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Nonmarket benefits of nature: What should be counted in green GDP?

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ABSTRACT

Green gross domestic product (green GDP) is meant to account for nature's value on an equal footing with the market economy. Several problems bedevil green GDP, however. One is that nature does not come prepackaged in units like cars, houses, and bread. Even worse, green GDP requires measurement of the benefits arising from public goods provided by nature for which there are no market indicators of value. So what should green GDP count? That is the subject of this paper. Ecological and economic theories are used to describe what should be counted—and what should not—if green GDP is to account for the nonmarket benefits of nature.

1. Introduction

The most visible and influential of the national economic indicators is gross domestic product (GDP). People familiar with national accounting know that GDP is but one of many accounting measures and that GDP captures only a part of what is important about an economy. Nevertheless, GDP deserves its special status because it represents an important bottom line: how much the market economy produces, and what it is worth. Other accounts depict inputs to production (e.g., labor and capital), but GDP gets right to the point: is the measured economy growing or shrinking?[1]

If a green GDP could be calculated, it also would get right to the point, describing the state of nature and its worth.[2] In this paper, *green GDP* is defined as a measure of what is valuable

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[1] Unfortunately, GDP ignores, for practical reasons, the future consequences of current consumption (e.g., depletion of resources). Depletion is a key ecological issue. Section 4 discusses depletion adjustments in the context of Green GDP.

[2] *Green GDP* is an accounting measure geared toward welfare measurement, the approach advanced by Mäler (1991), Peskin and Delos Angeles (2001), and Grambsch et al. (1993). It is different from, but not inconsistent with, accounting schemes that account for changes in ecosystem stocks (Repetto et al., 1989; U.S. BEA, 1994). For overviews, see Hecht (2005), Lange (2003), and Nordhaus and Kokkelenberg (1999).

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about nature,[3] excluding goods and services that are already captured in GDP.[4]

Why measure green GDP? For environmentalists, well-being provided by nature is as important as well-being provided by market consumption. Societies should be able to see how market consumption affects the consumption of public goods like beautiful views, clean air, and clean water. After all, consuming fewer manufactured products now in order to ensure more access to natural goods and services later may be in society's best interest. Another reason to measure green GDP is that environmentalists want to track the provision of nature's benefits over time, either to hold governments accountable or to compare their environmental conditions with those of another country. These reasons are also why economists want to measure green GDP. Economists want society to articulate trade-offs, measure performance, and maximize social well-being.[5] These tasks are impossible to achieve when nature's contribution to human welfare cannot be measured.[6]

However, green GDP requires measuring the benefits that arise from public goods provided by nature.[7] This measurement problem is referenced throughout the SEEA. So, too, are cautions about the practicality of such measurement.[8] But measuring benefits that arise from the "public good" aspects of nature is fundamental to green accounting. Nature's public goods must be counted if welfare is to be comprehensively measured.

To measure nature on an equal footing with the market economy, the first step is to define the appropriate units of account. GDP counts units in the market economy—cars, houses, legal services, loaves of bread, and so on. Unfortunately, nature does not come prepackaged in this way. So how to choose what to count? That is the subject of this paper. I use both ecological and economic theories to describe what should be counted—and what should not—by green GDP.

The focus of this paper is the challenge of measuring environmental benefit, thus described in SEEA 2003:

> Few attempts have been made to establish asset accounts for ecosystems. Many of the reasons are practical: determining a suitable unit of account, deciding how to deal with the "collective" nature of a complete ecosystem, delineating the borderline of the ecosystem of interest and defining the extent of possible duplication when an entity interacts in more than one ecosystem.[9]

To differentiate what should be measured from what should not I articulate a way to define the units of account. The authors of the SEEA strike a pessimistic note, suggesting that this challenge may be too great:

> The largest question is, can we calculate a measure of GDP that adequately accounts for demands placed on the environment? The simplest and most honest answer is that there is no consensus on how "green GDP" could be calculated and, in fact, still less consensus on whether it should be attempted at all.[10]

In contrast, I argue that the calculation of a green GDP can and should be attempted. The benefits of nature are too important and too large to be "left off the table" of national accounting. The real difficulties should not distract from the practical steps that can begin immediately. One reason that these steps have not been clarified is that economists have not previously integrated principles from accounting economics with those from environmental economics.

In this paper, I describe ways to define and measure units of ecosystem goods and services that are consistent with conventional national accounting. These methods are necessary if green GDP is to become a reality. If nature's benefits are to be characterized and tracked over time, then the units must be clearly defined, ecologically and economically defensible, and consistently measured. At present, the government and the public are presented with an overabundance of poorly defined measurement units that have unclear origins and that exacerbate the divide between economic and ecological analysis.[11]

The paper proceeds as follows. In Section 2, I describe the two essential components of an income or benefit index: quantities and prices. Much of the concern about the practicality and validity of green GDP arises from the very real difficulty of putting values on the aspects of nature that benefit society. Lost amid that concern has been analysis of a much more tractable problem: how to define the quantities to be counted. In Section 3, I describe the units of account in detail. In Section 4, I discuss the role of ecological analysis in interpreting and adjusting green GDP measures. In Section 5, I relate the units of account defined in previous sections to the broader ambitions of SEEA.

[3] This phrase was chosen carefully. "A measure of" a value is not the same as the value itself. GDP and green GDP are only approximations of value. This distinction is well known and goes back to the founder of welfare index theory, Pigou (1932).

[4] Part of nature's value is already captured in GDP. Whenever ecosystem goods and services are inputs to goods and services measured by GDP (marketed goods and services) part of their value is captured in GDP. The value of housing embodies the value of visual amenities enjoyed by residential owners, for example. Likewise, the value of commercial fish, crop, and timber harvests partially "captures" the value of goods and services used to produce the harvests. In other words *some* of the value of marine fish stocks, irrigation water, and forests is already captured in GDP.

[5] The 2003 edition of the Handbook of National Accounting, also referred to as SEEA for the System of Integrated Environmental and Economic Accounting (UN/UNEP, 2003). "The rationale for monetary accounts is that a consistent basis of valuation may be applied precisely so that aggregation across asset classes is possible and comparison can be made with non-environmental assets in terms of their respective contributions to the nation's wealth" (246).

[6] See Nordhaus (2005) and U.S. BEA (1994).

[7] GDP uses proxies for value (prices) to create an index of the market economy's "value." This means that GDP cannot be said to equal "the social benefit of the market economy," which cannot be practically calculated. In the same way, green GDP should never be equated with "the social benefit of nature." It is most accurately described as "an index of nature's value," not the value or benefit itself.

[8] "[Ecosystems] are the most difficult environmental assets to quantify. A comprehensive measurement of all the environmental services provided by ecosystems is conceptually possible, but not comprehensively covered by the handbook" (UN/UNEP, 2003, 269).

[9] UN/UNEP, 2003, 301.

[10] UN/UNEP, 2003, 415.

[11] For a broad overviews, see U.S. GAO (2004, 2005).

2. Quantities versus prices

To put a value on enjoyment or consumption, GDP and its green counterpart must first count what is enjoyed or consumed. GDP measures two basic things: quantities of goods and services (q) and the prices of those goods and services (p). Even if nothing else happens, counting the qs—hamburgers, lumber, software, and real estate—is valuable. For example, counting helps economists judge the productivity of factories and workers. Counting what is produced—even without accounting for prices—yields important clues as to how the market economy is doing. We need similar clues to the natural economy. When the beneficial aspects of nature are counted, nature's contributions to welfare can be much better described.

In Section 3, I use economic principles to define quantities (i.e., amounts of ecosystem goods and services) in a way that makes their units consistent with those counted in conventional GDP.[12] But first, green GDP accounting units must be distinguished from the material flow units described in the SEEA. Material flow units are a much more inclusive set of units that describe biophysical and technological relationships in the natural and market economy. What is the relationship between material flow units and ecosystem service units? The main point is that the two classes of units are not synonymous. In principle, material flow units can be used to describe and predict biophysical relationships. This makes them particularly useful in the analysis of depletion (the consequences of current consumption for future service availability). But from the standpoint of green GDP, material flow accounts measure too many things and do not adequately distinguish between inputs and outputs. Put another way, many if not most input-output variables will have little to do with how households experience nature. Green GDP requires us to clearly delineate between nature's final outputs (which are counted) and the inputs necessary to produce them.

Green GDP accounting units also should be distinguished from the many forms of counting that arise within ecology. Clearly, ecologists count many aspects of nature that are important to ecological science (e.g., biota).[13] However, to count society's enjoyment, use, or consumption of nature, economics—rather than ecology—is needed to define what is counted.

What about prices, the other core aspect of a welfare index? By their very nature, environmental public goods lack the prices that are used to weight outputs in GDP.[14] Indeed, the problem of missing prices spawned and continues to occupy an entire field of economics. It has also led many environmental accounting advocates to despair. To be sure, attaching weights (virtual prices) to environmental public goods is a significant challenge.[15] But a more significant hurdle is deriving those weights without the benefit of consistently defined units of account. Defining units is a crucial step that environmental economists have largely neglected.[16]

For several reasons, then, welfare-based accounting for environmental goods must begin with defensible definitions of the units to be counted. First, keeping track of these units (without prices) itself yields useful information. It is better to know how many cars and trucks are produced each year than to not know at all. The same is true for environmental public goods. Second, the missing price problem can be systematically addressed only if the units to which virtual prices are attached are consistently defined. Third, assigning prices to nature is controversial for philosophical and political reasons. Focus on the quantities part of the problem avoids distraction by those debates and resistance to "putting price-tags on nature." If green GDP is to be fully realized, then the price debates cannot be avoided forever. But they can be avoided for a while, while counting begins.

3. What should be counted? Deriving the units of account

Nature offers plenty of features to count. Indeed, this abundance is part of the problem. To date, ecology, environmental economics, and the growing field of green accounting have failed to provide adequate guidance on what in nature should be counted as defensible measures of nature's services. Despite calls for services to be the foundation of global environmental assessment (Millennium Ecosystem Assessment, 2005), practical measurement is thwarted by imprecision, confusion, and conflicting definitions.[17] This imprecision is a result of the failure to use ecological and economic theory to define services.

Terminology is a big part of the problem. Ecology and economics talk about ecosystem components, processes, functions, services, assets, stocks, and benefits. What are the relationships among all these terms? *Ecosystem components* include resources such as surface water, oceans, vegetation types, and species. *Ecosystem processes and functions* are the biological, chemical, and physical interactions associated with ecosystems that are described by biology, atmospheric science, hydrology, and so on. Should nature's processes and functions be counted? Absolutely, but not to determine green GDP.[18]

[12] The definition is described in more technical detail in Boyd and Banzhaf (2006) and Banzhaf and Boyd (2005).

[13] Ecologists, too, are calling for more consistent measurement to account for biophysical phenomena (Kremen, 2005).

[14] Higher prices signal greater value. GDP weights outputs (goods and services) by their prices. This concept is well known in economics to be far less desirable than weighting outputs by their overall contribution to welfare (net surplus, in economic parlance). So why are prices used? Only because they are easy to collect.

[15] Public goods are not traded in markets and thus do not have market prices to signal their value. The same is true of other public goods, such as national defense and police protection.

[16] Environmental economists tend to be concerned with the total value of environmental goods or policies. To most environmental economists, a consistent definition of quantity q is relatively unimportant because they are focused on calculating the total price $p \times q$ (an oversimplification). Welfare accounting, in contrast, demands a consistent distinction between quantities and prices so comparison can be made across goods and across time.

[17] See Smith this volume. Also see Binning et al. (2001) for excellent ecological and economic illustrations of services but using a far more expansive definition than the one used in this paper.

[18] Here again the distinction between current consumption and future depletion is essential. Analysis of processes and functions is necessary to the analysis of current consumption's effect on future consumption (see Section 4).

To account for nature's benefits, the most important definition is that of *ecosystem services*, which can be thought of as "flow units." Ecosystem services are the appropriate units of account.

Why not ecosystem assets? Assets are relevant economic units, as reflected in their routine use in conventional national accounts. For environmental accounts, however, the focus on assets is problematic. Conventional market goods (e.g., houses, forests, and oil deposits) are often bought and sold as assets. Markets can value both these bundles and the stream of rents that flow from them over time. In fact, the best way to value an asset is to systematically analyze the net present value of economic rents that arise from that asset. For public goods, unfortunately, counting assets is not particularly helpful. First, markets do not place a value on such assets because, by definition, public goods are not traded in markets. So how are these assets to be valued by welfare accounts? By measuring the value of ecosystem services derived from them.

3.1. *What are ecosystem services?*

The term *services* originates in economics but has been adopted in ecology as well to signify the connection between ecosystems and human well-being.[19] Ecosystem services arise from—and depend on—the broader sets of ecological components, processes, and functions but are different: they are the aspects of the ecosystem that are valued by people.

Economists ask how nature benefits society. The benefits of nature include many forms of recreation, aesthetic enjoyment, commercial and subsistence harvests, damage avoidance, human health, and enjoyment of life's diversity. *Ecosystem services* are the aspects of nature that society uses, consumes, or enjoys to experience those benefits. They are the end products of nature that directly yield human well-being.[20]

3.2. *Ecosystem services are the end products of nature*

The last part of the *ecosystem services* definition is particularly important: ecosystem services are "end products." *End products* are the aspects of nature that people make choices about. For an angler, such end products include a particular lake or stream and perhaps a particular species population in that water body. The choices involved include which lake, what kind of fish, what kind of boat and tackle to use, and how much time spent traveling to and from the site. The only way to ever know (or calculate) the benefits of nature is look at choices made by real people. Choices reveal the value that people place on these end products.[21] Constructing a green GDP consistent with conventional GDP requires counting in units that have concrete meaning to people in the same way that cars, legal services, and clothing have real meaning to people.

It is important to emphasize that many other aspects of nature are valuable but are not capable of being valued in an economic sense because they are not associated with social or individual choices.[22] Nature is composed of myriad processes, functions, and interactions; the oceans affect climate, climate affects plant life, plant life affects habitat, and on and on. All of these linkages are fundamental to life on Earth and thus fundamental to human well-being. And all are therefore valuable. But being valuable and being a service are not the same. In other words, just because something in nature is valuable does not mean that it should be counted by green GDP.

To think about this point another way, consider GDP. GDP counts only end products, not the intermediate products and manufacturing processes used to make end products. The reason is that the value of the intermediate goods and processes is included in the value of the final good. A car's value embodies the value of the parts and labor used to create it. Counting the intermediate goods and processes therefore would be double-counting. In the same way, green GDP should not count the many intermediate aspects of nature that make nature's services possible.[23]

This is very good news for green accounting practitioners, actually. An accounting-driven definition of *ecosystem services* massively shrinks the measurement task because it distinguishes between intermediate and final goods and between inputs and outputs. Everything need not be counted. It is important to understand that markets, rather than theory or principle, define the units counted in GDP. Consider a car. If people assembled their own cars, then car parts would be considered end products and would be individually included in GDP. Markets sell cars as fully assembled vehicles, however; that is why GDP counts cars. Alternatively, cars could themselves be thought of as inputs to more complex end products that consumers value, such as "transportation utility services" and "sex appeal." But markets do not sell these things; they sell cars.[24]

The implications for green GDP accounting are that ecosystem service units should be defined in a way that places ecosystem measurement on an equal footing with the units measured by conventional GDP. GDP tends to count items that are concrete and subject to tangible (market) choices. Ecosystem service units should have the same properties.

[19] See Daily (1997).

[20] For a technical, economic derivation of the definition, see Banzhaf and Boyd (2005) and Boyd and Banzhaf (2006).

[21] Economists use market prices (when markets exist) for just this reason. Markets are voluntary exchanges that reveal concrete choices and place a monetary value on that choice (i.e., the agreed-upon price). When markets do not exist, economists must exert themselves to derive monetary values. One way to do this is to ask people about the choices they would make or the prices they would pay in a hypothetical situation (otherwise known as contingent valuation or conjoint valuation). Another way is to look at the real choices that people make involving their time or the costs borne to enjoy an environmental experience. Finally, the value of some natural amenities is captured in asset prices, such as real estate.

[22] Many components of an ecosystem can be thought of as intermediate products in that they are necessary to the production of services but are not services themselves.

[23] The perspective advocated here is that the outcomes of the process, rather than the process itself, are all that matter. However, it should be noted that underlying processes can affect valuation of outcomes, at least experimentally (Bulte et al., 2005).

[24] This explanation oversimplifies what is counted in conventional GDP. The U.S. Bureau of Economic Analysis and other national statistical agencies often rely on proxies for difficult-to-measure service outputs (see Griliches, 1992 for a discussion). Financial intermediation services, for example, rely on "indirect" measures of output.

3.3. *Ecosystem services must be counted at fine spatial and temporal scales*

The units of account (ecosystem services) are quantity units. As noted earlier, nature does not come prepackaged; markets have not defined the units as they have for conventional goods and services.[25] The first step in defining *ecosystem services* is to identify—as comprehensively as possible—the ways in which nature directly benefits society. This task should not be difficult, because these benefits are inherently intuitive to individuals, households, and firms. Nature provides many benefits: beautiful views, clean air, ways to enjoy life's diversity (recreation), hazard avoidance, drinking water, and numerous resource materials. Starting with this intuitive notion of benefits, what should be counted?

A couple of points are immediately apparent. In particular, units should be counted in such a way that they can be distinguished spatially and temporally. Individuals benefit from water quality and availability in particular places at particular times. The implication is that services need to be counted so people know specifically where and when these benefits arise. To say that a trillion acre-feet of clean water are available nationally every year is meaningless; people need to know where that water is and when. This perspective is different from that currently taken by the SEEA, which states that "it is not generally the components of ecosystems that benefit humans, but the systems as a whole".[26] That is incorrect. People benefit from nature's components, just as they benefit from commercial and other market products. Although society surely benefits from ecological systems as a whole, the same can be said of the market economy as a whole. The focus of measurement should be on components rather than on broad systems. Aggregation can be meaningful only if it is "built up" from spatially and temporally distinct units.

The location and timing of ecosystem services matter economically because the benefit of services depends on where and when the demand for, complements to, and substitutes for those services arise. For example, natural areas may have recreational value only if complementary assets (e.g., trails or docks) are present.[27] Substitutes have the opposite effect. Many ecosystem services have no substitutes. For example, the existence value of wilderness or an endangered species has no clear substitute. Other services do have substitutes, however. If wetlands are plentiful in an area, then a given wetland may be less valuable as a source of flood pulse attenuation than it might be in a region in which it is the only such resource. Accordingly, economists must define service-specific zones or "service areas" across the landscape. Boundaries are needed to define the likely users of a service, the areas in which access to a service is possible, and the area over which services might be scarce or have substitutes.[28]

Again, consider GDP as a metaphor. National-level indicators like GDP are built up from economic units valued at the household and firm levels. Most ecosystem services must similarly begin with location-specific valuations, because complements, substitutes, scarcity, and demand are all driven by household-level conditions.

3.4. *Ecosystem services are benefit-specific*

Less intuitive is the property that units of account are benefit-specific. For example, a given natural characteristic can simultaneously be an end product and an intermediate product. Accordingly, that characteristic can simultaneously be counted and not counted by green GDP. Consider a hillside forest and two different kinds of benefit: beautiful views and the existence of biodiversity. Households, hikers, commuters, and office workers with visual access to the hillside directly enjoy the forest's beauty. In that particular place and time, the forest should be counted as an ecosystem service because in this context the forest is a desirable end in itself. The forest also provides habitat for diverse flora and fauna that are beneficial for recreation or simply for their existence. In this case, the forest should not be counted as an ecosystem service because although it supports diverse species, the forest serves an intermediate function, much as an automobile factory supports the production of cars. The species populations themselves are the end products that are directly valued where existence and recreational benefits are concerned.

Other examples of this phenomenon abound. Wetlands should be counted as services associated with flood protection because they directly protect against floods and are substitutes for constructed flood control; however, wetlands should not be counted as services for the water quality benefits they provide. The water quality itself should be counted because that is what people directly value. If the benefit specificity of what should be counted seems odd, refer again to GDP. Units of tomatoes, onions, lettuce, and ground beef are counted by GDP if sold in stores as final products; they are not counted when combined and sold together on a bun as a restaurant hamburger.

3.5. *Services are not benefits*

Economists themselves can fall prey to terminological confusion.[29] They commonly say, "Recreation is an ecosystem service." This statement is not correct. Recreation is a benefit that relies on and arises from a combination of

[25] This explanation oversimplifies the challenge that traditional accounting economists face. Even today, after a hundred years of debate and experimentation, the keepers of price and income statistics are faced with ever-shifting product heterogeneity (e.g., faster cars, bigger houses, more powerful computers). Such shifts make it difficult to determine the best way to define conventional marketed goods and services.

[26] This line of thought reflects the current overreliance on "asset" rather than "service" thinking in SEEA 2003, a subject addressed in Section 5, "Implications of SEEA 2003" (UN/UNEP, 2003, 257).

[27] Other types of benefit, such as the existence benefit of a wilderness area, do not require (and indeed may be reduced by) the presence of such features.

[28] This issue is well known in environmental economics (Kopp and Smith, 1993).

[29] Economists call many things "ecosystem services." For an example of high-quality research in environmental economics that describes several competing uses of the term, see Kopp and Smith (1993).

inputs, including time, human resources (skill), and capital (i.e., equipment such as boats, boots, and binoculars). The value of capital inputs (equipment) is already captured in GDP.

To arrive at green GDP, one must therefore count (and eventually weight) only the contributions of nature to recreation: lakes, mountains, trout populations, and so on. For counting purposes, ecosystem services should be isolated from non-ecological contributions to final goods and services. Once ecosystem services are combined with other inputs, such as human resources and capital, they cease to be identifiably "ecological." Again, the goal is to count nature on an equal footing with what GDP is already counting.

3.6. *Green GDP vs. An ecosystem services index*

The preceding discussion emphasizes that ecosystem services to be counted in Green GDP are "end products," or nature's "final goods." What about the case where nature's end products are inputs to marketed products? Should nature's final goods be counted if they are inputs—and thus intermediate—to marketed final goods?

This choice is between two alternative (but consistent) accounting strategies: Green GDP and what can be called an ecosystem services index (ESI). Green GDP aggregates all sources of well-being, including all market goods and services, into a single index. In effect, green GDP adds missing ecological elements to conventional GDP. Green GDP "trues up" GDP to account for nonmarketed ecological contributions to welfare. If a final ecosystem service is already counted as an input to a final market good, it should not be counted again. In this case we should add only missing ecosystem services to the set of final market goods already counted in GDP.

The ESI alternative has a different goal: to separately account for all nature's contributions to welfare, even those already captured in GDP as intermediate products. In an ESI (Banzhaf and Boyd, 2005) nature's benefits are isolated from other classes of input (e.g., labor, capital). When all ecosystem services are measured, the ESI aggregation represents a measure of nature's total contributions to welfare. It is not the same thing as green GDP, but can easily be adjusted—to avoid double-counting of ecosystem services already captured in GDP—to arrive at green GDP.

In both cases the definition of a final ecosystem services does not change. All that changes is the set of final ecosystem services that is aggregated.

4. The role of ecology

Although the definition of *units of account* is based on economic theory, it leads to the measurement of tangible biophysical characteristics—a wonderful property. For decades, economists and ecologists have sought a consistent point of contact between their analytical realms. As defined above, ecosystem services provide this link. The aspects of nature that—in principle—can be valued and weighted by economics are concrete, countable items subject to ecological measurement, prediction, and analysis. Economics has dominion over what should be counted if one wants to measure the benefits of nature. But ecology has dominion over the study of changes in services over time.

If one measures nature's value at only one point in time, then a great deal of ecological sophistication is not needed. One simply counts observable features, such as air, soil, and water quality; land cover types; and species populations. As envisioned here, green GDP also allows period-to-period comparison of the quantity of ecosystem services over time (e.g., has a particular government presided over an increase or a decrease in ecosystem services?). Degradation or enhancement of services can be directly measured and reflected in the year's green GDP numbers.[30]

However, green GDP should do more than this. For example, green GDP can be used to assess welfare losses arising from over-consumption. (Because many ecosystem services are public goods and provided by the commons, the possibility of overexploitation is more likely than for conventional market goods.) Also, green GDP can be used to judge the likely effect of public policy to protect, enhance, or increase ecosystem service provision. Both of these goals require knowledge of cause and effect in the biophysical realm.

4.1. *Depletion analysis*

Consider two human activities: commercial fishing and energy production. Both generate consumption (seafood and energy, respectively) that is reflected in GDP as a positive contribution to welfare. One reason to calculate green GDP is to reveal the effect of current consumption on future well-being. The concerns, of course, are that over-fishing today will lead to depleted fishing stocks and that excessive energy consumption today will lead to climate change and thereby a range of negative consequences for ecosystem services.

Economists believe that the effect of current consumption on future consumption should be "visible" in current measures of consumption.[31] In other words, current consumption should not be viewed as socially beneficial if it leads to lower future consumption.[32] Unfortunately, economists have little ability to make such predictions in the ecological realm. If green GDP is to incorporate adjustments for resource depletion—and it should—then only biophysical science will be capable of substantiating those adjustments.

In terms of welfare accounting, the biophysical and health sciences should be encouraged to develop the ability to predict the depletion (or the enhancement) of ecosystem services. For example, what affects water and air quality? What is the effect

[30] This approach is vastly preferable to damage-avoidance (or cost-based) estimation of degradation because it focuses on the important issue: the loss in welfare arising from the degradation. The distinction is addressed in the SEEA via an example: "If the excessive use of pesticides or fertilizers eventually reduces the fertility of the soil, the agricultural yield will fall, affecting GDP directly" (UN/UNEP, 2003, 62).

[31] GDP does not include adjustments of this kind. The term for GDP adjusted for future depletion is *Net* Domestic Product (or NDP). NDP is the preferred measure in principle.

[32] In some cases, of course, degradation will be offset by natural renewal. If so, there is no depletion.

of air and water quality on human health?[33] What predictions can be made regarding the size of individual species populations, water availability, or land cover types? The biophysical sciences already address these issues. But to meaningfully assess national or global depletion, the scale of the biophysical effort must increase.

Also, as argued in the previous section, the value of ecosystem services is often highly dependent on the location of the service. Localized depletion (e.g., of services important to recreation and aesthetics) will be important. Here, too, biophysical analysis of landscape effects is very important. The spatial nature of ecological relationships is a core topic in modern ecology. Welfare accounting demands additional development of ecological science to predict the landscape-specific depletion of services.

Scientific uncertainty and debate over the causes and consequences of climate change, global land use change, and species extinctions suggest that this predictive capability should not be expected soon. But its importance to welfare accounting cannot be overemphasized. If in fact natural resources are being overexploited to the detriment of future welfare, then it should be made visible today in the national welfare accounts.

4.2. *Public policy*

In the near term, green GDP could be used to judge the effects of public policy. Here, too, ecology plays an important role. Myriad public and private actions—regulation, industrial and real estate development, pollution, resource management, and conservation—alter the quantities of ecosystem services delivered to the public. The effects of policies on such services can be better tracked if those services are counted.

Over time, experimentation can be used to learn the effect of policies on ecosystem services. But existing ecology can also be used to enable prediction of the policies most likely to have a positive impact on social welfare. How will the management of a river basin affect services in the watershed (e.g., water availability, species populations, and visual amenities)? Hydrology, biology, and ecology are the sources of the answers.

5. Implications for the SEEA

In this paper, I discuss two aspects of the SEEA: measurement of the social benefits (as opposed to the biophysical production) of natural outputs and the benefits of nature not already captured in national accounts. In other words, I discuss the measurement of benefits that arise from environmental public goods. Without markets, easily collected proxies for value (prices) are lacking. The countable units to which value is attached also are lacking. I argue that ecosystem services are the units that should be counted to determine the beneficial products of nature. Importantly, economic principles are used to define these services.

The SEEA already advocates the measurement of many physical variables. But the units used in many of the SEEA accounts should not be confused with those advocated in this paper. For example, some SEEA accounts are focused on input-output (IO) analysis. The variables tracked in IO analysis will not as a rule be the same as the variables necessary to construct a measure of value. The goal pursued in this paper is identification of variables necessary to construction of a GDP-like value index. In that context, welfare economics must be used to define what is counted—as it is in the definition of what is to be counted in GDP. Far fewer items need to be counted to determine welfare than to do a comprehensive material input-output analysis, for example.

In conclusion, a couple of points are worth repeating. Although the focus of this paper is the measurement of services, this focus makes asset valuation possible. In fact, in the absence of markets, public good assets can be valued only by the systematic analysis of services. The material presented in this paper does not promise a magic solution to the problem of service valuation but does define the units around which the valuation should take place.

Finally, the SEEA is too pessimistic about economists' ability to account for ecological public goods. As I have argued, concrete steps can be taken immediately to count what is socially valuable about common property resources (i.e., those aspects not captured by market-based output and price measures). Economics can be used to define units of account that are consistent with the units used in conventional welfare accounting. Placing value-based weights on these units will remain a challenge for decades. But the features of ecosystems (and nature in general) that matter to people can be counted today.

[33] In principle, accounting measures of income can be adjusted to reflect human health.

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