What is the right elasticity of substitution when the environment is more than a single good?

Ethan T. Addicott[a] and Marc N. Conte[b*]

[a] Department of Economics and Land, Environment, Economics and Policy Institute, University of Exeter

[b] Department of Economics, Fordham University

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Extended Abstract

Background Many economic models reduce the environment into a single aggregate good with a constant elasticity of substitution relative to a composite market good(Ebert, 2003). Such representations have the benefit of tractability, but mask important patterns of substitution. At the heart of the large literature on weak and strong sustainability is whether and how we admit substitutability between stocks of environmental goods and consumption goods. As Karl Goran-Mäler put it, the defense of strong sustainability requires answers to three questions: (1) Is a particular resource essential? (2) Are there any substitutes in consumption? and (3) Are there any substitutes in production? That a resource is essential, Mäler argues, does not mean that it should be untouched. This implies that the nature of a resource's substitutability might change in relative abundance or scarcity, a property such two-good models often fail to reflect.

Conte, Addicott, and Millerhaller, 2025 provide a theoretical framework, based on a single rationed environmental good and a market composite consumption good (Ebert, 2003; Neary and Roberts, 1980; Flores and Carson, 1997), under which the elasticity of substitution can vary in the relative scarcity of the environmental good. Conte et al. then show through a meta-analysis that when species abundance decreases, the income elasticity of willingness to pay for species increases, which implies decreasing substitutability under a set of assumptions.

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In this simple, two good setting, there is only one relevant elasticity of substitution: between the market composite and the environmental public good. Aggregating biodiversity into a single unit, however, is challenging not just because of differences in the value of natural capital across space (Addicott and Fenichel, 2019), but also because of the challenges of collapsing the multiple attributes of environmental goods and functions provided through biodiversity into a single index (Fenichel, Dean, and Schmitz, 2024).

Mäler's three questions highlight the importance of considering species' substitutability in a model with multiple goods. The idea that elasticities between market consumption and environmental goods better reveal substitutability in preferences, whereas substitution between different environmental goods reveals substitutability in production provides a heuristic for recognizing the important differences in substitutability that a multiple goods model can reveal. Cross-substitutability between different environmental goods may be more important than aggregate rates of substitution between a market composite and an environmental composite (Hänsel, Conte, and Drupp, 2025). Further, researcher decisions about how to model the environment, for example how to nest preferences (Sato, 1967), in integrated environmental-economic assessment models can impose consequential restrictions on substitution possibilities. The ecological relationships that relate environmental goods in a multigoods model motivate the same rigorous interrogation of the elasticities of substitution for the environment as in other multigood settings (Blackorby and Russell, 1989).

Intended Contribution: Theory With multiple environmental goods, we derive comparative statics showing how Hicksian, Allen-Uzawa, and Morishima elasticities diverge in multi-good environmental settings (Blackorby and Russell, 1989). Our first contribution lays out different definitions of the elasticity of substitution in a multi-good setting and discusses how they depend on preferences and the equations of motion that govern the production of environmental public goods (cf. Mäler). Second, we extend results from Conte, Addicott, and Millerhaller, 2025 to provide comparative statics in the multi-good case on the elasticity of substitution with respect to the abundance of environmental goods. We show how the Sato, 1967 style nested-CES function can reflect different substitution patterns, but not scarcity-variable substitutability. We also discuss the shortcomings of modeling ecological production functions with symmetric cross-elasticities. Third, we interrogate the relationship between the elasticity of substitution and the income elasticity of willingness to pay in a multi-good model. Under the assumption of a single non-market environmental amenity, the elasticity of substitution, which cannot be directly measured, is proportional to the inverse of the income elasticity of WTP. A number of studies have relied on this relationship to explore the degree of substitutability between a variety of non-market environmental amenities and the market composite good. Allowing for multiple non-market environmental amenities changes this relationship. There are a number of reasons to

relax this strict assumption of perfect substitutability within non-market environmental amenities, including different growth rates, different damages from climate change, and different degrees of substitutability with the market composite. In a model with multiple non-market environmental amenities, the cross-elasticities among the environmental amenities impact the estimated elasticities of substitution with the market good.

Intended Contribution: Empirical Evidence Turning to a unique dataset of species abundance and willingness to pay for different species across the globe, we then evidence the sensitivity of estimates of the substitutability of different species to key assumptions. The final dataset in Conte, Addicott, and Millerhaller (2025) incorporates WTP values from 84 studies focusing on a combination of use and non-use values for particular species. The studies utilize choice experiments and dichotomous-choice, payment-card, and open-ended formats to elicit WTP values in contingent-valuation studies. When coding papers, the samples were blind cross-validated by the research team to ensure inter-coder reliability. We are extending the Conte, Addicott, and Millerhaller (2025) meta-analysis dataset by adding over 20 relevant studies that were published following the 2019 cutoff used in the comprehensive search of the literature.

With our new dataset of over 100 species-specific valuation studies, we will quantify how cross-elasticities among species alter aggregate substitutability with market goods. Preliminary results show, in the context of global biodiversity, that failure to account for substitutability in production can inflate the value of environmental goods, meanwhile failure to adequately reflect consumption preferences for environmental goods results in underestimates of the value of environmental goods and services. Given our estimates of the income elasticity of WTP for different types of species, we find that cross elasticities of reasonable magnitudes can easily result in elasticities of substitution that make the market composite more complementary with non-market environmental amenities. Without a systematic way to reflect the appropriate domains of substitutability, environmental-economic models will handle the critical concern of substitutability inconsistently, compromising the accuracy and comparison across bodies of work. Our approach provides a theoretical framework and empirical example for elasticity estimation in a setting with multiple market and environmental goods.

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