Ecological Economics 140 (2017) 46–57

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Methodological and Ideological Options

An Input-output Economic Model Integrated Within a System Dynamics Ecological Model: Feedback Loop Methodology Applied to Fish Nursery Restoration

Mateo Cordier [a,b,*], Takuro Uehara [c], Jeffrey Weih [e], Bertrand Hamaide [d]

[a] Research centre Cultures–Environnements–Arctique–Représentations–Climat (CEARC), Université de Versailles-Saint-Quentin-en-Yvelines, UVSQ, 11 Boulevard d'Alembert, 78280 Guyancourt, France
[b] Centre d'Etudes Economiques et Sociales de l'Environnement-Centre Emile Bernheim (CEESE-CEB), Université Libre de Bruxelles, 44, avenue Jeanne, C.P. 124, 1050 Bruxelles, Belgique
[c] College of Policy Science, Ritsumeikan University, 2-150 Iwakura-cho, Ibaraki 567-8570, Osaka, Japan
[d] Centre de Recherche en Economie (CEREC), Université Saint-Louis, 43 Boulevard du Jardin botanique, 1000 Bruxelles, Belgique
[e] Senior Adult Learning Center, Portland State University, PO Box 751, Portland, OR 97207, USA

ARTICLE INFO

Article history:
Received 10 January 2017
Accepted 14 April 2017
Available online 6 May 2017

Keywords:
Input-Output
System Dynamics
Ecological-Economic Modelling
Feedback
Nursery

ABSTRACT

While environmentally extended input-output (IO) models are commonly used for capturing interactions between ecosystems and economic systems, this kind of modelling cannot reflect interactions within the ecosystem. Isard's (1968) model has been the only exception. He entered interactions occurring within the ecosystem into IO. Nevertheless, given the linearity of IO, he could only analyze environmental issues in a linear fashion. We propose an alternative that reverses Isard's model types: the economic system is modelled within the ecosystem (not the contrary), as one of the ecosystem's components. To demonstrate its feasibility, we develop an ecological-economic model by integrating conventional economic IO within system dynamics (SD). After describing the methodological issues, we "test" the IO/SD model on ecological and economic data by applying it to the destruction and restoration of the Seine Estuary, France, where Common soles live. Our model brings insight into the consideration of feedback loops in the modelling of interactions between the ecosystem and the economic system. We believe such a tool may be of help to decision makers in mixing economic and environmental issues like, in our application case, fish habitat and harbour development.
© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Ecological-economic models are required to capture the complexity of ecological-economic systems, as complexity is an essential part of those systems (e.g. Levin et al., 1998; Limburg et al., 2002); otherwise severe misperceptions and policy failures can occur (Costanza, 1987). There are two main sources of complexity. The first one concerns the interactions between ecological systems and economic systems: an ecosystem's responses to human use are not linear, predictable, or controllable (Folke et al., 2002). Second, there are interactions between environmental elements within the ecological system: contrary to some economists' expectations, ecological systems are often non-convex (Dasgupta and Mäler, 2003). This non-convexity of ecosystems often indicates the existence of nonlinearity, multiple equilibria, thresholds, and positive feedback loops in which marginal analysis is of little use.

Various modelling techniques have been developed to investigate ecological-economic systems. However, there is still much room for improvement with regard to their reflection of complexity. One commonly used approach is extended input-output (IO) models. They are interesting because they can estimate not only direct but also indirect effects of policy instruments (or ecosystem modifications).

Between the end of the 1960s and the beginning of the 1970s, environmentally extended IO models were developed to simulate interactions between ecosystems and economic activities. The first operational versions of such models were developed by Isard (1968), Leontief (1970) and Victor (1972). In those IO models, physical units are used to describe non-market natural resources and pollutant emissions free of any tax or payment system. Monetary units are used for market natural resources and pollutants for which a price must be paid as a counterpart to their emission (e.g. ecological taxes, cost for landfill disposal, emission trading schemes, etc.). All these models describe interactions occurring at the interface between the ecosystem and the economic system: *i*) flows of pollutants or human waste

* Corresponding author at: Université de Versailles-Saint-Quentin-en-Yvelines, UVSQ, CEARC, 11 Boulevard d'Alembert, 78280 Guyancourt Cedex, France.
E-mail addresses: mateo.cordier@uvsq.fr, mcordier@ulb.ac.be (M. Cordier), jweih@yahoo.com (J. Weih), bertrand.hamaide@usaintlouis.be (B. Hamaide).

http://dx.doi.org/10.1016/j.ecolecon.2017.04.005
0921-8009/© 2017 Elsevier B.V. All rights reserved.

emitted from the economic system towards the ecosystem and *ii*) flows of natural resources extracted from the ecosystem towards the economic system. However, the impacts generated inside the ecosystem are not taken into account – for example, the impact of pollutants emitted into the sea on marine fish stocks. This means that feedback loops, defined as conditions whereby causal variables in the system (original causes) generate output variables (consequences) that will modify the initial causal variables through a series of relationships (Stepp et al., 2009; Deaton and Winebrake, 2000; Sterman, 2000), cannot be taken into account. For example, an economically-induced change (original cause) caused to marine fish populations (consequence) will have a feedback impact on the fishing sector and on other economic activities (original cause), but this is not considered in such extended IO models.

Most of the authors mentioned above have therefore disregarded interactions occurring inside the ecosystem, arguing the lack of data on ecosystem functioning (Victor, 1972). Moreover, those interactions are nonlinear and their impact on human activities is highly indirect. This makes them very difficult to model even if data were available, which explains why they have been largely neglected until now even though nonlinear dynamic ecological processes are at the productive source of final ecosystem services that impact human well-being (Cordier et al., 2014; Haines-Young and Potschin, 2010). Excluding such crucial interactions prevents ecological-economic models from analysing the impact of pollutant discharge or natural resource extraction on ecosystems. Isard (1968) was the first to enter into IO models interactions that occur inside the ecosystem. However, the lack of ecological data at that time drastically reduced the number of cases to which his model could be applied. In addition, given the linear property of IO models, he could only analyze linear environmental issues. Since then, not much improvement has taken place, either with extended IO models or computable general equilibrium (CGE)[1] models. Most researchers restrained their ecological-economic modelling to case studies related to predator-prey relations inside food webs, a typical purely linear relationship in ecosystems (e.g. Jin et al., 2003, 2012; Finnoff and Tschirhart, 2008; Hussain and Tschirhart, 2013). This is a considerable drawback given that nonlinearity is the rule rather than an exception in environmental issues. To our knowledge, one of the very few ecological-economic CGE models integrating nonlinear interactions inside the ecosystem is the one developed by Finnoff and Tschirhart (2011).

Another option for taking nonlinearity of ecosystems into account may be to build the model the other way around; that is, to put IO modelling into ecosystem models, rather than doing the opposite. We call this the "economic component principle": the economic system is modelled within the ecosystem, as one of the components of the ecosystem. This lifts the classical IO limitations that generally constrain the description of the ecosystem.

The choice of the type of model – IO, SAM (Social Accounting Matrix) or CGE – is crucial, since results differ depending on the model. The economic impacts (multipliers) from an IO model tend to be smaller than a SAM model but larger than a CGE model (Miller and Blair, 2009; West, 1995; West, 2002). Like in Mongelli et al. (2010), we adopted an IO model. Our reasons are as follows. First, our original motivation was to extend the ecological-economic IO model developed by Cordier et al. (2014), which targets the same study area. Second, because our focus is on methodological advancement rather than on policy implication, a simple IO seems to be a credible base for future extensions of our proposed modelling approach, as mentioned by West (1995). Third, IO models are suitable at the regional (sub-national) level and are one of the best options to planners, despite their known limitations (West, 1995). More complex models may require larger amounts of data. CGE models require, among other things, "hundreds or even thousands of elasticities of substitution to be quantified" (West, 2002), which is a huge challenge especially at regional levels. For example, at such subnational levels, price data are notoriously scarce, which strongly reduces the possibilities for the construction of CGE models (Rey, 1998). This is confirmed by various authors, among which are Sullivan and Gilless (1990), who encountered such difficulties for some price dependent functions, and others who claim that regional scale results are not always achievable with CGE models (Liew, 1988; Hudson and Jorgenson, 1974; West, 2002; Rey, 2000).

In order to apply the "economic component principle" in this paper, we develop an ecological-economic model based on the integration of IO within a system dynamics (SD) model. SD had its inception in the early 1960s, with Forrester (1961). It is a computer-aided approach based on differential equations (Richardson, 2013). It has been used for modelling ecological-economic systems (e.g., Costanza et al., 1998; Uehara, 2013; Uehara et al., 2015), as differential equations are suitable for capturing nonlinear dynamics. The central concept of system dynamics is to understand how elements in a complex system interact with one another over time. It deals with internal feedback loops, time delays, and stocks and flows that affect the behavior of the entire system (Forrester et al., 1997).

Applying SD concepts to IO modelling means that an IO model is embedded in an SD model as one of the components of the SD model. With such a perspective, the resultant IO/SD model represents an ecosystem where non-human components such as natural habitats, animals or plants interact with other components such as economic activities. In that perspective, the economic system is one component of the ecosystem.

To our knowledge, there is currently no system dynamics model *synchronized* with IO, nor any application to ecological-economic systems. Previous system dynamics models incorporating IO *translate* IO into system dynamics (e.g., Braden, 1983; Diehl, 1985). This translation is uncommon, although not impossible – as shown in previous studies (e.g., Dudley, 2004; Moxnes, 2005) – but it is laborious and inefficient, and it significantly increases the complexity of the model architecture (e.g., Ford, 1999). However, when SD focuses on nonlinear dynamics in an ecological system, and IO is implemented in some other platform suitable for it, it seems possible to more appropriately capture the complexity of an ecological-economic system.

The first advantage of integrating IO with SD is that it allows us to estimate indirect and induced economic impacts of ecosystem modifications on other economic sectors involved in the supply chain (that is, on sectors that supply the sectors directly impacted by ecosystem changes). The second advantage is that it describes a detailed economic structure, as all sectors of the economy are included. Thereby, impacts of policy measures and ecosystem changes can be estimated for each economic sector, and trade-offs can be identified; i.e., determining which sector is advantaged or disadvantaged. Third, entering IO into an SD model allows the static property of IO to be reduced. SD is inherently dynamic, so the ecosystem variables interacting with IO are made dynamic. In other words, input variables of the ecosystem that enter the IO component are endogenised in the model. The evolution of those variables over time is no longer linear. An attempt at making parts of the economic system dynamic was already carried out by Cordier et al. (2014), but the ecosystem part of the model remained static and linear. In this paper, modelling the ecosystem part with an SD tool (Powersim) solves that problem. Fourth, entering IO into an SD model enables us to incorporate feedback loops between an ecosystem of fish natural habitats and a coastal economic system.

The remainder of the paper is structured as follows. Section 2 presents the study area. Section 3 is devoted to the methodology used: Section 3.1 explains how the economic component is embedded within the ecosystem modelling, Section 3.2 develops the economic component of the model (IO equations), and Section 3.3 details the ecosystem component of the model (SD equations).

[1] CGEs are made of an I-O table to which equations have been added to take into account the impacts of prices on economic production (e.g., price modification caused by environmental measures).

Download English Version:

https://daneshyari.com/en/article/5048638

Download Persian Version:

https://daneshyari.com/article/5048638

Daneshyari.com