Renewable Fuel Standard: A historical evaluation of economic impacts using partial and general equilibrium models

Background
When a government imposes a regulation, it usually indicates that the market would not produce the socially desired outcome. The U.S. Renewable Fuel Standard (RFS) is a good example of such a regulation. Congress believed that markets would not produce the “desired” amounts of renewable fuels, so it established requirements for minimum levels of use of different kinds of renewable fuels, providing biofuels access to the fuels market. However, it is not always the case that the mandate becomes binding if market conditions change. It is possible that with unforeseen changes in market conditions, a biofuel would be produced and/or used due to market forces at least to some extent. This paper examines the extent to which biofuel production has been driven through time primarily by the RFS and the extent to which it was driven by market changes unforeseen at the time of RFS passage.

While the RFS has played a critical role in providing a secure environment to produce and use more biofuels, it was not the only factor that encouraged the biofuel industry to grow. To some extent, at least in the 2000s, the non-RFS biofuel policies and market forces have also influenced the rapid expansion in biofuels. Over the past decade, many papers have studied the economic impacts of biofuel production and policy. While, in general, the existing literature has successfully identified the key drivers of the growth in biofuels, it basically has failed to properly quantify the impacts and contributions of each of these drivers separately. This paper takes primary steps to fill this knowledge gap. Following an extensive literature review, it develops short and long run economic analyses, using Partial Economic (PE) and Computable General Equilibrium (CGE) models, to differentiate the economic impacts of the RFS from other drivers that have helped biofuels to grow. Unlike the existing PE and CGE modeling efforts that typically provided ex ante economic analyses for biofuels, this paper follows Taheripour, Hertel, and Ramankutty (2019) and develops a new approach that uses actual observations for the time period 2004-16 to construct ex-post historical baselines and counterfactual simulations to achieve the goals of this research. The existing literature has addressed the economic impacts of biofuel production and policy from different perspectives including but not limited to: welfare gains and loses; demand for and supply of transportation fuels; fuel prices; food and commodity prices; and contributions to agricultural resource utilization. This paper concentrates on the last two topics of this list and provides new important and critical insights in these areas.

The CGE baseline experiments simulate the changes in the global economy by country and by sector (including but not limited to crops, livestock, forestry and biofuels) based on the historical observations for two successive time periods of 2004-11 and 2011-2016. In these two time periods, the energy and agricultural markets behaved differently. The CGE counterfactual experiments alter the baselines to capture the impacts of ethanol and biodiesel mandates (separately and jointly) and expansions in biofuels (regardless of the drivers) on the economic variables such as crop and food prices, farmers’ incomes, employment, rate of land utilization, and etc. The paper fully describes these CGE experiments. The PE historical baseline experiment represents the annual changes in the US agricultural and energy markets from 2004 to 2016. The counterfactual PE experiment only isolates the impacts of RFS from all other drivers. Various national and international data sets were intensively used to support these experiments.
Major findings

From the data presentation and an extensive literature review alone, it became clear that the bulk of the ethanol production prior to 2012 was driven by what was happening in the national and global markets for energy and agricultural commodities and by the federal and sometimes state incentives for biofuel production. This conclusion is supported by examining the data, by the inferences of the recent literature, and by the fact that until 2012 the prices of Renewable Identification Numbers (RINs) were very low, indicating that the non-RFS policies and market forces (e.g. demand for ethanol as a fuel extender, demand for ethanol as an additive, the Clean Air Act Amendments of the 1990s, and MTBE ban) helped biofuels to grow, while the RFS provided a safety net for the whole biofuel industry to invest and extend its production capacity by requiring a minimum level of biofuels use.

The numerical results cover a wide range of outcomes. Here we only highlight some items. The CGE results confirm that, in general, the medium to long run price impacts of biofuel production were not large. Due to biofuel production, regardless of the drivers, crop prices (adjusted for inflation) have increased between 1.1% (for wheat) and 5.5% (for coarse grains) in the first time period (i.e. 2004-11). The model determines the contributions of RFS to the price increases due to biofuel production. For example, it assigns only one-tenth of the 5.5% increase in the price of coarse grains to the RFS. For the second time period (i.e. 2011-16) the long run price impacts of biofuels were less than the first time period, as in this period biofuel production increased at much slower rate. For the second time period, the crop price increases were less than 1%. However, unlike the first time period, the RFS was the main driver of these changes. In both time periods, the long run effects of biofuel production and policy on consumer food prices were negligible.

The long run CGE results indicate that biofuel production and policy made major contributions to the agricultural sector in both time periods, while they only affected the commodity prices moderately. Biofuel production, regardless of the drivers, has increased US annual farm incomes by $8.3 billion and $2.3 billion at constant prices in the first and second time periods, respectively. Hence, with no biofuels, US annual farm incomes would drop at least by $10.6 billion, ignoring the changes since 2016. The model assigns 28% the expansion in farm incomes of the first time period to the RFS. The corresponding figure for the second time period is 100%. This means that the additional gains in farm incomes were entirely due to the RFS in the second time period. The additional farm incomes are attributed to two factors: 1) slightly higher crop prices induced by biofuel production and 2) retaining and allocating agricultural resources (say land) in higher valued activities. Compared to the baseline, with no expansion in biofuels, nearly 2,563 thousand hectares (6.3 million acres) of the US cropland would go out of production in the time period of 2004-11. The corresponding acreage loss for the time period of 2011-16, is about 77 thousand hectares (190 thousand acres). The model assigns 16% and 100% of these areas to the RFS, respectively.

The short run PE analyses indicate that prior to 2011 the market based projections for annual consumption of ethanol were usually smaller than their real world observations, with one exception in 2008. That suggests a binding RFS in that year. Since 2011, the market based projections for annual ethanol consumption are smaller than their real world observations. That indicates the RFS pushed up consumption of ethanol in these years. Based on the PE results, the
RFS increased the demand for ethanol by 7% to 14% between 2011 and 2016. For example, in 2016 the actual consumption of ethanol was 14.3 billion gallons (BG) with a market based projection of 12.1 BG. This suggests that in this particular year the RFS increased consumption of ethanol by about 2.1 BG. The impact of RFS on the corn market in this year led to about a 5% higher price.

**Modeling framework**

This paper develops and uses a hybrid modeling framework consisting of a PE model and a CGE model. The PE model (AEPE: Agricultural Energy Partial Equilibrium) is introduced in several publications (e.g. Tyner and Taheripour (2008) and Tyner, Taheripour and Perkis (2010)). This model concentrates on the US commodity and energy markets. The CGE model is an advanced version of the GTAP-BIO model which has been developed and used frequently to address the economic and environmental impacts of trade-energy-environment policies and topics during the past decade (two recent applications are: Taheripour, Hertel, and Ramankutty (2019) and Yao, Hertel, and Taheripour (2018)). This global model traces production, consumption, and trade of all goods and services (aggregated into various categories including but not limited to crops, livestock, forestry, and biofuels) at the global scale. This CGE model captures the use of commodity feedstocks for food and fuel and the competition or trade-offs between those and other market uses. Both the PE and CGE models use exogenous variables and shift factors, some appear in both models. Figure 1 represents our hybrid modeling approach and the links between the CGE and PE models. This figure shows interactive links between the CGE and PE models through the shift factors. The shift factors were determined using an iterative approach between the CGE and PE models.

![Figure 1. The overall modeling approach](image)

**References:**


