MAKING THE MARKET: HOW U.S. POLICY INFLUENCES NEAR TERM AGRICULTURE AND BIOFUEL INDUSTRY PRODUCTION AND PROFITABILITY UNDER TECHNOLOGY ADOPTION

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Paper Title:
Making the market: How U.S. Policy influences near term agriculture and biofuel industry production and profitability under technology adoption.

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Abstract

The beneficiaries of technology adoption in agriculture and biofuels markets in the United States are heavily influenced by domestic biofuel policies and market context. Biofuel mandates, one of the key pillars of domestic biofuel policies, may significantly alter the elasticity of demand for biofuels as well as the derived demand for maize used to produce a significant share of ethanol in the United States. Using a stochastic agriculture and biofuels model, we assess how the introduction of technology may affect the crops and biofuel markets under binding and non-binding biofuel mandates and discuss the implications for analysis of EU biofuel policies.

Keywords: biofuels, policy, technology adoption, mandates

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INTRODUCTION

In his analysis of post-war American farm policy, Cochrane outlined four aspects of American society that intersected to create the curse of American agricultural abundance: the emphasis on technological solutions, the competitive market place, extremely inelastic demand for the farmer's output and the inability of resources and capital to shift to other more profitable uses (Cochrane and Ryan 1976). Unimpeded, these forces conspire to push supplies out against an inelastic demand, setting producers on an agricultural 'treadmill' forcing prices lower (Cochrane 1958). Agricultural policies of the period sought to raise and stabilize income in the context of growing supplies, ensuring further investment in technology and inevitably consolidation and structural change in American agriculture.

The subject of technology adoption within agriculture continues to garner significant attention and has been the subject of ongoing reviews of methodology and usage in the literature (Feder et al. 1985, Feder and Umali 1993, Sundig and Zilberman 2001). Cochrane's treadmill continued to operate seemingly unimpeded through the year 2004 as real crop prices continued to fall and production consolidated into fewer and fewer farm operations. Concerns of excess crop supplies have faded, at least for the moment, but policies are again playing a significant role in how technology adoption affects market prices and behavior in both crop and renewable energy markets.

At least until recently the U.S. maize market was often considered to conform to Cochrane's depiction of a typical agricultural commodity market. Much of the demand for maize was thought to be inelastic. A supply shift, through technology improvements, would result in substantive price changes with only modest increases in the quantity consumed (figure 1). While producers may see little benefit from technological progress, the users of maize such as livestock producers and consumers, both foreign and domestic, would see the majority of the benefits. If demand for maize were to become more elastic, producers would retain a greater share of the benefits.

As the biofuel industry began its rapid expansion in 2005, much was made of the tightening linkage between energy and agricultural markets. Demand for ethanol was expected to be very sensitive to the relative prices of gasoline and ethanol, and the supply of ethanol was expected to be very sensitive to relative prices of maize and ethanol. Thus, the prices of petroleum, ethanol and maize would be closely tied (Tyner and Taheripour 2008). With the significant increase in the share of maize being used in the production of ethanol, the implication was a slowing of Cochrane's treadmill. Ethanol production would both raise maize prices and provide the elasticity in demand that would lead to the benefits of technology adoption accruing to producers at last.

Biofuels markets in the United States are heavily influenced by public policy. Use of ethanol is subsidized by means of a blender's credit, which provides a tax credit to fuel suppliers who blend ethanol into the fuel they sell. Biodiesel has also been subsidized using a similar mechanism. Ethanol imports are discouraged by a significant tariff on product imported directly from Brazil, the main supplier in world markets. Finally, the Energy Independence and Security Act (EISA) of 2007 created a set of mandates requiring the use of at least specific quantities of different classes of biofuels. The blender's credit acts as a simple shift in demand, while the behavior of the mandate is more complex.

The demand for biofuel feedstocks and the demand elasticity faced by biofuel producers are highly dependent on domestic biofuel policies, and the relative importance of these individual policies has been shown to be highly context dependent (Meyer et al., 2009). The mandates introduced by EISA may, under certain circumstances, significantly reduce the demand elasticity for biofuels and thus the short run profitability gained by technology adopters.

The mandates represent volumetric quantities which the blenders are obligated to sell into the retail market. These requirements may be largely irrelevant, such as in the case where petroleum prices are extremely high relative to feedstock prices and the demand for ethanol in the marketplace exceeds the mandated quantities. Alternatively when the market would otherwise choose a quantity of ethanol below the mandate, it becomes binding and determines the quantity demanded in the biofuel marketplace. It is then probable that there are different elasticities of demand for maize over different demand quantities (figure 2). Demand for maize used in biofuel is a derived demand. When the mandate is binding, shifts in the supply from factors such as improved maize yields (ES_1 to ES_2), may simply result in a reduction in prices (P_1 to P_2) as the biofuel portion of demand remains at mandate levels ($Q_{1,2}$).

If the mandates are not binding, the shift in supply (ES_3 to ES_4) results in a greater quantity change (Q_3 to Q_4) and a much smaller reduction in prices (P_3 to P_4), allowing maize producers to retain a greater share in the benefits of technology adoption such as improved crop yields. Technology adoption directly by the biofuel producers can be similarly affected if we now consider figure 2 to represent the wholesale market for biofuels. In this case it is technology that shifts out the supply of ethanol from producers (ES_1 to ES_2 and ES_3 to ES_4) with effects on biofuel prices and quantities depending on where market demand is relative to the mandate. When mandates are binding, biofuel producers face a highly inelastic demand and the benefits of technology adoption in the biofuel processing sector would flow to biofuel consumers.

Technology improvements in the processing sector may have positive or negative effects in the feedstock sector (figure 3). The quantity of maize or other feedstocks used in ethanol production may increase if new technologies make ethanol production more profitable and if ethanol demand is sufficiently elastic (D_1 to D_2). Feedstock use may actually *fall* if the mandate is binding and the technology improvement improves extraction rates versus a pure cost reduction. Biofuel demand remains constrained at the mandated levels, but the quantities of feedstocks necessary to produce that quantity is less after the improvement in extraction rates. Should the technology improvement occur through extraction rates, there would be a shift inward of the vertical portion of the demand curve represented by the mandate.

Using a stochastic model of agricultural and biofuel markets, we can examine the effects of technology adoption by both feedstock producers and biofuel producers on their respective markets. In one case maize yields are increased from their baseline levels and in another ethanol extraction rates by producers are improved.

THE MODEL

The model used is a non-spatial partial equilibrium stochastic model of domestic crops, livestock and liquid biofuels markets. The model is closely related to the deterministic model used by FAPRI for the production of its annual baseline process, and is aligned to a common baseline (FAPRI 2010). The stochastic approach has value when there is an interest in the possible distribution of market outcomes. It is also valuable when policies or other market characteristics introduce important asymmetries (Binfield, et al., 2002). For example, a stochastic model is better suited to estimate government expenditures when policies only make payments when prices fall below trigger levels. These models have a long history of use in the analysis of agricultural policy (for example, Westhoff et al., 2008, FAPRI 2005, FAPRI 2000) and the market representation required for policy analysis makes it suitable for an industry wide analysis of the effect of structural or technological change under those policies.

The stochastic approach introduces uncertainty in exogenous variables and allows for market analysis over a wide range of conditions. The exogenous variables or error terms drawn on come from six basic areas: crop yields per unit of land, milk production per cow, exogenous energy and cost variables, domestic demand, domestic stockholding and reduced form equations for the rest of the world represented through trade equations. The stochastic draws maintain historic correlations within the six groupings, where the segmentation into these groupings is to ensure proper correlation among related variables and avoid spurious correlations which may arise between unrelated variable groupings. The draws on the variables are used to create 500 sets of 10-year correlated draws, which are then used to simulate the model (Westhoff et al., 2006).

The increasing importance of energy in agricultural markets has driven recent model developments. The model incorporates the EISA use mandates, as well as provisions of other legislation related to the blender’s tax credits and ethanol tariffs. The behavior of the mandates with their nested requirements is a significant source of complexity within the legislation but one which requires correct representation to understand the effects of other policies and external shocks on agricultural markets (Thompson et al., 2009). Policies, the credits and mandates, differentiate biofuels by type, ethanol versus bio-based diesel, as well as by feedstock and biofuel conversion process, all of which receives a representation in the model (see Thompson et al., 2008 for a partial representation).

The model explicitly represents both investment decisions related to biofuel production capacity and the decision to utilize existing capacity. This imposes short run constraints on ethanol production that are more apparent in a stochastic analysis. Likewise, the ability to utilize a product like E-85 (a blend of up to 85 percent ethanol) in motor vehicles depends on investment decisions by fuel sellers and consumers that are also incorporated in the model.

RENEWABLE IDENTIFICATION NUMBERS (RINS)

When a mandate is binding, the fuel blenders must bid up the supplier price of biofuel to obtain the needed quantities to meet their obligations. However, at the same time, fuel sellers must offer blended fuel at a price that consumers are willing to pay (Meyer and Thompson 2009). When mandates are binding, the price they can charge for blended fuel does not fully reflect the costs of the ethanol incorporated in the fuel. Instead, fuel merchandisers are forced to accept lower profits or pass along this cost to all fuel consumers, not just consumers of blended fuels. It is this cost that becomes the RIN value (Thompson et al., 2009).

The RIN, or renewable identification number, is the system by which the obligated parties show their compliance with the EISA mandates. The blender must show the volume of RINs necessary to meet their assigned obligation each year. These RINs are tradable and thus the price of the RIN is bid up to the point where the blender is indifferent between buying the ethanol at a high price and selling it at a lower price into a blend or simply purchasing RIN from another obligated party. Blenders can generate RINs to sell by incorporating more of one of the four classes of biofuels in the fuel they merchandise than the quantity they are required to use under the mandates. Blenders in areas with high ethanol costs or limited distribution infrastructure and markets for E85 use may find it less expensive to purchase RINs from other blenders rather than blend themselves.

The value of the RIN therefore provides us with a measure of just how ‘binding’ the mandates are. High RIN values indicate a significant effect of the mandate on the quantities blended where a lower value suggests a small effect. Other than transaction costs and speculative RIN holding to meet the subsequent year’s mandate requirements, RINs have no value when the market is willing to use more biofuels than required by the EISA mandates. The total value of the RINs used for compliance in the year for each mandate, conventional, advanced and bio-based diesel, is a measure of the costs borne by the consumer of enforcing the mandates.

Under EISA, there are specific mandates for the use of cellulosic biofuels and rules that are distinct from those that apply to other classes of biofuel. It is widely assumed that the cellulosic ethanol mandate will be waived each year because production capacity will be inadequate to satisfy the legislated mandate, as explicitly allowed under EISA. When the mandate is waived, the Environmental Protection Agency (EPA), enforcers of the mandate, must offer compliance cellulosic RINs at a legislated allowance value.[4] The EPA must then set a lower mandate which is attainable based upon their estimate of industry capacity. Therefore cellulosic ethanol production is unconstrained within the context of this analysis and the RIN price for cellulosic ethanol takes on the allowance value.

INCREASING YIELDS

The first scenario is intended to examine the consequences of technology growth in the feedstock sector. The maize trend yield is increased by adding 0.13 metric tons per hectare (2 bushels an acre) to the annual growth rate assumed in the baseline from 2011 to 2019, resulting in a 1.13 metric ton per hectare upward shift in yields in the year 2019 (figure 4). Table 1a shows the average effects of the increased crop yields over the 2015 to 2019 crop years relative to the 2010 FAPRI stochastic baseline for all 500 simulations. Results show that as yields increase, maize production increases, resulting in lower maize prices.

Lower maize prices result in higher maize consumption. More maize is fed to animals and more is exported. Lower maize prices also make ethanol production more profitable, so ethanol use of maize also increases. Overall demand is inelastic, so corn prices fall by a larger proportion than the increase in yields. The resulting reduction in net returns to maize production per hectare results in a reduction in the area devoted to maize production and an increase in the area devoted to competing crops. Increased production and cross-price effects

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[4] The allocation price is set at the greater of $0.79 per litter minus the wholesale unleaded gasoline price or $0.066 per litre, the credit is indexed to inflation after 2010.

in demand result in lower prices for wheat, soybeans and other competing crops. Overall crop area declines and is consistent with the decline in net returns to crop production.[5]

Table 1b shows the effects of the yield increase in the ethanol market and on aggregate measures related to biofuel and agriculture markets. Ethanol production increases by over 3 billion litres coming primarily from expansion of maize-based ethanol. There is some reduction in ethanol imports but it is small in comparison with the increases in domestic production.[6] The increase in ethanol supplies results in lower ethanol prices, and average consumption levels increase.

As Cochrane would have expected, the increase in maize yields leads to a reduction in net farm income. Crop receipts fall, as the increase in production is more than outweighed by lower prices. Livestock producers experience reduced feed costs, and so benefit. However, the resulting supply response results in lower livestock prices that moderate the increase in livestock producer net profits. Land rental costs and other production expenses decline, but not enough to offset the decline in receipts, so net farm income falls. Lower prices slightly increase government expenditures on farm programs funded by the Commodity Credit Corporation (CCC). , The increase is very small however, because market prices are generally above the levels that would trigger support under current U.S. farm policies.[7]

Consumers are the primary beneficiaries under the scenario, as total U.S. food expenditures fall by an average of 3 billion dollars a year relative to the baseline from 2015 to 2019. The value of the conventional RIN falls as the increased maize yields increase supplies and reduce prices, making the mandate less binding and lowering the average RIN value. The lowering

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[5] The crop and land areas tracked in the model include: maize, soybeans, wheat, upland cotton, sorghum, barley , oats, rice, sunflower seed, peanuts, canola, sugar beets, sugarcane, hay, conservation reserve, double cropped area and switchgrass.

[6] EISA establishes a submandate for “advanced biofuels,” and sugar-based ethanol qualifies under this mandate. Most baseline ethanol imports are intended to satisfy this mandate, but in some stochastic solutions, additional imports occur when U.S. ethanol prices in the conventional market rise high enough relative to Brazilian market prices that they cover the tariff and transportation costs.

[7] Price-based subsidies for grains and oilseeds only occur in a small fraction of the stochastic outcomes, even when average prices decline slightly from baseline levels. Under a different market situation that resulted in substantially lower baseline prices, the decline in prices resulting from higher maize yields would trigger a large increase in government farm program payments. This could could offset much or all of the estimated decline in net farm income reported here.

of the conventional RIN price reduces consumer costs from the mandate by an average of 600 million dollars a year. Because every gallon sold receives the government tax credit ($0.12 per litre for ethanol, $0.27 per litre for cellulosic ethanol and $0.26 per litre of bio-based diesel), as production increases the cost of the blenders credits to tax payers increases by 390 million dollars.

IMPROVING EXTRACTION RATES

To simulate technology growth in the biofuel sector, two scenarios assume increased ethanol extraction rates from each ton of feedstocks. In one scenario, extraction rates for maize dry mill ethanol production were increased. In a separate scenario, the same percent growth in extraction rates was applied to all significant pathways for ethanol production[8]. This covers maize dry mill and wet mill ethanol production as well as cellulosic ethanol from stover, switchgrass and other feedstocks. When ethanol extraction yields are not explicit in the model, production response to price signals were similarly adjusted as in the case of residual or other cellulosic ethanol production[9].

In both scenarios, extraction yields were increased by 5% in 2011 and by an additional 1% a year until reaching 10% above the baseline yield in 2016, after which the change from baseline was held constant. In both technology scenarios, in the dry mill ethanol process where maize is the primary feedstock, the increase in extraction rates of ethanol required an offsetting volumetric decline in the production of distillers grains, the co-product in the process. In the second technology scenario wet milling, the secondary source of maize-based ethanol in the United States, an offsetting volumetric reduction was made in maize gluten feed and maize gluten meal production. For cellulosic ethanol from maize stover and from switchgrass, extraction rates were increased, but no offsetting reduction in the co-products were made as the left over co-product is expected to be primarily burnt to produce electricity at the plant. For other cellulosic ethanol production where feedstock quantities and yields are not explicit, an adjustment to the supply responsiveness to prices was made to approximate the assumed improvement in extraction rates.

Improving dry-mill maize ethanol extraction rates

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[8] The technology employed by a small amount of ethanol production from non-maize cereals is left unchanged

[9] Other cellulosic ethanol is meant to represent disparate feedstocks such as sawdust, municipal solid waste and other proposed pathways.

With improved productivity in the ethanol processing sector, ethanol production increases (Table 1b). The additional 4.3 billion litres of maize-based ethanol displaces other sources of ethanol production as well as imports with a small amount of additional exports occurring. Conventional ethanol prices as well as conventional RIN prices are both pushed lower but the prices of other classes of ethanol are largely unchanged as maize starch-based ethanol processes, of which dry mill extraction is one, are prohibited from fulfilling the other mandate categories.

The increase in productivity means that the increase in ethanol production is possible even with a decline in the volume of maize processed (Table 1a). However, extracting more ethanol reduces production of distillers grains from each ton of maize and in aggregate. With less distillers grain available, the direct feed use of grain maize increases. This effect more than offsets the reduction in the amount of maize used for ethanol production, so overall maize demand increases slightly. This results in a very modest increase in maize prices, which in turn induces an increase in maize area at the expense of other crops.

Higher maize prices have spillover effects on other markets, resulting in higher prices for a wide range of commodities. Improved crop prices drive farm income slightly higher. The lower conventional RIN price reduces the average consumer cost of complying with biofuel mandates by a stochastic average of 870 million dollars annually. The expanded biofuel production results in an additional 470 million dollars a year in additional government expenditures on biofuel tax credits given to biofuel blenders. Higher commodity prices add 510 million to annual U.S. consumer food expenditures.

Improving all maize and cellulosic ethanol extraction rates

When the technology improvement is expanded to wet mill and cellulosic ethanol production, the improved extraction rates make cellulosic ethanol economically viable at an earlier stage and spurs production. The majority of the 9.7 billion gallon increase in ethanol production comes from cellulosic feedstocks (table 1b). While more widely expanding technology growth explains part of the difference in the two ethanol extraction rate scenarios, it is also heavily influenced by different treatment of maize and cellulosic ethanol in domestic policy.

Cellulosic ethanol production, unconstrained under the waived mandate, expands in all solutions and does not face the same inelastic portion of demand induced by a binding mandate that maize-based ethanol faces. Given this policy difference, despite extraction rate improvements in maize wet and dry mill ethanol production, growth in maize-based ethanol is actually smaller than when only dry mill ethanol extraction rates increase. The large increase in ethanol production pushes down retail prices, and limits the increase in maize-based ethanol. Together they displace ethanol imports and increases exports. Crop prices rise modestly in this technology scenario as a result of increased area competition from switchgrass. Feed use of maize is drawn up through a loss of production of distillers grains and gluten feed and meal from improved extraction rates in the dry and wet mill ethanol process. Maize area is largely flat while there is an overall increase in major crop area, much of it coming from an expansion in switchgrass, one of the primary feedstocks in cellulosic ethanol production (table 1a).

RIN prices fall for all ethanol categories, but because of the large increase in cellulosic ethanol production, the cost of the blenders credit to taxpayers increases as does the cost to motor-fuel consumers of the mandate. This occurs because the cellulosic biofuel mandate is assumed to be waived, and when it is waived, the cellulosic RIN price is essentially predetermined, and not dependent on production volumes. Net farm income and consumer expenditures both rise with higher commodity prices.

SEPARATING ELASTIC AND INELASTIC SEGMENTS OF DEMAND

Results in the two scenarios are consistent with expectations, but the average results over all 500 solutions hide the different response behavior across the kinked demand curve. The stochastic results are spread across portions of biofuel and feedstock demand that are both elastic and inelastic. If we take a subset of the solutions at either end of the kinked demand curve the effects of growth in feedstock technology as well as improvements in biofuel processing can be more fully explored. A case could be made to sort the results based on petroleum prices, with the lowest petroleum prices corresponding to more binding mandates and high petroleum prices corresponding to the least, or non-binding mandates.

If petroleum prices were the only factor in determining if the mandates are binding this analysis could be more easily accomplished by a comparative statics analysis with baseline, low and high petroleum prices. However, petroleum is only one of several factors determining where market demand for biofuels lies relative to mandates. Crop yields and foreign demand also play a significant role in this determination. To combine these effects we can return to the RIN price which, as previously discussed, is a direct measure of just how binding the mandate is. Taking the baseline results, all 500 solutions are sorted on the average conventional RIN value over the 2015 to 2019 period and 100 observations are selected at either end of the sort to represent the inelastic and elastic portions of demand.[10] The 100 solutions in the baseline with the highest average conventional RIN values over 2015 to 2019 represent the inelastic portion of the effective demand curve while the 100 observations with the lowest average conventional RIN values over the 2015 to 2019 time period represent the more elastic segment of demand. Figure 5 shows the results of sorting on the conventional RIN values associated with the overall mandate and the average petroleum price. While there appears to be an inverse relationship between conventional RIN prices and petroleum prices, it is clear other factors make a significant contribution to RIN pricing.

Table 2 shows the comparison of the 100 highest average conventional RIN price solutions in the baseline with those same observations under greater maize yield growth and increased ethanol extraction rates scenarios. The petroleum price draws in these solutions averaged \$71.33 a barrel versus \$93.53 for all 500 solutions and contributes to the binding nature of the mandate in this subset as does the average maize yield which is also lower than the overall average in these draws.[11] With the biofuel mandate relatively more binding in these solutions, the improvement in maize yields leads to a far more modest increase in maize ethanol production and maize prices are forced down along this inelastic portion of demand as the mandates set ethanol demand levels. Much of the technology gain is manifest in lower ethanol and RIN prices.

The decline in the conventional RIN price is naturally larger than in the overall average given that the distribution of RIN prices is truncated at zero. Because of the inelasticity of demand

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[10] In the elastic portion of demand RIN prices are essentially driven to zero so the 2015 to 2019 averaging of the conventional RIN values is largely those observations where the overall mandate was not binding in each of the 5 years.

[11] Given the approach used in constructing the stochastic draws, it is rare that five-year average crop yields will differ significantly from mean values, whereas an assumed autocorrelation process means that it is much more common for five-year average oil prices to differ significantly from mean values. In a given year, the inverse relationship between corn yields and RIN values would be stronger than these period averages suggest.

from the binding mandate, the negative effect of improved crop yield on net farm income is greater than in the unsorted solution and it falls 3.25 billion dollars annually. Lower crop prices increase government CCC program costs and the modest expansion in biofuel production leads to a modest increase in government expenditures on blender's credits. Consumers benefit to an even greater extent than before. Declines in consumer costs of the mandate as well total U.S. food expenditures are greater in the binding mandate case than in all 500 solutions.

With an improvement in extraction rates in dry mill ethanol we also see a limited increase in ethanol produced from maize as the mandate still largely determines demand quantities. Little growth in maize ethanol output coupled with the extraction improvements means that the quantity of maize needed for processing actually falls, pushing down maize prices and modestly reducing net farm income. The improved extraction rates reduce overall processing costs but because they also increase the effective ethanol processing capacity, the average producer is not able to capture the benefits of the technology improvement. The 10% increase in extraction rates is an effective 10% increase in processing capacity. With a binding mandate, the effective increase in capacity with little increase in output demand leads to idling of capacity so early adopters in the processing sector are more likely to see benefits while late adopters see no benefits or must idle capacity. Consumer mandate costs fall by over 2 billion dollars annually as the conventional RIN value falls and the government's expenditures on blenders credits are only slightly higher, linked to the modest increases in production.

When extraction rates are applied to all maize and cellulosic processing systems, the maize-based ethanol production has an even smaller response. A large increase in cellulosic ethanol production pushes down retail ethanol prices. Consumer mandate costs and government expenditures on blenders credits both rise substantially, tied to the large expansion in cellulosic ethanol production. When binding, the mandates place considerable constraint on growth in maize-based ethanol but don't similarly constrain cellulosic ethanol when mandate are waived and allowance credits established.

In each of the technology growth scenarios, imports decline by a very modest amount. These imports are assumed to meet the gap in the RFS mandate between the advanced mandate and the bio-based diesel and cellulosic mandate levels. Under this assumption, imports change little because the cellulosic ethanol volume is spoken for in its own mandate while maize ethanol is not allowed, by legislative fiat, to be used towards the advanced biofuel mandate. The small change in imports then occurs when the overall mandate had been so binding that the 'advanced' biofuel imports were being used to fulfill the overall mandate. With technology growth in either maize yields or ethanol extraction rates the overage in advanced ethanol will be pushed out.

Table 3 shows the comparison of the 100 lowest average conventional RIN price solutions over the same technology adoption scenarios. With a zero average conventional RIN value in each of these 100 baseline solutions the overall mandate was not binding in any of the solutions. The average petroleum price in this subset of draws was $122.19 per barrel compared to the overall average of $93.53 per barrel. In this elastic portion of demand, an increase in maize yields quickly translates into increased maize ethanol production of 4.4 billion litres annually. The more modest declines in crop prices results in more modest declines in farm income. With a more elastic demand for maize in the biofuel market, the decline in U.S. food expenditures show a smaller decline at 3 billion dollars annually. Government expenditures on biofuel credits expand by 550 million dollars annual while costs to consumers from the mandate are largely unchanged.

With the improvement in dry mill extraction rates along with mandates which are not binding, the increase in ethanol comes largely from maize-based ethanol. Production increases by over 7 billion litres a year actually pushing down cellulosic ethanol production slightly as the retail ethanol price declines. When both maize and cellulosic ethanol extraction rates increase in an unconstrained market, there is a large increase in maize and cellulosic ethanol production. In both cases some imports are squeezed out by additional domestic ethanol production. With the increased competition for land and the boost in crop prices, net farm income rises along with total U.S. food expenditures in both extraction rate scenarios.

When only dry mill ethanol extraction is increased, government biofuel credit expenditures rise along with increased maize-based ethanol production. Government mandate costs increase only slightly on a small additional amount of cellulosic ethanol production. With broader improvement in ethanol extraction rates, the large increase in cellulosic ethanol production drives up government credit expenditures along with consumer mandate cost. Increased feedstock use as well as land competition brought about by increased switchgrass area for cellulosic ethanol production drives up net farm income along with total U.S. food expenditure by over 1.3 billion dollars annually in this elastic segment of demand.

The effect of maize technology adoption on commodity price movements show only modest differences between the baseline and the two sorts on conventional RIN prices, in part because low petroleum prices and below trend maize yields, both of which raise conventional RIN prices, have conflicting effects on maize prices. In other cases, the change may not be just the magnitude of the change from technology adoption but the direction of the change. When mandates are binding, technology reduces net farm income while on the opposite end of the demand curve, where mandates are not binding, increases in technology increase farm income.

In all cases, improved maize yields increases maize production and reduces maize prices. However, when examining improvements in ethanol extraction technology, binding mandates reduce maize prices and production while in those cases where the mandate is not binding, maize prices and production rise. The effect of technology adoption on the feedstock sector is highly dependent on market context. The results of policy analysis in a deterministic framework are therefore highly dependent on the underlying baseline and provide results which may be misleading given the uncertainty about petroleum prices and other factors which influence how binding the mandates are likely to be. The implications for ethanol producers are similarly disparate. When mandates are binding, technological advance, be it in feedstocks or maize ethanol extraction rates, is quickly passed on to consumers. Cellulosic ethanol producers do not face a similar inelastic demand due to the specific features of U.S. biofuel policies. As a result, technology improvements increase production and the per-unit subsidies and consumer costs both rise proportionally.

POTENTIAL IMPLICATIONS FOR THE EUROPEAN UNION EXPERIENCE

EU policy differs for that in the U.S. in a number of important respects. The most significant of these is that although there is an EU policy regarding the overall level of renewable energy consumption, member states are responsible for devising their own policies to meet the percentage targets. Therefore there are, and will continue to be, a variety of policy approaches taken across the EU member states.

The overall EU policy is that 10 percent of transport energy in 2020 should come from renewable sources. Fuel from ‘second generation’ sources such as cellulosic ethanol count double towards the target while renewable energy used in electric cars is multiplied by a factor of 2.5. Despite pressure from a number of sources, including the EU parliament, a strict limit on ‘first generation’ biofuels was not imposed. There are a number of environmental and sustainability requirements which fuels must meet in order to count towards the target, but there are not the same restrictions on volumes by renewable fuel classification which appear in the U.S. biofuel mandates, at least not at the EU level.

The impact of technology change will depend on the policy choices made by different member states. In general these policies have increasingly moved towards setting percentage targets in terms of volumes (in energy equivalents or otherwise) of biofuels in overall transport use. For some member states minimum targets are set for each biofuel, in others just an overall target is stipulated. An additional consideration is that there are also limits on the maximum blend rates of ethanol or biodiesel in fuel. Until now consumption of higher blend rates such as B-100 or E-85 have been limited to certain member states.

Previous studies of the impact of alternative biofuel targets for the EU have generally assumed a specific volume of biofuel demand at the EU level and allocated that among the respective fuels, ethanol and biodiesel, in a fixed allocation (Al-Riffai et al., 2010, Banse et al., 2010). In this representation when the targets are binding, the impact of changing technology in feedstock production or ethanol conversion would show results similar to the U.S. results under a binding mandate. So any technological improvement would potentially reduce incomes at the farm level in such a structure. However this representation could be overly restrictive given the less compartmentalized biofuel requirements in some member states.

EU demand is likely to be less elastic in the short run with respect to ethanol (and oil prices) even if ethanol is priced competitively with gasoline, as a smaller proportion of the fleet uses gasoline when compared to the U.S. and conversion to E-85 would likely be more costly, since it would involve additional changes in distribution infrastructure beyond simple increased blending rates for several EU member states.

Alternatively, demand for ethanol in the EU could be more elastic than in the U.S. even where an overall 10 percent target is imposed and high level blends are rare. As the target is set in terms of a percentage of overall fuel use, technological improvements that would reduce the price of ethanol would increase both the total volume of fuel used and the proportion of fuel that came from gasoline and ethanol mixes. Given the inelastic nature of total fuel demand and the small proportion from renewable fuels this impact is likely to be small. However, if member states choose not to set individual targets for each fuel or feedstock, this would add demand elasticity to the ethanol market. In this instance, changes in cereal yields or ethanol extraction rates could have impacts similar to the case where mandates are not binding in the U.S., with ethanol price reductions potentially increasing market share of overall biofuels from ethanol, at least up to the blend wall. For the EU this shift would occur at the expense of other renewable feedstocks and fuels and could involve displacing cellulosic ethanol, biodiesel or electricity and would result in a larger reduction in costs associated with meeting the 10 percent target than more restrictive biofuel share schemes.

The different member state biofuel policies are likely to continue to evolve, influenced by the costs of the various biofuels, their perceived impact on the environment, and the impact of their consumption on their feedstock markets. With no specific allocation of biofuel shares at the EU level and varying member state policies, the representation of EU biofuel policies where feedstocks or even fuels are rigidly allocated to meet targets is likely to overstate the inelasticity of demand for the various biofuels. For example, in the UK, the “Renewable Transport Fuel Obligation (RTFO)” sets a proportion of fuel that must come from biofuels, but suppliers are free to choose which biofuel to use. However, the restriction that blends cannot be higher than 5 percent biofuel means that in practice, as the overall obligation rises, the potential to substitute biofuels falls (UK Department for Transport, 2005).

CONCLUSION

In general, increasing maize yields result in lower crop prices and additional ethanol production with much of the benefit flowing to consumers of maize, while growth in ethanol extraction rates results in higher crop prices and significantly larger ethanol production with feedstock producers and ethanol processors deriving much of the benefit. Using a stochastic model of U.S. agriculture and biofuels sector it can be shown that the blending mandates under the Energy Independence and Security Act of 2007 reduce demand elasticity in both the maize markets and wholesale ethanol markets when they are binding. This potential inelasticity recalls Cochrane's treadmill and the effects of technology adoption on agricultural markets and producer consolidation.

These results, however, are highly dependent on the whether the overall biofuel volumetric mandate is binding. When mandates are more binding and conventional RIN prices higher, increasing maize yields result in much smaller increases in ethanol production than when the mandates are not determining ethanol blended quantities. The same is true for increasing extraction rates. When mandates are binding, increasing extraction rates do not have a substantive effect on maize-based ethanol production and actually reduce feedstock demand as the quantity of feedstocks needed to meet the mandated quantities falls.

When mandates are not binding and RIN prices are low, improved ethanol extraction rates lead to substantial increases in maize-based and cellulosic ethanol and the demand for feedstocks to fuel the process. There is also additional competition for land as dedicated crops such as switchgrass are drawn into production. Mandates are more likely to be binding when oil prices are low or maize yields are below trend. When mandates are binding, the benefits of introduction of technology in either the maize market or the ethanol processing market largely flow to food, feed and transportation fuel consumers.

Given the effect of U.S. biofuel policy, market context relative to binding mandates is critically important in understanding the winners and losers from technology adoption. In some cases, it isn't just a matter of the magnitude of the effects, but even the direction in which important variables move in response to the change. This study further underlines the importance that the baseline in deterministic modeling efforts can have on subsequent policy analysis. This highlights the advantages of a stochastic approach when markets are characterized by non-linear behavior and asymmetric policies.

The EU chose not to constrain the mix of renewable energy required to meet its target for the contribution to transport fuel. This may increase the ability of a given fuel to increase its market share as a result of technological improvements and therefore allows some of the benefits of these improvements to be passed back to the producers of the required feedstocks. However, many member states have opted to implement their own policies to specify blending level for biodiesel and ethanol, with some even specifying targets for particular feedstocks. Furthermore, technical restrictions on blend rates and feedstocks also restrict the flexibility of a member state's policy options. Where this is the case, the policy operates more in line with that of the U.S. where the mandates are binding. Our analysis suggests that the proper representation in the modeling system of of the policy instruments that are in place in Europe is important when considering issues such as the impact of technological advancement on agricultural or biofuel markets and the actors therein.

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Table 1a: Average of 500 stochastic model solutions, years 2015 to 2019, crops market

September-August year 2015-2019	2010 FAPRI Stochastic Baseline	Change from: Improved growth in maize yields	Change from: Improved extraction rates in ethanol	
			Dry-mill only	All ethanol extraction
Area Planted		(Million hectares)		
Maize	37.11	-0.48	0.10	0.02
Soybeans	31.19	0.12	0.02	0.06
Wheat	21.59	-0.22	-0.01	-0.15
Switchgrass	0.54	0.00	-0.02	0.98
Major crops	127.15	-0.63	0.07	0.70
CRP	11.96	0.22	-0.04	-0.06
Major crops and CRP	139.11	-0.41	0.03	0.64
Yield		(Metric tons/hectare)		
Maize	10.98	0.87	0.00	0.00
Soybeans	3.04	0.00	0.00	0.00
Wheat	3.09	0.00	0.00	0.00
Maize market		(Million metric tons)		
Production	375.45	24.50	1.13	0.34
Feed and residual use	137.95	7.40	4.36	5.48
Fuel alcohol use	145.31	6.62	-2.81	-5.07
Exports	58.13	9.28	-0.41	-0.06
Distillers grains production	40.82	1.84	-5.01	-5.75
Other crop production		(Million metric tons)		
Soybeans	93.95	0.27	0.09	0.24
Wheat	56.74	-0.67	-0.03	-0.39
Crop prices		(Dollars/metric ton)		
Maize	156.54	-17.61	1.40	1.25
Soybeans	373.28	-12.01	3.60	5.74
Wheat	188.71	-12.16	1.20	1.97

Table 1b: Average of 500 stochastic model solutions, years 2015 to 2019, biofuels market and aggregates

September-August year 2015-2019	2010 FAPRI Stochastic Baseline	Change from: Improved growth in maize yields	Change from: Improved extraction rates in ethanol	
			Dry-mill only	All ethanol extraction
		(Dollars/barrel)		
Petroleum, refiners acquis.	93.53	0.00	0.00	0.00
Yield		(Metric tons/hectare)		
Maize	10.98	0.87	0.00	0.00
Maize market		(Million metric tons)		
Production	375.45	24.50	1.13	0.34
Feed and residual use	137.95	7.40	4.36	5.48
Fuel alcohol use	145.31	6.62	-2.81	-5.07
Exports	58.13	9.28	-0.41	-0.06
Crop prices		(Dollars/metric ton)		
Maize	156.54	-17.61	1.40	1.25
Soybeans	373.28	-12.01	3.60	5.74
Wheat	188.71	-12.16	1.20	1.97
Ethanol supply and use		(Million liters)		
Production	67734	3080	4146	9672
From maize	61683	2819	4353	3687
Other conventional	1417	53	-94	-123
Cellulosic	4634	208	-113	6107
Imports (ethyl alcohol)	7440	-102	-78	-253
Domestic disappearance	74595	2881	3990	9186
Exports (ethyl alcohol)	417	58	61	118
Ending stocks	3879	169	223	506
Ethanol prices		(Dollars per liter)		
Conventional rack, Omaha	0.53	-0.02	-0.02	-0.03
Cellulosic rack	0.89	0.00	0.00	-0.01
Other advanced rack	0.64	0.00	0.00	-0.01
Effective retail	0.56	-0.01	0.00	-0.01
RIN values				
Conventional ethanol	0.03	-0.01	-0.02	-0.01
Advanced ethanol	0.14	0.00	0.00	0.01
Cellulosic ethanol	0.24	0.00	0.00	0.00
Aggregate measures		(Billion dollars)		
Net farm income	79.90	-2.74	0.52	0.64
Net CCC outlays	10.02	0.16	-0.02	-0.03
RFS consumer mandate cost	4.82	-0.60	-0.87	1.12
Gov. biofuel credit expend.	10.78	0.39	0.47	2.03
Total US food expenditures	1510.20	-3.12	0.51	0.79

Table 2: Average of 100 stochastic model solutions with highest baseline conventional RIN values, years 2015 to 2019

	2010 FAPRI Stochastic Baseline	Change from: Improved growth in maize yields	Change from: Improved extraction rates in ethanol	
September-August year 2015-2019			Dry-mill only	All ethanol extraction
		(Dollars/barrel)		
Petroleum, refiners acquis.	71.33	0.00	0.00	0.00
Yield		(Metric tons/hectare)		
Maize	10.86	0.87	0.00	0.00
Maize market		(Million metric tons)		
Production	367.05	21.97	-2.48	-3.14
Feed and residual use	140.98	8.52	5.47	6.28
Fuel alcohol use	132.09	2.10	-9.05	-10.55
Exports	59.53	9.98	0.99	1.18
Crop prices		(Dollars/metric ton)		
Maize	153.37	-19.22	-1.63	-1.12
Soybeans	371.93	-13.78	0.18	3.08
Wheat	185.90	-13.45	-1.28	0.11
Ethanol supply and use		(Million liters)		
Production	64323	1334	876	9041
From maize	56067	892	938	577
Other conventional	1289	8	-141	-161
Cellulosic	6966	433	79	8624
Imports (ethyl alcohol)	7893	-103	-92	-318
Domestic disappearance	71688	1133	699	8490
Exports (ethyl alcohol)	357	82	91	105
Ending stocks	3735	93	75	485
Ethanol prices		(Dollars per liter)		
Conventional rack, Omaha	0.50	-0.03	-0.04	-0.04
Cellulosic rack	0.91	0.00	0.00	-0.01
Other advanced rack	0.59	0.00	0.00	-0.01
Effective retail	0.48	0.00	0.00	-0.01
RIN values				
Conventional ethanol	0.08	-0.03	-0.04	-0.02
Advanced ethanol	0.18	0.00	0.00	0.01
Cellulosic ethanol	0.35	0.00	0.00	0.00
Aggregate measures		(Billion dollars)		
Net farm income	81.42	-3.25	-0.44	-0.15
Net CCC outlays	10.04	0.19	0.02	0.00
RFS consumer mandate cost	9.75	-1.52	-2.17	1.73
Gov. biofuel credit expend.	10.71	0.21	0.10	2.33
Total US food expenditures	1482.72	-3.37	-0.06	0.30

Table 3: Average of 100 stochastic model solutions with lowest baseline conventional RIN values, years 2015 to 2019

September-August year 2015-2019	2010 FAPRI Stochastic Baseline	Change from: Improved growth in maize yields	Change from: Improved extraction rates in ethanol	
			Dry-mill only	All ethanol extraction
		(Dollars/barrel)		
Petroleum, refiners acquis.	122.19	0.00	0.00	0.00
Yield		(Metric tons/hectare)		
Maize	11.09	0.87	0.01	0.01
Maize market		(Million metric tons)		
Production	391.15	27.11	4.17	3.58
Feed and residual use	132.32	6.70	3.78	4.96
Fuel alcohol use	170.64	10.37	2.19	0.04
Exports	54.06	9.01	-1.67	-1.32
Crop prices		(Dollars/metric ton)		
Maize	165.38	-16.70	4.18	3.87
Soybeans	383.31	-10.77	6.84	8.68
Wheat	197.47	-11.40	3.42	3.98
Ethanol supply and use		(Million liters)		
Production	78027	4579	7298	11263
From maize	72452	4417	7670	7138
Other conventional	1625	90	-65	-97
Cellulosic	3950	72	-307	4221
Imports (ethyl alcohol)	6876	-109	-66	-202
Domestic disappearance	84205	4368	7132	10799
Exports (ethyl alcohol)	454	40	56	142
Ending stocks	4341	235	372	578
Ethanol prices		(Dollars per liter)		
Conventional rack, Omaha	0.59	-0.01	-0.01	-0.02
Cellulosic rack	0.88	-0.01	-0.01	-0.02
Other advanced rack	0.69	0.00	-0.01	-0.01
Effective retail	0.64	-0.01	-0.01	-0.02
RIN values				
Conventional ethanol	0.00	0.00	0.00	0.00
Advanced ethanol	0.11	0.00	0.00	0.01
Cellulosic ethanol	0.14	0.00	0.00	0.00
Aggregate measures		(Billion dollars)		
Net farm income	81.72	-2.40	1.38	1.45
Net CCC outlays	9.85	0.13	-0.05	-0.05
RFS consumer mandate cost	2.18	0.07	0.00	0.82
Gov. biofuel credit expend.	11.93	0.55	0.81	1.94
Total US food expenditures	1536.52	-3.00	1.04	1.34

Figure 1: An inelastic demand for agriculture commodities consistent with Cochrane's treadmill

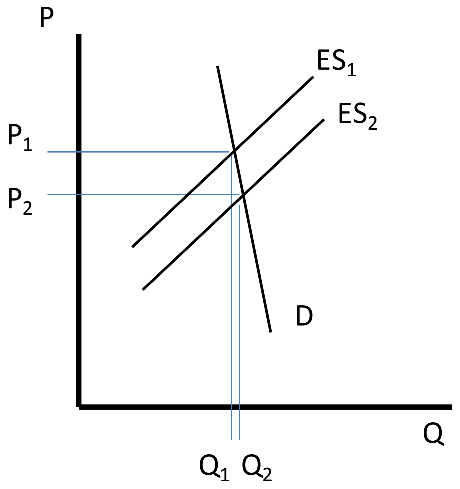

Figure 2: The influence of biofuel mandates on the market effects of 1) technology adoption in maize production 2) technology adoption in ethanol processing.

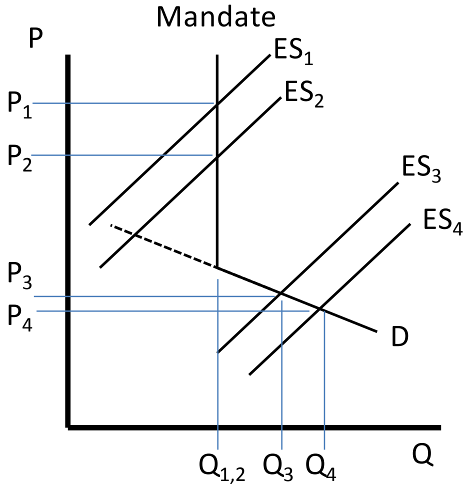

Figure 3: The influence of biofuel mandates on the market effects technology adoption in ethanol processing in maize markets.

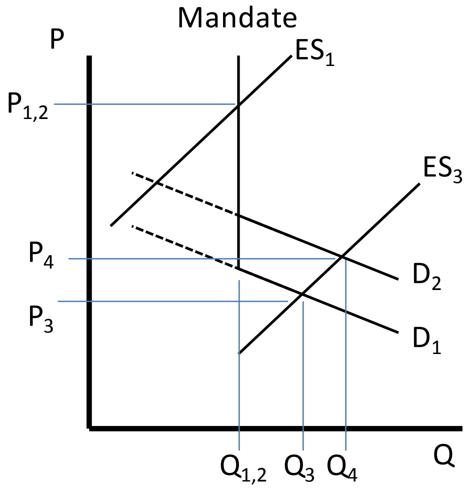

Figure 4: Baseline and scenario stochastic average maize yields, metric tons per hectare.

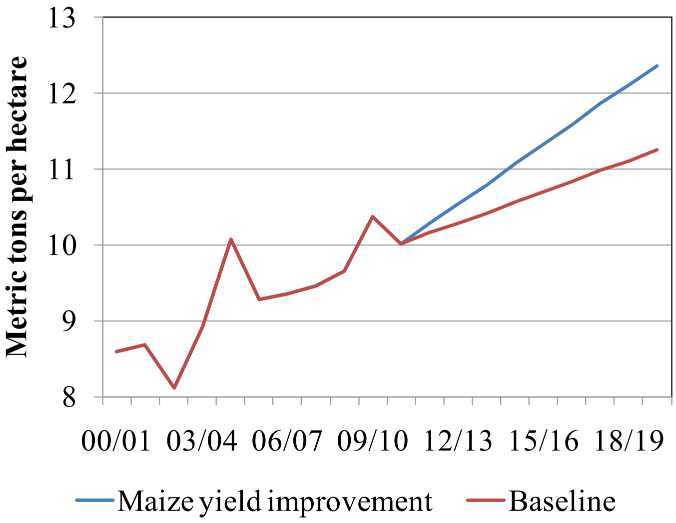

Figure 5: Sorted 2015 conventional RIN prices and corresponding petroleum price.