'.[15]

To proceed, it will be helpful to first distinguish basic ecological conditions from ordinary goods in standard consumer choice theory (Mas-Colell, Whinston, & Green, 1995). Goods merely yield subjective utility to agents that already exist. They are deemed 'goods' because of this utility-making role and not by virtue of any other factor. Basic ecological conditions, on the other hand, are objective conditions that must be satisfied for the continued existence of a given agent. What makes these conditions essential for this purpose is independent of the agent's subjective preferences. While basic ecological conditions are, in most cases, expected to contribute to agent welfare, a fact that is ultimately determined by the structure the agent's subjective preferences, basic ecological conditions are special because, unlike ordinary goods, they are required for the existence of an agent.[16] For there to be an agent with subjective preferences, that agent must be situated in a 'viable environment' that is constituted by basic ecological conditions.

The reason why basic ecological conditions are essential to the continued existence of agents is because for any given agent with a particular constitution, such conditions possess objective characteristics or properties that afford a causal role to the agent that is not available in any other kind of ecological condition (they are not multiply realizable). To put it more precisely, we can define a basic ecological condition as follows:

> x is a basic ecological condition for agent α in environment E at time $t \leftrightarrow$ if all variables other than x were held fixed at their values at t, and x were removed from E, then α would cease to exist (shortly after t).[17]

Many ordinary objects might qualify as basic ecological conditions for specific agents. Take the obvious example of oxygen molecules.[18] At this particular time, there is some minimum quantity of O_2 that is required for the continued existence of certain agents, namely, aerobic organisms, because O_2 is consumed by such organisms during cellular respiration. Since O_2 is the only kind of molecule capable of executing a causal role required for the continued existence of aerobic organisms, there is some quantity and quality of such molecules that qualifies as a basic ecological condition for these agents. The same could be said of many other ecological conditions, including a subsistence quantity and quality of water. No matter what the structure of the agent's subjective preferences, the agent will go out of existence without standing in the right kind of causal relation to such basic ecological conditions.

These statements appear to be truisms, but remember that economics makes *no* firm distinction between goods that merely yield subjective utility to agents that already exist and the ecological conditions required for the agent's continued existence. This distinction, however common in ordinary language, must be drawn in order to specify the objective ecological conditions denoted by the concept of critical natural capital.

It is to be remarked that basic ecological conditions are always agent-relative. Without specifying the particular agent at hand, basic ecological conditions cannot themselves be specified. These conditions are defined as having no substitutes for a specific agent because they afford causal properties that cannot be realized in any other kind of ecological condition at a particular *time* and *place*, with a *given level of* *technology*. If any of these elements – time, place, or technology – were to change, then the set of basic ecological conditions – the agent's viable environment – might also change. Indeed, it is to be expected that viable environments will undergo constant change and, moreover, that agents are themselves changing self-reproducing physical systems that are capable of modifying themselves, their technologies, and their environments (Lewontin, 1983). As Dan Dennett explains:

> A tiger is viable now, in certain existing environments on our planet, but would not have been viable in most earlier days, and may become inviable in the future (as may all life on Earth, in fact). Viability is relative to the environment in which the organism must make its living. Without breathable atmosphere and edible prey – to take the most obvious conditions – the organic features that make tigers viable today would be to no avail. And since environments are to a great extent composed of, and by, the *other* organisms extant, viability is a constantly changing property, a moving target, not a fixed condition. (1996, 115)

Viable environments are not fixed. They have what Dennett refers to as a 'moving target quality' and the account of basic ecological conditions given here is sensitive to this quality.

To illustrate this point, consider a somewhat artificial example. Let us suppose that a subsistence level of H_2O – a minimal quantity and quality of H_2O – is a basic ecological condition for a specific agent. Since H_2O is the only kind of molecule capable of executing a causal role required for the continued existence of agents at a particular time and place, it qualifies as a basic ecological condition for these agents. Now, suppose that a large batch of synthetic molecules – call it 'functional water' – is designed, developed, and subsequently made available to these agents at a future time and place. This innovation affords agents with the same objective causal role as H_2O. And, because the causal properties of H_2O are now realized in functional water, H_2O would cease to be a basic ecological condition for these agents. These agents are no longer required to stand in a particular causal relation with H_2O for continued existence. Why? Although H_2O was essential to the continued existence of agents in the first time period, this is no longer the case in the second time period since functional water affords agents with the same causal properties required for this purpose.

5. The Substitutability of Basic Ecological Conditions

Basic ecological conditions have been defined as conditions required for the continued existence of an economic agent, and although such conditions have no *actual* substitutes, we still need to explain what, in principle, would be required for some item to *potentially* serve as a substitute for such conditions. Without a definite account of substitutability, we would be unable to explain why some ecological conditions (and not others) have no substitutes.

Any item *y* can serve as a potential substitute for the basic ecological condition *x* if and only if it meets the following two conditions:

(1) *y* affords the same objective causal role to the agent as *x*; and
(2) *y* leaves the agent as well-off (subjectively) as *x*.

		Agent Welfare	
		Equally Well-off or Better-off	Worse-off
Functional Property	Same	YES	NO
	Different	NO	NO

Figure 1. *Would* y *serve as an overall substitute for basic ecological condition* x*?*

Neither (1) or (2) should strike the reader as controversial. Condition (1) simply upholds the defining characteristic of basic ecological conditions: for any item to serve as a potential substitute for a basic ecological condition, that item must possess the same causal properties required for continued existence. Condition (1) is objective and we can describe it as a *functional substitute*. Item *y* is a functional substitute for *x* if and only if *y* affords the same causal property *x*, for agent α.[19]

Condition (2) is equally uncontroversial: it simply adopts the notion of substitutability from standard consumer choice theory (Mas-Colell et al., 1995). This theory states that, among ordinary goods, each substitute good must leave the agent equally well-off or better-off. A particular good is a substitute good because of its utility-making role in relation to the agent and not by virtue of any other factor. Substitution, in this sense, is defined in terms of interchangeability in the agent's utility function (and is cashed-out behaviorally in terms of the agent's willingness to trade one good for another). Condition (2) is subjective and we can describe it as a *welfare substitute*. Item *y* is a welfare substitute for *x* if and only if *y* is interchangeable for *x* in such a way that it leaves agent α equally or better well-off.

An *overall substitute* for a basic ecological condition will be a functional substitute and a welfare substitute. As depicted in Figure 1, only the north-west quadrant answers this question affirmatively, where item *y* has both the same functional property as the basic ecological condition it supplants and leaves the agent no worse-off. The other three quadrants identify instances that fail to satisfy this dual requirement. In all of these cases, item *y* either leaves the agent worse-off, does not possess the same functional property as the basic ecological condition it supplants, or both.

6. The Argument from Critical Natural Capital, Redux

The original argument from critical natural capital failed to specify why certain ecological conditions are essential to the continued existence of economic agents and, therefore, it could not be properly evaluated. This state of affairs motivated the last two sections, which specified an account of critical natural capital and explained what, in principle, would be required for any item to serve as a substitute for these essential conditions. We are now in a position to evaluate this revised argument from critical natural capital.

First of all, it is to be remarked that the account of basic ecological conditions given does not, on its own, establish the existence of such conditions. This is an empirical question that is to be ultimately answered by life scientists, such as conservation biologists and ecologists. It does, however, seem reasonable to assume that *some* basic ecological conditions exist for agents, and as long as this is true, then we can speak of such conditions as being not only essential for continued existence but essential for agent welfare, too. Because the social scientific approach to sustainable development invariably requires that welfare-enhancing production does not decline over time, it follows that basic ecological conditions must be maintained to achieve this goal. Even if basic ecological conditions are to be supplanted with future technologies at some future time and place, as long as basic ecological conditions exist at a particular time and place, then the agents that depend on them will need to stand in the right kind of causal relation to them for continued existence. Therefore, we can reasonably conclude that strong sustainability – in this sense – is almost certainly true. Sustainable development depends, in part, on sustaining certain ecological conditions *in kind*.

Be that as it may, it should be clear that some truths don't matter. The beauty of the Sistine Chapel matters, but the number of seconds Michelangelo took to paint it does not. Similarly, strong sustainability may be true, but it may not matter. I propose that strong sustainability will matter for policy if and only if the following two conditions are met.

The proponents of strong sustainability (1) endorse a policy that ensures basic ecological conditions are sustained and (2) this prescription is significantly different from that endorsed by the proponents of weak sustainability.

Those wedded to strong sustainability have long argued that the stock of critical natural capital has no substitutes and, therefore, must be maintained for the goal of sustainable development. Because the specific account of critical natural capital developed in this paper only bolsters the case for strong sustainability, the proponents of this view are not expected to deviate from their original policy position. To the contrary, they will almost certainly continue to endorse a policy that ensures, at minimum, critical natural capital is sustained. After all, if the argument given in this paper is sound, then sustaining this subclass of natural capital is a necessary condition for sustainable development.

Is this prescription expected to be significantly different from that endorsed by those committed to weak sustainability? If basic ecological conditions exist then, in most cases, they will not only be essential for the continued existence of economic agents, but economic production and agent welfare.[20] And, since the proponents of weak sustainability would never endorse a policy that reduces either of these variables, then we can conclude that strong and weak sustainability collapse into the same position.[21] Thus, despite the fact that strong sustainability is probably true, there is a good reason to believe that it does not matter for public policy since the proponents of weak and strong sustainability would endorse the same position: critical natural capital ought to be sustained.[22]

7. Conclusion

This paper has argued that three out of the four main arguments for the non-substitutability of natural capital fail. Once revised, the fourth argument from critical natural capital establishes that strong sustainability is probably true: some version of this position is the correct view. For human economic activity to take place, the world can be many different ways, but it cannot be *any* possible way.

Be that as it may, for the purpose of public policy, weak and strong sustainability collapse into the same position. No one would prescribe running down the stock of critical natural capital when this concept is made to denote ecological conditions essential for the continued existence and, therefore, agent welfare. Whereas the proponents of strong sustainability are wont to emphasize that critical natural capital must be maintained for the goal of sustainability, the proponents of weak sustainability have been more likely to suspend judgment on whether this subclass of natural capital actually exists. Nevertheless, if it were to turn out that there are basic ecological conditions, and these conditions are essential to sustaining agent welfare, then the proponents of weak and strong sustainability would arrive at the same policy position. This is a happy conclusion for sustainability since it implies that the goal is without any real adversary.

Notes

1. This literature includes Dobson (1998), Page (1999), Gardiner (2006), and Habib (2013).
2. This terminology was introduced by Bryan Norton (1992).
3. A third position, "absurdly strong sustainability", will not be considered in this paper. See Holland (1997) for a philosophical defense of this position.
4. Such journals include *Environmental Values* (Beckerman, 1994, 1995; Daly, 1994), *Ecological Economics* (Daly, 1997; Solow, 1997; Stiglitz, 1997), the *Journal of Economic Perspectives* (Arrow et al., 2004), and *Conservation Biology* (Arrow et al., 2007; Daly et al., 2007). See Neumayer (2003) for an overview of the debate between weak and strong sustainability.
5. See Daly (1990) for the source of these arguments; see Jamieson (1998) for a response to some of these arguments.
6. This does not imply that the production process can violate the laws of thermodynamics (Georgescu-Roegen 1971). Nor does it imply that production is possible without a material basis.
7. See Sagoff (2004).
8. See Daly (1990) in Sagoff (2004, 162).
9. For the original passage, see Barnes [(1984) 1995]. Also, see Sagoff (2004, 164–5).
10. To be clear, the claim is *not* that economic production can transpire without any material whatsoever.
11. Of course, there might be other well-founded objections to the technological optimist's position.
12. Critical natural capital was first introduced by scholars at the London Centre for Environmental Economics and it was meant to denote those specific instances of natural capital required for basic life support. Several economists have used "critical natural capital" in this sense (see especially Folke, Hammer, Costanza, & Jansson, 1994; Barbier, 2011). Most recently, the environmental economist, Edward Barbier asserts that there are forms of natural capital that are "so essential for life" and that "humans depend on and use this natural capital for a whole range of important benefits, including life support" (2011, 6).
13. Critical natural capital has also been used in a second sense: to denote ecological conditions that are essential to agent welfare (see Farley, 2008).
14. For evidence to support this claim, see Hueting and Reijnders (1998), De Groot, Van der Perk, Chiesura, and van Vliet (2003), Ekins *et al.* (2003), Chiesura and De Groot (2003),

Millennium Ecosystem Assessment (2005), Farley (2008), Brand (2009), and Pelenc and Ballet (2015).

15. It is to be remarked that the claim that certain ecological conditions are required for the agent's continued existence is a logical extension of arguments given by liberal theorists (Michael, 2000).
16. For the purpose of this paper, it will be assumed that agent welfare is determined by the satisfaction of subjective preferences. Of course, there are many well-known objections to this account of agent welfare (Hausman & McPherson, 2006).
17. The symbol "↔" should read as "if and only if". This definition of a basic ecological condition should be read in light of J.L. Mackie's (1980, 63) "causal field": a set of background conditions, not completely specified but taken as fixed. The causal field fixes everything but some set of variables that one is interested in.
18. Of course, to claim that some set of ecological conditions is required for the continued existence of an agent because they possess objective causal properties that are not multiply realizable is not to claim that they are scarce or expensive. They may be ubiquitous and cheap. Either way, the definition of basic ecological conditions stands.
19. John O'Neill, Holland, and Light (2009) make a similar distinction between technical substitutes and economic substitutes.
20. One cannot assume basic ecological conditions are essential for agent welfare in *every* case. Agents may prefer death to continued existence (they may prefer a state of the world without basic ecological conditions to a state of the world with basic ecological conditions). If agents hold such preferences, then utility maximization would coincide with death.
21. For similar reasons, others have also argued that weak and strong sustainability collapse into the same position (Beckerman, 1994, 1995; Holland 1997).
22. Of course, there may be other ways to formulate critical natural capital (beyond critical natural capital *qua* basic ecological conditions) that not only vindicate the truth of strong sustainability but its policy relevance as well.

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