Available online at www.sciencedirect.com

SCIENCE DIRECT

ACADEMIC PRESS

Journal of Environmental Economics and Management 46 (2003) 513–538

JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT

http://www.elsevier.com/locate/jeem

Production, consumption, and general equilibrium with physical constraints

Frank C. Krysiak* and Daniela Krysiak

Faculty VIII, Economics and Management, Technische Universität Berlin, Str. des 17, Juni 135, Berlin, Germany

Received 26 February 2000; revised 9 July 2001

Abstract

This paper analyzes the consequences of integrating the conservation laws of mass and energy into the microeconomic models of production, consumption, and general equilibrium. We show that abstract models and especially general equilibrium theory are consistent with these physical constraints, but most applied and environmental economic models are not. We analyze the consequences of physical conservation laws for substitution possibilities and show that these constraints limit the number of independent substitution processes but not the value of the substitution elasticities. Finally, we propose a method for integrating physical constraints into static microeconomic models with a minimum of changes.

Keywords: Production; Consumption; General equilibrium; Conservation law; Mass; Energy

1. Introduction

The use of models in scientific research, whether in economics or in the natural sciences, always implies some abstraction from reality. This leads to the question which aspects of reality should be included into models and which can be safely neglected. In economic modeling, such a question arises with the treatment of physical laws, like the conservation of mass and energy. These laws are successfully used in the natural sciences and in engineering but are not explicitly included in most economic models, although these models describe physical processes like the production or consumption of physically measurable quantities. The discussion whether this neglection leads to substantial problems has started more than 30 years ago and has not found a definite conclusion yet.[1]

*Corresponding author.
E-mail address: krysilca@sp.zrz.tu-berlin.de (F.C. Krysiak).

[1] See, e.g., the discussion in [4,14,15].

0095-0696/03/$ - see front matter
doi:10.1016/S0095-0696(03)00028-7

Beginning with [3,11], several approaches to include the conservation laws of mass and energy into economic models can be found in the literature. Some of them, like those in [1,6], or the process analysis approach in [2], use partial analytic models, others, like those in [3] or [12], concentrate on models of the economy as a whole. But all use highly specialized models, so that they neither provide a general answer to the question whether the neglection of physical conservation laws in economics is problematic, nor supply a broadly applicable method for including these laws into economic models.

In this paper, we analyze in a general setting the consequences of including mass and energy conservation into the models of production, consumption, and general equilibrium. In addition, we introduce a method that allows this inclusion with only slight changes to these models. Our results suggest that although physical conservation laws can be seen as implicitly accounted for in general equilibrium theory, they are relevant for applied modeling and especially for environmental economics. We show that most of the functional forms that are commonly used in applied modeling are not consistent with any meaningful set of physical constraints. However, this inconsistency is not caused by too large substitution possibilities, as has sometimes be suggested (see, e.g., [4]), but by allowing for too many independent substitution processes. Furthermore, our results suggest that a physically consistent model for environmental economic analysis has to be rather large, that is, it has to include a large number of environmental goods. Static models with only one or two physically measurable environmental goods, a type of model that prevails in environmental economics, have to be either physically inconsistent or economically uninteresting, since physical consistency implies that the environmental goods in such a model are not used in equilibrium.

By these results, we provide at least a partial answer to the debate about the relevance of physical conservation laws for economics. The neglection of physical constraints does not undermine the validity of economic models per se. Nevertheless, their explicit inclusion seems desirable to avoid misspecifications of functional forms in applied modeling and to prevent disregarding important couplings between environmental problems in environmental economics.

The paper is organized as follows: first, we model the conservation laws of mass and energy (Section 2) and integrate them into production theory (Section 3) and into consumption theory (Section 4). We then analyze the consequences of these physical constraints for general equilibrium and for general equilibrium with environmental interactions (Section 5). Two examples and a discussion of our results conclude the paper.

2. Physical constraints

Since production and consumption are physical processes, they are subject to physical constraints. A minimal set of these constraints is formed by the conservation laws of mass and energy.[2]

[2] An inclusion of the second law of thermodynamics would also be interesting, but since the entropy content of substances is not directly measurable and can only be calculated on the basis of idealized models, such an inclusion would not lead to applicable results.