Accounting for the increasing benefits from ecosystems

As people get richer, and ecosystem services scarcer, policy-relevant estimates of ecosystem value must grow

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Governments are catching up with economic theory and practice by integrating ecosystem service values into national planning processes, addressing the initial challenge of making these values visible in the first place. This ensures that policy decisions appropriately reflect current and future benefits of ecosystems, often evaluated using benefit-cost analysis. Yet, because benefits and costs generally accrue at different points in time, benefit-cost analysis requires information about how expected benefits change over time. We address a key implementation barrier by providing a tractable and consistent toolkit that can help ensure that policy decisions do not miss this crucial aspect of ecosystem values: that benefits of ecosystems increase as societies get richer and as the scarcity of ecosystems changes. Making these adjustments will lead to substantial upward revisions of estimates of future ecosystem service values, and thereby more appropriately take into account the overall values of ecosystems reflected in benefit-cost analyses and policy decisions they inform.

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Governments are making progress integrating the value of ecosystem services in policy planning frameworks as they implement the Global Biodiversity Framework under the United Nations (UN) Convention of Biological Diversity and work towards the UN Sustainable Development Goals. Yet, while the principle of relative scarcity is recognized in policy guidance on benefit-cost analysis, the changing benefits from scarce ecosystem services over time is, with few notable exceptions (*4*), overlooked. One of the barriers to including ecosystem services in benefit-cost analysis is the lack of a straightforward approach for adjusting future WTPs in response to growing real incomes and changing scarcities of ecosystem services. Several recent initiatives have put the issue on the policy agenda. The UK Treasury recently convened an expert Working Group to develop guidance on this matter (*5*). The US Office of Management and Budget (OMB) draft update to Circular A-4 for regulatory analysis raises relative scarcity adjustments for non-market goods, which was recently accompanied by a newly proposed guidance on "Assessing Changes in Environmental and Ecosystem Services in Benefit-Cost-Analysis". These movements reflect a window of opportunity to rectify how we account for ecosystem services in regulatory guidance and policy decisions. Here, we propose a simple and transparent policy rule for estimating future WTPs that can be applied independent of how current WTP is estimated.

Ecosystems provide a diverse set of unique benefits to humans (*1,2*). We regularly exchange some of these benefits, such as agricultural production or timber, for other goods in market economies, and can see the value of those benefits to the people procuring them reflected in the price they pay. Other benefits, often called non-market goods or services, provide real value to humans without involving market transactions. Examples include water and air purification by forests, soil nutrient cycling by earthworms, the enjoyment of natural areas through recreation or aesthetic appreciation, and the importance people attach to the existence of species or biodiverse ecosystems (*3*). The benefits to society of these non-market services can be assessed in monetary terms using what economists refer to as "shadow" prices (2). One can estimate current shadow prices from information on current marginal "willingness to pay" (WTP) for changes in ecosystem services. WTP for ecosystem services can be estimated with nonmarket valuation techniques using revealed consumer behavior (e.g., in housing markets, travel behavior, or donations) or surveys (3, 4).

RECOGNIZING THE INCREASING RELATIVE SCARCITY OF NATURE

While the consumption of market goods continues to grow—reflected in real per-capita GDP growth of around 2% per year (*6*)—the supply of ecosystem services is far from keeping pace. Many ecosystem services are in decline because of habitat destruction, over-harvesting, or climate change (*3*). Global forest areas and populations of threatened species are on a downward trend. Even in a case in which nature was preserved in current conditions (denoted as "Environmental Stagnation"), ecosystem services would increase in scarcity relative to real income (Figure 1A).

Rising real incomes coupled with a stagnation or decline of ecosystem services means that society's benefits derived from these non-marketed ecosystem services grow over time. This is similar to how people's WTP for ecosystem services increases with income (*7-9*). Estimates of future WTPs that do not reflect the increasing scarcity of ecosystem services relative to market goods will systematically undervalue the ongoing contribution of these systems to society. As a result, the increasing importance of the natural environment for future generations will be overlooked and society will underinvest in measures to safeguard nature (*8-10*).

Economic theory provides a path for governments to reflect changes to the relative

scarcity of non-market ecosystem services in benefit-cost analysis (*8-13*). A simple framework allows us to estimate how benefits from ecosystem services increase as real incomes grow and scarcities change. The adjustment of future benefits is determined by the rate at which the WTP for ecosystem services changes with income (the income elasticity of WTP), and the growth rates of ecosystem services and market goods, which measures the changing relative scarcities over time.

To derive a simple rule for performing relative price adjustments to estimate future WTPs, we follow the constant elasticity framework that typically underpins guidance on benefit-cost-analysis, including the simple Ramsey Rule often used to specify social discount rates (*4*). In this standard framework (*8-13*), the change in WTPs for ecosystem services over time is determined by the income elasticity of WTP (denoted as ξ) multiplied by the difference in growth rates between market goods and ecosystem services ($g_C - g_E$). Thus, the relative price change (RPC) rule (Figure 1B), is given by: $RPC = \xi \times [g_C - g_E]$.

In this standard framework, the income elasticity of WTP is directly related to the degree to which people are willing to trade off market and non-market goods (*8-9,14*). Economists refer to this as the degree of substitutability or complementarity. Intuitively, the more strongly people perceive ecosystem services as complementary to market goods (the greater ξ), the more rapidly the benefits from ecosystem services rise as real incomes grow. This effect becomes stronger when the real scarcity of ecosystem services rises. The adjustment consists of two effects: A real income effect ($\xi \times g_C$), and a real scarcity effect ($-\xi \times g_E$). The first necessary step for integration in policy guidance—accounting for the real income effect—is already routine practice for other non-market goods (e.g., as income grows, the value that people place on their health and on their time spent travelling grows, and policy analyses can account for this).

By contrast, real scarcity effects are not considered in policy guidance on other non-market goods. Considering real scarcity effects for ecosystem services is more relevant the more strongly ecosystem services are in decline. In a functioning market, when the price for a good increases, firms have an incentive to produce more of the good. Such an increase in supply counteracts the price increase. By contrast, ecosystems do not respond to (shadow) prices. It is the job of policy to respond. As real incomes rise, ecosystem services turn relatively more scarce and their relative value (shadow price) rises. To properly reflect the future value of ecosystems in public decision-making, policy guidance has to incorporate the relative price change rule to adjust estimates of future WTPs for ecosystem services.

Our proposal relates closely to two standard concepts in benefit-cost analysis: discounting and benefit transfer. First, an alternative to estimating future WTPs adjusted for relative price changes is to instead use different discount rates for ecosystem services compared to discount rates used for market goods *(9-13)*. Although mathematically equivalent, adjusting future WTPs and using a single discount rate schedule for both market and non-market goods and services is conceptually simpler, more transparent, and often more compatible with how guidelines deal with other non-market goods (*4,5*). It further enables an easier application across different ecosystem services, which would otherwise require multiple good-specific discount rates (see Supplementary Materials (SM)).

Second, benefit-cost analysis routinely draws on benefit transfer to estimate missing WTPs, using WTP estimates from a study site to transfer or scale it to another geographical setting. Benefit transfer "in space" commonly adjusts for differences in average incomes across locations (*14*). The relative price change rule can be thought of as a dynamic extension to perform benefit transfer "in time", adjusting past or current WTP estimates to future dates where real incomes and real scarcities have changed.

A NEW DEFAULT FOR POLICY GUIDANCE AND ACTION

Most current policy guidance implicitly assumes that the benefits from non-market ecosystem services do not increase with income ($\xi = 0$). This ignores both income and scarcity effects—in stark contrast to empirical evidence (*7-9*)—and adjustments for real income effects in other areas of benefit-cost analysis for non-market goods. We propose to shift policy guidance to a new default, in which the real valued benefits of ecosystem services are considered to increase proportionally with income ($\xi = 1$). This strikes a balance between indirect evidence from non-market valuation studies (*7-9*) and expert judgments (*8,10*), and accords with what governmental bodies use for valuing reductions in mortality risk (*15*) or travel time. Under the new default, future WTPs for stagnating ecosystem services would increase along the growth of real income (blue line, Figure 1C). For declining ecosystem services, future WTPs would grow faster, accounting as well for changes in the real scarcity of ecosystems (Figure 1C).

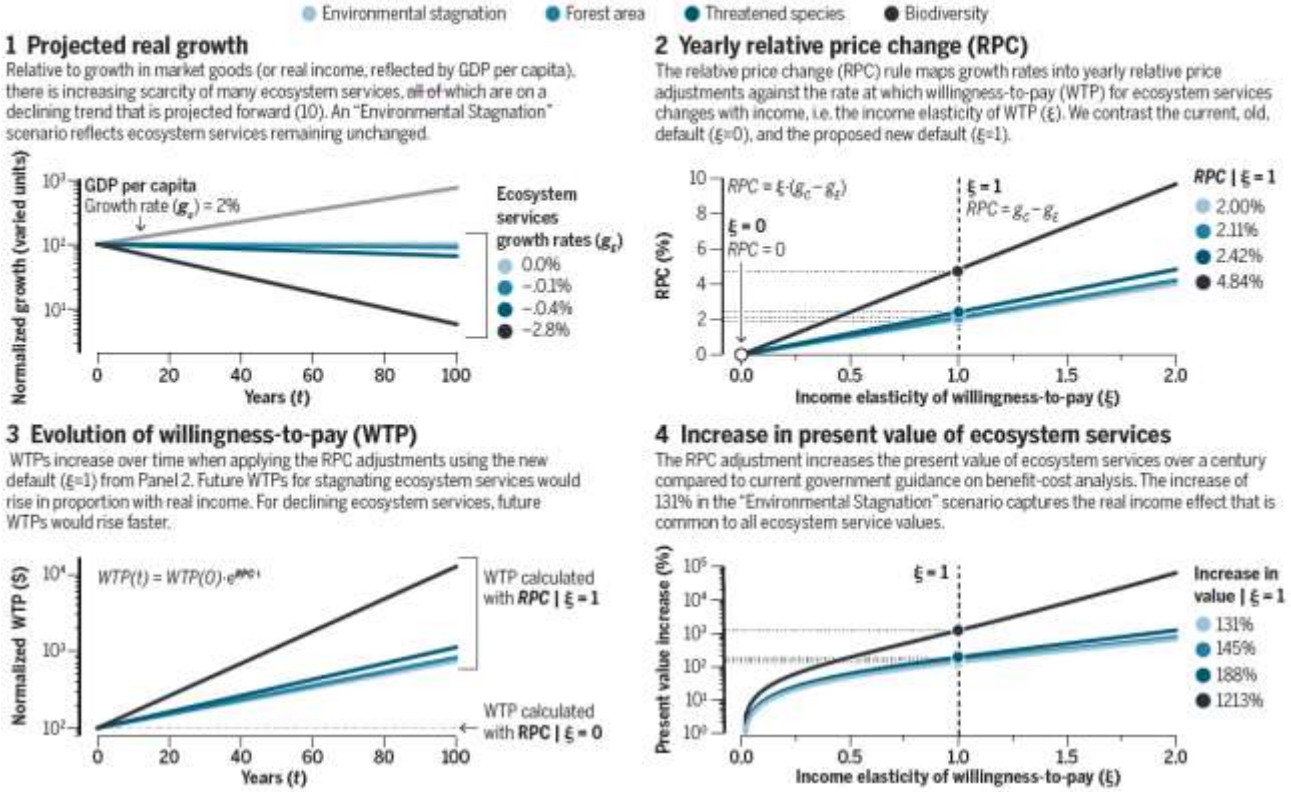
Figure 1D illustrates how shifting from current valuation practices to our proposal affects today's value of ecosystem changes. We compare the discounted sum of relative price adjusted future WTPs using the new default to the present value of unadjusted WTPs as in current policy guidance (see SM). Against the backdrop of expected increases in real incomes, first consider the case of "Environmental Stagnation". In this case, a proportional increase in the WTP for ecosystem services—the new proposed default—results in the shadow price of ecosystem services increasing by 2% per year (Figure 1B). Considering adjustments to future WTPs over a century (Figure 1C), at a discount rate of 2% as proposed in the US OMB Circular A-4 update, the relative price change adjustment yields an increase in the present value of ecosystem services of 131% (blue line, Figure 1D), while the value increase would amount to 100% for a 3% discount rate (see SM). Projecting forward the decline rate of global forest areas (brown line), populations of the International Union for the Conservation of Nature (IUCN) Red List Index for threatened species (red line), or biodiversity according to the Living Planet Index (purple line), the increase in present values at a 2% discount rate would be more than 140%, 180%, and 1200%, respectively. These results show that the effects of growing real income and increasing scarcities of ecosystems matter. Reflecting changes to future WTPs emphasizes the importance of ecosystem services in policy appraisal. In a benefit-cost analysis of climate change, for instance, neglecting relative price changes of non-market goods may underestimate the social cost of carbon (an estimate of the cost of damage resulting from each additional ton of carbon emissions) by more than 50% (*8*). It will, likewise, make projects that have long-term positive effects on ecosystem services more attractive.

To put this shift in guidance into action, we recommend, as a first step, that governments take on board the real income effect with a proportional increase of ecosystem service benefits as real incomes grow; a step closely aligned with how guidelines commonly value the benefits of travel time reductions and health benefits (*15*). Focussing on the real income effect is pragmatic, as forecasts for GDP growth are readily available (*6*), while forecasts for ecosystem services require further research (*9*). Real scarcity effects should be integrated whenever forecasts for ecosystem services are available.

Policy guidance should be periodically revised, following practice for valuing health benefits. Governments may consider creating advisory groups, following the UK example (*5*), to distil evidence on income and scarcity effects, including growth rates of various ecosystem services, and to inform setting income or substitution elasticities, which may vary across ecosystems and geographies. Periodic revisions

Scarce ecosystems and increasing ecosystem-service values

Several estimates of ecosystem services trends are used, reflected by global forest area, populations of the International Union for Conservation of Nature's Red List Index for threatened species, and biodiversity as reflected by the Living Planet Index. See SM for details and further analyses.



will allow fine-tuning WTP adjustments as more evidence becomes available. For instance, elasticities are likely heterogeneous, as are the roles of ecosystem services as inputs to producing market goods (*13*). Estimates of elasticities and growth rates are also inherently uncertain. Incorporating this uncertainty will likely lead to more substantial increases in future WTPs (*12*). Future refinements should seek to reflect these complexities.

Our proposal helps level the playing field so that ecosystem services are treated more consistently with other market and non-market goods, whose (shadow) prices, or marginal WTP estimates, change over time. As governmental guidelines are currently undergoing major updates, our proposal would help governments operationalize guidance on assessing the changing values of ecosystem services over time. A simple relative price change rule would ensure that the importance of scarce ecosystems for future generations is appropriately reflected when deliberating over public investments, evaluating regulatory change and meeting sustainability requirements.

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Supplementary Materials

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