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Driving with Eyes on the Rear-View Mirror—Why Weak Sustainability Is Not Enough

Alan Randall 

Sustainability Institute and Department of Agricultural, Environmental & Development Economics,
The Ohio State University, Columbus, OH 43210, USA; randall.3@osu.edu

Abstract: Weak sustainability, WS, attempts a comprehensive notion of sustainability, sustaining human welfare directly, or equivalently, sustaining inclusive wealth, IW, sufficient to sustain welfare. Sustainability is, in principle, forever, and accordingly, IW is conceived and assessed in a very long-term context. Given that future outcomes are unobservable, IW assessments are conducted in terms of expectations. However, this introduces pervasive circular reasoning: the calculated value of IW assumes that our expectations will be met, but that is the question. Optimistic expectations (for example) increase calculated IW, which, in turn, increases our confidence that our society is on a sustainable path. Given the logical difficulties of projecting IW into the future, analysts resort to tracking IW at regular intervals through the recent past. This reduces, but does not eliminate, the circularity problem. The signals from tracking IW are less than perfect from a policy perspective: they are too aggregate, perhaps masking impending crises regarding particular resources until it is too late; and too dependent on imperfect markets; and they document the recent past, so policy managers are always playing catch-up. WS-based sustainability policy frameworks include WS-plus, which invokes ad hoc strong sustainability, SS, patches to address threatened resource crises. It may also be possible to allow a degree of WS flexibility for individual jurisdictions within the constraints of a global safe operating space, SOS.



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1. Introduction

1.1. Context

The human mind struggles to understand sustainability. We tackle it piecemeal, or we reach for organizing principles that might make it comprehensible. The sustainability indicators, SIs, approach aims to rationalize real-world interventions on behalf of sustainability. However, consistent with its roots in the Sustainable Development Goals, SDGs, which address sustainability in the context of a broader set of concerns, it readily generates more indicators than it can organize coherently [1]. For example, a careful recent study [2] took more than seventy SIs and reduced them to six principal components, which were used to evaluate the sustainability of each of the more than seventy administrative districts in France. A problem common to the SIs approach is that the results tell us a lot about wellbeing in these districts, but not so much about their long-term sustainability.

In contrast, strong sustainability, SS, and weak sustainability, WS, begin with a manageable set of organizing principles focused directly on sustainability [3]. SS is founded on the principle that nature really is different from other assets and, accordingly, encourages interventions in response to crises in natural systems. Applications include the following: a farmer may restrain grazing on perennial pastures to increase the chance of regeneration when a drought breaks; a fisheries manager may suspend commercial fishing when fish stocks fall below a prescribed limit, to encourage regeneration; a government may protect

the critical habitat of an endangered species; and international treaties may prohibit trade in endangered animal and plants, to discourage poaching.

WS is quite different, uplifting one of many conceivable motivations for sustainability, a commitment to long-term human wellbeing, and claiming comprehensiveness by including, at least in principle, all sources of wellbeing. The organizing principle is faith in the technological potential to resolve scarcity issues by developing substitute processes, inputs, goods, and services [4,5]. History provides some evidence to support this notion: concerns about running out of charcoal in the 18th century and whale oil in 19th were resolved by innovation and substitution [6]; however, of course, appeals to history do not clinch debates about future prospects. Nevertheless, WS embraces technological optimism and assumes generous substitutability at every level, from raw materials to final goods and services. These assumptions are tightly linked—the point of technological advance is to enhance substitutability. Given the strong assumptions about innovation and substitution, WS is mostly concerned with sustaining the totality of assets, i.e., inclusive wealth, IW. It is easiest to think of WS at the global level because national borders may be permeable to assets, especially financial capital and human capital. Nevertheless, the World Bank [7] and the United Nations [8] have maintained accounts of genuine savings and/or adjusted net savings, i.e., approximations of IW, for more than 200 countries, in some cases for as long as 50 years. There have been attempts at IW accounting at subnational levels, regional and local [9], but permeable borders remain problematic.

1.2. Objectives and Outline

The organizing principle of SS is that nature is unique in some important dimensions such that reliance on the emergence of substitutes to forestall resource scarcity is foolhardy and the assumed substitutability among different kinds of capital that underlies WS is grossly optimistic. In contrast, SS proponents argue that sustaining some forms of natural capital in-kind is necessary [3]. SS starts with concern for renewable resources that are threatened in some way, and this focus on specific resources and contexts allows people with quite different principles, values, and motivations—e.g., human welfare, intrinsic values, and deep ecology—to coalesce around support for SS remedies in some, but not all, cases [10]. The standard SS formulation envisions piecemeal interventions to protect threatened natural resources: a set of specific and perhaps uncoordinated interventions to troubleshoot the business-as-usual, BAU, economy to avoid or forestall specific threats to sustainability. Not much attention is paid to BAU itself. Often, it is implicitly assumed that BAU means a fairly well-articulated economy responding to ordinary economic incentives. However, it is not clear that BAU economies are so close to sustainability that a manageably few SS patches can make them sustainable. WS, which begins with the BAU economy but corrects for market failures and imposes neutral time preference, would provide a better foundation for piecemeal SS interventions [11].

There have been two kinds of attempts to develop a more holistic SS framework: the natural capital, NC, approach [12,13], and planetary boundaries, PBs [14,15]. The NC approach conceptualizes SS as non-diminishing NC. It assumes substitutability within a vast set of diverse natural resources, adjusting continually as substitutions take place, but not between NC and other forms of capital. The assumed sharp separation of NC and other kinds of capital raises apparently insurmountable difficulties for economic valuations of baseline and alternative NC packages [16], but Ott [13] argues that a discourse process among well-meaning citizens would yield coherent rankings of alternative NC suites.

Within the PBs, it may be claimed that the safe operating space, SOS, for human activities provides a comprehensive SS framework [17]. However, the comprehensiveness of the PBs at the planetary scale is strained. For example, the assimilation capacity for atmospheric carbon and greenhouse gases, C-GHGs, is unambiguously a global resource, and downscaled PBs can be useful in suggesting local responsibility for contributing to a global abatement effort. However, freshwater is used and managed at local and regional scales and land resources are meaningful at multiple scales: from global, for food supply;

to local, for urban greenspace. Much of the appeal of SS lies in its applicability to local and regional issues as exemplified by freshwater and land resources, and the PBs framework has relatively little to offer in these contexts.

Returning to WS, sustaining welfare, $w(t)$, through a far distant time horizon is equivalent to sustaining inclusive wealth, IW, at time zero, W_0^∞ , i.e., the present value of an indefinitely long welfare stream (for notation and definitions, see Section 2). Following Dasgupta [18], IW and welfare usually are expressed in per capita terms. The equivalence of IW and present-valued cumulative $w(t)$ (Equation (1)) suggests two approaches to assessing WS: projecting $w(t)$ and calculating IW. In deservedly respected contributions to the WS literature, Arrow et al. [19,20] argue that projecting the $w(t)$ time path is overwhelmingly difficult, but IW is much more accessible via shadow prices that “... contain all the information ...” about future prospects. However, Smulders [21] contends that the relevant shadow prices are less than transparent, and the impediments to projecting $w(t)$ are not so daunting as Arrow et al. suggest. Here, I make the case that calculating IW involves circular reasoning: W_0^∞ is not observable; so, we substitute $\hat{W}_0^\infty$, the IW equivalent to the expected welfare stream. This process implicitly assumes that our expectations about future prospects will be met, but that is the question. Sections 3 and 4 elaborate the case that a reader is unable to distinguish whether an optimistic IW report reflects an objectively sustainable future or merely the prevailing optimism in this respect.

For their empirical exercise, Arrow et al. settle on the problem of assessing the change in WS status between two dates. This is a simpler question: can we get the sign right and magnitude approximately correct for $\hat{W}_\tau^\infty - \hat{W}_{\tau-1}^\infty$? There are respected and relatively long-standing programs for tracking the time path of observed IW at the country level, with a modest time lag while waiting for the necessary data [7,8,21–27]. This involves two consequential changes from the “calculate W_0^∞ ” project: focus on ΔIW over a relatively brief time interval and implement the calculation with data from the recent past, which eliminates some, but not all, of the problems introduced by expectations (Section 5).

The resort to tracking ΔIW over relatively brief time intervals is not in itself problematic: our time on Earth is brief, so we experience sustainability as an interval on a time-path. The sustainability obligation of the living is to keep society on a sustainable time-path [28], implementing course corrections as necessary. The plausible claim for tracked $\hat{W}_\tau^\infty(\tau)$ is not that it assesses WS accurately, but that it can provide alerts with a relatively modest time-lag when there is a deviation from the established $\hat{W}_\tau^\infty(\tau)$ path. The criterion from year to year is that w_t and ΔW_t should be non-diminishing. W_t should generate enough production to sustain itself and secure a surplus that maintains welfare.

Intergenerational equity requires that both w_t and ΔW_t , $\forall t$, be non-diminishing: welfare should be sustained without reducing IW, i.e., without dis-saving.

For want of better approaches, we track the recent past—driving with eyes on the rearview mirror—alert for evidence of any deviation off-track. The objective is to avoid diverging so far from the sustainable path that getting back on track requires intolerable sacrifices. $\Delta W(t) < 0$ would deliver the warning, but its value is limited for several reasons, as discussed in Section 5.

It follows that a coherent WS policy based on tracking $\Delta W(t)$ must operate within guardrails of various kinds: correcting market failures, monitoring a suite of sustainability indicators [1], and implementing policy patches, i.e., targeted correctives. Despite the need for guardrails, we persist with WS because it introduces some vital considerations—substitutability of resources and the ability of technology to enhance substitutability—without which the prospects for sustainable development would be truly grim. SS brings important ideas, too: nature really is different, which challenges the WS notion that sustainability is possible even as natural capital approaches zero [4]; and there is a role for policies directed specifically to threatened natural resources.

This article raises some serious caveats concerning WS, motivated by the realization that expectations are inherent in the fundamental identity of WS (Equation (1)) and introduce an unavoidable element of circular reasoning into forward-looking WS assessments.

Accordingly, a coherent WS-based sustainability framework will pay serious attention to natural resources per se (Section 6). I conclude with some speculations about how best to incorporate SS considerations. In many jurisdictions, we see elements of a WS-plus framework—WS with piecemeal SS restrictions imposed when necessary and lifted when the crisis has passed [11]—in operation, although I am unaware of a systematic WS-plus commitment anywhere. A constant natural capital requirement has not yet been imposed in any jurisdiction, and there are good reasons why not. The jury is out regarding frameworks based in the Safe Operating Space concept from the planetary boundaries literature [14,15], but it may be possible to devise approaches that might make SOS-based policies effective and acceptable at the jurisdictional level.

2. Materials and Methods

The standard comprehensive accounts of sustainability [7,8,22–27] are founded on WS. This article challenges the conventional understanding that IW offers a valid and accessible assessment of WS. Theoretical reasoning about the value of capital, assets, and wealth is prominent in the argument, but my purpose is mostly practical: to rigorously examine the conceptual foundations of our empirical sustainability assessments in order to improve those assessments and to better understand the consequences and limits of what they are telling us. The distinction between inclusive wealth, W_t^∞ , which is unobservable, and its observable proxy, $\hat{W}_t^\infty$, is crucial, and reliance on expectations in IW assessment introduces inescapable circular reasoning. Six rigorous propositions are generated concerning the limitations of assessing WS via IW. There have been whispers among scholars that the way intangible capital is inferred and projected in IW accounting involves circular reasoning, but the basic circular fallacy—the influence of current expectations on assessed sustainability prospects—pervades tangible assets, too.

The best-known WS accounting efforts [7,8] have effectively dispensed with the goal of calculating $IW = W_0^\infty$ and settled on tracking the annual change in IW, which reduces but does not eliminate the problem of expectations. The implications of the tracking approach to WS assessment are examined in some detail.

To examine claim of circular reasoning, it is necessary to introduce some notation.

$w(t)$:	The time stream of welfare, for t in $(0, \dots, \infty)$.
$\hat{w}_\tau(\tau)$:	The time stream of expected welfare. The “hat” indicates expectations, which are revised over time, i.e., as τ becomes larger, for τ in $(0, \dots, \infty)$.
W_0^∞ :	The unobserved true value of IW evaluated at $\tau = 0$.
$\hat{W}_\tau^\infty$:	The expected IW evaluated at time τ ; when $\tau = 0$, expected IW is $\hat{W}_0^\infty$. Expected IW is revised over time, i.e., as τ becomes larger.
$\hat{W}_\tau^\infty(\tau)$:	The time path of expected IW. Although W_0^∞ is, in concept, an integral with a fixed numerical value given the operative assumptions undergirding it, its expectation is revised at times τ .
K_{k0}^∞ :	The value of a long-lived asset k at $t = 0$, given perfect foresight.
$\hat{K}_{k\tau}^\infty$:	The value of k given the expectations operative at time τ .
$\hat{K}_{k\tau}^\infty(\tau)$:	The time path of expected value of k , as revised at times τ .

With this notation established, the argument proceeds.

3. Welfare, Wealth, and Weak Sustainability

3.1. Welfare and Wealth—The Promise of WS

With a far distant time horizon, sustaining welfare $w(t)$ is equivalent to sustaining inclusive wealth. IW at time zero, W_0^∞ , is the present value of an indefinitely long welfare stream:

$$W_0^\infty = \int_0^\infty w(t)e^{-\delta t} dt \quad (1)$$

where g is the rate of growth in the value of output and wellbeing is not discounted because the time preference is zero [29]. Following Dasgupta [18], IW and welfare are expressed in per capita terms.

Equation (1) suggests two approaches to assessing WS: projecting $w(t)$ and assessing $IW = W_0^\infty$. Arrow et al. [19] argue that projecting the $w(t)$ time path is overwhelmingly difficult, but IW is much more accessible and “... contains all the information ...” about future prospects. For a finite accounting period ending at τ ,

$$W_0^\infty = \int_0^\tau w(t)e^{-gt}dt + W_\tau^\infty, \text{ where } W_\tau^\infty = \int_\tau^\infty w(t)e^{-gt}dt \quad (2)$$

Thus, IW includes a stream of welfare through time τ and the present value of the wealth remaining at τ .

Given the possibility of sustaining welfare for a finite period by drawing down IW—eating the seed corn, to invoke a metaphor—an accounting of $w(t)$ and the change in IW, $\Delta W(t)$, is required. At a minimum, their sum over the relevant time interval should be non-diminishing. For intergenerational equity, both components should be non-diminishing, i.e., the goal is to sustain contemporaneous welfare without diminishing wealth. The World Bank [7] and the United Nations [8] have developed accounting systems that track national performance in terms of weak sustainability criteria by tracking indicators of ΔIW : adjusted net savings and/or genuine savings. The goal is to implement (2) as an annual accounting of $w(t)$ and $\Delta W(t)$ with a modest lag for data availability,

$$\int_{t-1}^t w(t)e^{-gt}dt + (W_t^\infty - W_{t-1}^\infty) \geq 0 \quad (3)$$

An economy is judged to be on a sustainable path if $w(t)$ and $\Delta W(t) \geq 0$.

Returning to Equation (1), the key equality suggests that we can assess future prospects by projecting a very long stream of welfare, $w(t)$, and calculating its present value; or more directly, by consulting W_0^∞ , the value at time 0 of the assets that produce future welfare. Given the difficulty of projecting $w(t)$ into the far future, assessing WS by consulting W_0^∞ has been suggested as the obvious path of least resistance [19]. However, calculating IW involves circular reasoning at several steps: the observable proxy for IW, $\hat{W}_0^\infty$, assumes our expectations about future prospects will be met, but that is the question. We want to know if $w(t)$ is sustainable for a very long time, but the best attainable indicator, $\hat{W}_0^\infty$, tells us only whether we expect it to be sustainable.

3.2. IW Is the Sum of Several Categories of Capital

There are many categories of capital—one list includes financial, FC; natural, NC; produced, PC; human, HC; social, SC; and governance, GC, capital—and IW, being inclusive, is the sum across all categories:

$$IW = FC + NC + PC + HC + SC + GC \quad (4)$$

Some of these are more tangible than others, in that markets are more complete and provide more information about value; thus, tangible and intangible are relative rather than absolute terms. For example, the World Bank in 2006 [26]—regarding HC, SC, and GC as intangible—estimated their combined value as the unexplained residual in a multi-country regression of output as a function of FC, NC, and PC. The idea was that some countries consistently produce more than others from a unit of tangible capital (FC, NC, and/or PC), and the difference is attributed to greater intangible capital. More recent assessments estimate some components of HC including education [27], but substantial components of HC, SC, and GC remain intangible.

3.3. Accounting for Intangible Capitals—The Problem of Circular Reasoning

Intangible does not mean insubstantial: worldwide, the contribution of intangible wealth to output—measured as the value of national product that cannot be attributed to tangible assets—has been estimated to be a little more than 55% of the total, and the percentage is greater in countries with advanced economies and relatively competent and corruption-free governance [19]. There being some unease with the top-down approach (estimating intangible capital as the otherwise-unexplained residual), the World Bank in 2018 made substantial efforts to develop independent estimates for some components thereof, e.g., education and workforce skills [27]. Nevertheless, intangible capital remains large because other forms of capital do not account for observed productivity. There are more kinds of intangible capital than we may realize: even the assets we consider tangible have intangible components (e.g., established businesses and public institutions accumulate valuable goodwill), and there are missing data on components that are tangible in concept.

The assertion that wealth “... contains all the information ...” about future prospects tells us more about the convenience of using wealth for this purpose than its validity. Capital markets do not reveal the future: they reveal what today’s market participants expect about the future.

Proposition 1: *We do not observe IW; we have only an estimate based on expectations subject to revision.*

When expectations are revised in light of new information, there will be a time path of expectations about IW, $\hat{W}_\tau^\infty(\tau)$. In the case of static systems whose outcomes can be modeled as draws from an unchanging distribution, revisions over time might be expected to introduce additional information that improves estimates, narrowing the gap between expectations and realized outcomes. However, because the coupled human and natural systems that determine sustainability are complex and dynamic, the reality is itself a moving target. Thus, unlike the case with static systems, there is little reason to expect that revisions over time will systematically narrow the gap between expectations and long-term outcomes.

Proposition 2: *The system is complex and dynamic; therefore, we cannot assume that revision systematically narrows the gap between expectations and long-term outcomes.*

Expectations about W_0^∞ , and hence WS are incorporated in $\hat{W}_0^\infty$ systematically. Optimism, for example, about WS systematically impacts $\hat{W}_0^\infty$ in an optimistic direction. Optimists consult IW to determine whether their optimism is justified, but their optimism nudges the available indicator, $\hat{W}_\tau^\infty$, in an optimistic direction.

Proposition 3: *Substituting $\hat{W}_\tau^\infty$ for W_τ^∞ introduces a circular reasoning problem.*

$\hat{W}_\tau^\infty$ incorporates our expectations about sustainability. Thus, using $\hat{W}_\tau^\infty$ to assess WS prospects assumes that our expectations will be met, but that is the question. Other authors have expressed concern that assessing sustainability requires clairvoyance [21]. Acknowledging that impediment, I raise a different concern. Circular reasoning is systematically misleading: in the example immediately above, optimistic expectations nudge IW assessments in an optimistic direction.

The circularity problem is obvious in evaluating the intangible components of IW. We infer the value of social and governance capital by estimating the unexplained residual in time-series estimates of the relationship between the value of output and the endowment of tangible assets. Then, we estimate $\hat{W}_\tau^\infty$ by assuming that intangible capital will be maintained. However, maintenance of intangible capital is one of the questions that a WS assessment attempts to answer.

Proposition 4: *Circular reasoning contaminates assessments of intangible capital.*

Estimates of intangible capital are substantial because other forms of capital account for only a fraction of total output. Assessments of IW assume that high intangible capital will be maintained, but that is the question. Given the substantial component of intangible capital in IW and the circular reasoning issues it poses, perhaps the notion that the IW route to WS assessment is justified by its convenience deserves more scrutiny.

4. Asset Values in General Have a Circular Reasoning Problem

The circular reasoning issue is not confined to intangible capital. The purchase price of a long-lived asset k is not the present value of its contribution to future output, but the expected present value thereof. Valuations of long-lived assets always reflect expectations about their productivity and profitability. However, as the long history of asset bubbles and stranded assets demonstrates, expectations can be wrong, sometimes to devastating effect [30–33]. Asset prices play a large role among the tangible components of IW, and asset prices will generally be greater when expectations are optimistic; therefore, the circular reasoning problem in IW assessment applies generally, not just to intangible forms of capital.

$W(t)$ is an aggregate consisting of a multitude of assets that may be classified into distinct kinds of capital—typically financial, natural, produced, human, social, and governance—so it makes sense dig a little deeper into the nature of capital. The essential argument may be easier to grasp in the context of a particular produced capital asset, K . Its value at the outset should be equal to its purchase price,

$$K_0^\infty = \text{Asset value}_{k0} = \text{Investment}_{k0} \quad (5)$$

where the investment draws down savings or increases debt. The asset's value at $t = 0$ is equal to the initial investment in the asset. This notion has normative implications—savings should not be wasted, and investments should be worth what they cost—and predictive power: we assume the investments selected are the most productive available in terms of the incremental welfare $w_k(t)$ attributable to the asset. Given perfect foresight, the value at $t = 0$ of an asset K held forever is

$$K_0^\infty = \int_0^\infty w_k(t) e^{-rt} dt \quad (6)$$

where w_k is the net increment in w attributable to K and r is the rate of discount.

Equation (6) is idealized and needs to be amended to accommodate uncertainty about future contributions to wellbeing and finite asset life. First, in the absence of perfect foresight, rather than $w_k(t)$ we observe $\hat{w}_{k0}(\tau)$, the contribution to wellbeing expected at the time of purchase, such that the purchase price $\hat{K}_0^\infty$ reflects the expected stream of welfare $\int_0^\infty \hat{w}_k(\tau) e^{-r\tau} d\tau$. At any time $\tau > 0$, the asset's value will diverge from K_0^∞ to reflect adjustments to $\hat{w}_{k\tau}(\tau)$ since $t = 0$, i.e.,

$$\hat{K}_\tau^\infty = \int_\tau^\infty \hat{w}_{k\tau}(\tau) e^{-r\tau} d\tau \quad (7)$$

Second, asset life is rarely infinite. Let L be the anticipated serviceable life of the asset; then,

$$\hat{K}_\tau^L = \int_\tau^L \hat{w}_{k\tau}(\tau) e^{-r\tau} d\tau \quad (8)$$

At τ , the asset's value is the discounted present value of the expected net increment in welfare that it will generate in the remainder of its lifetime. As time passes, the asset depreciates in expected value to a potential buyer:

$$\hat{K}_\tau^L = \text{Investment}_{k0} - \text{accumulated depreciation}_{k\tau} \quad (9)$$

where depreciation is manifested in three ways: we are inexorably approaching the time when the asset needs replacement, ordinary wear and tear may decrease the asset's productivity, and obsolescence may accelerate the asset's loss of value [34,35]. Equation (8) differs from Equation (6) in the length of service life and the uncertainty surrounding the expected welfare stream attributable to K , $\hat{w}_k(\tau)$ which reflects, among other things, the anticipated depreciation over time. Empirically, depreciation, especially its obsolescence component, introduces the possibility of surprises, i.e., discrete adjustments to expectations. Obsolescence arises from improvements in replacement assets and shifts in demand: an asset may suffer obsolescence because newer models are more productive, or because demand for its product has decreased. Observed asset values are conditional on the market expectations prevailing at the moment of observation, and eventual outcomes are likely to diverge from these expectations to an increasing extent as the time horizon becomes longer.

Returning to inclusive wealth, a time path of experienced IW is observable, but even past observations of wealth reflect the expectations about future prospects at the time of observation. It is $\hat{W}(\tau)$ for τ in $(0, \dots, t-1)$ that is observed in retrospect. In the real world, we substitute Equation (10) for Equation (2),

$$\hat{W}_0^\infty = \int_0^\tau \hat{w}(t)e^{-gt}dt + \hat{W}_\tau^\infty, \text{ where } \hat{W}_\tau^\infty = \int_\tau^\infty \hat{w}(\tau)e^{-g\tau}d\tau \quad (10)$$

In addition to recognizing the role of expectations, (10) discounts at the rate g rather than r , as is appropriate for calculating IW [29]. If the actual time-path of wellbeing, $w(t)$ is lower than $\hat{w}(\tau)$, then $W_\tau^\infty < \hat{W}_\tau^\infty$ and an economy judged sustainable on the basis of $\hat{W}_\tau^\infty$ may actually be unsustainable. We would have erred in assessing the economy as sustainable by appealing to expectations that effectively assume its sustainability.

Proposition 5: *The circular reasoning problem in WS assessment applies generally, i.e., to tangible and intangible assets.*

Value is higher in markets for tangible assets, just as it is for intangibles, when we are optimistic about the future. Using those values to calculate IW assumes that the prevailing optimism (for example) is valid, but that is the question. Lack of clairvoyance is a problem, but this is worse: we have drifted into self-deception via circular reasoning.

Circular reasoning also infects some standard procedures used in calculating IW. Data problems in WS assessment are often addressed by calculating the contribution to the expected IW of some component c , $\Delta\hat{W}_{c\tau}^\infty$, from evidence about its contribution to welfare $w_c(t)$, for t in $(0, \dots, \tau-1)$ and vice versa. For example, the common expedient of capitalizing GDP to update $\hat{W}_\tau^\infty$, in the large or for particulars (e.g., place-bound built and/or natural capital), assumes what it sets out to assess—the sustainability of current output and the welfare it generates—and therefore, fails to address the question of whether $w(t)$ is being sustained by drawing-down wealth.

Proposition 6: *The problem of circular reasoning inherent in substituting expectations for observations infects some practices common in IW assessment.*

For example, evaluating NC by capitalizing the value of environmental services, ES, involves circular reasoning: capitalization assumes that ES production will be sustained, but the sustainability of ES production is one of the questions.

5. Tracking, Rather Than Projecting, Changes in IW

5.1. Tracking ΔIW

Given the difficulties in evaluating IW over a very long time, it is unsurprising that there are respected and relatively long-standing programs for tracking the time path of experienced annual changes in IW (or credible proxies thereof) at the country level, with a modest time lag while waiting for the necessary data [7,8,22–27]. This involves two

consequential changes from the “calculate W_0^∞ ” project: focus on ΔIW over a relatively brief time interval and implement the calculation with data from the recent past. This scaling back our WS assessment objectives makes intuitive sense: our time on Earth is brief; therefore, we experience sustainability as an interval on a time-path, whether of human welfare, $w(t)$, expected inclusive wealth, $\hat{W}_t^\infty$, environmental services, $E(t)$, or resource stocks, $S(t)$. The sustainability obligation of the living is to keep society on a sustainable time-path, implementing course corrections as necessary.

Nevertheless, if the goal is to assess sustainability into the future, the problem of expectations is unavoidable, whether we project $\hat{w}_t(\tau)$ or $\hat{W}_t^\infty$. Resort to assessing not IW, but the change in IW between two dates does not eliminate the problem of expectations. We still encounter the “forever” problem: so long as we rely on wealth rather than welfare, we are dealing with $\hat{W}_t^\infty - \hat{W}_{t-1}^\infty$. Assessing the change over a relatively short time interval is likely, however, to reduce the magnitude of distortions.

Tracking $\hat{W}_t^\infty(\tau)$ identifies deviations from a steady path. However, it is a $\hat{W}_t^\infty(\tau)$ path; therefore, we cannot be sure that it is sustainable, i.e., that the path itself will support non-diminished $w(t)$ forever. For that, we need clairvoyance, not just expectations from our current perspective. What we can learn is whether a society has become more sustainable or less sustainable over time. Tracked $\hat{W}_t^\infty(\tau)$ has the advantage that expectations can be updated, e.g., annually, along with everything else. Thus, the plausible claim for tracked $\hat{W}_t^\infty(\tau)$ is not that it assesses WS accurately, but that it can provide alerts with a relatively modest time-lag when there is a deviation from the established $\hat{W}_t^\infty(\tau)$ path. Such alerts are a little less than timely due to data lags, and they offer incomplete assurance that the established path would secure WS because the circularity problem remains. Regular and relatively frequent reassessment would provide relatively early warning of, say, a turn toward more pessimistic expectations, increasing the chances of successful intervention.

The WS criterion from year to year is that $w_t + \Delta W_t$ should be non-diminishing. W_t should generate enough production to sustain itself and secure a harvest, literally in simple rural societies and metaphorically in all kinds of societies, which maintains welfare. Welfare can be maintained, at least for a while, by consuming capital. Thus, intergenerational equity requires that both w_t and ΔW_t , $\forall t$, be non-diminishing: welfare should be sustained without reducing IW, i.e., without dis-saving. The present should not over-consume at the expense of the future nor over-save at the expense of its own wellbeing.

We track $w(t)$ experienced welfare up until the most recent reporting period, and $\Delta \hat{W}(\tau)$, and judge an economy to be on a sustainable path so long as $w(t)$ and $\Delta W(\tau)$ remain non-diminishing in the interval $(\tau - 1, \tau)$, year after year. Thus, we track the recent past—driving with eyes on the rearview mirror—alert for evidence that we have deviated off-track, and implement course corrections, again with a modest time lag. That way, we hope to avoid deviating so far from the sustainable path that getting back on track requires intolerable sacrifices.

This tracking approach to WS delivers the warning imperfectly. WS is itself too aggregate: signals of impending scarcity for particular resources may be lost in aggregate IW assessments. In principle, ideal markets can correct the problem, perhaps barely noticed by those not directly impacted. This is not a trivial point: WS relies on markets to do much of its work beyond the policy spotlight, redirecting resources but not necessarily restoring the ex ante level of $w(t)$. However, WS is too dependent on markets that are far from perfect. Market failures are all too common in the resources sector which, of course, is crucial for sustainability. Some relevant market failures (e.g., in the fossil fuels sector) are direct consequences of asking prices to serve conflicting purposes: providing incentives for changes that are needed and cushioning the blow to those who bear the costs. For these reasons, the warning that an economy has deviated from the sustainability path may be delivered a little late, such that ameliorating adjustments are usually invoked after the fact. Thus, any coherent sustainability policy based on WS will be tracking IW, correcting market failures in the resources sector, monitoring a suite of sustainability indicators [1], and implementing

patches (targeted correctives) often derived from SS principles. Thus, a coherent WS-based sustainability will be playing catch-up while operating within guardrails.

This raises a legitimate question: given the clear need for guardrails, why persist with WS? WS brings some very important ideas to the table: the substitutability of resources and the ability of technology to enhance substitutability. Without these possibilities, sustainability may be conceivable, but it is difficult to imagine sustainable development. SS brings important ideas, too. Nature really is different, so surely there are limits to substitutability: the WS notion that sustainability can be achieved even as natural capital becomes very small strains credibility.

5.2. Guardrails for WS:SS Suggests Three Kinds of Approaches

The standard SS discussion implicitly assumes a piecemeal approach: a business-as-usual default in need of ad hoc SS patches. The WS-plus idea recommends a WS baseline and formalizes the notion of SS patches, one by one as needed [11]. This is a piecemeal, whack-a-mole, approach. In addition to tracking WS, a substantial set of sustainability indicators, SIs, is monitored; SS remedies would be applied to particular cases when the alarm is sounded and lifted when the signals are “all clear”. WS-plus would always be playing catch-up but, at best, crises would be addressed while the costs of remediation are still manageable. In the real world, we see specific SS patches in many jurisdictions, but we have yet to see systematic WS-plus, i.e., a WS BAU augmented with a fairly comprehensive evolving set of SS patches.

There is also a natural capital approach to SS: NC-SS sets up a dichotomy—nature vs. everything else—and assumes substitutability within the nature set, but not beyond. NC is a difficult concept. Dietz and Neumayer [16] argue that SS offers no coherent approach to valuation of NC, thus challenging the practicability of a constant NC criterion. Ott [13] resolves the valuation issue, in principle, by invoking a discourse-based deliberative process among well-meaning citizens that would rank alternative NC bundles. He has a lot of sensible ideas that nevertheless challenge the sharp boundary between nature and other forms of capital: for example, nature is not limited to wilderness, but extends a long way into the stocks and funds of managed and cultivated natural capital; and given the damage humanity has already inflicted on nature, restoration ecology has a role encouraging the revitalization and restoration of the natural world as a whole. Ott’s NC has a lot of WS thinking in it: substitution among NC components, embrace of technology (so long as it respects NC), recognition of the complementarities between nature and other kinds of capital. However, Ott’s NC is nevertheless bounded, although general principles for locating these bounds are elusive. I am inclined to see Ott’s NC-SS as a plea to take NC seriously, which is not such a bad idea given the implication in the early WS literature [4], that NC could become infinitesimally small without threatening sustainability. However, I imagine that Ott would disagree sharply, claiming that his NC is much more than a metaphor. My tentative conclusion is that NC in its current configurations fails to provide a foundation for the SS component of a policy framework that calls upon the best in WS and SS.

The planetary boundaries, PBs [14,15], and safe operating space, SOS [17], framework suggests that the planet needs to live within its means with respect to accounts for nine, or perhaps eleven, categories of natural resources. If $d_{ij}SOS_i$ is the downscaled SOS for pollutant i in jurisdiction j [36–40], that jurisdiction would be compliant if its footprint for i is no more than $d_{ij}SOS_i$. The literature downscaling various PBs for regions, cities, etc., is growing [41,42]; however, I am not aware of any jurisdiction that has committed to a $d_{ij}SOS_i$ limit.

The SOS idea would seem to require that a society be safe on all accounts but free to pursue its interests, perhaps in achieving WS, within that safe space. However, preliminary accounting, comparing country footprints with downscaled PBs, suggests that most countries fail on one or more accounts [43]. Some of the PB accounts are global (carbon and climate); others are regional and/or local (green space and freshwater). For

some, the bounds are defined quite precisely; for others, the range of uncertainty is quite wide [15]. These differences among the PB accounts suggest that the PB concept is at least a little untidy. Nevertheless, a closer look suggests interesting possibilities. At what level should PBs apply, e.g., (i) can exceedance on one account in one place be mitigated by unused capacity in that account in other places, and (ii) can a particular jurisdiction offset exceedance on one account with unused capacity in another? Can we imagine trade in allowances between jurisdictions such that localities may be in exceedance on some accounts so long as the planet is within the SOS and all jurisdictions face incentives for abatement? It is also conceivable that trade in allowances might stimulate trade in goods and services, which might allow jurisdictions to better align their economies with their resource bases. Tentatively, I conclude that a framework based on downscaled SOS is still a work in progress. Perhaps it can be systematized to work at a global scale while providing some flexibility, via trading or similar mechanisms, for regional and local jurisdictions.

6. Conclusions

Sustainability policy seeks to assess sustainability and implement interventions as necessary. Sustainability is forever—which is manifested in the weak sustainability, WS, concept of inclusive wealth and is prominent among the motivations for strong sustainability, SS—but our time on earth is brief, so we experience sustainability as an interval on a time-path, whether of human welfare, inclusive wealth, environmental services, or resource stocks. The sustainability obligation of the living is to keep society on a sustainable time-path, implementing course corrections as necessary. This article presents conclusions regarding some limits of weak sustainability, and some thoughtful speculations about how SS considerations might be used systematically to provide guardrails for sustainability policies based on a WS business as usual.

Inclusive wealth is forward-looking and hence unobservable; thus, we rely on expectations, which introduces unavoidable circular reasoning into IW assessments. Tracking the time-path of experienced inclusive wealth at regular intervals minimizes but does not eliminate this problem, and it does so at the cost of working with lagged signals and incomplete assurance that the observed sustainability path is really sustainable. Welfare and IW are tracked with a modest time lag and an economy is judged to be on a sustainable path so long as $w(t)$ and $\Delta\hat{W}(\tau)$ remain non-diminishing in the interval $(\tau - 1, \tau)$, i.e., policy managers track the recent past, alert for evidence that the economy has deviated off-track, and implement course corrections, again with a modest time lag. The WS signal thus obtained is imperfect for several reasons: (i) IW is a highly aggregate measure of wealth that may not provide timely warnings of impending crises regarding particular resources; (ii) WS relies on market signals, but market failures are common, especially in the resources sector; (iii) the warning that an economy has deviated from the sustainability path is delivered a little late, such that ameliorating adjustments are usually invoked after the fact.

All of this suggests that a sustainability policy based on WS requires guardrails to impose WS on the business-as-usual economy, correct market failures, and address impending resource crises, some of which may not be visible in WS accounts until too late. WS-plus is a piecemeal approach, applying SS patches to protect against impending resource crises. For those looking for a more systematic SS component, there are two candidates: the natural capital formulation and the safe operating space. My tentative conclusions find serious impediments to operationalizing NC-SS, but I am more optimistic that we may be able to develop flexible arrangements, perhaps involving trading, for jurisdictions within global SOS constraints.

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