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**Savings, Sustainability, and Equity**

## Introduction

Global concern about sustainability is evident in policy discussions at many scales, including international global climate negotiations, regional trade agreements, and local land use plans. The principle of sustainability takes many forms. In this paper, I define sustainability as the indefinite maintenance of human welfare. I take it as a given that most reasonable people would agree that reducing human well-being ought to be avoided, and that ensuring human welfare is a laudable goal. In other words, we should seek to meet a sustainability criterion of non-declining human welfare. However, the only macroeconomic indicator currently developed that does so suffers from fundamental problems that need to be resolved.

This paper points out three problems with the application of Genuine Savings, a macroeconomic sustainability indicator that has been developed and applied over the past few decades. Genuine Savings (GS) is meant to provide information on how well the current generation is meeting the sustainability criterion, and guide policy action based on the measure's results. While GS, even as currently implemented, provides more information on sustainability than current macroeconomic indicators like Gross Domestic Product, it can fundamentally fail to ensure sustainability in three ways. First, because GS does not account for the inherent uncertainty in the estimation of natural resources' contribution to human well-being, even strict use of measure will likely under-estimate the value of natural resources. Therefore, a nation employing it without consideration of uncertainty violates its obligations to future generations by incompletely compensating for the resources it uses today. Second, because the measure is implemented on a national scale and does not account for international trade, a nation that is reliant on an unsustainable trading partner will appear sustainable up until the moment its trading partner implodes, bringing the "sustainable" nation with it. The third problem extends this trade scenario, but assumes that the sustainable nation has limited its national risk by trading with many unsustainable nations. I will argue that even if the application of the sustainability metric guarantees sustainability within a nation's borders, the drive to appear "sustainable" by such a macroeconomic indicator may create the perverse incentive for "sustainable" nations to exploit "unsustainable" trading partners.

This paper takes the following form. In the first section, I describe why macroeconomic indicators are important and argue that environmental issues need to be included in order to provide accurate information about human well-being. I then describe the indicator that is the focus of my paper, Genuine Savings. The second section explains why it is so difficult to estimate the value of natural resources and illustrates the implications of incorrect valuation for a case study. It then describes the resulting problem, that of violating obligations to future generations. The third section uses a hypothetical two-country model to challenge the indicator's claim as a "sustainability metric." The fourth section discusses how the indicator may encourage exploitation of trading partners. Finally, I conclude with some cautionary notes.

## I. What are macroeconomic indicators and why should I care?

Macroeconomic indicators are numbers that represent large-scale economic phenomena, such as growth and trade balance, and are usually reported for a given period of time, such as a year or quarter. They provide policy makers with crucial information about the economy, and are used by planners and analysts in the public and private sectors to monitor the consequences of economic policies, evaluate programs, and compare competing proposals, such as the impacts of a national program focused on reducing unemployment versus a program focused on increasing K – 12 education. Macroeconomic numbers provide a broad perspective on the economy that cannot be gained from smaller scales, and thus are valuable sources of information for large-scale analysis.

Certain macroeconomic measures, such as wealth and savings, are theoretically linked to human well-being.[1] Decision-makers often use such indicators and proxies for well-being; depending on which macroeconomic figures they use, they may or may not be theoretically justified in doing so. Samuelson [44] showed that in order to make welfare comparisons across countries, one should compare their aggregate wealth, not their incomes. This built on insights from Fisher [18] and Smith [49], that wealth, or wealth-like measures, is a better correlate to well-being than income. The argument is that consumption and well-being over an extended period (or one's lifetime) depends more on wealth than on

[1] Consistent with most economic literature, I use welfare and well-being interchangeably. I realize that this is not consistent with the philosophical literature, where welfare is a formal theory of well-being (it is a mechanism for determining what is "good" for someone) and well-being is what is ultimately good for a person or society. Welfarism allows for competing theories of well-being. Economics employs a satisfaction of personal preferences approach to determining what is good for a person. Not all scholars think that an individual is the best judge of what is ultimately good for her. Sometimes we have poor judgment, are influenced by advertising, are forced to decide without full information, and often choose things that are not in our personal best interest for altruistic reasons. For these reasons, some propose adopting objective criteria for determining what is "good" for you. For example, Amartya Sen famously calls for focusing on "human capabilities" and the freedom to take advantage of them as the constituent components of well-being [46-48]

income, because income can change radically from year to year, while wealth, the stock, reflects cumulative income. Fisher [18] established that total wealth is equal to the present value of future consumption, a notion supported by Weitzman (who stated that "consumption is the ultimate end of economic activity") [55, p. 159], and formalized by Hamilton and Hartwick [24].

Macroeconomic figures (or statistics) are useful for policy analysis because they provide aggregate information for an economy as a whole. Microeconomic tools are also important, but these might miss cumulative effects and interactions between the economic, environmental, and social systems. Macroeconomic tools are better able to capture indirect effects of policies. For example, a microeconomic analysis of a road building program might focus on the cost of infrastructure, the benefits of increased access to market, and the environmental and social impacts of construction, while the macroeconomic analysis might better capture any larger regional and national impacts, such as health effects of the road corridor, changes in market shares of the sectors using the roads, and indirectly caused land-use change.

Many nations and international organizations use macroeconomic numbers to set policy. One commonly used indicator is Gross Domestic Product (GDP). It is the key aggregate measure of overall economic return to human and physical capital used in production. GDP is a measure of the total output, income, or expenditure (depending upon the method used) of an economy. Examples abound of the use of GDP in setting powerful policies. The amount of international aid a country gets depends in large part on its GDP. The grace period for loan payback and the interest rates for the loans from the World Bank depend on a nation's GDP. Private equity flows more slowly into nations with low GDP growth, because of the low perceived rate of return on investment. National governments use GDP to steer domestic policies, such as agricultural subsidies, tax breaks, and unemployment benefits. In short, macroeconomic indicators, and in particular GDP, are very much relevant to our every day lives.

A major problem, however, arises with GDP's ubiquitous use as a one-stop indicator of welfare. Despite the fact that GDP is not meant to be a measure of how well we are doing as a society, it is often used as such for lack of a consistent alternate indicator. Nations often seek to increase their GDP, as it is erroneously perceived as an indicator of real economic growth. This despite the fact that theoretically, GDP has very weak linkage to welfare [18, 44, 55]. Further, empirical evidence abounds disputing GDP's correlation to change in "real" or comprehensive economic growth. For example, China has experienced rapid growth in per capita GDP over the period 1995-2000, averaging 7.4% a year, but once natural resource depletion and environment are taken into account, per capita comprehensive growth is significantly lower, 5.1% [6].

There are many reasons to disallow GDP as an indicator of welfare, including its omission of unpaid labor. I focus on its treatment of the environment. GDP does not differentiate between wealth-increasing production and that which is a result of drawing down the natural resource stock. In fact, the quest for GDP growth can actually provide incentives to liquidate the natural resource stock to increase production. GDP also perversely credits economic activity dedicated to restoration, replacement, or compensation of environmental services or avoidance of public nuisances. For example, water treatment plants purify once-clean source water contaminated by industrial emissions. Their construction and operation *add* to GDP. Secondly, many harmful activities are net contributors to GDP, yet are detractors from real wealth. The Exxon Valdez oil spill is a good example. The costs of clean-up, medical services, and so forth all increase GDP, while the decline in environmental quality is ignored [2, 33, 42]. Many economic activities are associated with defensive expenditures elsewhere in the economy, yet all of these are considered positive. These are all environmental reasons to worry about GDP's ubiquity and power in setting policy.

This problem is not unique to GDP. Natural resources and the environment are currently ignored in all common macroeconomic measures. Traditional economic measures of income, wealth, and savings are incomplete. In traditional measures, income is the flow of revenue generated by manufactured and human capital, wealth is the total stock of manufactured and human capital, net of foreign assets, and savings is the remainder of income that is not consumed or spent by government; if positive, savings augments wealth. Natural capital does not appear in traditional accounts and measures, except insofar as it is an input to manufactured or human capital. Drawing down the soil, water, minerals, fossil fuels, forests, fisheries, and other resources is not accounted for at all in standard accounting [2, 13, 20, 31] despite the fact that these capital stocks are crucial for human well-being.

Over the past 35 years, economists have worked to develop a macroeconomic measure that accurately reflects a nation's change in well-being. The aim is to replace traditional indicators currently used in setting policy which have little relationship to policy's aim of ensuring society's well-being.

*Genuine Savings*

Newer, holistic measures have been developed that capture a broader array of welfare-generating capital. Traditional measures limit welfare-generating capital to manufactured capital, but increasingly economists acknowledge that human well-being depends upon much more than manufactured capital. We all "consume"[2] many things to generate our well-being, including food, art, aesthetic beauty, and a clean environment. Our wealth, therefore, constitutes much more than our stock of industry and machineries; also included are unexploited minerals, rivers, agricultural land, parks, air quality, and so forth. The value of this broader array of capital has been called our "comprehensive wealth" (World Bank 2006), and refers to the entire stock of resources that yields the capacity to generate goods and well-being now and in the future. These assets include manufactured, human, and natural capitals. Manufactured capital includes the traditional forms of reproducible capital, including machinery and buildings. Human capital is made up of the skills and know-how of the population.

It follows from this broad definition that any depletion or degradation of these capital stocks should also be included in a wealth indicator if the aim is to accurately represent welfare-generating capital stock. In this paper, I focus on one promising indicator, Genuine Savings (GS) that seeks to include a broader array of welfare-generating capital stock.

GS is a measure of the change in comprehensive wealth. It measures how much the stock of comprehensive wealth increases or declines over a period of time. Because its purview is broader than traditional wealth measures, it is theoretically more robust, and it can be rightly claimed that the change in comprehensive wealth, i.e., GS, is related to changes in welfare. If GS is negative, it indicates that comprehensive wealth is being depleted, and portends a decline in human welfare.

Decision-makers have long sought a sustainability indicator, i.e. a figure that can be used as a warning sign that economic welfare is endangered. Welfare is generated by consumption of the comprehensive wealth that we have at our disposal. Because a perennial decline in welfare is by definition unsustainable, a persistent decline in comprehensive wealth is also unsustainable. What we need, then, is an indicator that tells us whether our comprehensive wealth is declining if we want to know something about sustainability. GS fulfills this role, and claims to be a "sustainability indicator." A persistently negative GS indicates a declining capital base and, by extension, a decrease in human welfare.

GS has become the preferred measure in some policy circles because it is feasible to implement, values natural resource wealth where GDP does not, and can be easily integrated into macroeconomic datasets. To calculate GS, one draws upon existing data collected within common macroeconomic indicator frameworks, and therefore requires minimal additional information. The ethical motivation for GS is a

[2] Consumption is economic jargon, and does not necessarily imply that the capital is altered in any way. We can generate well-being by "consuming" (or watching) a sunset.

concern for future generations, a concept inherent to economic sustainability. GS also addresses the concern that natural resources and the environment are poorly represented in macroeconomic data and traditional indicators. Common macroeconomic measures, such as income, saving, and production, give an inaccurate and often perverse signal of how well a nation is actually doing. GS offers an alternative to these figures, which are often misused as indicators of progress. Aggregate indicator databases are used to set policies as wide-ranging as development lending, production strategies, and trade liberalization. The ability for GS to be integrated into existing datasets is a huge advantage.

In practice, GS is usually applied at a national level. It aggregates the changes in a nation's capital stocks over a particular period of time, usually a year. Notably, it monitors the change in capital stock that a nation *owns*. A nation's negative GS is an indication that its nationally owned resource base is declining.[3] In the section above, I showed that in theory GS is a useful sustainability indicator because it can track change in comprehensive wealth, upon which human well-being is dependent. If GS is negative, it implies that the resource base is being drawn down unsustainably. This is undoubtedly an important piece of policy-relevant information. Governments can take action to reverse a negative savings rate, including protection of natural resources, increase in educational funding, or other domestic policies.

GS has been applied to most nations of the world, and is reported as part of the World Development Indicators [57]. For many nations (especially in Eastern Europe and Central Asia, Middle East and North Africa, and Sub-Saharan Africa), it is a revealing exercise, indicating that what seemed like sustainable growth measured by GDP, when adjusted, is actually unsustainable because the capital base is declining. Under the non-declining welfare rule, at a global level, we are sustainable; most regions of the world are sustainable, with the exception of the Middle East and North Africa, which are persistently negative, and Sub-Saharan Africa, which hovers near 0% [56]. The real test is how well estimates of GS reflect social welfare. Ferreira and Vincent [17] used historical data on both consumption and genuine savings, to test whether past GS estimates accurately predicted trends in consumption. They found that the relationship between GS and consumption holds best for non-OECD countries. Importantly, they show that the

[3] Bolt, Matete et al [9] and World Bank (2006) provide methodological guidance for empirically estimating GS (formerly called Adjusted Net Savings or ANS). The GS estimate builds on the conventional net savings metric (the portion of production that is not consumed, adjusted for depreciation). GS then includes depreciation or investment in other assets that are important for human well-being. The formula for calculating GS is:

$$GS = NNS + EE - ED - MD - NFD - CD - PMD$$

where genuine savings (GS) is net national savings (NNS) plus education expenditures (EE) minus energy depletion (ED), mineral depletion (MD), net forest depletion (NFD), carbon damages (CD), and damages from local air pollution (PMD).

relationship between savings and future consumption improves as the savings measure becomes more comprehensive – in other words, GS performs better than traditional savings.

**II. The Unaccounted Uncertainty Problem**

All the problems I raise are based on critiques of the practical, empirical application of GS, not its theoretical underpinnings. I take the theoretical basis of GS as valid, and focus on enumerating issues that arise from its use in policy making.[4]

The first problem arises because of numerous empirical problems that render it difficult to accurately estimate the shadow price of natural resources. In this paper, I simplify greatly for the sake of clarity. The economics of valuation can become devastatingly complex in short order, but my point here is to raise broad problems which render accurate valuation difficult, without losing the reader, so my technical economist readers will have to forgive the superficiality of my discussion. (I refer you to the Appendix for a somewhat more thorough treatment of my case, equations included.)

The GS approach requires that a value is assigned to a resource. This value is related to the welfare the resource generates. In other words, our welfare will decline a certain amount due to deforestation. How much? The physical change in forest stock will affect welfare more or less depending on the forest's contribution to welfare. The value we impute to a resource is the estimate of how much better or worse off we will be given a unit increase (or decrease) in an asset. Economists call this the "shadow price" of a resource. So, for example, the shadow price of deforestation is how much worse off we are due to an incremental loss of forest. Our total welfare loss is the product of the shadow price and the physical change is the forest area change between this year and last year, i.e. the unit cost of deforestation multiplied by the total area lost. Importantly, shadow prices are *not* market prices; they are prices that adjust for imperfections in the market, flawed information, and other distortions that drive a wedge between the asset's market price and its value to society.[5] Shadow prices are important inputs into the macroeconomic measure, yet they are notoriously difficult to estimate.

One reason the shadow price of natural resources is difficult to estimate is uncertainty about all the various services these resources provide, compounded by hurdles to correctly estimating their

[4] There are also innumerable assumptions about the validity of environmental economics, welfare economics in general, incommensurability of natural resources, non-substitutability of natural capital, and so forth that, for purposes of this paper, I bracket.
[5] Some philosophers have used the term "well-being value".

contribution to welfare from now into the far distant future. Even assuming that these services can all be monetized, a very contentious assumption, simply attaining comprehensive knowledge about all the well-being that a given resource provides and will provide might be an impossible task. For example, we know that the Brazilian Amazon acts as an important carbon sink and is crucial to global freshwater cycles. Lesser known services it might provide now or in the future include medicinal discoveries, mineral supply to the ocean and its fisheries, and protection of habitat for countless species and human cultures. Simply put, we lack complete information on the myriad ways natural resources contribute to human welfare, which makes accurate valuation even more difficult. Furthermore, as resources become more scarce or as we discover previously unrecognized ways that a natural function provides us with service (think the climate), the estimated value must reflect this. But it is very difficult to predict future value, and such dynamic price functions are even antithetical to most economic models.

An additional problem in accurately estimating the shadow price of natural resources involves how we include the long-term nature of the goods and services nature provides. If the forest is expected to provide food and recreation opportunities far into the future, how do we include that in an economic estimate of the forest value today? Economists use a technique called discounting, which basically translates predicted future value to a present value using a negative exponential function. A simple analogy is the time value of money: you prefer to have a dollar today than a dollar tomorrow. Similarly, a dollar of benefits that a forest provides today is worth more than a dollar's worth tomorrow. Without going into too much arcane detail, the crucial point is that the shadow price of a natural resource is incredibly sensitive to the chosen rate; a higher rate reduces the shadow price, and a lower rate increases it. There is no consensus on what discount rate to use. The choice is largely based on normative considerations, including how to weigh future trade-offs, and how risk averse one is in the face of uncertainty. The result of misestimating the discount rate has serious practical implications: if too low a value is assigned to a natural resource, we will deplete it too quickly, while if we overestimate the value, we will preserve the resource without achieving the countervailing future welfare gains.

What are the implications of getting the shadow price wrong? To illustrate this, I employ an empirical example: deforestation of the Brazilian portion of the Amazonian rainforest. In this example, I refer to a model that I developed, one module of which estimates the value of the Brazilian deforestation [36]. My hope is to illustrate the difficulties and implications of inaccurate estimation, not to defend the model itself. For that, I refer the reader to other sources [7, 36].

*The Amazonian rainforest*

The Amazon forest covers about 40% of the South American continent, an area roughly equivalent to the continental United States. The Amazon Basin, referred to as Amazonia, contains the largest extent of tropical forest on Earth, over 5 million $km^2$.[6] It also contains over 2 million $km^2$ of savanna vegetation to the north and to the south of the domain of the tropical forest. The annual discharge of the River Amazon into the Atlantic Ocean of more than 200,000 cubic meters per second contributes about 18% of the global flow of fresh water into the oceans. This vast equatorial ecosystem is home to one fifth of the planet's plant and animal species, more than 200 indigenous cultures, and 30 million people.

For most of the last 12,000 years that humans have inhabited Amazonia, the forests were left relatively untouched, including the period known as the "rubber boom" (during the second half of the 19th century to about 1910). By the 1950s only about 1% of the forest of Amazonia had been cleared (INPE). The occupation and development of Amazonia since the 1950s and its impact on the vegetation cover and on the composition of the atmosphere have changed dramatically, with most of the changes taking place over the last 30 years. During the 1950s and 1960s many countries of South America started to implement government plans to develop and integrate the economy of Amazonia. The plans called for a network of roads criss-crossing the region and put emphasis on agricultural development. For Brazil, that was accomplished through government incentives and tax benefits to attract large companies for cattle ranching, and a program to settle millions of landless peasants from other parts of Brazil in Amazonia. As a result, deforestation in Brazil reached nearly 650,000 square kilometers in 2004 (for reference, the state of Texas is 695 thousand square kilometers), with 5-year average[7] annual deforestation of 21.5 thousand square kilometers a year (about the size of New Jersey) [16, 29].[8]

Major environmental concerns arise from this deforestation. Biodiversity loss and contributions to greenhouse gas emissions are ones of global concern, while local concerns involve loss of soil fertility impacting agriculture, erosion and agricultural chemical runoff polluting rivers and streams, converted forests alter hydrological regimes, which in can lead to flash floods followed by periods of no stream flow, and loss of habitat for local food and medicinal flora and fauna. Each hectare of Brazilian forest lost leads to a release of anywhere from 145 to 210 tons of carbon per hectare depending upon the ecosystem and assumptions about soil carbon [28]. This means that in 2005, anywhere from 270 to 395 million tons

[6] Brazil´s political definition for the Amazon, the so-called Legal Amazon, has a surface of 5.2 million $km^2$, corresponding to 61% of the Federal Republic. Two of the nine states in the Amazon, Para and Amazonas, contain 55% of the surface area. The Amazon Biome has a surface area of 4.1 million hectares representing 42% of the national territory.
[7] For 2000-2005; note that in 2005 19.8 thousand square kilometers were deforested, and there is evidence that the upward trend is slowing.
[8] The Brazilian Amazon accounts for approximately 85% of Amazon basin deforestation.

of carbon were emitted from Brazil's Amazonian deforestation, which is equivalent to 16 to 24 percent of total US carbon emissions in 2005 or 4 – 5 percent of total global emissions in 2004 [14]. These environmental concerns are of course augmented by serious social impacts that I leave out of my analysis, such as loss of cultures, increased disease transmission from improved transportation, and so forth.

These environmental impacts have consequences for human welfare on many spatial and temporal scales. At the local level, if habitat for game animals is destroyed, local communities might lose a major source of nutrition. At the regional level, if nutrient cycling is hampered, nutrient run-off may cause local rivers and streams to become anoxic and unsuitable for drinking or swimming. At the global level, if carbon currently stored in the biomass and soils of forests is released, global climate change could accelerate causing direct impacts, such as destruction of coastal cities, and ancillary impacts, such as reduced agricultural production.

These environmental impacts also have real economic costs. Using very conservative economic estimates, my research shows that the value of non-timber forest benefits lost from Brazilian deforestation during the 1995-2000 period was nearly double that of the timber value in Brazil [36]. The framework I used for valuing the costs is the Total Economic Value framework [39], which describes three categories of non-timber values provided by forests: *extractive* use values (such as plants and animals), *non-extractive* use values (these include services the forest provides such as recreation, aesthetic enjoyment, erosion control, and carbon sequestration), and *preservation* values (which include the option value of preserving the forest for future use or future generations and the existence value, which is the value of knowing the forest exists, over and above any extractive and non-extractive use values).

Three obstacles to estimating the value of the Amazon quickly emerge. The first has to do with the heterogeneity of the natural environment, complicating identification of the ecosystem functions. The second obstacle is estimating whether or not humans are actually benefiting from the ecosystem function, i.e. whether or not there is an ecosystem service being provided. The third surrounds putting an accurate value figure on the service being provided.

In my model, I deal with the first and second obstacles simultaneously. Given the heterogeneity of natural ecosystems and human settlement in the Amazon, it is obvious that not every hectare of forest functions the same nor provides every service. Recreation might only be provided by forest within a certain radius of villages, rivers, or lodges. Subsistence food is likely only extracted from areas near human settlements, and marketable food might only be harvested in areas near means to get the products to market. Carbon sequestration is provided by all forested land, but not all forests provide equal sequestration benefits due to varying carbon content in the biomass [27, 28].

I model these uncertainties by assuming that only a fraction of the forest provides ecosystem services. In the model, I assume that 80% of Brazil's forests provide a stream of non-timber goods and services. The 80% fraction of forested area providing services is far greater than some estimates [for example 30, 56 only use 10%], but which I felt better reflected recent scientific literature on the importance of the goods and services provided by forests [1, 8, 19, 34, 37, 40].

The third obstacle arises because in order to assign values to these services, the ecological functions must be coupled with economic values, and must be translated from an annual flow of benefits into a capitalized amount[9] [35]. Guidance on appropriate valuation methods abounds in the literature [10, 21, 26]. So, too, does criticism of the various methods and approaches. For example, Daily [12] worries about legitimacy of values derived from valuation techniques that assume minor changes when, in actuality, major changes are occurring to the environmental functions in question. Goulder and Kennedy [21] question the real-world transferability of hypothetical situations used in some valuation methods.

In my model, the value of the benefit stream provided by forests is based on estimates from a global literature survey. The benefits range in the literature from $14 - $292 per hectare per year [3, 4, 16, 32, 38, 40, 51, 54]. The value of carbon sequestration is another important part of the NTFBs a forest provides – often the value swamps the value of other goods and services derived from the forest. Drawing upon literature on the marginal social price of carbon [50, 52] and on estimates of the carbon content of a given hectare of forest [4, 15, 27, 45, 53], I use a range of estimates for the marginal price of carbon of $50 - $312 per ton carbon and a range of carbon release between 100 – 200 tons carbon per hectare (see above).

What does all this mean in terms of the estimated value of the forest? Recall that the value of the loss or gain of non-timber forest benefits is a function of the area deforested, the portion of that area that was providing the service in question, the estimated value stream (i.e. the dollars per year that the service provides), the discount rate, and the time horizon. For simplicity sake, let us hold all but the estimated value stream constant. If the value of the deforested area was closer to the lower bound (i.e. $14 per hectare annually), then Brazil's accounted losses are a negligible 0.1 percent of gross national income

[9] In other words, the annual benefit stream must be converted into the present value.

(GNI)[10] per year. This implies that in order to be "sustainable" per the definition provided above, for the natural capital depletion made up by net deforestation, Brazil only has to make up for an accounting loss of 0.1% of its GNI each year to keep its Genuine Savings from turning negative. But say that $15 per hectare per year is a gross underestimate, and the annual benefits the forests provide are actually worth closer to the upper bound of $292 per hectare. In that case, deforestation is costing Brazil 5% of its Gross National Income a year [36].

The difference between these two numbers is policy relevant. Now policy makers must pay attention: an annual income growth rate of 5% would be an admirable macroeconomic achievement for any government; similarly, losing that much to natural resource depletion would be a significant drain on a nation's wealth. Put another way, to make up for the cost of deforestation, Brazil has to find an off-setting 5% growth in wealth somewhere else in its economy. They might find such growth by educating their public, restoring other forms of natural capital, or increasing industrial incomes, but this magnitude of wealth expansion will not be easy to achieve; it is likely much more efficient to curb deforestation rates.

*Unaccounted Uncertainty*

With this background, let us return to the problem at hand, namely that measurement error results in violation of the sustainability criterion. Let us imagine Country C, a resource rich country that strives to keep its GS positive. We can imagine three different scenarios, all with different normative force.

The first scenario is called "the good." In this case, Country C employs the best empirical techniques available to estimate the shadow price of its natural resources. It adjusts its national policies to ensure that GS remains positive. For every dollar of natural resource depletion recorded, Country C reinvests a dollar elsewhere in the economy, thereby ensuring that its capital base never declines. Country C's economists carefully document the uncertainty related to their calculations of the value of natural resources. They explicitly recognize how few resources are incorporated, and extrapolate as best they can to other resources, basing their estimates on the best science available. They work out the probability range of value that should be deducted from the ledger, and give decision-makers information on the likely underestimation that the GS figure reports. The decision-makers carefully consider these numbers and enact conservative policies that prevent over-exploitation of the natural resource base. In so doing, Country C fulfills its obligation to meet the sustainability criterion.

[10] Similar in concept to Gross Domestic Product, only it reflects a different accounting method

The second scenario is labeled “the dumb.” Country C’s economists know that there is uncertainty, but fail to quantify it or incorporate it in any way into their calculations. They report the GS measure as if it was a perfectly accurate representation of the true losses of natural resource wealth, and decision-makers use GS to set policy. Their blind adherence to the macroeconomic figure results in them failing to fulfill their obligation to meet the sustainability criterion.

The third scenario involves “the bad.” The economists try their best to calculate and report uncertainty, but the decision-makers ignore it when making policies. They decide to promote domestic industries that are natural resource-intensive despite the warnings that the economists provide that this is a dangerous path to follow. In this case, Country C fails in its obligation to its citizens to interpret a positive GS with caution. It does not implement policies that would preserve resources and ensure a seemingly very highly positive GS, even though it knows that the “true” GS is well below the reported number. In this case, they also fail to meet the sustainability criterion.

We know that there is great uncertainty in the shadow values that we impute to natural resources. GS, however, reports figures without any indication of uncertainty, a violation of best practice in most quantitative disciplines. In ignoring uncertainty, GS provides misleading information to decision makers. Its authoritative, seemingly accurate representation of the increase or decline in national comprehensive wealth belies the uncertainty of the underlying valuations. There are ways to incorporate – or at the very least indicate – uncertainty within the GS framework. Not doing so seems objectionable because it confines decision makers into the first scenario. They remain ignorant of the uncertainty and could therefore be absolved of responsibility for acting conservatively. Without uncertainty bars, using GS to set policy might actually imperil the well-being of citizens.

**III. The Shaky Foundation Problem**

The fact that GS monitors the change in national wealth is the basis for the second problem: a nation can look sustainable according to GS up until the moment that an external (and completely knowable) effect renders it unsustainable. This external effect is the implosion of its trading partners due to unsustainable practices.

To illustrate this problem, imagine stylized world with two countries. Country A is resource-rich. For this case, let us assume that all the uncertainties explained in the Unaccounted Uncertainty Problem have been solved. Each year, using the best information available about the value of its natural resources, its decision-makers calculate the Genuine Savings rate, and see that it is negative. The negative rate is driven by the fact that they harvest a significant portion of their forests every year and do not reinvest enough of the profits to make up for the full costs of forest depletion. For whatever reason, they are unconcerned about the negative GS rate, and report it publicly in the World Development Indicators.

Consider now Country B. Country B has no natural resources itself, and for years been importing timber from Country A as raw materials for its furniture-making industry, the only industry it has. The furniture industry is growing, requiring more and more timber as raw material. Country B uses the profits from its furniture sales to educate its populous and provide universal health care. In all, Country B's comprehensive wealth is growing each year. Because it has no natural resources, it has no deductions from its ledger for natural resource depletion. According to the positive GS its macroeconomics tout each year, it looks like there are no concerns about Country B's sustainability.

But Country B cannot continue to get the raw materials from Country A indefinitely. One of two things will happen: Country A will realize that the loss of its forests is actually depleting its wealth, and will halt (or increase the cost of) its exports, or Country A will allow the forest to be completely depleted. Either way, at some point, Country B will also crash.

This raises a serious concern about an indicator that claims to provide information about the sustainability of a nation. GS, by virtue of its exclusive focus on assets that a nation owns, gives no indication whatsoever of this impending crash. If decision-makers in Country B were to rely exclusively on GS as an indicator of its sustainability, it would violate its sustainability principle and not ensure the well-being of its population. It is a stupid omission of Country B's decision makers to not consider the GS of its trading partners. Country B can easily access Country A's information, and they should in order to fulfill their obligation to ensure the well-being of their population.

My main point is that GS applied at a national level cannot be taken as a national indicator of sustainability given the transnational era in which we live. Doing so provides a misleading picture of the sustainability of a nation. GS ignores international interactions, something that might have been acceptable in past eras where international trade was less crucial to the economic health of a nation, but certainly should be looked upon with suspicion in a globalized age where trade flows are growing at almost 10% annually and where trade in goods and services constitutes over a quarter of global GDP [57].

## IV. The "Sustainable" Exploiter Problem

The final problem also focuses on the result of GS' national focus, but asks a slightly different question than the Shaky Foundation Problem. In the Shaky Foundation Problem, there was only one Country A, and once it was fully exploited, Country B had no source of resources and therefore followed Country A into poverty and violated its sustainability criterion. My point in that example was that a nation's GS does not indicate this completely knowable danger.

But my point here is quite different. Imagine a world with an endless number of Country As. Upon full destruction of one Country A, Country B moves on to the next one. In this way, Country B will be sustainable forever, leaving a long line of depleted Country As in its wake. So the issue here is not the sudden unsustainability of Country B. The issue here is the intuition that it seems inconsistent for a sustainability indicator to label one nation sustainable when its sustainability relies on the unsustainability of another nation.

Country A is fully aware that its GS is negative, but for whatever reason, Country A has chosen not to remedy its negative GS rate. It may be that Country A is "dumb" (failing to quantify the uncertainty in their natural resource values and acting blindly) or "bad" (fully aware of the uncertainty and acting anyway). Imagine that Country B is also fully aware of the draw-down its consumption is causing in Country A. In other words, Country B observes that Country A's GS is negative, and knows that that is due to the export of its natural resources. Country B may give any number of justifications for continuing to import natural resources from Country A, including claiming that adequate protection of environmental resources in Country A was an issue of national sovereignty, or that Country A had the right to use its natural resources as fuel for economic development. But Country B knows that Country A, for whatever reason, is unsustainably managing its resources. Further, Country B knows that natural resources are very difficult to value, and it suspects that Country A has likely undervalued its resources. In this case, I believe an equity issue arises.

Country A is obviously violating the sustainability criterion if it knowingly allows GS to be negative. But Country B is also violating an obligation. If it is aware that Country A's decision makers do not have the interests of their citizens in mind, are knowingly over-exploiting natural resources, or systematically undervaluing their natural resources, I believe that Country B also has an obligation to Country A's citizens. Country B cannot knowingly abet the mismanagement of Country A's resources.

My critique of GS in this case is that it encourages exploitative behavior by virtue of focusing on resources that fall within national borders. If decision-makers are only accountable for ensuring GS is positive, they can readily do so by locating nations that are selling their resources at below what they value domestic resources. In theory, this is the point of international trade. Nations that have abundant resources should export them to nations that have scarce resources, and who are willing to pay a premium for the resources. In this way, exporting nations exploit their comparative advantage and make a profit. In reality, however, the gains from trade are not so clear. I discussed one reason above, i.e., that natural resources are terribly difficult to accurately value, but many other reasons exist apart from measurement difficulties why one nation might sell resources at below their theoretical shadow price (government corruption, power imbalances leading to disadvantageous trade agreements, poverty, illegal extraction, and weak institutions come to mind). As currently set up, GS is similar to a mandate to keep your personal bank account balance positive, without any question about how you do so. You might have earned an honest wage, but you also might have sold your mother's jewelry or, perhaps more to the point, swindled your next door neighbor.

Surely, a nation's trading patterns should affect its sustainability as measured by GS. Trade can be environmentally beneficial because it can facilitate dissemination of clean technologies, accelerate adoption of good environmental practices, improve international cooperation, and allocate natural resources efficiently, given correct pricing [see, e.g., 11]. But trade also has losers because market failures can derail the theoretical gains from free trade [43, 58]. Because trade at below social value is not accounted for in GS, it is impossible to say whether nations are actually gaining wealth from opening their borders. Determining who really benefits from trade will require significant research on the externalities associated with extraction and production. Nations seek to make economic gains from trade, but if in the process they are trading away their natural resource wealth, the actual economic gains enjoyed by the nation will be diminished. The welfare implications could be important, and thus could have an impact on sustainability.

## V. Conclusions

GS monitors the change in three broad categories of capital that make up comprehensive wealth: manufactured, human, and natural. It is theoretically linked to human welfare, an improvement over traditional indicators that are currently employed in setting macroeconomic policy, which have only tenuous theoretical links to welfare. Replacing traditional indicators, which myopically focus on easily-measured types of capital, with GS, which includes natural capital, would be an improvement. Policy decisions based on GS would consider changes in a nation's *comprehensive* – not traditional – wealth. Doing so would include draw-down or degradation of natural resources and the environment in the decision-making calculus. If the goal of public policy is to ensure continued human welfare, GS could provide a useful sustainability indicator.

A problem arises when GS is applied at the national level. A country's sustainability might be jeopardized by the unsustainability of a trading partner, a peril that a national GS measure ignores. A second problem results from the fact that for GS to be a reliable indicator of non-declining human welfare, and thus sustainability, it needs to accurately measure changes in the total value of capital. The uncertainty of the shadow prices of natural resources are a major hurdle to this goal. Due to the difficulty in accounting, applications of GS typically omit most natural resources altogether. Indeed, in two of the most updated current accounting attempts, the only resources included are thirteen metals and minerals and forests, coupled with two dimensions of environmental quality, carbon emissions and local air pollution (World Bank 2006, Oleson 2007). When natural resources are included, the uncertainty in their shadow price is poorly reflected in the reported GS figures. One important improvement to GS is to better reflect uncertainty in the reported figures. Further, policies based on GS need to be cautious, and should reflect the understanding that the value of lost natural resources is likely much higher than GS records. In short, governments cannot rely on GS as the only sustainability metric.

Finally, a third problem arises due to international trade of natural resources at below their shadow price. The disparity in world market prices and the true value of natural resources may underlie trade of natural resources and natural resource-intensive products. In other words, the mere fact that nations are incorrectly accounting for the external costs of their natural resource depletion could be driving their exports, while other nations who correctly estimate the true value of environmental preservation of domestic assets seek cheap imports as a way to avoid domestic depletion or degradation. This imbalance causes inequities amongst nations. Yet, as currently implemented, GS does not capture this.

Indeed, if external costs remain unaccounted for, nations that seek a "sustainable" GS rate have incentive to exploit cheap resources abroad. This problem can be extended to global climate change. GS, by deducting only the impacts on a nation's assets caused by global climate change, encourages nations to "export" the cost of pollution (or any other external costs of production). In this way, policies based on GS could actually exacerbate international inequities. A rich area of future research is developing a manner to account for transnational interactions. One way suggested by my research is explicitly enumerating the losses (or gains) from trade at below social prices. A possible way forward could be weighting the external costs to trading nations in their national accounts relative to some equity considerations.

In sum, developing macroeconomic indicators that better reflect the broad base of welfare-generating capital is an important pursuit, considering the ubiquity of pernicious proxies currently in use, such as GDP. That said, whether GS will get us to the ultimate goal of developing a macroeconomic sustainability indicator is an open question given the issues that I raised about its notion of "national level sustainability" and the difficulties of accurately estimating the values of natural resources. Given its current empirical limitations, GS should be carefully considered by decision makers, but not trusted to be the unique sustainability indicator.

**Appendix**

Formally, the index of intertemporal welfare (here represented by "V") is generally expressed as the present value at time (t) of all current and future utility, where utility (U) is a function of consumption (C) over all future time (s ≥ t), discounted at a chosen utility discount rate ( ):

$$V(t) = \int_t^\infty e^{-\delta(s-t)} U[c(s)] ds \qquad (1)$$

***Sustainability criterion***
This then leads to the issue of how to define a formal, measurable sustainability criterion. Many various sustainability criteria have been explored in the literature [see, e.g., 41]. Adopting the weak sustainability paradigm, one way of defining sustainability is that the intertemporal index of social welfare not decline at any time. In other words, the present value of utility may not decline. Formally:

$$dV/dt \geq 0 \qquad (2)$$

It is important to note that this sustainability criterion is not equivalent to stating that *utility* cannot not decline from one period to the next. Formally, the non-declining utility criterion is:

$$dU/dt \geq 0 \qquad (3)$$

The difference between Equations (2) and (3) may seem subtle, but is important if one is concerned about sustaining each generation's utility. Maintaining non-declining social welfare ($dV/dt \geq 0$) does not guarantee that utility in each future period will not fall ($dU/dt \geq 0$) [5, 23, 25]. The criterion of non-declining social welfare only guarantees any decline in utility for a given time period is compensated at other points, such that all current and future utility, summed and discounted over an infinite time horizon, does not decline from one time period to the next. This raises the question whether, when we set a goal of sustainability, we are aiming to maintain an aggregate index of welfare, or each generation's utility.

That said, Hamilton and Withagen [25] point out the conditions under which maintaining non-declining social welfare as a sustainability criterion also maintains non-declining utility (in other words, satisfying (2) also satisfies (3)). They assume a competitive economy, in which producers maximize their profits and households maximize their utilities, and a constant discount rate to show that utility will continuously increase so long as the change in comprehensive wealth is positive, and the growth of change in comprehensive wealth is less than the rate of time preference.

***Genuine savings as a sustainability indicator***
The index of intertemporal social welfare, V, is related to comprehensive wealth. Therefore, changes in comprehensive wealth should be related to changes in this index. As sustainability is also related to social welfare, changes in comprehensive wealth should provide insight into sustainability. Below, I provide the formal proofs for this.

Social welfare (V) at any given time (t) is a function of the consumption of the array of capital (K), a vector representing the stock of each distinct type of capital (manufactured, human, natural) at a given time (t):

$$V(t) = V[K_1(t), K_2(t), K_3(t), \ldots, K_n(t)] \qquad (4)$$

From this, we can derive the following sustainability requirement:

$$dV/dt = \sum(\partial V/\partial K_i)(dK_i/dt) \geq 0 \qquad (5)$$

This sustainability criterion requires that the sum of the product of two elements remain positive. These elements are: 1) the amount of welfare we gain or lose for a given change in a capital stock ($\partial V/\partial K_i$) and 2) the change of that capital stock over time ($dK_i/dt$). Maintaining this sum to be greater than zero requires that any decline of a capital stock ($\partial K_i$) either be offset by an increase in the *value* of that stock ($\partial V/\partial K_i$), or a *substitutable* gain in another capital stock ($(\partial V/\partial K_j)(dK_j/dt)$).

Linking this sustainability criterion to wealth, comprehensive wealth is the sum of the value of all capital stocks (manufactured, human, and natural), where value is defined as the imputed value of a given type of capital (called its shadow price, $l_i$) times the stock of that capital ($K_i$). Comprehensive Wealth (W) is therefore defined as:

$$W=\sum (l_i*K_i) \qquad (6)$$

The change in wealth at any given time is the sum of the change in value of each form of capital. The change in wealth at constant prices is:

$$dW/dt = \sum (\partial V/\partial K_i)(dK_i/dt) \qquad (7)$$

because shadow price is formally defined as:

$$l_i = \partial V_i/\partial K_i \qquad (8)$$

As dW/dt is equivalent to dV/dt if shadow prices are assumed to be constant, the sustainability criterion can be translated from a requirement that social welfare not decline to a requirement that comprehensive wealth not decline. The change in comprehensive wealth (dW/dt) is commonly called Genuine Savings (GS)[11]. Put another way, the sustainability rule – if defined in terms of V (and not U) – is that GS must be positive.

Crucially, GS in practice is a one-sided test of *un*sustainability. A negative rate implies that the resource base is being drawn down unsustainably and thus violates the sustainability criterion. A positive rate, however, is a necessary but insufficient criterion for ensuring that utility not decline. A positive GS ensures sustainability as defined as non-declining welfare (V), but does not necessarily ensure non-declining *utility* from one generation to the next [22, 25]. It signals a path of non-declining utility only under strict conditions; if these conditions are not met, GS will not guarantee sufficient reinvestment and will not ensure that utility is rising at all points in time.

[11] Formerly known as Adjusted Net Savings [9]

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