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The impact of biofuel growth on agriculture: Why is the range of estimates so wide?

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ABSTRACT

The rapid expansion of biofuel production has generated considerable interest within the body of empirical economic literature that has sought to understand the impact of biofuel growth on the global food economy. While the consensus within the literature is that biofuel emergence is likely to have some effect on future world agricultural market, there is a considerable range in the estimated size of the impact. Despite the importance of this topic to policy makers, there has been no study that has tried to reconcile the differences among various outlook studies. This paper undertakes an in-depth review of some key outlook studies which quantify the impacts of biofuels on agricultural commodities, and which are based on either general-equilibrium (GE) or partial-equilibrium (PE) modeling approaches. We attempt to reconcile the systematic differences in the estimated impacts of biofuel production growth on the prospective prices and production of three major feedstock commodities, maize, sugar cane, and oilseeds across these studies. Despite the fact that all models predict positive impacts on prices and production, there are large differences among the studies. Our findings point to a number of key assumptions and structural differences that seem to jointly drive the variations we observe, across these studies. The differences among the PE models are mainly due to differences in the design of scenarios, the presence or absence of biofuel trade, and the structural way in which agricultural and energy market linkages are modeled. The differences among the GE models are likely to be driven by model assumptions on agricultural land supply, the inclusion of the byproducts, and assumptions on crude oil prices and the elasticity of substitution between petroleum and biofuels.

Introduction

The world has seen rapid growth in biofuel production in recent years. Global biofuel production has tripled from 18 billion liters in 2000 to over 62 billion liters in 2007, 90% of which was concentrated in the US, Brazil, and the EU (Coyle, 2007; OECD, 2008). Global ethanol production – dominated in growth by the US and Brazil – reached 52 billion liters in 2007 and the production of biodiesel – centered mostly within the EU – increased more than 10-fold during the same period, to more than 10 billion liters (OECD, 2008).

Correspondingly, the use of major feedstock crops for biofuel production has increased dramatically. The International Grain Council reported an overall growth in the use of cereals for ethanol production by 32% in 2007/2008 and by 41% in the US from the previous year (International Grain Council data cited in von Braun (2008)). The global use of maize for ethanol grew especially rapidly from 2004 to 2007 and used 70% of the increase in global maize production (Mitchell, 2008). Biodiesel production in 2007 accounted for 7% of the global vegetable oil supplies, and one-third of the increase in consumption from 2004 to 2007 was due to biodiesel (Mitchell, 2008). Among the largest biofuel producers, the US used 25% of its maize production for biofuels in 2007 (USDA, 2007); Brazil used 50% of its sugar cane for biofuels; and the EU used 68% of its vegetable oil production, primarily rapeseeds, for biofuels (World Bank, 2008).

The potential impact of the emergence of biofuels on food commodity prices and production has generated considerable interest in the empirical economic literature. A great deal of research has been undertaken to understand the implications for agricultural markets – both at the country-specific and international level. Generally-speaking, there are two groups of studies: backward-looking ones and forward-looking ones. The first group estimates the degree to which biofuel demand has influenced the recent food and commodity price trends based on historical data. Estimates vary widely. For instance, the USDA (2008a) believes that biofuels only accounted for 3% of the retail food price increase. In contrast, others have suggested that more than 70% of the rise in food prices was due to biofuels (Mitchell, 2008). Lipsky (2008) estimates that

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biofuels account for 70% of the maize price increase and 40% of the soybean price increase.

Unfortunately, these *ex post* estimates are difficult, if not impossible to compare. The estimates differ widely due to the fact that authors examined different time periods, used data from different price series (export, import, wholesale, and retail) and focused their attention on different types of food products (Mitchell, 2008). For example, the estimate by USDA (2008a), which is low in comparable terms, is in part because the authors only considered the impact of maize prices, directly and indirectly, on retail prices (Mitchell, 2008).

This paper focuses on the second group of studies, the forward-looking ones, which generate medium- and long-term predictions of the impacts of biofuel expansion on commodity market, using equilibrium modeling techniques. For example, US-focused studies mostly have looked at the implications of energy policy (e.g., Energy Independence and Security Act or EISA) on food and feed prices (e.g., FAPRI, 2008); EU-focused studies have frequently examined the implications of EU-directives and impact on world prices and production (e.g., Banse et al., 2008); Outside of the US and EU, other studies have sought to predict the impact on prices in the developing world (e.g., OECD-FAO, 2008), malnutrition (e.g., Rosegrant et al., 2008) and implications for poverty (e.g., Yang et al., 2009). While the consensus within the literature is that biofuel growth is likely to have at least some impact on future commodity prices, there is a considerable range in the estimates. Some studies claim strong linkages (e.g., Qiu et al., 2009). Others suggest that the linkages between biofuels and commodity prices are relatively weak (e.g., Banse et al., 2008). Studies that project the impact of future biofuel production on agricultural prices provide important guidelines for setting long-term agricultural, food security, and energy policies, as well as development agenda. Therefore, when predictions vary so much, policy makers face uncertainty about which ones to depend on. Despite the importance of this topic to policy makers, there have been few studies that have tried to reconcile the differences among these outlook studies, except Golub and Hertel (2011), Dumortier et al. (2011) and JRC (2011), which indicate that the land use change and carbon emission impacts of biofuels policies are extremely sensitive to model assumptions. The study aims to put the range of numbers regarding the impact of biofuel production on agricultural market in the literature into perspective and provide a guide to the range of assumptions and modeling techniques necessary to draw policy conclusions.

This paper reviews the results of a number of the key medium- and long-term forward-looking partial and general equilibrium models. Above all, we are interested in understanding why the predictions about the future effects of biofuels vary widely among the studies. Our study focuses on a subset of the studies—in particular, on the prices and production of three biofuel feedstock crops, maize, sugar cane and oilseeds. To reach this goal we have two specific objectives. First, we will describe the range of projections from a group of papers that are focused on forecasting prices and production of the three key biofuel feedstock crops globally as well as in different parts of the world. Second, we seek to explain the differences in the projections by examining the differences in underlying assumptions and model structures.

To meet these objectives the rest of the paper is organized as follows. In Section ''Issues to consider when trying to make the studies comparable'' we review a number of issues that need to be considered when trying to produce a set of studies that can be compared. In Section ''Identifying differences in projected impact of biofuel growth'' we compare the studies and identify the variations in their results with respect to the impact of biofuel emergence on food prices and production. In Section ''Explaining the differences'' we examine, in detail, the underlying assumptions and structure of the analytical approaches used in the studies and draw implications of these factors on model outcomes. Finally, in Section ''Conclusions'' we highlight key findings of the study and suggest future research directions.

Issues to consider when trying to make the studies comparable

Because of the broad nature of this study, we have to limit the scope of this paper. Specifically, we try to include all economic papers that are global in scale. The models in the study all use partial- and general-equilibrium trade models to track the impact of biofuels. We exclude studies that are solely focused on individual countries (e.g., Arndt et al., 2008). We also exclude science-based papers that mainly examine biofuels and the environment and climate (e.g., Utrecht University-FAO, 2008). In addition, we only consider those studies that have adequately described their modeling approaches and have included scenarios that enable the effects of the emergence of biofuels on agricultural prices and production to be isolated. Because of this, for example, we do not include Elobeid and Tokgoz (2008) or the USDA (2008b). In some cases, the model versions that are included in our review contain assumptions made specifically for the analysis and thus are not identical to the standard models that the research teams maintain. Therefore, it is important to refer to the individual studies and the specific versions of the models being used in those studies for technical modeling issues.

Based on these criteria, we review nine papers (Table 1). Specifically, we review four papers that are based on partial equilibrium (PE) modeling frameworks: (a) a paper using the Aglink-Cosimo model developed by OECD and FAO (henceforth called the *OECD model*—OECD-FAO, 2008); (b) the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model developed by the International Food Policy Research Institute (henceforth, called the *IFPRI model*—Rosegrant, 2008; Rosegrant et al., 2008); (c) a paper using the FAPRI model that was produced by the Food and Agricultural Policy Research Institute (henceforth, the *FAPRI model*—FAPRI, 2008); and (d) the WEMAC model, version 2.0 (henceforth, called the *WEMAC model*—Benjamin and Houee-Bigot, 2008). When taken as a group, we call these four papers that use *PE modeling frameworks (or PE models)* the *PE studies*.

We also review five papers that use general equilibrium (GE) modeling frameworks (Table 1): (a) a model by the Agricultural Economics Research Institute (LEI) of Wageningen University (henceforth, the *LEITAP model*—Banse et al., 2008); (b) a model by Hertel et al. (2008—henceforth, called the *Purdue I model*); (c) a model by Taheripour et al. (2008—henceforth, called the *Purdue II model*); (d) a model produced by the Economic Research Service of the United States Department of Agriculture, or the USDA-ERS (henceforth, called the *FARM II model*—Fernandez-Cornejo et al., 2008); and (e) a model created by a consortium of researchers that is supported by the Gates Foundation (henceforth, called the *GF model*—Yang et al., 2009). When taken as a group, we call these five papers that use *GE modeling frameworks (GE models)* the *GE studies*.

In order to make the results of the studies comparable, it is necessary to make some adjustments and organize some of the studies in ways that make the inter-model comparisons as straightforward as possible. First, we organize the studies by the modeling approach taken by the authors. In particular, we examine and compare the results of PE studies and GE studies separately. These must be separated because GE models seek to account for the supply, demand and prices in the entire economy, which includes simultaneously considering multiple markets, with inputs accounted for. In contrast, PE models examine the conditions of equilibrium in an individual market or within a single sector of a national economy. When using PE models, researchers hold prices,