



Valuing nature in a general equilibrium



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ABSTRACT

We explore the consequences of modeling the demand for environmental quality improvements as a fully integrated part of a general equilibrium demand system in an applied general equilibrium (or CGE) analysis. Demand for non-market goods depends on a full range of relative prices as well as environmental outcomes. We simulate the effects of reducing two air pollutants to improve human health and three ecosystem services provided to households. The ecosystem services make non-separable contributions to household utility. We find that willingness to pay measures of use-based ecosystem services are impacted by changes in demand for complementary market goods. Demand for these goods shifts due to pollution reductions that enhance ecosystem services. Partial equilibrium estimates of these use values can be measured with substantial error if they fail to account for the general equilibrium adjustments caused by pollution. Over 300 calibrations of the model identify the model features important to these errors. We find that effects on ecosystem services associated with non-use values have important implications for the feedback effects on use related measures of economic tradeoffs. This is due to how our model integrates market and non-market effects, reflecting the non-market services importance to general equilibrium market outcomes.

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1. Introduction

While applied general equilibrium (or CGE) analysis is now well accepted as a method for evaluating the economy-wide effects of new environmental regulations, most policy analyses assume the important general equilibrium effects these rules generate can be limited to the market-based activities that enter the benefit-cost equation. That is, they model the market-based costs that these policies generate as the product of complex patterns of relative price adjustments throughout the economy. Meanwhile, the values of the non-market benefits of improvements in environmental quality are treated as if they are small enough or exceptional enough that they are independent of these adjustments. Some authors model the value of environmental quality improvements as a simple function of pollution levels (see Nordhaus [18] for example). Some do not model damages explicitly. Instead, they implicitly assume that the changes in pollution levels are constant across their policy experiments and that this alone assures that the economic value of these changes is constant as well (see Hazilla and Kopp [10] for example).

Both approaches are inconsistent with the idea that demand for environmental quality responds to relative price changes (and changes in other dimensions of the non-market services, environmental as well as other public goods, that are

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available outside markets) the way other goods in economic models do. Both strategies are also inconsistent with the way that environmental economists conceive of these goods in the models used to recover empirical estimates of the tradeoffs people make to obtain them.

In this paper, we propose a new, general approach for including environmental benefits in CGE analyses of environmental regulations and use illustrative policy simulations to identify scenarios in which a general equilibrium treatment of benefits will substantially alter the conclusions of benefit-cost assessments. We argue that a full treatment of environmental benefits in general equilibrium analyses must acknowledge a number of important sources of interactions that are not admitted by models used in previous studies.

These inconsistencies with the historical treatment of non-market values are not simply logical inconsistencies. A moment of reflection reveals that people routinely combine market goods and services and their time to make use of environmental services. They spend on medical services to offset the adverse health effects of air pollution. The enjoyment of outdoor recreation requires significant expenditures of resources in the form of leisure time and the contracted services of hotels, restaurants and transportation.¹ If one accepts this idea, then the value of the health and amenities delivered by the environment to individuals must depend on the prices of these related goods and, conversely, the demand for these related goods must depend on the state of the environment. This is the logic that is the basis for revealed preference estimates of non-market benefits. These estimates underlie almost all benefit-cost analyses of existing environmental regulations. Yet analysts regularly employ them without acknowledging the nature of the behavioral relationships that allow them to be identified and estimated. The open question that remains is whether or not these relationships are empirically important to general equilibrium policy experiments.

As an acknowledgement of the idea that the market economy and the environment might interact in important ways, academic evaluations of the changes in air quality in the US and Europe have begun to conduct analyses that alter the assumption that environmental benefits do not interact with the general economy over the past half-decade [15,16,29]. A prominent example can be found in the EPA's Second Prospective Analysis, completed as part of a continuing evaluation of the 1990 Clean Air Act Amendments (CAAA) in March 2011. To our knowledge, it is the first benefit-cost analysis of a set of rules prepared by a government agency to include a general equilibrium treatment of both the costs and the benefits. These studies have advanced the literature by including connections between the environment and human health in their models, but they do not resolve the issues that are the focus of our analysis. Fundamentally, the new models are no less problematic than the past literature in the sense that they do not model demand for environmental quality as an expression of economic tradeoffs, in effect as the result of a choice. As we will show, this is not just a conceptual issue; it also limits the scope for finding quantitatively important economy-environment interactions in policy experiments.

The generic issue extends well beyond the specific treatment of benefits used in the EPA's Second Prospective Analysis. What is at stake is establishment of a set of accepted practices for quantifying the net benefits of any regulation that produces measurable changes in the levels of environmental services and is large enough to generate important economy-wide impacts. Almost by definition, it is the policies of national (as the case of the CAAA) or global (as in the case of global warming policies) significance that best fit this description. We argue that the treatment of environmental benefits in existing general equilibrium analyses deserves serious scrutiny and, in many cases, revision. We construct an illustrative CGE model of the effects of air pollution on ecosystem services and health to highlight the main concepts in the paper. Central to the analysis is the idea that these services connect with the demand and supply system for market goods through different channels that illustrate a few generic design principles for models of environmental quality improvements. First, policies that change pollution levels are assumed to affect multiple environmental services concurrently but through distinctive technical relationships. Thus, in our example, emissions of sulfur and nitrogen oxides contribute to acidic deposition that affects forests and the health of fisheries and have a separate influence of hospital admissions. These relationships need to be specified in ways that are consistent with the ecology and health sciences that define the physical impacts as well as measures of the tradeoffs people make to avoid them. As a consequence, values of different sources of benefits interact as components of a larger package of changes to the economic system.

Second, use-based environmental activities—those routinely associated with the revealed preference methods of non-market valuation—interact with each other and with market goods in contributing to consumers' well-being. In our illustrative model, we find that these complementary relationships can significantly alter the values associated with improvements in environmental services. The intuition behind this result is that the policy intervention required to affect the environmental change leads to changes in the prices of complementary goods which can either raise or lower the value of environmental services depending on the pattern of adjustment.

Third, and finally, non-use or existence services must also be accounted for in consumer preferences. By definition, these services have no observable choices involving other market goods that allow us to infer their value—they represent the ultimate separable good in some sense. It would be tempting, in light of this, to conclude that changes in the services labeled to reflect existence motives do not impact the rest of the economic system. However, we show that even this conclusion is incorrect; they exert an important influence on the values of other goods through the effect on the marginal utility of income.

Despite extensive research in non-market valuation over the past 50 years, an important obstacle to developing the types of models we consider here is that often we do not have an empirical basis for specifying the relative strength of the

¹ U.S. expenditures on outdoor recreation were approximately \$645 billion last year. In comparison, expenditures on pharmaceuticals totaled \$331 billion and spending on motor vehicles and parts totaled \$340 billion [17].

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