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From a rise in B to a fall in C? SVAR analysis of environmental impact of biofuels

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ABSTRACT

This is the first paper that econometrically estimates the impact of rising *B*ioenergy production on global CO_2 emissions. We apply a structural vector autoregression (SVAR) approach to time series from 1961 to 2009 with annual observation for the world biofuel production and global CO_2 emissions. We find that in the medium- to long-run biofuels significantly reduce global CO_2 emissions: the CO_2 emission elasticities with respect to biofuels range between −0.57 and −0.80. In the short-run, however, biofuels may increase CO_2 emissions temporarily. Our findings complement those of life-cycle assessment and simulation models. However, by employing a more holistic approach and obtaining more robust estimates of environmental impact of biofuels, our results are particularly valuable for policy makers.

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1. Introduction

An often used argument for supporting biofuel is its potential to lower greenhouse gas emissions compared to those of fossil fuels. Carbon dioxide (CO_2) is of particular interest, as it is one of the major greenhouse gases which cause climate change. Although, the burning of biofuel produces CO_2 emissions similar to those from fossil fuels, the plant feedstock used in the production absorbs CO_2 from the atmosphere when it grows.[1] After the biomass is converted into biofuel and burnt as fuel, the energy and CO_2 is released again. Some of that energy can be used to power an engine, whereas other part of CO_2 is released back into the atmosphere.

The extent to which biofuels lower greenhouse gas emissions compared to those of fossil fuels depends on many factors, some of which are more obvious (direct effects), whereas others are less visible (indirect effects). An example of the former is the production method and the type of feedstock used. An example of the latter is the indirect land use change, which has the potential to cause even more emissions than what would be caused by using fossil fuels instead [14]. Therefore, when calculating the total amount of greenhouse gas emissions, it is highly important to consider both the direct and the indirect effects which biofuels may cause on the environment [34,9,16,17,11,5,29,38,33,6].

Considering all these aspects makes the calculation of environmental impacts of biofuels a complex and inexact process, which is highly dependent on the underlying assumptions. Therefore, when comparing the amount of greenhouse gas emissions across different types of fuels, usually, the carbon intensity of biofuels is calculated in a "Life-cycle assessment" (LCA) framework, the main focus of which is on the direct effects: emissions from growing the feedstock (e.g. petrochemicals used in fertilisers); emissions from transporting the feedstock to the factory; emissions from processing the feedstock into biofuel; emissions from transporting the biofuel from the factory to its point of use; the efficiency of the biofuel compared with standard diesel; the benefits due to the production of useful by-products (e.g. cattle feed or glycerine), etc.[2]

One of such LCA calculations, which was done by the UK government, is presented in Fig. 1. The estimates reported in Fig. 1 suggest that depending on the type of fuel and the place of biofuel production, biofuels can emit 34–86% CO_2 compared to fossil fuels (100%) per energy unit. The figure also suggests that there is a large variation in the CO_2 savings between different types of biofuels, ranging from 38% for palm oil to 73% for soy grown in Brazil.

While serving as a practical tool for assessing the environmental impacts of biofuels (and comparing with those of fossil fuels), most of the LCA calculations do not consider the induced indirect effects, such as the indirect land use change, carbon leakage, changes in crop yield, substitution between fuels, and consumption effects, and hence may be biased [10,23]. Depending on the relative strength of the different indirect channels, the bias can be either upward or downward. Moreover, the LCA studies provide little insights about the inter-temporal dynamics of environmental impacts of biofuels, which however are important for policy makers.

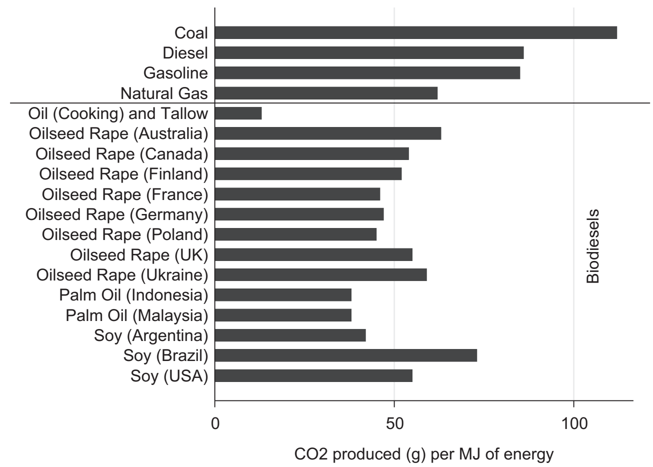

Fig. 1. Carbon intensity of biofuels and fossil fuels. Source: own calculations based on the UK Government data. Notes: *X* axis measures the CO_2 in gram emitted per Megajoule of energy produced.

In order to account for the induced indirect effects of biofuels, simulation models (partial equilibrium (PE) and computable general equilibrium (CGE)) have been developed and applied. Usually, PE and CGE models take the technical coefficients of biofuel production and CO_2 emission as given, and simulate CO_2 emissions under alternative policy regimes or model assumptions. An important advantage of simulation models is that they allow for substitution possibilities both on the energy production side and energy consumption side and, in addition, CGE models account for economy-wide induced general equilibrium effects.

While being able to account for important indirect environmental effects, both PE and CGE models suffer from their sensitivity to calibrated parameters. This in turn significantly widens the confidence interval of simulation results, and increases uncertainty about the true impact of biofuels on environment.[3]

The objective of the present study is to fill this research gap and to estimate the environmental impacts of biofuels, by explicitly addressing the above mentioned weaknesses of both LCA and CGE studies. First, by employing a structural vector autoregression (SVAR) approach, where all variables can be modelled as endogenous, we are able to account for all direct and induced indirect effects. Second, by estimating the underlying structural parameters on reasonably long time-series data econometrically, we are able to ensure statistically significant and robust results.

We find that in the medium- to long-run biofuels significantly reduce global CO_2 emissions. The estimated global CO_2 emission elasticities range between -0.57 and -0.80. In the short-run, however, biofuels may increase CO_2 emissions temporarily (elasticity 0.57). Our findings complement those of life-cycle assessment and simulation models. However, by employing a more holistic approach and obtaining more robust estimates of environmental impact of biofuels, our results are particularly valuable for

[1] Plants absorb CO_2 through a process known as photosynthesis, which allows it to store energy from sunlight in the form of sugars and starches.

[2] For a detailed review of LCA studies, see Janda et al. [20,21].

[3] There exist few studies in the literature, where a particular emphasis is devoted to parameterisation and empirical implementation of applied general equilibrium models.