The Global Bioenergy Expansion: How Large Are the Food-Fuel Trade-offs?

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Abstract: We summarize a large set of recent simulations and policy analyses based on FAPRI's world multimarket, partial-equilibrium models. We first quantify and project the emergence of biofuel markets in US and world agriculture for the coming decade. Then, we perturb the models with incremental shocks in US and world ethanol consumption in deviation from this projected emergence to assess their effects on world agricultural and food markets. Various food-biofuel trade-offs are quantified and examined. Increases in food prices are moderate for the US ethanol expansion and even smaller for the ethanol expansion outside the United States, which is based on sugarcane feedstock, which has little feedback on other markets. With the US expansion, the high protection in the US ethanol market limits potential adjustments in the world ethanol markets and increases the demand for feedstock within the United States. Changes in US grain and oilseed market prices propagate to world markets, as the United States is a large exporter in these markets. With changes in world prices, land allocation in the rest of the world responds to the new relative prices as in the United States but with smaller magnitudes because price transmission to local markets is less than full.

1. Introduction

This chapter summarizes a large set of recent simulations and policy analyses focusing on US and global biofuel markets. These were undertaken at the Center for Agricultural and Rural Development at Iowa State University and based on the world multimarket, partial-equilibrium agricultural models of the Food and Agricultural Policy Research Institute (FAPRI). We first quantify and project the emergence of biofuel markets in US and world agriculture for the coming decade using the *FAPRI 2008 U.S. and World Agricultural Outlook and earlier editions*. Then, we perturb the models with incremental shocks in US and world ethanol consumption in deviation from the projected emergence to assess their effects on world agricultural and food markets. Various food-biofuel trade-offs are quantified and examined. We discuss how trade and energy policy conditions these trade-offs, in both the United States and the world.

The world FAPRI[1] models capture the biological, technical, policy, and economic relationships among key variables within a particular commodity and across commodities and countries or regions. They are based on historical data analysis, current academic research, and a reliance on accepted economic, agronomic, and biological relationships in agricultural production and markets. The analysis incorporates major trade-offs among bioenergy, feedstock, feed, and food production and consumption arising with the emergence of biofuels. The analysis accounts for grain- and sugar-based ethanol, biodiesel, and the potential for cellulosic ethanol production. See Appendix A for further details on the model description.

The food-biofuel trade-offs appear first in the competing demand for feedstock crops among food demand, feed demand, and energy demand. These competing demands increase the

[1] These sets of models are jointly developed by a consortium, with the international models developed by FAPRI at Iowa State University and the US models by FAPRI at the University of Missouri. The individual commodity models or the full set of models have been employed for numerous studies, such as Abler et al. 2008, Elobeid et al. 2007, Fabiosa et al. 2007, , Elobeid and Beghin 2006, and Fabiosa et al. 2005. The FAPRI models have been used by several organizations to develop baselines as well as for policy analysis.

prices of feedstock crops and hence the prices of feed and food items intensive in these crops and intensive in feed, namely meat and dairy products. Second, the change in prices of feedstock crops translates into supply effects. Land use is attracted to profitable feedstock crops and moves away from other crops. As a result, the prices of the non-feedstock crops increase, and have a second-round effect on food prices for products intensive in these other crops, namely oilseeds and products. Another important feedback effect originates in grain-based ethanol production, which generates 30% co-product called distillers dried grain (DDG), which can be used to substitute corn at a rate close to one-for-one, alleviating the pressure for more land (see Appendix B, available from the authors, for more details on this substitution). The use of DDG in animal feed varies depending on the type of livestock; it is highest in the beef cattle sector at a maximum inclusion rate of 40% (for wet distillers grain), followed by the dairy sector at 20%, the pork sector at 20%, and the poultry sector at 10% (Fabiosa 2008a). A major concern of livestock and poultry producers in the adoption of DDG as a feed ingredient is its quality, including stability of its nutritional content, storability, and ease of transport (Fabiosa 2008b).

In Section 2, we examine the projected evolution of production, consumption, trade, and land allocation under biofuel emergence by type of crop for key countries growing feedstock for ethanol (corn, barley, wheat, sugarcane, and other grains) and for major crops competing with feedstock for land resources, such as oilseeds. We incorporate feedback effects on prices for meat, dairy, oil, and food products intensive in these crops, and on live-animal production. Section 2 is based on recent issues of the *FAPRI U.S. and World Agricultural Outlook*.

We then report on two major analyses that identified the effects of growing energy demand for agricultural inputs. We decompose the global biofuels emergence in terms of domestic (US) and rest-of-the-world components. Using the analysis of Tokgoz et al. (2007), we look at the implications of a domestic (US) ethanol expansion driven by higher oil prices combined with extensive adoption of flexible fuel vehicles (FFVs) using E-85 fuel. In this analysis, we compare the long-term equilibrium imposed in 2016/17 under a baseline established for the analysis with the long-term equilibrium under a scenario with higher oil prices and no bottleneck in FFVs and E-85 markets. Long-term equilibrium means that on the supply side, profit margins for ethanol producers have been exhausted, no incentives exist to enter or exit the ethanol industry, and returns in the dairy and livestock industry are normal, while at the same time on the demand side the price of ethanol approaches its energy value, removing any incentive to invest in FFVs.[2] In a second analysis by Fabiosa et al. (2007), we shocked the models with exogenous expansion in ethanol demand in Brazil, China, the EU, and India. The scenario captures the essence of the global expansion outside the United States. We compute shock multipliers for land allocation, production, consumption, trade, and prices for the various crops, food items, and countries of interest. The multipliers, reported as the average of 10 annual multipliers between 2007/08 and 2016/17, show how sensitive (or not) these variables are to the growing demand for ethanol in foreign countries with sizeable ethanol markets and other countries growing feedstock crops. We also highlight the movement of area away from major crops that compete with major feedstock crops used for ethanol production.

These investigations include all major policy distortions affecting relevant markets and international feedback effects through world commodity prices and trade. Because of the high US tariffs on ethanol, higher US demand for ethanol essentially translates into a US ethanol production expansion. This production expansion has strong global effects on land allocation and

[2] See Tokgoz et al. 2007, pages 3-5, and Elobeid et al. 2007 for further discussion of these conditions and implications. The two scenarios (expansions inside and outside the United States) are, respectively, based on dedicated baselines. Changes in assumptions occur between these baselines although their underlying modeling approach is the same.

output because the prices of coarse grains, the major feedstock in the United States, transmit significant shocks worldwide. These price effects eventually trickle down to all crops, meat and dairy prices, vegetable oil prices, and other food prices worldwide. In contrast, expansion in ethanol use and production in the rest of the world chiefly affects sugarcane area and production, the major feedstock in Brazil and other countries, and to a lesser extent, in other sugar-producing countries. Land uses and food prices other than those for sugar show little change in most countries.

The impact of the US expansion on US food prices is significant but moderate overall because agriculture's share of food cost is small for many food items. Following large increases in corn prices and their direct effect of higher feed costs, US food prices would increase by more than 1.1% over baseline levels. Beef, pork, and poultry prices would rise by more than 4% and egg prices would rise by about 7% (Tokgoz et al. 2008). The impact on world food prices of this expansion is likely to be larger wherever agricultural inputs represent a larger share of the food cost for households consuming food that is less processed and closer to the farm-gate.

Finally, we look at the effect of conditioning exogenous factors of the identified trade-offs, such as fossil energy prices, and policy distortions (US tariffs on ethanol and the US ethanol tax credit). The impact of altering these policy distortions is assessed.

2. Stylized facts on the global emergence of biofuels

2.1 Biofuels in the United States

US ethanol production increased dramatically in the last few years, from 2.1 billion gallons in 2002 to 6.5 billion gallons in 2007 (EIA 2008a). Consequently, the demand for corn used in ethanol production has increased accordingly, exceeding the level of corn exports in 2007. Higher demand for corn translated into higher corn prices and higher corn acreage. In 2007, corn area increased by more than 15 million acres in response to rising corn prices, which have doubled in the past couple of years (USDA-NASS 2008). The increased area dedicated to corn came at the expense of competing crops such as soybeans and wheat. This led to lower production and therefore higher prices for these crops. Hence, the ethanol expansion in the United States has resulted in higher agricultural commodity prices and land being bid away from competing crops to corn. With the minimum target levels of use of various biofuels required by the Energy Independence and Security Act of 2007 (EISA) (see Chapter xx for a detailed discussion of the EISA 2007), corn production is expected to continue to increase in subsequent years to meet growing demand for fuel, feed, and food. The higher demand for ethanol is also met by higher imports from countries like Brazil despite high US border tariffs. The US biodiesel industry is relatively small and the demand for biodiesel is primarily driven by the mandates issued in the EISA.

2.2 Biofuels in the world

Prior to 2006, Brazil was the major producer and consumer of ethanol. However, Brazil has produced less ethanol than the United States in the past three years. US production increased from 4.1 billion gallons in 2005 to 5.2 billion gallons in 2007 (USDA-FAS 2008a). Countries such as China and India are emerging as significant producers of ethanol, as more countries begin to promote ethanol as an alternative fuel, mainly through mandates and/or directives.[3] As countries increase their production of ethanol, the higher supply leads to a decline in the world ethanol price. However, with increased use of “advanced biofuels” under provisions of the EISA in the United States, including imported sugar-based ethanol, the world ethanol price is expected to increase. The EU-27 has the most mature biodiesel industry in the world market. The biofuel targets in each member state push up the production for biodiesel; however, domestic demand

[3] Although the Chinese government has stopped approving new grain-based ethanol plants because of food security concerns, the Chinese Renewable Energy Plan mandates an almost tenfold increase in fuel ethanol production, to 3.3 billion gallons (mostly from non-grain feedstock) by 2020 (USDA-FAS 2008b).

still needs to rely on imports from emerging producers, such as Argentina, Brazil, or Southeast Asia.

2.3 Comparison among FAPRI Outlooks: Catching up with reality and policy changes

Table 1 presents the evolution of the ethanol sector pre- and post-EISA 2007 using the current (2008) and previous (2006 and 2007) *FAPRI U.S. and World Agricultural Outlook*.[4] The 2006 FAPRI Outlook projected that US corn-based ethanol production and consumption would reach 8.1 billion gallons and 8.3 billion gallons, respectively, by 2015, an increase of about 80% over 2006 levels. Ethanol imports were projected to increase by 67%. As the ethanol sector continued to expand under the 2005 US energy bill, the 2007 FAPRI Outlook presented higher production, consumption, and trade projections with production and consumption of ethanol reaching well over 12 billion gallons by 2015 and net imports projected to be 2.5 times higher than what they were in the 2006 FAPRI Outlook. With the implementation of the EISA at the end of 2007, these projections were adjusted again in the 2008 FAPRI Outlook such that US ethanol production would reach 15.5 billion gallons and consumption would reach 16.6 billion gallons by 2015, more than three times their 2006 levels. Under the EISA of 2007, ethanol net imports are projected to reach 1.2 billion gallons by 2015 compared to only 0.3 billion gallons projected by the 2007 FAPRI Outlook. Part of these changes has been driven by unanticipated increases in fossil fuel prices, which stimulated substitution toward ethanol. Furthermore, ethanol imports from Brazil to the United States are expected to increase significantly since, under the EISA, Brazilian ethanol qualifies under the “advanced biofuel” category. Hence, the increase in US imports of ethanol is primarily policy driven.

According to the 2006 FAPRI Outlook, Brazilian sugarcane-based ethanol production

[4] For each year, the *FAPRI U.S. and World Agricultural Outlook* provides 10-year projections. For comparison among Outlooks, we chose the years 2006, 2009, 2012, and 2015, although the first year and last years of the projection differ across the three Outlooks.

and consumption were projected to increase to 6.6 billion gallons and 5.4 billion gallons, respectively, by 2015, an increase of 30% for production and 24% for consumption when compared to 2006 levels. Projections were higher for 2015 in the 2007 FAPRI Outlook, with ethanol production at 7.2 billion gallons and ethanol consumption at almost 6 billion gallons, a reflection of higher FFV use in Brazil. The provisions of the EISA of 2007 resulted in significantly higher projections in the 2008 FAPRI Outlook. With higher demand from the United States, ethanol net exports in Brazil were projected to almost triple to 2.7 billion gallons by 2015 (compared to 1.2 billion gallons projected in the 2007 FAPRI Outlook), as domestic production was to double compared to that in 2006, reaching 8.8 billion gallons. This additional increase of 1.5 billion gallons of ethanol between the 2007 and 2008 FAPRI Outlooks would translate to well over 850,000 additional hectares of sugarcane.[5] In the most current Outlook, Brazilian ethanol consumption is projected to reach 6.1 billion gallons, 65% higher than 2006 levels.

[Insert Table 1a. here]

[Insert Table 1b. here]

Subsequent projections for the EU ethanol sector also increased over time. Ethanol production, consumption, and net trade increased significantly between the 2006 and 2008 FAPRI Outlooks. A comparison of the two most recent Outlooks also reflects higher production and consumption of ethanol in India and China and higher import demand from Japan, South Korea, and the aggregate of "Other Countries."

As a result of the continued higher demand for ethanol from the United States, Brazil, and other countries, projections for the world ethanol price increased from $1.31 per gallon by 2015 in the 2006 FAPRI Outlook to $1.41 per gallon for the same year in the 2008 FAPRI

[5] This is calculated based on 23 gallons of ethanol per ton of sugarcane and 75 tons of sugarcane per hectare.

Outlook. US ethanol price projections also increased, from $1.73 per gallon to $2.13 per gallon for the same period between the two Outlooks.

3. Land allocation effects of biofuel expansion

3.1 US expansion

To gauge the US expansion effects, we use the scenario with no bottleneck in the ethanol market and with a $10 increase in the oil price, as in Tokgoz et al. (2007). This scenario implies a large shock on the US ethanol market but with a modest increase in ethanol imports into the United States. Hence, the direct feedstock effect is on the US corn market and US crops competing with corn for land, namely, oilseeds and other crops. These shocks propagate worldwide through relative world prices. Land devoted to corn and other coarse grains increases, whereas land devoted to wheat and oilseeds decreases. This movement into coarse grains and out of oilseeds occurs worldwide. The impact multipliers in percent changes for area from ethanol expansion are presented in Table 2 for major crops and countries. Corn area in the United States has a multiplier of 23.4, which means that a doubling of ethanol use in the United States would increase area devoted to corn by 23.4%. Corn area in Argentina and Brazil has a multiplier of 13.6 and 6, respectively. World corn area has a multiplier of 8.1. Area devoted to other coarse grains increases in aggregate in the United States and the world but with much smaller multiplier values than those of corn (e.g., 4 for US and Argentine barley, 0.4 for world barley). US oat area actually decreases (multiplier of -5.9). US wheat area decreases considerably (multiplier =-10.1) as land moves to corn production. In other countries, the changes are moderate, summing up to a small decrease in world wheat area (-0.3). The most noticeable change is in the United States. This is explained by the fact that outside the United States, relative prices change moderately (most nominal prices went up by related proportions). Because area allocation is driven by relative prices, the changes are moderate.

The amount of land devoted to oilseeds falls in the United States and in aggregate. US soybean area falls substantially (multiplier of -14.6). Soybean area in Brazil and Canada increases (multipliers of 6.6 and 1.7). In aggregate, world soybean area decreases slightly (multiplier of -1.7). Area devoted to other oilseeds is also affected but to a lesser extent than soybean area, with the notable exception of sunflower acreage in Argentina, which falls substantially (multiplier of -7.9). Land devoted to sugar increases slightly for US sugar cane area (multiplier of 3.5) but changes very little in any other country.

Table 2 also presents multipliers for total crop area for world and major producers. In response to a US ethanol expansion, world crop area increases, with a multiplier of 1.7. Most of the increase in world crop area is through a world corn area increase, which has a multiplier of 8.1. Brazil and South Africa respond the most, with multipliers of 5.2 and 5.3, respectively. They are followed by Mexico, the US, and India.

3.2 Global emergence scenario

We use scenario 2 of Fabiosa et al. (2007), in which ethanol consumption in the rest of the world is increased by 10%, to gauge the effect of an expansion of ethanol use on land use in Brazil, the EU, China, India, and the rest of the world (non-US). The impact is mostly felt in land allocated to feedstock in these countries, and with an overwhelming impact on sugar crop area in Brazil and to a lesser extent in India. Further sugar-crop area in other sugar producing countries increases slightly as the world price of sugar is impacted positively. Because few crops compete with sugar crops in the land allocation, these sugar-related changes have little impact beyond sugar crops. The US ethanol market is insulated from the world ethanol market by trade restrictions (two tariffs and some tariff rate quotas). Hence, the US ethanol market is nearly unaffected, and so too the corn market and land devoted to corn and competing crops remain nearly unchanged. The shock imposed on the EU ethanol market has some effect on EU grain markets but small effects on world grain markets and resulting land allocations. This moderate impact is explained by the modest size of EU biofuels in world grain use. Land effects in the United States are even smaller. Worldwide, sugarcane land area increases with a multiplier of 13.8, but world sugar output falls slightly as expected (multiplier of -1.2). The impacts on most other crops and sectors are modest (multiplier values near 0 to 2 with the exception of Brazil, with a multiplier of 44.4).

In response to a global ethanol demand expansion, Brazil's total crop area responds the most, with a multiplier of 5.8, whereas most of the expansion is through sugarcane area, with a multiplier of 44.4. Following Brazil are the EU-25 and South Africa, both of which have a multiplier of 0.4 for total crop area. Total world crop area expands very modestly, with a multiplier of 0.1.

The world crop area multiplier in response to a global (non-US) ethanol expansion is very small relative to a US ethanol expansion. This is also the case for other countries, with the exception of Brazil. Since the United States is a major exporter of grains and oilseeds, any change in US corn demand impacts world markets considerably. This leads to indirect land use changes in the world in response to a US ethanol market expansion, and inclusion of these changes is crucial in estimating greenhouse gas emissions and savings from ethanol, as discussed in Searchinger et al. (2008).

[Insert Table 2. Here]

4. Trade-offs among feed, feed crops, and bioenergy

We begin with an important stylized fact: With the actual expansion of US ethanol production, mostly using a dry milling process, DDG production and use has increased. Livestock feeders have found a way to incorporate DDG into their feed rations. DDG enters the rations of ruminant animals and replaces corn mostly and soybean meal only to a limited extent. With large US and international markets for DDG in ruminants, the DDG market price reflects its feed value in ruminant rations as a replacement for corn. That is why DDG prices closely track corn prices in the market, especially since 2006, with the implication that rations, with or without DDG instead of corn, exhibit similar costs.

With the US ethanol demand shock, the derived demand for corn in ethanol production increases by more than one in the United States and worldwide. In response to an increase in US corn ethanol use, corn feed use declines for most countries. In the United States and Mexico, DDG feed use increases more than does sorghum feed use. DDG feed use is quite responsive in all countries, as indicated by high multipliers. For the global ethanol demand shock, Chinese and EU-25 demands for corn for ethanol production are the most responsive. However, US demand responds the most for the increase in DDG feed use and the decline in corn feed use in response to higher prices. Corn use for feed declines in all countries, whereas sorghum feed use declines for all but the United States.

The US ethanol demand expansion introduces shocks in the protein meal market, primarily through the reduction of soybean production and to some extent as increasing DDG production replaces the share of protein meal in the feed ration. In the United States, the use of soybean meal for feed declines considerably (-11), as seen in Table 3. Soybean meal use for feed in Brazil, Canada, and Argentina also declines but to a lesser extent. Rapeseed meal use drops significantly in the United States (-18.5), while other countries are not much affected by US ethanol expansion. Sunflower meal use decreases slightly in the world and in individual countries. Ethanol demand expansion outside the United States does not create enough shocks to move the protein meal markets because it has a small impact on oilseed markets. In addition, the ethanol production expansion does not generate co-products that can be used to substitute for protein meal in feed rations.

[Insert Table 3. Here]

5. Trade-offs among food, food crops, and bioenergy

5.1 Meat and dairy consumption

The impacts of the two scenarios are shown sequentially in Table 4a for beef, pork, and poultry, and for nonfat dry milk, cheese, butter, and whole milk powder consumption. The table covers selected key countries. Detailed results on other countries are available from the authors. As explained in the previous section, expansion of the US biofuel sector exerts an upward pressure on the prices of all feed ingredients. Facing higher costs of production, livestock and poultry producers reduce their supplies, causing meat prices to increase as well. There is a differential in the magnitude of price changes by meat type because the share of feed cost in total cost as well as the ability to use biofuel by-products as substitute feed ingredient varies by animal type, favoring ruminant over monogastric animals. Even within the ruminant category, differences in production practices such as the use of grains for supplemental cattle feeding in some countries (e.g., US and Canada) versus pure pasture-based production in others (e.g., Australia and Brazil) will explain differences among country-specific impacts. In general, consumers lower their demand for meat products in response to the higher prices of all meat products.

The change in the price of pork and poultry is two to three times larger than the change in the price of beef. This differential is the main driver in the consumption response, whereby poultry and pork declined the most in many countries and beef declined the least. In fact, beef consumption increased in some countries, as the effect of the larger price increases in pork and broiler induced substitution in favor of beef, which dominated the response to the smaller increase in beef price. Moreover, where entry and exit in the livestock sector is allowed to impose the long-run equilibrium condition, the magnitudes of price changes and their corresponding impacts on consumption adjustments are much larger compared to the case in which a long-run equilibrium is not imposed. The impact of the global ethanol shock outside of the United States is very small, since grain markets are moderately influenced by the expansion of sugarcane-based ethanol.

In US dairy markets, increased feed prices force milk producers to switch to some lower-cost but less efficient feed and consequently push down dairy yield per cow. And higher production costs force producers to reduce cow numbers. Together, these two factors reduce total milk output. Consequently, tight milk supplies constrain production of dairy products and put an upward pressure on dairy prices. Higher prices of dairy products induce lower consumption, but with magnitudes varying by country. The expansion of ethanol use in the United States has the greatest effect on world nonfat dry milk (NFD) consumption with a multiplier of -0.7, as the United States is the biggest exporter of NFD. In the US domestic market, butter consumption is affected the most, with a multiplier of -1.2, a moderate change.

The global expansion of ethanol use in the rest of the world has similar effects to those under the expansion in the United States, but the effects are even smaller, not only for each country but also for the world (e.g., the multiplier for NFD world consumption is -0.7 under the

US expansion of ethanol use versus negligible under expansion of ethanol use in the rest of the world). The main reason for this result is the low impact of this global scenario on grain-based feed costs.

[Insert Table 4a. here]

5.2 Vegetable oils

As shown in Table 4b, the US ethanol demand expansion scenario affects vegetable oil consumption slightly in most countries. Soybean oil use for food generally declines, except in the United States. Palm oil use for food increases significantly in the EU-25 (12.8). This scenario assumed that biodiesel would not expand further than planned in the baseline, as margins are negative in biodiesel production. By design, the global scenario focuses exclusively on ethanol production because biodiesel worldwide is unprofitable given the high vegetable oil prices. Hence, the global ethanol demand shock has very limited impacts on vegetable oil consumption.

5.3 Sugar

The impact of a US ethanol expansion on world sugar consumption is small, as shown in Table 4b. Global sugar consumption falls by a negligible amount (multiplier of -0.1). Sugar consumption has a multiplier of -0.3 in both India and South Africa, while multipliers for the rest of the countries range between -0.1 in China and -0.2 in Australia. On the other hand, sugar consumption in the United States increases, with a multiplier of 1.8, as a result of an increase in the price of high-fructose corn syrup (HFCS). Since the expansion of ethanol occurs predominantly in the United States, most of the impact occurs in the United States and we see less of a response in the rest of the world.

In the global scenario, the expansion of ethanol use in Brazil, the European Union, China, India and the rest of the world results in a small increase in US sugar consumption (multiplier of

0.2) while it results in a decline in sugar consumption in the rest of the world, ranging from -0.5 in China to -2 in India. Global sugar consumption declines by 1.1%, which is 10 times higher than the impact from the US ethanol expansion. This is because with the expansion occurring in countries other than the United States we see a relatively larger impact of the shock in countries like Brazil and less of an impact on the United States when compared to the effects of the US ethanol expansion.

However, the overall impact of the global expansion is relatively small in magnitude in comparison to some of the other commodities, and this is for two reasons. First, in sugarcane producing countries, the acreage response to price changes is limited, especially in the short run, because of the biology of the slow growth of sugarcane and the fact that several annual crops can be harvested from one planting of sugarcane. Second, Brazil, one of the major sugarcane producers, has the potential to expand area significantly. Sugarcane area in Brazil increased by almost 9% in 2007 and has averaged an annual increase of over 6% in the last five years. This helps explain the relatively small impact on sugar resulting from an expansion of global (non-US) ethanol use.

5.4 Grains

Table 4b presents the impact multipliers for grains. In the US expansion scenario, wheat replaces corn in food use in Brazil, China, Canada, and Mexico, whereas barley replaces corn for food use in Brazil, China, Mexico, and South Africa. World barley food use increases slightly, whereas world wheat and corn food use declines. In the second scenario, world wheat food use and barley food use increase, whereas world corn use decreases with a global ethanol demand shock. These effects are moderate in both scenarios, even more so for the second scenario, for which multipliers are often one order of magnitude smaller than in the US shock scenario.

[Insert Table 4b here]

6. Policies and exogenous factors conditioning the trade-offs

The foregoing discussion illustrates that the expansion of the biofuels sector has had significant impacts on world agricultural and food markets. There are multiple factors that caused this expansion, such as domestic policies that support and promote the expansion of the biofuels sector as a supplier of fuel needs for transportation purposes and higher crude oil prices. This has important consequences for the US and world agricultural sectors since ethanol is mostly produced from corn in the United States, and the United States is a major exporter of agricultural commodities. In this context, a clearer understanding of the fundamentals of the ethanol market and analysis of the impacts of some potential policy changes might be helpful for policymakers and other stakeholders.

The volatility of domestic ethanol prices in the United States and the recent increases in crop and food prices in US and world markets have led to discussions of eliminating the tariffs on US ethanol imports. One study that contributed to this discussion was Elobeid and Tokgoz (2008), which analyzed the impact of removing US trade barriers and the federal tax credit on ethanol markets. Table 5 presents the impact of the trade and tax credit removals on ethanol markets both in the United States and in Brazil, which is the major exporter of ethanol. The results are reported as the average of the annual percentage changes (2006 to 2015) between the baseline and the respective scenarios. This analysis shows that US trade barriers have been effective in protecting the US ethanol industry and in keeping domestic prices strong in most countries of the world, except when domestic ethanol prices are extremely high. Under current policy and with the caveat on high prices, there is separability of the US ethanol market from world markets. With trade liberalization, the ethanol market deepens, making it less susceptible to price volatility.[6] The effect of trade liberalization extends beyond ethanol markets, affecting crop markets. The results also show that the impact of removal of the tax credit overrides the impact of the tariff removal. The removal of trade distortions lowers the US domestic ethanol price by an average of 13.6%, which results in a decline in US ethanol production and an increase in consumption when compared to the status quo. Consequently, US net ethanol imports increase significantly. The resulting higher world ethanol price leads to an increase in ethanol production and a decrease in total ethanol consumption in Brazil, causing net exports to increase relative to the baseline.

[Insert Table 5. Here]

According to Elobeid and Tokgoz (2008), the effect of the removal of trade distortions extends beyond the ethanol market, affecting corn and other crop markets and their by-products. The US corn price decreases by 1.5% on average with the decline in demand for corn used in ethanol production. This affects the prices of other crops in the United States, as well as the area allocation among them since area allocation depends on relative net returns. US ethanol protection has exacerbated the food-biofuel trade-offs in the United States and beyond.

The removal of the US federal tax credit of 51¢ per gallon for refiners blending ethanol leads to a reduction in the US refiners' and final consumers' demand for ethanol. Thus, this scenario shows a lower increase in the world ethanol price relative to ethanol trade liberalization (16.5% versus 23.9%). The tax credit acts as consumption subsidy for US ethanol consumers. This is based on the assumption that the tax credit is passed on completely from the blenders to the final consumers. The removal of the tax credit overrides the impact of the tariff removal.

The recent surge in crop and food prices has generated much debate about the impact of

[6] This statement holds *ceteris paribus*, i.e., factors such as crude oil prices may have a larger impact on ethanol prices, which override supply-side forces in the ethanol market. This is indicated in Tokgoz et al. (2008), wherein a moderate increase in crude oil prices has a significant impact on ethanol prices.

the recent policies of the United States, EU-27, and Brazil that support the biofuels sector and how much these policies were responsible for the increases in food prices. Although expansion of the biofuels sector is one of the reasons for the increase in crop and food prices, it is not the only reason for this increase. Energy policies such as the EISA of 2007 and the energy bill of 2005 have contributed to the expansion of the biofuels sector in the United States, but they are not the only reason why the US ethanol sector has grown. Higher crude oil prices increased gasoline prices, which in turn made ethanol a good alternative as a fuel for transportation and contributed to this demand increase.

US refiners' acquisition cost of imported crude oil increased 78% between May 2006 and May 2008 (EIA 2008b). This led to higher gasoline and diesel fuel prices since they are derived from crude oil. This increase has also contributed to the increase in retail food prices through higher transportation, refrigeration, and production costs. For example, the ocean freight rate from the US Gulf to China increased 194% between May 2006 and May 2008. The ocean freight rate from the US Gulf to the EU increased 333% between May 2006 and May 2008, adding to the cost of internationally traded products (IGC various). Costs of inputs such as fertilizers and irrigation have increased with higher crude oil prices as well.

Tokgoz et al. (2008) look at the impact of higher energy prices on the US ethanol sector and crop prices. They show that since the ethanol sector has become integrated into the agricultural sector, the agricultural sector's susceptibility to volatility from the energy prices has increased considerably. With the emergence of biofuels, crude oil prices have a much more direct impact on the US agricultural sector compared to the pre-biofuels era when it mostly affected the cost of production. The expansion of FFVs is a crucial element in this integration.

7. Conclusions

Favorable policies such as the EISA of 2007, the energy bill of 2005, and high crude oil prices have largely contributed to the emergence and expansion of the biofuels sector in the United States and in several other countries including Brazil, the EU, India, China, and Japan. This study contributes to the current debate on the food-fuel trade-offs by providing a systematic and quantitative analysis on how biofuel emergence and expansion affect US and world food and agricultural markets under the most recent policy environments. It also provides information on the impacts of some potential policy changes, which might be helpful for policymakers and other stakeholders. In particular, we quantify various food-biofuel trade-offs. To do this, we summarize major analyses based on FAPRI's world multimarket, partial-equilibrium agricultural models. Two scenarios on the expansion of biofuels are compared to a baseline situation to assess their effects on world agricultural and food markets.

This study highlighted that the impact of the emergence and expansion of biofuels on world agricultural markets and food-biofuel trade-offs is influenced by a host of factors. These include

- policy regimes such as border protection and domestic support;
- biofuels conversion technology, including the different feedstock used such as corn in the United States, sugarcane in Brazil, and wheat and other grains in the EU;
- crop and livestock production technology such as less flexibility in land allocation between sugarcane and other crops, and supplemental grain feeding in cattle production in North America versus mostly pasture-based cattle production in South America and Oceania;
- market structure, including the size of the biofuel market in respective countries, as

well as the market shares of impacted countries in the world export market.

In particular, where biofuel growth occurs, that is, in the US or in the rest of the world, will determine the market outcome. Biofuel growth originating in the US results in larger and more widespread impacts. This is because the energy conversion technology in the United States uses mostly corn as feedstock in a dry mill process, producing substantial amounts of co-products that are good substitutes, primarily for corn, in feed rations for livestock production that practices supplemental feeding of grains. Also, there is more flexible land substitution, especially between corn and soybeans, in the major producing area of the Midwest, significantly impacting production and available exportable surpluses of commodities where it is a major supplier in the world market. The United States accounts for 62% of world corn exports, 42% of soybeans, 25% of wheat, 29% of pork, 36% of poultry, and 28% of nonfat dry milk. Land allocation adjustments in the rest of the world follow the same direction as in the United States but at much smaller magnitudes, as most prices changed by related proportions. In contrast, the dominance of sugarcane feedstock in Brazil's conversion technology, the lack of co-products useful for livestock production, the less flexible changes in allocation for land planted with sugarcane, and the policy-induced insulation of the biggest ethanol market in the world—the US—mute the impact of biofuel expansion originating from the rest of the world and mitigate its spillover effects.

Production of DDG in the US conversion technology favors ruminants, as livestock producers can use (lower cost) wet distillers grain at higher inclusion rates than can producers using rations for monogastric animals that use dry distillers grain at lower rates of inclusion. Moreover, with feed cost of ruminants accounting for only 29% of production costs compared to 55% in monogastric animals, the price impacts on beef are much smaller than those on pork and poultry. This favors consumers in the Americas, who have higher beef consumption, rather than consumers in Europe and Asia, who have higher pork consumption.

Overall effects on food prices are moderate for the US expansion since agricultural commodities make up a small share of the cost of food in the United States.[7] Moreover, with only a small fraction of their income allocated to food, the impacts for consumers in the US are modest as well. In contrast, because households in developing countries spend a substantial proportion of their income on food, consumers in these countries may feel the impact of higher prices more deeply.

References

Abler D, Beghin J, Blandford D, and Elobeid A (2008) Changing the U.S. Sugar Program into a Standard Crop Program: Consequences under NAFTA and Doha. *Rev Agr Econ* 30(1): 82-102.

Elobeid A and Beghin J (2006) Multilateral Trade and Agricultural Policy Reforms in Sugar Markets. *J Agr Econ* 57(1): 23-48.

Elobeid A, Tokgoz S (2008) Removal of US ethanol domestic and trade distortions: Impact on US and Brazilian ethanol markets. *Amer J Agr Econ* 90(4):918-932

Elobeid A, Tokgoz S, Hayes DJ, Babcock BA, Hart CE (2007) The long-run impact of corn-based ethanol on the grain, oilseed, and livestock sectors with implications for biotech crops. *AgBioForum* 10(1):11-18

Energy Information Administration (EIA) (2008a) Fuel ethanol overview. Historical Energy Data, Monthly Energy Review, Renewable Energy. Energy Information Administration, http://www.eia.doe.gov/emeu/mer/pdf/pages/sec10_7.pdf Accessed June 2008

Energy Information Administration (EIA) (2008b) Monthly Energy Review. State and US Historical Data. http://www.eia.doe.gov/overview_hd.html Accessed June 2008

Fabiosa JF (2008a) Distillers dried grain product innovation and its impact on adoption, inclusion, substitution, and displacement rates in a finishing hog ration. CARD Working Paper 08-WP 478, Center for Agricultural and Rural Development, Iowa State University

Fabiosa JF (2008b). Not all DDGS are created equal: An illustration of nutrient-profile-based pricing to incentivize quality. CARD Working Paper 08-WP 481, Center for Agricultural and

[7] The conclusion that the biofuel expansion has had some impact on food prices but that most of the recent dramatic increase in prices is a result of other factors including high crude oil prices and income growth has been put forth by other studies, including OECD (2008) and Trostle (2008).

Rural Development, Iowa State University

Fabiosa JF, Beghin JC, Dong F, Elobeid A, Tokgoz S, and Yu T (2007) Land allocation effects of the global ethanol surge: Predictions from the international FAPRI model. Economics Department Staff General Research Paper No 12877, Iowa State University, September

Fabiosa J, Beghin J, De Cara S, et al. (2005) The Doha Round of the WTO and Agricultural Markets Liberalization: Impacts on Developing Economies. *Rev of Agr Econ* 27(3): 317-335.

International Grains Council (IGC) Grain market report. Various issues. http://www.igc.org.uk/en/Default.aspx Accessed June 2008

Organization for Economic Cooperation and Development (OECD) (2008) Economic assessment of biofuel support policies. Directorate for Trade and Agriculture. http://www.wilsoncenter.org/news/docs/brazil.oecd.biofuel.support.policy.pdf Accessed February 2009

Searchinger T, Heimlich R, Houghton R, et al. (2008) Factoring greenhouse gas emissions from land use change into biofuel calculations. *Science* (February 29):1238-1240.

Tokgoz S, Elobeid A, Fabiosa J, et al. (2008) Bottlenecks, drought, and oil price spikes: Impact on US ethanol and agricultural sectors. *Rev Agr Econ* 30(4):604-622.

Tokgoz S, Elobeid A, Fabiosa J, et al. (2007) Emerging biofuels: Outlook of effects on US grain, oilseed, and livestock markets. Staff Report 07-SR 101, Center for Agricultural and Rural Development, Iowa State University, July (revised)

Trostle R (2008) Global agricultural supply and demand: Factors contributing to the recent increase in food commodity prices. USDA Economic Research Service Report WRS-0801, July, http://www.ers.usda.gov/Publications/WRS0801/WRS0801.pdf Accessed February 2009

USDA Foreign Agricultural Service (USDA-FAS) (2008a) Brazil: biofuels annual report 2008. Global Agriculture Information Network Report Number BR8013, July 22, http://www.fas.usda.gov/gainfiles/200807/146295224.pdf Accessed July 2008

USDA Foreign Agricultural Service (USDA-FAS) (2008b) People’s Republic of China: Biofuels annual report 2008. Global Agriculture Information Network Report Number CH8052, June 26, http://www.fas.usda.gov/gainfiles/200806/146295020.pdf Accessed July 2008

USDA National Agricultural Statistics Service (USDA-NASS) (2008) Quick stats: U.S. and all states data – crops. USDA-NASS. http://www.nass.usda.gov/QuickStats/Create_Federal_All.jsp#top Accessed June 2008

Table 1a. Evolution of the Biofuel Market: Comparison of 2006, 2007, and 2008 FAPRI Outlooks for Ethanol

	2008 FAPRI Outlook				2007 FAPRI Outlook				2006 FAPRI Outlook			
	2006*	**2009**	**2012**	**2015**	**2006***	**2009**	**2012**	**2015**	**2006**	**2009**	**2012**	**2015**
Ethanol Prices					(U.S. Dollars per Gallon)							
Anhydrous Ethanol Price, Brazil**	1.92	1.41	1.25	1.41	1.80	1.55	1.43	1.36	1.21	1.16	1.24	1.31
Ethanol, FOB Omaha	2.58	1.90	1.78	2.13	2.58	1.71	1.63	1.58	1.89	1.81	1.66	1.73
Biodiesel Prices												
Central Europe FOB Price **	3.34	4.40	5.06	5.57	--	--	--	--	--	--	--	--
Biodiesel Plant	3.12	3.87	4.67	5.01	--	--	--	--	--	--	--	--
U.S. Production & Consumption												
Ethanol					(Million Gallons)							
Production	4,884	11,274	12,283	15,458	4,856	11,501	12,290	12,436	4592	6,438	7,704	8,146
Consumption	5,436	11,554	12,668	16,594	5,370	11,684	12,594	12,750	4635	6,501	7,797	8,261
Net Trade	-686	-402	-397	-1,178	-679	-288	-306	-322	-74	-98	-111	-124
Biodiesel												
Production***	268	638	1,081	1,109	385	578	534	472	--	--	--	--
Consumption	246	403	950	1,000	--	--	--	--	--	--	--	--
Net Trade	21	235	131	109	--	--	--	--	--	--	--	--
Brazilian Production & Consumption												
Ethanol												
Production	4,536	6,076	7,058	8,756	4,763	5,386	6,201	7,153	5038	5,667	6,108	6,554
Consumption	3,696	4,946	5,500	6,094	3,848	4,606	5,192	5,954	4325	4,762	5,059	5,352
Net Trade	905	1,127	1,558	2,664	928	779	1,007	1,198	712	905	1,050	1,203

Table 1b. Evolution of the Biofuel Market: Comparison of 2006, 2007, and 2008 FAPRI Outlooks for Ethanol

	2008 FAPRI Outlook				2007 FAPRI Outlook				2006 FAPRI Outlook			
	2006*	2009	2012	2015	2006*	2009	2012	2015	2006	2009	2012	2015
EU Production & Consumption												
Ethanol					(Million Gallons)							
Production	1,244	1,359	1,607	1,899	864	1,031	1,218	1,398	601	752	819	831
Consumption	1,145	1,440	1,785	2,164	935	1,175	1,409	1,628	604	810	904	951
Net Trade	99	-82	-180	-268	-71	-145	-193	-232	-3	-59	-86	-121
Biodiesel												
Production	1,548	1,401	1,924	2,286	5,504	6,526	6,639	7,161	--	--	--	--
Consumption	1,633	2,131	2,313	2,724	--	--	--	--	--	--	--	--
Net Trade	-29.72	-688.8	-348.3	-397.6	--	--	--	--	--	--	--	--
Rest of the World Net Trade												
Ethanol												
Canada	-11	-124	-192	-261	--	--	--	--	--	--	--	--
China	267	86	26	24	42	-8	-72	-121	--	--	--	--
India	0	52	-67	-158	-118	-152	-179	-193	--	--	--	--
Japan	-165	-224	-261	-290	-171	-222	-258	-292	-155	-193	-226	-258
South Korea	-66	-96	-116	-132	-75	-96	-116	-135	--	--	--	--
Rest of the World	-344	-337	-370	-401	23	11	-5	-25	--	--	--	--

* Historical numbers not projections

*** U.S. biodiesel production is in marketing year (Oct-Sept) in the 2007 FAPRI Outlook.

Note: Different data sources were used in the 2008 FAPRI Outlook, which explains the significant difference in numbers between Outlooks for some countries.

Table 2. Impact Multipliers for Area from Expansion Scenarios
(In percent change 100 * %ΔX/%Δethanol use)

	US Ethanol Demand Expansion (Tokgoz et al. 2007)) (Long-Run Equilibrium)						
Countries	Corn	Wheat	Sorghum	Sugarcane	Soybean	Rapeseed	Crops*
World	8.1	-0.3	2.0	0.0	-1.7	-1.2	1.7
US	23.4	-10.1	3.9	3.5	-14.6	2.4	2.6
Brazil	6.0	-0.6	--	-1.1	6.6	--	5.2
EU-25	0.8	0.5	--	--	1.7	-2.6	0.3
China	2.8	1.4	--	0.0	0.4	0.3	1.5
India	7.1	1.3	1.8	0.3	2.5	-2.4	1.7
Argentina	13.6	-0.8	2.8	0.2	-1.2	--	0.1
Australia	2.3	0.3	0.9	0.3	--	-0.1	0.4
Canada	2.6	0.3	--	--	1.7	-0.8	0.2
Mexico	2.1	5.5	6.7	0.7	--	--	2.8
South Africa	6.1	0.0	-0.2	0.5	--	--	5.3
	Global Ethanol Demand Expansion (Fabiosa et al. 2007) (10-year average)						
Countries	Corn	Wheat	Sorghum	Sugarcane	Soybean	Rapeseed	Crops*
World	0.3	0.0	0.1	13.8	-0.1	0.0	0.1
US	0.9	-0.1	0.2	0.3	-0.6	-0.1	0.1
Brazil	0.3	0.0	--	44.4	0.2	--	5.8
EU-25	0.4	0.4	--	--	0.0	-0.1	0.4
China	0.1	0.1	--	0.3	0.0	0.0	0.1
India	0.4	0.0	0.1	1.7	0.1	-0.1	0.2
Argentina	0.6	-0.1	0.1	1.5	-0.1	--	0.0
Australia	0.1	-0.2	0.0	1.8	--	0.0	-0.1
Canada	0.1	0.0	--	--	0.0	-0.1	0.0
Mexico	0.1	0.2	0.3	0.1		--	0.1
South Africa	0.3	--	0.0	2.5	--	--	0.4

* Crops include corn, wheat, sugarcane, sugar beet, sorghum, soybean, rapeseed, sunflower, peanuts, and barley.

Table 3. Impact Multipliers for Feed use from Expansion Scenarios
(In percent change 100 * %ΔX/%Δethanol use)

	US Ethanol Demand Expansion (Tokgoz et al. 2007)) (Long-Run Equilibrium)						
Countries	Corn use for ethanol	DDG	Corn feed	Sorghum feed	Soybean meal	Rapeseed meal	Sunflower meal
World	116.3	124.8	-6.5	-0.3	-2.1	-1.0	-0.5
US	118.8	70.9	-15.1	32.1	-11.0	-18.5	2.6
Brazil	0.0	0.0	-6.7	0.0	-4.6	--	--
EU-25	0.0	756.1	0.9	0.0	0.0	-0.1	-0.1
China	-2.7	1030.5	-1.9	0.0	0.6	1.1	0.6
India	0.0	0.0	-7.9	-7.2	-0.2	-0.4	--
Argentina	0.0	0.0	2.4	-2.4	-3.1	--	-2.7
Australia	0.0	0.0	-2.6	-1.6	--	-0.4	--
Canada	0.0	1098.9	-5.3	0.0	-3.6	-1.6	--
Mexico	0.0	463.4	-0.6	-4.2	--	--	--
South Africa	0.0	0.0	-5.5	-23.7	--	--	--
	Global Ethanol Demand Expansion (Fabiosa et al. 2007) (10-year average)						
Countries	Corn use for ethanol	DDG	Corn feed	Sorghum feed	Soybean Meal	Rapeseed Meal	Sunflower Meal
World	5.4	4.2	-0.3	0.1	-0.1	0.0	0.0
US	4.2	4.5	-0.7	1.0	-0.3	-0.3	-0.2
Brazil	0.0	0.0	-0.3	0.0	-0.2	--	--
EU-25	34.0	1.9	-0.1	0.0	0.0	0.0	-0.1
China	75.3	0.0	-0.1	0.0	-0.1	-0.1	0.0
India	0.0	0.0	-0.3	-0.3	0.0	0.0	--
Argentina	0.0	0.0	0.0	-0.1	-0.2	--	-0.2
Australia	0.0	0.0	-0.1	-0.1	--	-0.2	--
Canada	0.0	0.9	-0.2	0.0	-0.2	-0.2	--
Mexico	0.0	0.7	-0.1	-0.1	--	--	--
South Africa	0.0	0.0	-0.2	-0.7	--	--	--

Table 4a. Impact Multipliers for Meat and Dairy Consumption
(In percent change 100 * %ΔX/%Δethanol use)

	US Ethanol Demand Expansion (Tokgoz et al. 2007) (Long-Run Equilibrium)						
Countries	Beef Cons.	Pork Cons.	Broiler Cons.	NFD Cons.	Cheese Cons.	Butter Cons.	WMP Cons.
World	-0.3	-0.9	-1.4	-0.7	-0.3	-0.1	-0.2
US	-1.9	-1.7	-3.4	-0.5	-0.5	-1.2	--
Brazil	0.0	-0.9	-1.0	-0.8	-0.3	-0.1	-0.7
EU-27	-0.1	-0.3	-0.5	-0.4	-0.2	0.1	-0.3
China	0.0	-0.8	-1.0	-1.3	-0.1	-0.1	0.1
India	0.4	--	-1.6	-0.6	--	-0.1	--
Argentina	-0.6	-0.6	-1.1	-0.9	-0.3	-0.1	-0.5
Australia	-0.3	-0.8	-2.2	-1.1	-0.4	0.0	-0.3
Canada	-0.7	-1.6	1.2	0.0	0.0	1.1	0.0
Mexico	0.4	-1.1	-0.2	-1.4	-0.4	-0.1	0.0
South Africa	0.8	--	-0.3	--	--	--	--
	Global Ethanol Demand Expansion (Fabiosa et al. 2007) (10-year average)						
Countries	Beef Cons.	Pork Cons.	Broiler Cons.	NFD Cons.	Cheese Cons.	Butter Cons.	WMP Cons.
World	0.4	-2.8	-7.1	0.0	0.0	0.0	0.0
US	-0.3	-4.7	-17.0	0.0	0.0	-0.1	--
Brazil	0.6	-2.3	-4.2	0.0	0.0	0.0	0.0
EU-27	-0.8	-3.3	-6.7	0.0	0.0	0.0	0.0
China	0.6	-2.2	-2.8	-0.1	0.0	0.0	0.0
India	-0.4	--	-8.0	0.0	--	0.0	--
Argentina	-1.5	-1.6	-4.1	-0.1	0.0	0.0	0.0
Australia	-0.5	-1.7	-7.7	0.0	0.0	0.0	0.0
Canada	0.0	-8.6	4.6	0.0	0.0	0.0	0.0
Mexico	2.7	-5.0	-0.6	-0.1	0.0	0.0	0.0
South Africa	1.7	--	0.8	--	--	--	--

Note: NFD indicates nonfat dry milk, and WMP indicates whole milk powder.

Table 4b. Impact Multipliers for Grain, Sugar, and Oil Food Use (In percent change 100 * %ΔX/%Δethanol use)

	US Ethanol Demand Expansion (Tokgoz et al. 2007) (Long-Run Equilibrium)						
Countries	Wheat	Barley	Corn	Soybean Oil	Rapeseed Oil	Sugar	Palm Oil
World	-0.8	0.0	-3.6	0.0	0.0	-0.1	0.0
US	-2.1	-2.3	-3.9	0.5	5.9	1.8	--
Brazil	0.4	4.8	-3.7	-2.1	--	-0.1	--
EU-25	0.0	-0.7	-1.6	-3.6	0.1	0.0	12.8
China	0.4	0.1	-3.0	-1.8	-0.3	-0.1	0.0
India	-5.0	0.0	-3.6	-2.0	-0.3	-0.3	0.1
Argentina	-2.2	-5.5	-4.6	-2.4	--	-0.1	--
Australia	-1.4	0.0	-7.6	--	0.3	-0.2	--
Canada	0.1	-2.4	-4.9	-2.1	-0.7	-0.1	--
Mexico	0.6	14.9	-0.3	--	--	-0.1	--
South Africa	--	0.0	-8.8	--	--	-0.3	--
	Global Ethanol Demand Expansion (Fabiosa et al. 2007) (10-year average)						
Countries	Wheat	Barley	Corn	Soybean Oil	Rapeseed Oil	Sugar	Palm Oil
World	0.3	0.7	-0.3	-0.1	0.0	-1.1	0.0
US	-0.1	-0.1	-1.3	-0.2	-0.1	0.2	--
Brazil	0.0	-0.2	-0.1	0.0	--	-0.9	--
EU-25	-0.4	-0.2	0.1	-0.1	0.0	0.0	0.0
China	0.0	-0.1	-0.3	0.0	0.0	-0.5	0.0
India	-0.2	0.0	-0.2	0.0	0.0	-2.0	0.0
Argentina	-0.1	-0.2	-0.3	0.0	--	-1.0	--
Australia	-0.1	0.0	-0.4	--	0.0	-1.0	--
Canada	0.0	-0.1	-0.2	0.0	0.0	-0.9	--
Mexico	0.0	-0.2	0.0	--	--	0.0	--
South Africa	--	0.0	-0.3	--	--	-1.7	--

Table 5. Impact of Removal of US Trade Barriers and Federal Tax Credit on US and Brazilian Ethanol Markets (Average percent change between baseline and scenario)

Average 2006-2015	**Removal of US Trade Barriers**				**Removal of US Trade Barriers and Federal Tax Credit**		
Prices	World Ethanol Price	US Ethanol Price	US Corn Price		World Ethanol Price	US Ethanol Price	US Corn Price
	23.9%	-13.6%	-1.5%		16.5%	-18.4%	-2.1%
	Ethanol Production	Ethanol Consumption	Ethanol Net Imports		Ethanol Production	Ethanol Consumption	Ethanol Net Imports
US	-7.2%	3.8%	199.0%		-9.9%	-2.1%	137.0%
	Ethanol Production	Ethanol Consumption	Ethanol Net Exports		Ethanol Production	Ethanol Consumption	Ethanol Net Exports
Brazil	9.1%	-3.3%	64.0%		6.3%	-2.3%	44.0%

Adapted from Elobeid and Tokgoz (2008).

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