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Fuzzy Inoperability Input-Output Analysis of Mandatory Biodiesel Blending Programs: The Philippine Case

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Abstract

Biofuels are regarded as one of the major low-carbon energy options currently available for large-scale use. Many countries have implemented biofuel programs that involve blending of bioethanol with gasoline, or biodiesel with diesel, at varying proportions. These programs are designed to address pressing concerns such as climate change, environmental quality, energy security and rural development. However, recent works suggest that biofuel resources may be at risk due to aberrant climatic events that are anticipated in the near future. Potential climate-induced disruptions include changes in precipitation levels, pest infestation, plant diseases, or increased frequency of extreme weather events. The incidence of such disruptions not only affects biofuel producers, but also energy-dependent economic sectors, resulting to "ripple effects" that further increase economic losses. We apply the inoperability input-output model (IIM) proposed by Haimes and Jiang (2001) and later enhanced by Santos and Haimes (2004) to assess the economic effects of implementing mandatory biodiesel blending programs in the Philippines. The IIM is based on the well-established technique of input-output analysis that quantifies risk through the inoperability metric, which is a dimensionless index whose value ranges from 0 (for a system functioning normally) to 1 (for a system in a state of total failure). Using the IIM, we determine the adverse effects of climate-induced biofuel disruptions on interdependent economic sectors. We estimate the resulting crop losses using the storm damage scenario from Stromberg et al. (2011) under no blending and a proposed blending rate of 5% as considered by the Department of Energy. Different ranking strategies are evaluated to determine sector vulnerability using inoperability levels, economic losses and weighted inoperability levels. For the latter scenario, equal weights are considered. Uncertainties within the modelling framework are captured through the use of fuzzy numbers.

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Keywords: risk assessment; climate vulnerability; biodiesel, inoperability input-output model

1. Introduction

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The use of biofuels is one strategy which can help reduce the generation of greenhouse gases. Because of this, several countries have mandated the blending of fuels such as biodiesel with diesel and bioethanol with gasoline, in different proportions. However, the main feedstock for the large scale production of biofuels is sourced from agricultural products which are affected by the onset of extreme weather events resulting from climate change. With an increased reliance on agricultural feedstock, climate change induced disruptions will affect not only the agriculture sector but also other energy-dependent sectors resulting in increased economic losses and system inoperabilities. It is thus important to analyze the effect of climate change induced disasters on an economy upon the implementation of a biofuel policy. This will provide insights for the development of disaster risk management and recovery strategies as well as in the selection of the appropriate biofuel policy. The interdependence between economic sectors is best represented by the input-output framework and the inoperability input-output model (IIM) which will be discussed in Section 3. A case study on the biofuel policy implementation in the Philippines is used to demonstrate the model.

2. Problem Statement

The implementation of a biofuel policy will modify the structure of an economic system by potentially increasing its reliance on the agricultural sector. The formal problem statement is that given an economic system characterized by the interdependency matrix (**A***) resulting from the implementation of a biofuel policy, how should economic sectors be prioritized based on economic losses and inoperabilities caused by climate change induced disasters.

3. Methodology

The Inoperability Input – Output Model (IIM), which is an extension of the Leontief IO model [1], is utilized in this work to demonstrate the impact of storm damages in an economy implementing a biofuel program. The IIM defines inoperability as the "inability of a system to perform its intended function" [2]. It utilizes the parameter defined as inoperability, which is a dimensionless number ranging from 0 to 1, where 0 represents a fully functioning system and 1 corresponds to a system with total failure. The inoperability of an economic sector (**q**) results from an initial perturbation (**c***), caused by a reduction in final demand due to a disruption such as a disaster. This perturbation propagates throughout the economic system due to the interdependencies (**A***) between the economic sectors. Equation 1 describes the demand based IIM [2,3] indicating the relationship between the perturbation, inoperability and the interdependency matrix.

$$\mathbf{q} = \mathbf{A}^* \, \mathbf{q} + \mathbf{c}^* \tag{1}$$

4. Case Study

The Biofuels Act of the Philippines (Republic Act 9367) was signed into law in the year 2007, mandating the utilization of at least 1% biodiesel blend and 5% bioethanol blend for all diesel and gasoline utilized in the country. Coconut is the main feedstock as coconut plantations make up 26% of the total agricultural land in the country [4]. This case study considers the impact caused by typhoons when no biofuel policy is implemented and if the proposed 5% coconut biodiesel blend [5] is implemented.