SOME NOTES ON PROSPECTS FOR INCLUDING NATURAL LANDS AS SOURCES OF ECOSYSTEM SERVICES IN NATIONAL ACCOUNTS

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Introduction

One way in which national economic accounts might be "greened" is by including the value of ecosystem services. In some respects the values of such services are included: if agricultural productivity declines for want of pollination or pest control services, or if manufactured assets are destroyed in floods that might have been prevented or mitigated, the decline in production or disinvestment in assets should be reflected in current economic activity. National accounts are intended not only to measure current performance but to project future well-being, however. For this reason it would be useful to incorporate investment or disinvestment in the systems that provide ecosystem services. For terrestrial services, at least, such systems are landscapes retained in or restored to more or less "natural conditions".

While the argument for including such assets is impeccable *in theory*, it is, regrettably, far from practicable. I emphasize two reasons for this statement in this note. The first is that natural ecosystems are not commodities in the sense that some forms of manufactured capital are. Not only do different ecosystems differ widely in their composition and function, they differ widely in their context. It is a sort of paradox that many of the services of natural ecosystems are valuable only to the extent that they can be clearly linked with decidedly *un*natural landscapes. Not only is it devilishly difficult to estimate nonmarket values associated with natural ecosystems, it is also very difficult to transfer the results of one study to a different setting. The implication of this observation for national accounts is that a country would have to conduct an extensive series of careful studies of all the different ecosystems it wanted to include in its accounts if it were to perform the exercise in any reasonably comprehensive and meaningful way.

A second concern is that any estimate of the value of natural ecosystems will be unavoidably imprecise. An analysis in which one thing affects another, and then, often, a third (e. g., land use affects ecosystem services, ecosystem services affects provision of goods, provision of goods affects their price) will result in estimation errors at each stage being propagated through the analysis. This implies that estimates of the value of natural ecosystems will be imprecise, but also, and probably more importantly, that the value of natural ecosystems may not lie so much in their provision of ecosystem services under normal conditions as with their function as insurance against unlikely but potentially devastating events.

Ecosystem services, natural capital, and land use

Properly calculated national accounts would measure and report the value of all goods whose consumption is currently enjoyed as well as the value of all investments and disinvestments in the economy. Under certain assumptions the value of net investment would be an exact indicator of sustainability (Weitzman 1976; Hartwick 1976).[1] Investments may be made in a variety of forms of capital. There is manufactured capital, such as machinery and equipment. There is human capital and knowledge. There is social capital, the institutions of society. And of greatest interest to us at present, there is natural capital, the endowments of nature.

Much has been made of natural capital in recent years. It features prominently in the titles of well-known work (see, e. g., Costanza *et al.* 1997), and in ventures involving natural and social scientists, such as the Natural Capital Project. One revealing measure of the currency of the term is that when one Googles "natural capital" the phrase generates nearly a million hits. It is a problem, though, that "natural capital" is somewhat difficult to define. One could say that "natural capital" is the generic term for those assets that yield "ecosystem services," but that term is also difficult to put one's finger on (Fisher, *et al.* 2009 suggest several alternative definitions). If we are to record investments or disinvestments in natural capital, is it important that we be able to define what it is.

I would suggest that what natural capital is, in most operational aspects, is land retained in or restored to a more-or-less "natural" state. There is, of course, a great deal of wiggle room in that "more-or-less", but it seems that the notion of *natural* capital will only be meaningful if we can refer to some component of nature that is being preserved or augmented..

The next question is how we can assign values for accounting purposes to wild lands that have been preserved. A couple of considerations are obvious immediately. First, natural systems are very different. While both arctic tundra and tropical rainforests provide ecosystem services, they are so different as to preclude any meaningful aggregation on the basis of physical area alone. If we are to combine measures of natural capital investment/disinvestment, the only conceptually reasonable metric (as regards received principles of national income accounting and welfare economics) for weighting disparate quantities is economic value. While I do not mean to dismiss the entire idea of incorporating land use changes in national income accounts out of hand, much of the rest of this paper will argue that the exercise of valuation is exceedingly difficult. We have a very long way to go before the values assigned to land use change could be measured with anything like the precision possible when simply recording the market value of investments in machinery and equipment in current national income accounting.

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[1] These assumptions include symmetric information, competitive actors, and the usual underpinnings for a competitive economy. Under these circumstances Weitzman shows that properly measured current national income divided by the utility discount rate is equal to the net present value of utility from all future consumption. Current national income divided by the utility discount rate is the net present of receiving the current national income forever. If the net present value of all future consumption is greater than the net present value of that portion of current national income accounted for by present consumption, can only be because the other component of current national income, net investment, is positive. Hartwick notes that a necessary condition for investment to be nonnegative is that all rents resulting from the depletion of resource stocks be invested in other forms of capital. Of course this presumes that the other forms of capital are sufficiently substitutable.

A host of statistical difficulties bedevil efforts to infer the nonmarket value of ecosystem services and the systems that provide them. I have written on these at some length in Simpson (2010), and will not recite the arguments here. Suffice it to say that considerable effort is required to derive estimates of value for even relatively small systems. Consider, for example, the painstaking efforts in estimating the value of pollination services to a Costa Rican coffee plantation as reported in Ricketts, *et al.* (2004). One can only be skeptical of sweeping claims for larger system made on the basis of much less effort.

Moreover, estimates of the ecosystem service values afforded by natural capital must be highly place- and context-dependent. It is something of a paradox that many of the ecosystem services that have been identified as rationales for the preservation of natural landscapes arise only to the extent that such landscapes adjoin more developed areas. The pollination and pest-control services provided by areas of natural habitat are most valuable when such areas abut expanses of intensive agriculture. Flood-control is more valuable the more valuable are the properties in danger or flooding. Pollution retention and neutralization are only valuable when there are pollutants to be retained and neutralized.

An immediate corollary to the above observation is that just because the value of land for providing ecosystem services is high relative to the value of land *elsewhere* it does not necessarily mean that the too little land is being allocated to the provision of ecosystem services and that devoting sizable investments to restoring natural ecosystems would generate great values. Consider as an example a recent paper by Robert Costanza and others (2008). The authors found that a hectare of coastal wetland could be worth as much as a million dollars in terms of the protection it affords against storm damage.[2] Urban property sells for a million dollars per hectare or more in many locales, however. Land is optimally allocated between intensive use and the provision of ecosystem services when its value would be the same in each use.

I have made a related point in some recent work (Simpson 2008). Consider the value of land for pollution retention and neutralization. I examined the context of agriculture, in which farmers apply fertilizers to their crops. Some of the fertilizer inevitably runs off. When it enters nearby water bodies it can lead to eutrophication and loss of commercial and recreational values. An extensive literature in the natural sciences documents the ability of field-edge buffers of natural vegetation to retain pollution (see, e. g., Mayer *et al.* 2007 and Rupprecht, *et al.*, 2009). Some estimate this capacity to be quite prodigious. If so, considerable social value may be generated by setting aside land as a buffer to retain pollution. In this case, however, a little may go a long way. Perhaps we should be investing in *some* more land to retain pollution, but it would not be wise to make large investments in such land if substantially all of the pollution can be retained by devoting a relatively small area to buffers.

It could, however, prove to be the case that buffers are not very effective in retaining pollution. If this is the case though, the question would arise as to whether pollution might most effectively be controlled by setting aside more land as “natural capital” to intercept it, or by using less polluting fertilizer. I find that the latter option may make the most sense if set-aside buffers are not very efficient. Under such

[2] Costanza *et al.* found figures as high as $50,000 per hectare per year. If capitalized at a five percent discount rate, this would translate into a million dollars per hectare.

circumstances there would be no argument for increasing investment in the natural capital of field-edge buffers. Moreover, if productive land is scarce and private farmers use fertilizers and other inputs to the point at which their marginal contribution to profit is zero (as economic theory predicts that private profit-maximizers would), there should always be *some* reduction in fertilizer use, while it may not be optimal to set aside land in order to meet relatively modest constraints.

The case of pollutant retention is an interesting one, as the ecosystem service provided is a relatively pure public good: the benefits of pollution control may accrue to people hundreds or even thousands of kilometers downstream. Other ecosystem services provided by preserved landscapes may give rise to more local public goods or, in the extreme, private goods. In the example of the work by Ricketts *et al.* (2004) which I cited above, the authors found that retaining some natural forest led to a demonstrable increase in coffee productivity in an adjoining plantation. As the effect was relatively localized, however, their results begged the question as to whether the private landowner was not maximizing his own profits by retaining the area of forest he did.[3] In short, then, valuation of ecosystem services and the natural landscapes that provide them might not always point to the need to retain or restore more natural landscapes.

Valuing natural landscapes under uncertainty

The value of an asset is equal to the discounted present value of the stream of earnings it will generate over its lifetime. Natural landscapes will, presumably, be here forever if left undisturbed. Hence estimating values requires peering into the indefinite future.

The problem is compounded by considerations in discounting. While economists refer to a typically constant, but often unspecified, "utility discount rate" for weighting the enjoyment of consumption between time periods, the discount rate used for weighting anticipated dollar amounts between periods is a quantity that varies with circumstances. The discount rate is itself a price that, like all other prices, is determined by the relative scarcity of the commodity being priced. If in the future consumption goods are anticipated to be relatively abundant, their prices, as determined by the discount rate, will be relatively low.[4] Conversely, if we anticipate tough times ahead, we will value future consumption as much or, conceivably even more than, present consumption.

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[3] In fact, the numbers derived by Ricketts *et al.* (2004) do not necessarily preclude the possibility that the landowner might have been retaining *too much* forest relative to his own profit-maximizing interests. While yields were higher as a result of the pollination services provided, they may not have been *enough* higher as to justify forgoing cultivation of the remaining forest land. It is also interesting to note that the plantation studied by Ricketts *et al.* was subsequently cleared in favor of planting pineapple, which does not require insect pollination at all (Macauley 2006).

[4] This is a little confusing, as we need to distinguish between the discount *rate* and the discount *factor*. If the rate is a small fraction r, the factor is $\exp(-rt)$, where t is time. When the discount rate increases the discount factor decreases.

In recent work Martin Weitzman (2004, 2010) has argued that we have an extremely difficult time pricing benefits and costs that may accrue in the far-distant future because it is extremely difficult to predict our circumstances in the far-distant future. While Weitzman makes his point in the specific context of climate change, his findings pose a challenge for the valuation of any resources whose future worth is uncertain and for which potential impacts could be large. This could also be the case for valuing areas of natural habitat, as the ecological implications of humanity's continuing modification of the landscape are uncertain, and those implications are likely both to affect and to depend on how the future climate evolves.

Uncertainties concerning values are even greater inasmuch as the methods of nonmarket valuation compound errors in estimation. Consider, for example, the problem of estimating the value of ecosystem services that may be regarded as factors of production. Elementary economic theory establishes that the rental price of a piece of capital equipment (that is, the payment that would have to be made to secure its services at any given point in time) should be the price of the output in whose production it is used times the marginal product of the input in the production of the output. For factors of production that are traded in established markets we often simply assume that their observed prices follow this formula. For goods that are not traded in markets, however, we must make an educated, but inescapably imprecise, estimate as to their marginal contribution to production.

Moreover, if we are attempting to infer the value of an area of natural habitat, we layer another element of uncertainty on the estimation process. How much does additional land add to the ecosystems service which then goes into the production of marketed output? Consider again the value of pollination services as estimated by Ricketts, *et al.* (2004). To infer the value of an additional hectare of preserved forest, they would have to not only relate pollination to coffee output, but also forest area to pollination.

Let me give another example based on my own work (Simpson, *et al.*, 1996). Consider the value of natural habitat and the native biodiversity it supports to the discovery of new products. One of the arguments often cited for concern with maintaining biodiversity is that it might prove useful as the source of new agricultural, industrial, or, particularly, pharmaceutical products. Let us suppose that a new product, if discovered, will yield a value of R. Suppose that there are N species that might prove to be the source of such a new product, that there is a probability p that any given species would be useful in developing the new product, and that it costs c to test any given species for its potential. Then it can be shown that the value of any one species chosen at random for developing the new product would be

$$v = (pR - \mathrm{c})(1 - p)^{N-1}.$$

While my coauthors and I derived this expression from a more complicated mathematical model, the intuition is straightforward. The value of the "marginal species" is the expected payoff from testing it: the probability it yields a "hit", p, times the value of a "hit", R, minus the cost of testing, c, *all times the probability that the same product could not be found by testing any of the $N - 1$ other equally likely leads*. This latter expression is the $(1 - p)^{N-1}$.

This analysis gave us an expression for the value of the marginal species, but what about the marginal hectare of land supporting multiple species? Here we appealed to a formula often used in the biological literature[5] to estimate the number of species found in an area of size *A*:

$N = kA^{\alpha}$,

where *k* is a constant that depends on the particular area under consideration and α is a constant often found to be on the order of one quarter in empirical studies. It then follows that the rate at which the number of species changes as the area of habitat supporting them changes is[6]

$\Delta N/\Delta A = \alpha N/A$

Combining expressions, we found that the value of a hectare of habitat with respect to its contribution to the discovery of a new product could be written as

$V = (pR - c)(1 - p)^{N-1} \alpha N/A.$

This expression describes the value of the "marginal hectare" of habitat with respect to the provision of the "marginal species" in the search for one among what could be a huge number of potential new products. My intention in reprising this analysis from an earlier paper is not to argue that this value is large or small.[7] It is, rather, to note that even in this case when first principles and extensively documented biological relationships facilitate the derivation of an explicit expression the value is extremely uncertain. What is the likelihood that any particular species will yield a particular product of commercial value? How many species are there in the world? How many will there be in 20 years? 50? 100? What is the present extent of the world's remaining "natural" habitat? Is one-quarter a reasonable and robust value for the species-area curve? Perhaps most importantly, should we infer the value of new product discoveries, *R*, from the experience of the recent past, or might far scarier threats motivate the search for new products in the future?

One point I want to make with this example is simply that estimates of the value of ecosystem services are inescapably imprecise. Over and above that, however, this example illustrates another point. Not only will estimates of ecosystem service values be imprecise, their distribution will likely be highly skewed. Consider again the expression

$(pR - c)(1 - p)^{N-1} \alpha N/A$;

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[5] This is the so-called "species-area curve" from the theory of island biogeography pioneered by MacArthur and Wilson (1967).

[6] Formally, this results from differentiating the species-area relationship with respect to *A*.

[7] In the original paper we argued that the value is likely small, as we were able to show that *whatever* the number one assigns to *p*, the probability of discovery, the expression $(pR - c)(1 - p)^{N-1}$ will be small for plausible values of *N* and values of *R* observed in recent decades.

not only does it contain a great many uncertain quantities, but they also enter in *multiplicative form*. When there is a small probability that one quantity is large and a small probability that another is large, then there is a very small probability that their product is very large. I have argued in earlier work that the value of natural ecosystems in discovering new products is very likely to be disappointingly small, at least relative to the hopes of some who have advanced this argument as a motivation for conservation. As a statement of likelihood, I think this is probably unexceptionable. It may, however, be in this instance as it is with some of the other most vexing environmental issues that our attention should not be focused only on the most likely outcomes, but also on the worst-case scenarios. Might it be the case with biodiversity that it is better to have it even if we probably won't need it, than to face the remote but perhaps not entirely negligible possibility that we (or our descendents) might need it but not have it?

Let me conclude this section with another example drawn from work in which I am currently engaged. The United States Environmental Protection Agency (EPA) has recently announced plans for reducing the loads of nutrients and sediment entering into Chesapeake Bay.[8] Economists from my office, EPA's National Center for Environmental Economics, have been charged with conducting analyses of the benefits and costs[9] of these plans. One of the questions that arises in this context concerns the value of ecosystem services of land set aside to prevent nutrients and sediments from farms, urban areas, roadways, and other sources from entering the Bay.

There are a number of ways in which these values might be estimated. Water quality in the Bay is affected by the load of nutrients and sediment that reach it, and by calculating the effect of water quality on commercial fisheries, recreational use, waterfront property values, and other measures of well-being, we hope to estimate the value of pollution reduction and, by extension, land use practices that affect it.

The recently announced EPA plans contemplate reductions of nearly 30% in the loadings of reactive nitrogen with reductions of similar amounts in other pollutants. These are, however, based on "typical" years. Not all years are "typical". Year-to-year variations in pollutant loads reaching the Chesapeake can be significantly greater than the 30% reduction contemplated from current "typical" levels (http://www.chesapeakebay.net/status_nitrogen.aspx).

2011 was an *extremely* atypical year. In the summer two large storms hit the Chesapeake Bay watershed and caused extensive flooding. The *Washington Post* newspaper featured a satellite photograph one day of a plume of sediment-laden brown water making its way from the Susquehanna River into the Chesapeake Bay. This plume largely originated from the Conowingo Dam, a hydroelectric facility constructed in the late 1920s. Nutrient-laden sediment has collected behind the dam for

8 Chesapeake Bay is the largest estuary in the United States, and is unusual in that the ratio of the area of its watershed to the surface area of the bay is so large. Consequently, a great deal of material from the land is swept into the water.

9 We are collaborating with EPA's Chesapeake Bay Program Office in this work.

decades. In 1936, 1972, and 2011, however, the floodgates of the dam were opened following major storms, and a great deal of sediment was expelled. Such massive pulses of pollutants entering the Bay all at once might have very dramatic effects on it.

My colleagues and I have not yet begun to generate estimates for the value of preserving or restoring land that might sequester nutrients that might otherwise end up in the sediment behind the Conowingo Dam and retain floodwaters that might otherwise necessitate reopening the dam's floodgates. This example illustrates the points I want to underscore in this note, however. The first is context-dependence. The fact that farming and other activities result in the generation of nutrients and sediments means that lands advantageously positioned to intercept and retain them may have some appreciable value if preserved or restored. The further fact that a particular piece of manufactured capital – an aging hydroelectric dam, in this case – lies downstream also affects that value.

The second point is that the value of land retained in a natural state may depend as much or more on the ecosystem services it provides in unusual, and perhaps even very rare, circumstances as it does on the services it provides on a regular basis. Flood protection, for example, is by definition a service that only comes into play under unusual circumstances, but the Conowingo example shows that a little more flood protection may be most valuable as a protection against extremely unusual circumstances.[10]

Conclusion

Land preserved in or restored to a natural state cannot currently be valued with anywhere near the precision as is realized in recording the actual market transactions from which national economic accounts are now assembled.[11] For this reason most efforts to record the destruction of natural capital when land is converted from a more-or-less "natural" state to one in which more intensive use is made of it, or to credit efforts to restore degraded land to a more natural state would likely be premature. It seems wiser for the present to continue to record changes in land use in physical terms, while simultaneously continuing the research efforts that will be required to to place this form of natural capital on an equal footing with investment in manufactured capital in the accounts.

[10] It is worth saying again that we are not prepared at this point to hazard any guesses as to the value of natural landscapes in providing this service in this context. It may be that areas of preserved or restored habitat are too limited to be of much quantitative significance, or that flooding experienced in the summer of 2011 would have overwhelmed any measures intended to mitigate it. My point is only that the stochastic nature of such events may require that we think of valuation in somewhat different ways.

[11] It might be objected with some justice that the market valuations of certain capital assets are not as accurate as one might hope. Who is to say whether the price of a large and idiosyncratic piece of industrial machinery is "right", in the sense that it accurately projects the net present value of the stream of earnings anticipated to arise from its employment? Certainly the markets that economists purport to reflect business earnings aggregate, the global equities markets, have been spectacularly sporadic in recent years. Be this as it may, however, there does seem to be a big difference between recording the prices at which capital assets are actually acquired in private markets and estimating the prices they would command in hypothetical ones. While existing national accounts are incomplete, they are reasonably accurate and objective in recording the transactions they do record.

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