INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2017) 1–17

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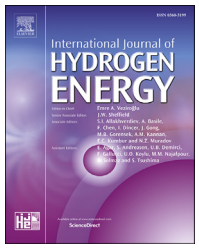

Econometric assessment of bioenergy development

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ARTICLE INFO

Article history:
Received 1 April 2017
Received in revised form
5 August 2017
Accepted 8 August 2017
Available online xxx

Keywords:
Econometric assessment
Bioenergy economy
Biofuel
Circular economy
Bioeconomy

ABSTRACT

Bioenergy is regarded as an attractive, low-carbon energy source because it supports environmentally friendly conversion of biomass to bioenergy, and has low CO_2 emissions. Forecasting the development of bioenergy using econometric models can help decision makers to optimize strategies and plan roadmaps for the bioenergy industry and its supply chain. This investigation surveys nine econometric assessments that are relevant to the development of bioenergy, including those based on regression, time-series models, simultaneous equations, input-output model, linear/nonlinear programming model, computable general equilibrium models, engineering economics, data envelopment analysis, and the integrated assessment model. The fundamentals of each model are reviewed, their advantages and disadvantages are addressed; representative models in various categories are provided and compared. Eleven aspects of these models are rated. The results provide useful references for choosing econometric model to evaluate numerical impacts of circular economy, bioeconomy and bioenergy economy for decision makers of countries.

Introduction

The new generation of bioenergy and bio-based materials offer promising alternatives to fossil fuels [1] as they generate neutral-carbon energy [2] with less damage to the environment, lower greenhouse gas (GHG) emissions [3,4] and greater energy security [5] which are driven power to transitioning to circular economy, bioeconomy and bioenergy economy [6,7]. The first generation of biofuels may be causing problems for agricultural production, such as the need of land and water to produce biomass feedstock, increasing food prices [8,9]; reducing the number of people with access to cheap food, and even increasing GHG emissions [10,11]. The second [5] and third generation of biofuels, including microalgae biofuels, may not have such problems [12–15].

Numerous new-generation bioenergy [1] have been developed as a result of technological progress; they include biohydrogen [16–19], biobutanol [20–22], biomethane [23,24], and biomethanol [25]. Technological advances depend on extensive funding from private investors and governments, and this in turn depends on solid evidence of the bright future that will be offered by bioenergy, including financial feasibility and profits. Economists have used classical probability theory, statistics and econometric theory to construct econometric models to support evaluations of bioenergy based on reasonable assumptions and the reasonable rational economic behaviors of economic participants including firms, consumers, investors, governments, and international traders [15]. Econometric models suffice to evaluate development of bioenergy because they can comprehensively account for and interacting factors related to alternative fuels, land use, biomass feedstocks and transportation, agricultural waste, supply chains, transportation [26], international trade and the macroeconomy, climate change, environmental protection, landscapes, and human life. Bioenergy involves many production technologies and regional economic interactions that

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http://dx.doi.org/10.1016/j.ijhydene.2017.08.055
0360-3199/

must be comprehensively described through econometric assessments, to provide accurate simulations that support the development of a new generation of biofuel, and provide references for investors, government and other decision makers.

This investigation reviews nine econometric models that support economic simulation of the development of bioenergy industry and have been developed in recent decades. Through pairwise and group comparisons among econometric models, this investigation scores 11 aspects of the models, and makes suggestions and offers guidelines for bioenergy econometric modelers.

Models

Most economic models of the use of bioenergy combine techno-economic methods, which provide technological, experimental and practical data, with econometric models, which use econometric evaluating models to generate numerical solutions to provide references for decision makers. This section introduces concepts associated with two types of model, and reviews nine familiar econometric models, which will be compared in the following section.

Economic models

Econometric model

An econometric model is a quantitative-qualitative model that is based on probability theory, probability distributions, statistical theory, and econometric and economic theories which are applied using special software with quantitative databases to provide numerically the impacts of particular shocks. The results of simulations based on econometric models are credible as they have a solid theoretical basis, so they guide economic participants under risky conditions.

The regression model (RM), time-series model (TSM), simultaneous equations model (SEM), engineering economics model (EE), data development analysis (DEA), linear programming model (LP), input-output model (IO), computable general equilibrium model (CGE), and integrated assessment model (IAM) are major econometric models that are used by most of economic researchers in energy fields. All of these models are regarded econometric models [27]. They provide estimates of required endogenous variables based on time-series, cross-section or panel data, which are used in the model equations as parameters and model variables. Statistical tests, in-sample forecasting and expert opinions verify their effectiveness in describing the effects of policy shocks in the real world.

To evaluate the economic impact of introducing bioenergy into a petro-based economy, solid economic evaluations using econometric models that are especially modified for the bioenergy industry and its supply chain must be used. This investigation will provide guidelines for bioenergy modelers and researchers in selecting effective econometric models for various fields of bioenergy research to yield useful results in support of the development of the bioenergy industry.

Techno-economic analysis

Developing the bioenergy industry involves developing not only bio-energy-related technologies through research and development, but economic feasibility evaluations, which are required to attract funding from the private and public sectors to make commercialization successful. Techno-economic analysis of a project that involves bioenergy production includes economic evaluation, which may involve econometric models and an engineering economics/cost-benefit analysis [28]. Such analysis is required to support the development of bioenergy as part of a future low-carbon economy. Conventional economic evaluations of the future of the bio-industry use quantitative methods and econometric tools. Newly developed bioenergy econometric models are based on economic theory, statistics, econometric theory, and demand and supply behaviors. Computer programs are modified for the bioenergy industry, and data concerning bioenergy production processes and the economic costs of bioenergy are used perform simulations and make practical and reliable forecasts [5,13,14]. Each techno-econometric model that is applied to bioenergy production has many versions with various settings, advantages and disadvantages, and researchers must choose the model according to the issues they are addressing.

Guidelines for choosing bioenergy econometric models are crucial to providing evaluation results to decision makers. This investigation will introduce the main types of bioenergy econometric model for use by bioenergy model builders, which are the RM, TSM, SEM, EE, DEA, LP, IO, CGE and IAM models. All models are compared and a rating system developed to enable deeper analysis in this study.

Main econometric models

Regression model

The classical regression model was developed by Ref. [29], who identified a relationship between the heights of fathers and sons. The regression model reveals the causality between dependent and independent variables. When combined with statistical analysis and solving methods including least square, method of moments, likelihood method, and owing to the continuous improvement of regression theory, regression models, such as quantile regression, stepwise regression, ridge regression, lasso regression, elastic net regression and meta-regression, are still effective enough for use in modern simulations and forecasting in complex economic environments. They can reveal implicit industrial structure and forecast the development of bioenergy (specified by dependent variables) as a result of technological improvements, cost reductions, and supply chain operations.

Econometric models that use data Y_i and X_i to generate numerical solutions and are numerically solved, including regression models, have the following explicit form.

$$Y_i = \widehat{\alpha}_i + \widehat{\beta}_i X_i + \varepsilon_i \quad (1)$$

where Y and X, are independent and dependent variables of time series data of bioenergy, for instance, Y is bioenergy production value and X could be factors influence variation of Y such as price of bioenergy, $\widehat{\alpha}_i$ and $\widehat{\beta}_i$ are intercept and slope of the sample regression model, respectively. Researchers estimate parameters $\widehat{\alpha}_i$ and $\widehat{\beta}_i$ of the regression model using econometric estimation methods, such as least square

Please cite this article in press as: Lee D-H, Econometric assessment of bioenergy development, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.08.055