Impact of Eliminating Biofuels Production on US Gasoline Prices: An Equilibrium Analysis*

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Executive Summary

A combination of mandates, credits, and subsidies are employed in the US to encourage biofuel production. Recent demands for reduced federal spending have increased scrutiny on these incentives just as many are set to expire if not soon renewed by Congress. In this context, it becomes important to understand what impacts ethanol production has had on food and fuel markets, and what changes can be expected if ethanol production is eliminated. We report here on a modeling study of this question. Using a computable general equilibrium model that captures the market effects of the various interactions between fuel production, imports, exports, and consumption in equilibrium, we study 2 policy scenarios to illucidate the effects of ethanol production: 1) the future hypothetical in which ethanol production is eliminated at the end of 2011 and 2) the historical counterfactual in which ethanol production is eliminated in 1999, before it becomes a substantial proportion of US fuel markets.

In order to evaluate the relative effects of various production and demand scenarios in the US fuel market, we examine the sensitivity of model outputs along two parameter dimensions: the price elasticity of the global oil supply and of US consumer demand for gasoline. Within acceptable ranges of both parameters, we find that elimination of US ethanol production results in a median 8.2% (with a range from 4.5% to 14.1%) increase in gasoline prices in 2025, relative to the 2025 value in the baseline scenario in which ethanol production stays fixed.

We compare these results to a series of recent estimates of similar measures from Xiaodong Du and Dermot Hayes, finding that their published results [Du and Hayes, 2009] are largely consistent with the estimates. Re their recent unpublished extension [Du and Hayes, 2011], we discuss a number of compounding circumstances that could contribute in whole or in part to the very high price effect estimates. While we cannot compare our results directly to either of these estimates, due to significant methodological differences, we conclude that the highly non-standard treatment of fuel imports and the selection of elasticity parameters well below typical values is likely responsible for much of the extraordinary result. Though highly inelastic fuel supply conditions, such as might lead to large price spikes given sudden

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supply shocks in ethanol production, are certainly not impossible in the very short-run, we note 2 things: 1) a return to the peak levels of gasoline imports from 2006 itself could make up for more than half the fuel lost from a complete elimination of fuel ethanol and 2) given the size of the ethaonol production market in the US and the import market for sugarcane based ethanol, we find it highly unlikely that a single disturbance, be it from drought or public policy, could provide as strong a shock as considered in Du and Hayes [2011] (i.e. a complete and immediate elemination of all fuel ethanol production).

1 Introduction

A combination of mandates, credits, and subsidies are employed in the US to encourage biofuel production and consumption. The Energy Independence and Security Act (EISA) of 2007 mandates an increase in domestic biofuel use to 36 billion gallons annually by 2022, suggesting a production rate nearly three times that of 2010. EISA also established a federal renewable fuel standard (RFS), which sets mandatory blend levels for renewable fuels. The national RFS sets a minimum standard of nine billion gallons of renewable fuel in 2008, rising to 36 billion gallons by 2022, by which time 21 billion gallons must be obtained from cellulosic ethanol and other advanced biofuels. Beginning in 2010, a percentage must be cellulosic biofuel, biomass-based diesel, or other advanced biofuel. Starting in 2016, all of the increase must be met with advanced biofuels.

In addition to the provisions of EISA, three major federal tax credits are available to domestic producers and blenders of biofuel. The Volumetric Ethanol Excise Tax Credit (VEETC) provides blenders with a tax incentive of $0.45 per gallon of pure ethanol blended with gasoline, with a limit of 15 billion gallons; this credit is currently set to expire December 31, 2011. Small ethanol producers may be eligible for a direct tax incentive of $0.10 per gallon of ethanol, the Small Ethanol Producer Tax Credit (SEPTC). This incentive is also set to expire December 31, 2011. Further, many states provide additional incentives for biofuel use and production. Currently, 20 states offer producer incentives, 28 states provide blend incentives, and 10 states have their own renewable fuels standards.

The presence of such a collection of economic policies raises many questions about their impacts on various sectors of the US and world economy–and about the implications of major changes to current policies, such as the termination of the national RFS. In studying such effects, it is important to consider not only the direct impacts of a policy change on an effected sector (e.g., increased biofuel production will substitute for gasoline) but also potential amplifying or offsetting market effects. For example, the U.S. EPA states in the Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis that

> [In] our emissions (GHG and non-GHG) and air quality analyses we have assumed that the production of renewable fuels to satisfy the RFS2 results in an energy equivalent decrease in production of petroleum-derived fuels. This is despite the fact that our other analyses predict that increased renewable fuel use will reduce worldwide crude oil prices, which in turn could lead to an increase in the quantity of crude oil demanded. [EPA, 2010, pg 4]

Studies that seek to model such causal relationships and thus to describe the broader impacts of policies are said to apply Consequential Life-Cycle Analysis (CLCA) [Ekvall and Weidema, 2004], in contrast to simpler Attributional Life-Cycle Analysis (ALCA). CLCA studies require economic models that include demand for inputs, prices, supply, and effects of co-products. Such models often take the form of computable general equilibrium (CGE) models.

We describe here a study that uses a global CGE model, CE-Bio, that includes biofuels and agriculture sector detail that allows us to account for changing demand for inputs, prices, supply, and effects of co-products that result from policy changes. We use this model to evaluate the medium and long term market effects of both historical ethanol production and counter-factuals such as sudden elimination of biofuels production–a potential extreme consequence of the elimination of the RFS. (In practice, as we discuss below, transition effects associated with elimination of the RFS would surely result in biofuels production reducing over time, not stopping instantaneously.) Our model outputs provide insights into the implications of such policy changes for a range of economic sectors, including gasoline prices.

While the CE-Bio model captures interactions not represented in simpler models, substantial uncertainties are present due to the many assumptions required to represent complex economic systems, avenues for feedback, and stochastic elements [Brander et al., 2009]. As a first step towards characterizing the impact of those uncertainties, we perform multiple CGE simulations while varying the demand elasticity of gasoline and the price elasticity of supply of the global oil supply. These results allow us to project, for example, that future gasoline prices following elimination of ethanol are relatively insensitive to the demand elasticity of gasoline, and more sensitive to the price elasticity of supply of the global oil supply.

The rest of this report is structured as follows. We briefly describe some key elements of the OSCEF model instance, CE-bio, designed to evaluate economic issues of food and fuel around the production and demand for first and second generation biofuels. We then present estimates of key economic effects in food and fuel markets and evaluate some key sensitivities. We discuss the relationship of this work to recent studies by Du and Hayes [2009, 2011] and then conclude.

2 The OSCEF Biofuels Model

A CGE model aims to quantify the effects of policies on equilibrium allocations and relative prices using standard general equilibrium theory. Such models typically employ nested constant elasticity of substitution (CES) production and utility functions. CES functions are defined by cost share parameters and the elasticities of substitution among commodities. Cost share parameters are derived from base-year data, while the elasticities of substitution are chosen by either expert opinion or econometric estimates from time-series data.

We work here with the Open Source CIM-EARTH Framework (OSCEF) Elliott et al. [2010b], a collaborative, multi-institutional project that is designing a large-scale, integrated, and open-source CGE modeling framework as a tool for decision makers in climate and energy policy, and as an input to CLCA type models such as GREET [Wang, 1999]. OSCEF's modular architecture facilitates the creation of problem-specific models that add detail in a particular sector of interest. It has also been constructed in a manner that facilitates large-scale parameter sweeps to characterize parameter uncertainty.

In the work reported here, we use the OSCEF biofuels model (CE-bio), a global CGE model that we have constructed in order to conduct analyses of the economic and environmental impacts of biofuels production and demand. CE-Bio includes a detailed representation of the global biofuels market, with a focus on US biofuel production. It includes representations of the RFS, VEETC, and SEPTC polices mentioned previously. Figure 1 shows the nesting structure that we use for these sectors.

The OSCEF biofuels model (CE-bio) contains significant detail in agriculture and related services. Figure 1 shows the nesting structure that we use for these sectors. The primary data source for CE-Bio model calibration is the Global Trade Analysis Project (GTAP) data base, specifically the GTAP version 7.1 data base of global expenditure values [Gopalakrishnan and Walmsley, 2008] and GTAP-BIO [Taheripour et al., 2008] for ethanol and biodiesel values. The GTAP 7.1 Data Base has a 2004 base year, 57 sectors and 112 regions. We also combine several studies on the production costs of corn, sugar cane, and cellulosic ethanol and soy biodiesel to obtain the cost shares used in our analysis, including Tiffany and Eidman [2003] and Shapouri and Gallagher [2002]. Total production costs from these studies for corn ethanol range from 1.34-1.50 USD per gallon.

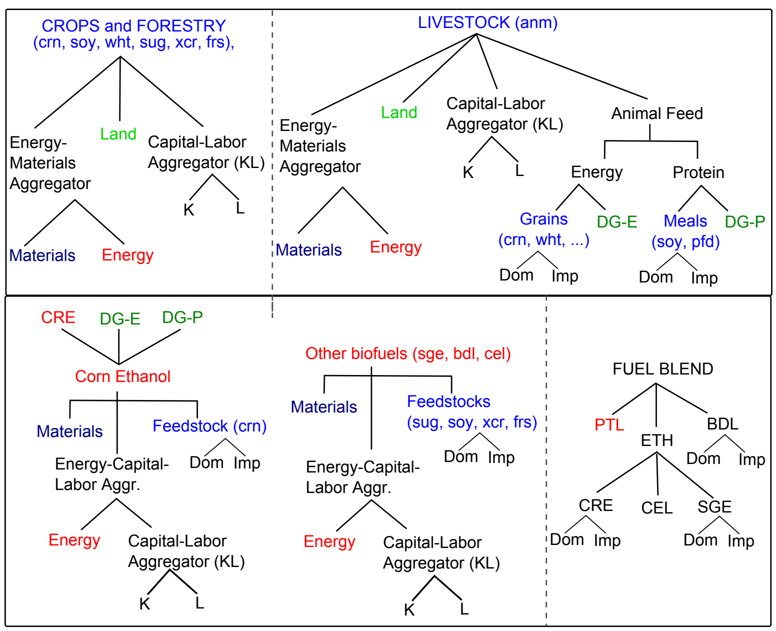

Figure 1: Nesting structure for the extended production functions in CE-bio. In addition to those of the standard CE trade model, CE-bio adds production functions for biofuel production and commercial gasoline blenders and modifies the production function for livestock industries to include explicitly the substitution of distillers grains in animal feed. Further, the model includes a multiple output production function for corn ethanol which includes distillers grain as a production bi-product. In order to model the substitution of DGS for both the energy (coarse grains) and protein (soy and other oil meals) parts of animal feed, DGS is modeled as two separate commodities (the energy and protein fractions).

Note that new industries are difficult to model in a CGE framework, both because little historical data exists to calibrate production functions in the base-year and because rapid growth and technological changes are primarily driven by transition dynamics. Industries like cellulosic ethanol or advanced biofuels production are thus significantly more sensitive to scenario assumptions such as technological change and land availability. While its not difficult to include these industries in principle, we have ignored their impacts for the current analysis so that the interpretation of the scenarios and results will be more straightforward.

Since we expect that the demand elasticity for blended gasoline will play an important role in the medium-term market impact of ethanol, we generalize the utility function to distinguish gasoline consumption from other consumption as in Figure 2. Further details on the model structure and calibration methodology are provided in Elliott et al. [2010b].

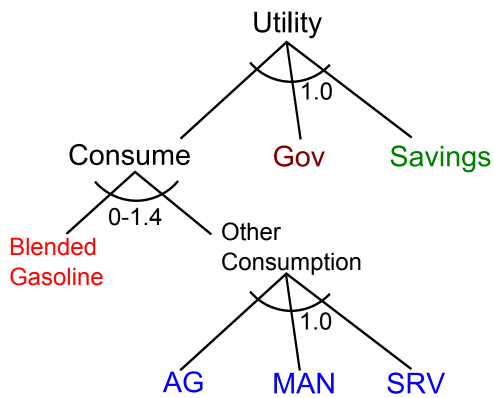

Figure 2: Utility function nesting structure for CE-bio.

3 Scenarios

Biofuels mandates, credits, and subsidies have contributed to the rapid increase in U.S. corn ethanol production over the past decade. We have addressed elsewhere the implications of extending current biofuel subsidies and other policies [Loudermilk et al., 2011]. Here, we ask what effect removing these credits may have both on the market for corn ethanol and on the nascent cellulosic ethanol market. We consider two scenarios: 1) production of ethanol is eliminated completely at the end of 2011, and 2) ethanol is eleminated in 1999, before it has a chance to grow to a substantial portion of fuel consumption. We compare both scenarios against a baseline case under which current ethanol policy is continued (i.e., corn based ethanol quickly hits a maximum of 15 Bg y^{-1} and remains flat there for the future, while imports of sugarcane based ethanol continue to increase slowly). For simplicity, we ignore advanced and second generation biofuels for the duration of this discussion and in all scenarios. Though the model is calibrated with a snapshot of the global economy from the year 2004, we "back-cast" the simulations to the year 2000 in order to better compare with historical data.

Figure 3 shows the baseline scenario. Gasoline demand begins to flatten off in 2015, though demand for refined petroleum and imported sugarcane ethanol continues to rise slowly. This baseline largely consistent with the 'high economic growth' case (which is likely the most similar set of input assumptions) in the 2011 EIA energy outlook [EIA, 2011], which

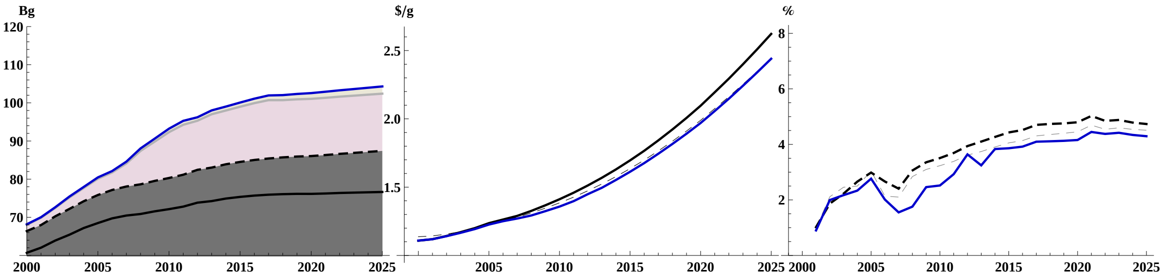

Figure 3: Gasoline production and prices in the baseline. From left to right: 1) total demand for U.S. gasoline (blue line) divided into corn ethanol consumption (pink shaded), imported sugarcane ethanol consumption (small yellow shaded), gasoline imports (dashed) and domestic (solid black), 2) wholesale price blended gasoline (blue line), domestically refined petroleum (solid black line), and imported refined petroleum (dashed line), and 3) year over year growth rate in wholesale gasoline price (blue line), crude oil (black dashed line), and domestically refined petroleum (light dashed line).

estimates a maximum gasoline demand peaking in 2016 at a value 6.7% larger than 2009 demand and then declining to a value only 3.8% higher by 2025.

One notable detail of Figure 3 is that the blended gasoline price increases at a rate substantially below that of refined petroleum in the early years, but at a similar rate in later years. This effect is due in large part to a 64% increase in U.S. corn ethanol prices between 2011 and 2025 (see Figure 4), driven by a 78% increase in corn prices. Though the model clearly does not capture the recent volatility in corn prices (and is not expected to), the steep long term trend in the baseline does lead to substantial increases in corn ethanol prices. This effect deserves future study.

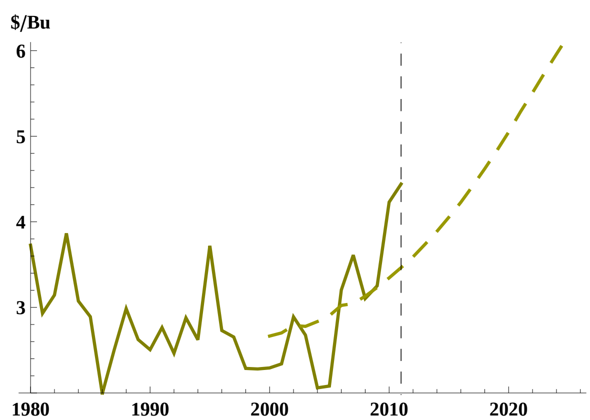

Figure 4: U.S. corn price. Historical data (solid yellow) from USDA is adjusted with the farm products producer price index. The modeled price for corn (yellow dashed) is for the baseline scenario. We attribute the rapid price increase for corn to growing demand.

Figure 5 shows results for scenario 1. Through 2011, a substantial portion of U.S. gasoline demand is met with fuel ethanol. During this time, the price of gasoline increases by an average of 2.1% per year, whereas the prices of crude oil and domestically refined petroleum increase by 2.7% and 2.5% per year, respectively. When fuel ethanol is eliminated, we see

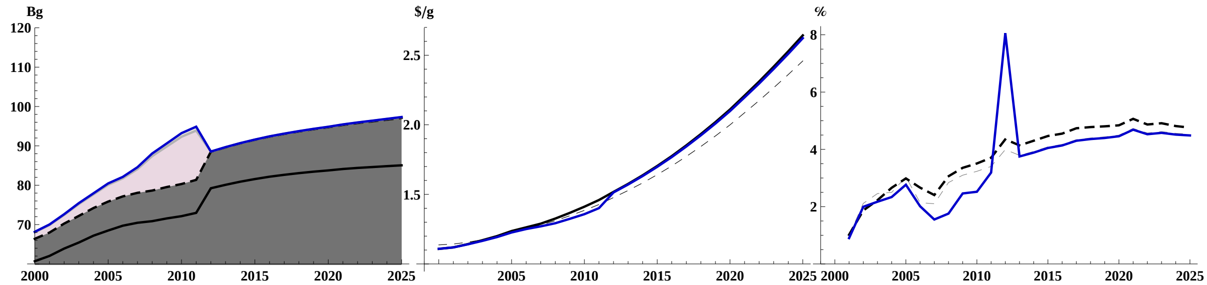

Figure 5: The gasoline market effects of ethanol in scenario 1

a spike of 8% in the price of blended gasoline, after which time the price tracks that of domestically refined petroleum, as expected. The effect on the price of crude oil and refined petroleum is noticeable, but much more subtle. We see this result as reasonable for oil, which is a huge global market that should be able to absorb a sudden 8% increase in U.S. demand (which amounts to less than a 2% increase in global demand), although recent studies (most notably Du and Hayes [2009]) estimate that limited availability of immediate refinery capacity could lead to increased prices for refined petroleum in the short term. Again, we stress that the model considered here assumes perfect capital mobility and so does not capture these short term dynamics. The primary measure of interest for this analysis is the percent increase in blended gasoline prices in the no-ethanol counterfactual scenario, relative to the current policy baseline, which is 5% in 2012, growing to 7.9% by 2025.

Figure 6 shows the similar plots for the counter-factual scenario where ethanol production never occurs. The long-term effect of scenarios 1 and 2 are very similar, though the more immediate elimination of ethanol actually leads to a slightly lower long term increase in gasoline price relative to the baseline, as consumers have more time to adjust to the decreased supply. This comes as no surprise given the small impact that the ethanol industry has on the supply side of the petroleum market.

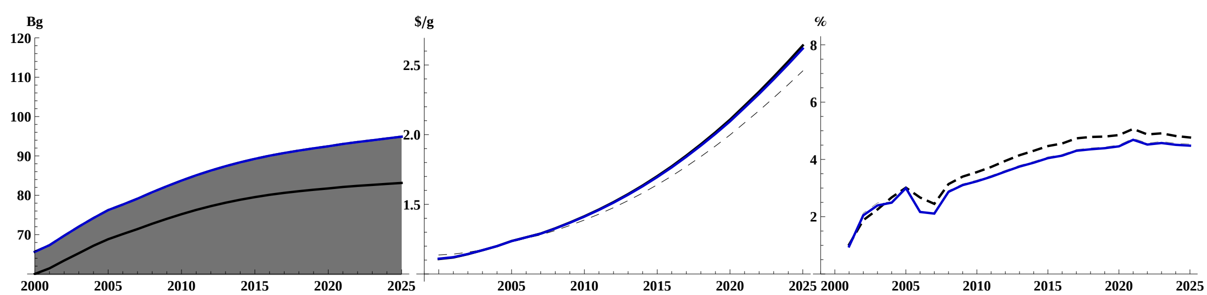

Figure 6: The gasoline market effects of ethanol in scenario 2

4 Model Sensitivities

As a first step towards characterizing feasible ranges for these measures, we evaluate their sensitivity to two key parameters for gasoline production and demand: the elasticity of consumer demand for gasoline and the price elasticity of crude oil supply.

Several studies have looked at the short- and long-run elasticities of gasoline demand [Espey, 1998, Krichene, 2002], with estimates of the short-run elasticity between 0 and −1 and a median of −0.23 and long-run elasticities between 0 and −1.5 and a median of −0.43. Some more recent studies have estimated that long-run demand elasticity may be on the decline (in absolute terms) [Lin and Prince, 2009] while short run elasticities may be increasing [Hughes et al., 2008, Lin and Prince, 2009], with both effects possibly due to recent increases in gasoline price volatility [Lin and Prince, 2009]. More study of these effects is likely needed. Here we simulate a range of elasticities from −0.03 to −1.43. While we accept this full range as plausible, we note that growth rates in gasoline consumption implied by the very low elasticities are well outside both historical observations and EIA forecasts. For example, Figure 4 shows the total gasoline demanded (in billions of gallons) for 8 scenarios spanning this range of demand elasticity and for historical data back to 1991 from the EIA. Up to the start of the recession in 2008, the rate of growth in demand is very linear and far lower than what would be implied by the three lowest elasticity scenarios, spanning −0.03 to −0.43. For this reason, we choose to use −0.63 as the central value for the results in Section 3, in order to remain consistent with EIA. Varying only the demand elasticity, we find that elimination of US ethanol production can result in anywhere from a 4.9% to an 8% increase in gasoline prices in 2025 (relative to the 2025 baseline scenario value), or about \$0.13 to \$0.19 per gallon.

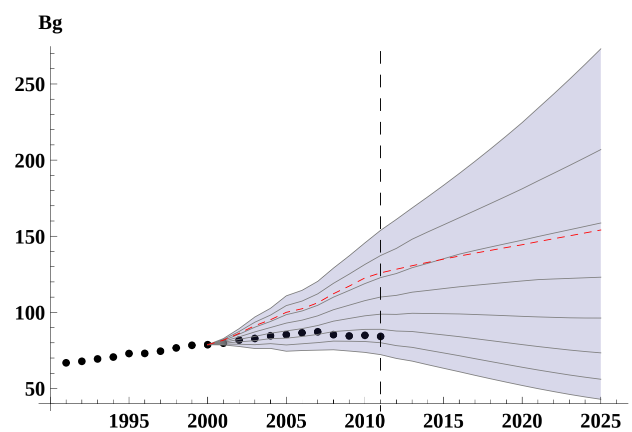

Figure 7: Gasoline consumption in the baseline (gray lines) for 8 different values of the elasticity of demand ranging from −0.03 to −1.43, historical observations of consumption from EIA (black dots), and the implied consumption using elasticity parameters from Du and Hayes [2009] (red dashed line).

For the price elasticity of the global oil supply, defined as

$$\psi_{oil} = \sigma_{oil} \frac{1 - \alpha_R}{\alpha_R} \,, \tag{1}$$

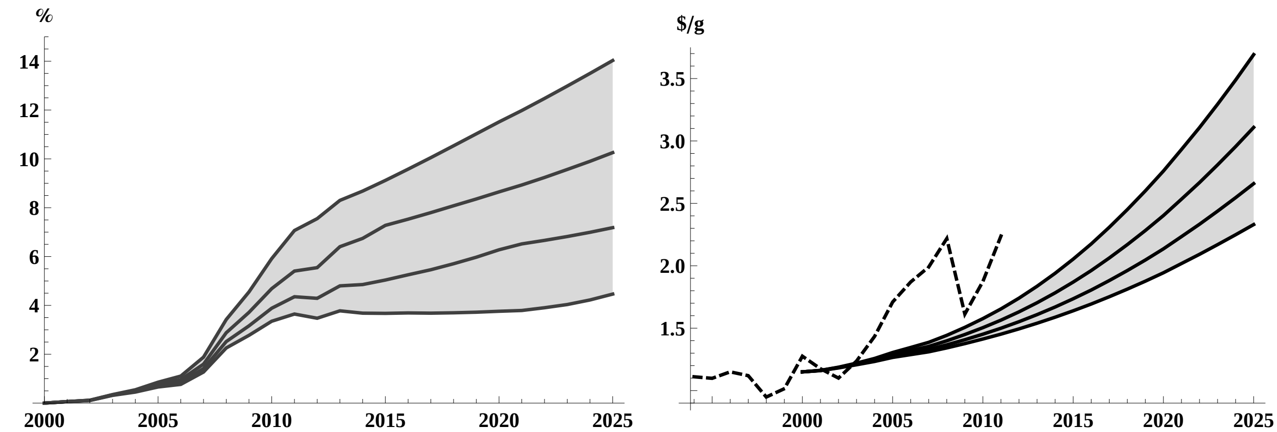

Figure 8: Price effects of ethanol production for several values of the price elasticity of oil supply: historical (dashed) and baseline wholesale gasoline prices for different values of the oil supply elasticity (right) and the percent difference with the respective version from scenario type 2 (left).

where α_R is the cost share of the fixed resource factor in the production function for oil and σ_{oil} is the top level elasticity of the oil producer, the few quantitative estimates that are available show substantial variation over time. Instead, we consider a range from $\psi = 0.32$ to 1.26 ($\sigma_{oil} = 0.1$ to 0.4), constructed from studies using similar models as in Gerlagh and Kuik [2007]. Values reported in Section 3 use a default value of $\sigma_{oil} = 0.3$. Varying the supply elasticity over this range has a more dramatic effect, with an impact to gasoline prices in 2025 ranging from 4.5% with high elasticity to 14.1% for low elasticity. Figure 4 shows the baseline price and the scenario 2 price difference as we vary σ_{oil}. The gross price and the relative price effect are both affected substantially by the supply elasticity of oil, leading to a gross effect as high as $0.45/gallon in 2025 in the very low elasticity scenario. We consider this extreme value as unlikely, but not impossible. Clearly more study is needed to clarify this important issue.

5 Comparisons with Du and Hayes

It is instructive to compare our results with those obtained by Xiaodong Du and Dermot Hayes, who have used an analytic partial equilibrium model to study two related questions to those considered here, namely (a) the historical effect of U.S. ethanol production on US gasoline prices and (b) the short-term effects of an immediate elimination of US ethanol production.

Using data up to and including 2008, Du and Hayes [2009] estimate that the historical effect of U.S. ethanol production on average wholesale gasoline prices was a reduction of about $0.14/gallon (8% relative to the mean price over the sample period of 1995 to 2008) on average, with wide variation by region. A recent modification of the analysis and update to include data through 2010 [Du and Hayes, 2011] estimates a revised effect of as much as a $0.25/gallon average reduction (roughly 16%) between 2000 and 2010. However, these two estimates are not directly comparable, as changes in data collection between 2008 and

2011 prevent them from correcting for endogeneity in gasoline imports, which accounted for about 14% of US gasoline in 2007, in the latter study.

Du and Hayes [2009] employs an instrumental variables technique to correct for this issue, using EIA-supplied data on gasoline prices at the Amsterdam-Rotterdam-Antwerp (ARA) refining hub to capture prices in the European market. Those ARA data were discontinued by EIA after September 2008), preventing them from applying a comparable correction in [Du and Hayes, 2011]. While the overall effects of this correction in [Du and Hayes, 2009], and the lack of this correction in [Du and Hayes, 2011], are unknown to us, they could account for much of the difference between these estimates. According to the EIA, refined gasoline imports increased by 365% from 1995 - 2006 (from 4774 Mg, or 5.1% of total demand, to 17424 Mg, or 16.2% of demand) and then decreased 23% between 2006 and 2010 (to 13459 Mg, or 12.7% of total demand), in what appears to be a fairly elastic response to price. Failing to account for this trade response could be a major reason for the large effects estimated in Du and Hayes [2011]. For comparison, our baseline simulations have a gasoline import share of 9.3% in 2000, 11.2% in 2011, and rising to 12.9-14.1% in 2025.

Du and Hayes [2011] also briefly address the impacts of an immediate halt to US ethanol production, although only from a short-run perspective. They state that "[u]nder a very wide range of parameters, the estimated gasoline price increase would be of historic proportions, ranging from 41% to 92%"–due primarily to limited slack in existing domestic refinery capacity. This estimate has attracted much attention. Our analysis here does not provide much direct insight into the accuracy of this extraordinary claim, because CE-Bio assumes perfect mobility of capital and so has little to say about short-term transition effects. While this assumption of perfect mobility of capital and labor is likely a poor one in most industries in the short term, it is reasonable for estimating measures in the medium term, i.e., after markets have around 5-10 years to equilibrate [Barro et al., 1995]. However, we note that similar short-run market and capital dynamics to those that make perfectly mobile capital unrealistic in the very short term, also make it unlikely that ethanol production would disappear fully in a single year. Some domestic production, and certainly imports of sugarcane ethanol, would likely remain stable or taper off slowly (especially if refinery capacity was stretched and refined petroleum prices rose substantially), implying that the constrained fuel supply conditions leading to the 41% to 92% effect are unlikely to be met in reality, even in the short term.

Further, we take exception to the elasticity values used in this estimate. For the median scenario, Du and Hayes [2011] use a short-run demand elasticity of -0.06 and a short-run domestic supply elasticity of 0.06. We consider both values to be extremely low given the estimates from the literature.

In addition, the extraordinarily low values reported in Du and Hayes [2011] for gasoline import elasticities appear to have been erroneously derived. Following the characterization of imports for ethanol described in Lee and Sumner [2010], Du and Hayes estimate the gasoline import elasticity as a function of the U.S. domestic supply and demand elasticities as

$$\epsilon_i = \left(\frac{Q_{tu}}{Q_i}\right)\epsilon_d - \left[\frac{Q_{tu}}{Q_i} - 1\right]\epsilon_s\,, \tag{2}$$

where ϵ_d and ϵ_s are the short-run domestic demand and supply elasticity respectively, and Q_{tu}/Q_i is the inverse of the import share to the U.S. gasoline market. This expression gives values of the import elasticity ranging from −1.25 to −2.87, which is consistent with standard values (we use a value of −1.98 in the simulations described here). This expression reproduces the values in Du and Hayes [2011] if ϵ_d is replaced with $-\epsilon_d$, so we conclude that the expression was applied incorrectly. This has the effect of dramatically reducing the response of gasoline imports to increased prices, removing a primary market mechanism that would act to moderate the extreme short-term price fluctuations one might rightly expect from the sudden elimination of 10% of the domestic fuel supply, especially given that, as described above, gasoline imports have fallen substantially from their peak values in 2006, implying substantial slack in the import market that could make up for some of the lost supply. A return to 2006 import levels alone would account for about half of the eliminated ethanol, in an energy equivalent basis, and historically US imports has had a strong response to domestic gasoline prices (see Figure 5).

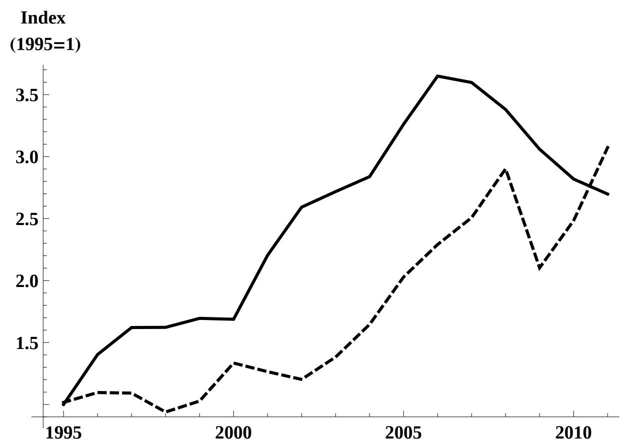

Figure 9: Index of wholesale gasoline prices (dashed) and US gasoline imports (solid) normalized so that f(1995)=1.

6 Conclusion

We have reported on a general equilibrium study of the market effects of eliminating US ethanol production. We find that the effect of eliminating ethanol production, whether by assuming it never existed or allowing the industry to "die off" at the end of 2011, can result in a 4.5–14.1% increase in gasoline prices in the medium term (10-15 years). We have compared this result to a series of recent estimates of similar measures from Xiaodong Du and Dermot Hayes, finding that their published results [Du and Hayes, 2009] are largely consistent with the estimates. Re their recent unpublished extension [Du and Hayes, 2011], we have discussed a number of compounding circumstances that could contribute in whole or in part to the extraordinary estimates. While we cannot compare our results directly to either of these estimates, due to significant methodological differences, we have concluded that the highly non-standard treatment of fuel imports and the selection of elasticity parameters well below typical values is likely responsible for much of the extraordinary result. Though highly inelastic fuel supply conditions, such as might lead to large price spikes given sudden supply shocks in ethanol production, are certainly not impossible in the very short-run, we note 2 things: 1) a return to peak levels of gasoline imports itself could make up for more than half the fuel lost from a complete elimination of fuel ethanol and 2) given the size of the ethaonol production market in the US and the import market for sugarcane based ethanol, we find it highly unlikely that a single disturbance, be it from drought or public policy, could provide as strong a shock as considered in Du and Hayes [2011] (i.e. a complete and immediate elemination of all fuel ethanol production).

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