US Biofuel Policies and Markets

Gal Hochman, Michael Traux and David Zilberman

Abstract The United States has established various policies to support a transition to biofuels from fossil fuels as part of its strategy to achieve energy security and independence. These policies include mandates, tax credits, and import tariffs aimed at developing the nascent biofuel industry. To compare the impact of various energy sources requires a comprehensive understanding of both direct and indirect effects. This chapter discusses some of the indirect effects, including land use change, fuel rebound effect, and balance of trade effect. It finds that due to the ubiquity of energy, indirect effects impact numerous markets and that an already noncompetitive energy market that is capital intensive exacerbates the challenge of introducing biofuels. While first-generation biofuels contributed to rural development and reduced dependency on imported fuel sources, they have failed to reduce GHG emissions significantly. Introduction of advanced biofuels is challenged by the blend wall in the US and high costs, there is much opportunity for them to contribute significantly to energy security but also reducing GHG emissions.

Keywords Balance of trade · Benefit and costs · Biofuels · Energy security · Greenhouse gases · Policy · Risk

1 Introduction

For years now, the United States has been attempting to find a way to have energy security and independence (Yergin 2006). With decades of net importation of petroleum and natural gas, the idea of developing a source of energy from the staple crop

G. Hochman (✉) · M. Traux
Department of Agriculture, Food and Resource Economics, Rutgers University, New Brunswick, NJ, USA
e-mail: gal.hochman@rutgers.edu

D. Zilberman
Department of Agricultural and Resource Economics, University of California at Berkeley, Berkeley, CA, USA
e-mail: zilber11@berkeley.edu

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of corn seemed to be a promising way to achieve energy security and independence from fossil fuels (Lapan and Moschini 2009). It was believed that with improving technology in both biofuel production, and agricultural techniques, producing ethanol would become competitive with imported petroleum, allowing the market to help develop the infant industry. After years of stagnant development for ethanol fuels (the 1980s and 1990s), the United State government developed policies aimed at promoting the use and production of ethanol to compete with gasoline.

The government established a biofuel mandate in 2005, which required a minimum amount of ethanol to be blended with transportation fuel (the Energy Policy Act of 2005[1]). It also implemented the now repealed tax credit, and import tariff, which together were supposed to protect the domestic industry by making foreign ethanol more expensive and less competitive with the domestically produced corn ethanol. Although these policies were intended to benefit the domestic energy sector and provide a variety of competitive fuel sources for consumers, the infant industry led to unintended consequences as it developed. While the biofuel industry has matured, the adverse effects of its growth are causing policy makers to reconsider if the benefits outweigh the side effects (Hochman and Zilberman 2016, and references therein).

Land use and rising food prices have caused the most concerns for policy makers, with food prices increasing 2.7% annually[2] since the implementation of these policies. The amount of available land for agriculture transitioned to producing ethanol crops affects the cost of other staple crops now no longer being produced at the same levels (Hertel et al. 2010; Chen et al. 2012a; Roberts and Schlenker 2013).

Although initially not a direct goal of the enacted policies, greenhouse gas (GHG) emissions were explicitly introduced into the regulation in May 2009 (Renewable Fuel Standard—RFS2) and were expected to contribute to the development of low carbon fuel sources. Research into GHG emissions from burning ethanol has shown mixed results against the supposed benefits of ethanol fuels (Hochman and Zilberman 2016), with some research showing that ethanol fuel worsen the problem of GHGs in the atmosphere (Hertel et al. 2010).

Although the environmental benefits of current crop-based biofuels are much more limited than initially thought and the cost of producing advanced biofuels much higher than many hoped, biofuels did affect the U.S. balance of trade and contributed to its reduction in recent years (Hochman and Zilberman 2016). The rest of the chapter begins by describing the biofuel industry (Sect. 2). This is followed by a discussion of biofuel policies in the U.S. (Sect. 3) and a summary of the policy instruments used (Sect. 4). The U.S. biofuel policy has affected commodity markets and international trade that are discussed in Sect. 5. We conclude with Sect. 6.

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[1]The Energy Policy Act of 2005 is available at http://energy.gov/sites/prod/files/2013/10/f3/epact_2005.pdf.

[2]See USDA Food Price Outlook website, available at http://www.ers.usda.gov/data-products/food-price-outlook/ (viewed: January 21, 2016).

2 Biofuel Production

Biofuels are seen as an energy source that could help reduce the United States reliance on fossil fuels, and the amount of GHGs emitted into the atmosphere. The many advantages of biofuels include lower GHG emissions intensity, domestic availability, renewability, higher combustion efficiency, lower sulfur, and aromatic content and biodegradability (Hertel et al. 2010). The disadvantages of biofuels include lower energy efficiency and its contribution to air pollution (Brown 2008). However, because the perception was that the benefits outweigh the costs and because of the high cost of production of biofuels relative to fossil-based fuels, governments instituted policies that promoted the industry's growth.

The most efficient country (in terms of fuel yields per unit land) in the world at producing ethanol is Brazil, using sugarcane as a source of ethanol (Demirbas 2009). The majority of this sugar cane is grown in Mato Grosso, Sao Paulo, and Parana, along with other eastern-coastal states within the country (see Fig. 1).

There are many different reasons believed to be responsible for Brazil's success with ethanol production. Sugarcane itself is a more efficient crop than other sources, with it being seven times more efficient than corn in terms of fuel yield per unit land (Crago et al. 2010). Brazilian sugarcane ethanol has a production cost that is, on average, 24% lower than United States corn ethanol, mainly because it is possible to produce 45% more ethanol per unit of land from the sugarcane plant than from corn (Crago et al. 2010). In addition, the tropical weather of Brazil provides a more suitable climate for sugarcane (Crago et al. 2010).

The Untied States is the second most efficient country at producing biofuel, relying heavily on corn ethanol (Hochman and Zilberman 2016). The majority of corn comes from the "corn belt" region, which is composed of Iowa, Illinois, Indiana, Southern Michigan, Western Ohio, Eastern Nebraska, Eastern Kansas, Southern Minnesota, and Northern Missouri. This region is the most suitable for corn production in the United States because of the vast, flat fields naturally available in the Great Plains (Miller et al. 2009). Figure 3 depicts the top four U.S. corn ethanol producing states in 2013. These regions are the most productive in terms of corn production, mainly because of the naturally nutrient rich soil, and the long growing season (Miller et al. 2009) (Fig. 2).

Corn is used as a primary source of feed for livestock production. Corn also uses more land per unit of ethanol compared to sugarcane (Bundy 2007). While sugarcane has an energy balance of 8.3–10.2, corn only has a balance of 1.3–1.6 (Bundy 2007), meaning higher energy input is required to produce the same amount of energy for corn when compared to sugarcane. This also means the productivity of the land is higher in Brazil than in the United States. In Brazil, there is roughly 355 million hectares (Mha) of land available for agricultural production, with 3.6 Mha dedicated for ethanol production in 2006 (Bundy 2007). In the United

Fig. 1 Brazil's regions. *Source* Ezilon Maps, available at ezilon.com

States, there is 270 Mha available for agricultural use, with 10 Mha dedicated to ethanol production in 2006 (Crago et al. 2010).[3]

Europe produces biodiesel primarily from sugarbeet and is the most expensive of the top three-ethanol producers in the world. This stems from poor growing conditions in Europe, along with the lower energy content of sugarbeets [see ebb-eu.org (viewed: January 22, 2016)]. Figure 4 depicts the top sugarbeet producing nations in 2011. The entire European Union allocated 8.6 million tons of sugar beet to biodiesel in 2011, yielding the most biodiesel produced in the world [see ebb-eu.org (viewed: January 22, 2016)].

[3]See also Demirbas (2009).

Fig. 2 The map of the United States. *Source* Ezilon Maps, available at ezilon.com/maps

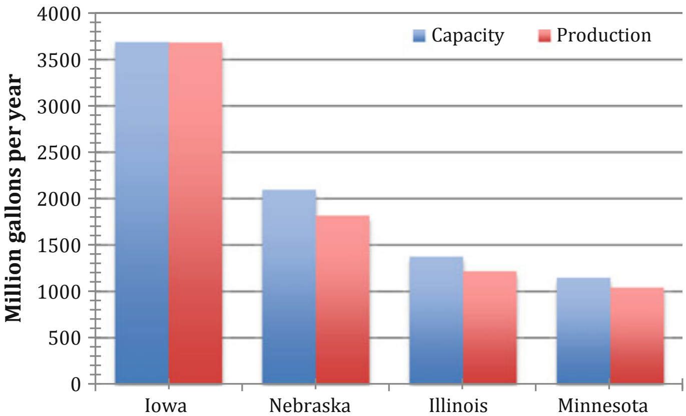


Fig. 3 Top four U.S. corn ethanol producing states in 2013 [see neo.ne.gov (viewed: January 10, 2016)]

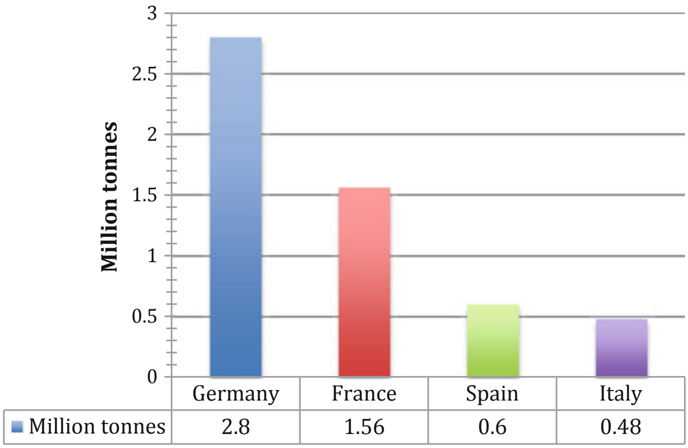


Fig. 4 Top European sugar beet producers in 2011 (*Source* European Biodiesel Board)

3 U.S. Biofuel Policy

In pursuing energy security, the United States began developing policies that would promote the production and consumption of biofuel in the early 2000s. Since the United States is the biggest producer of corn in the world, policy makers saw the use of the crop as a promising path for a sustainable fuel source. Corn is also one of the most energy dense crops that the United States produces and thus believed to be a crop suitable for competition with gasoline (Gardner and Tyner 2007; Gallagher et al. 2003; Rajagopal et al. 2007; Cui et al. 2011). In 2000, the United States produced 1.65 billion gallons of corn-based ethanol; this was before any significant policies were put into place at the federal level to promote its use. In 2008, after two prominent laws were passed in 2005 and 2007, production rose to 9 billion gallons (Lapan and Moschini 2009).

3.1 The U.S. Biofuel Mandate

The Energy Policy Act of 2005 took the first noticeable step towards building the biofuel industry in the United States by requiring a specific amount of ethanol to be consumed as fuel. It was followed by the Energy Independence and Security Act of 2007 (EISA 2007), which established the Renewable Fuel Standard (RFS) that set the apportioned mandated quantity for the different feedstock. The RFS was updated in 2010 (RFS2) to differentiate among different types of renewable feedstock, depending on whether it was cellulosic biofuel, biomass-based diesel, advanced biofuel, or renewable fuels. This mandate is implemented by assigning a Renewable Identification Number (RIN) to each unit of biofuel, which can be bought or sold to and from other fuel blenders after the fuel attached to the RIN is bought by the blender. This encourages some blenders to produce more ethanol mixed fuel than they are required to, with the opportunity to trade RINs and earn money from their competitors. If a blender does not purchase enough biofuel to meet their required mandate, they are able to purchase the RIN from other blenders who produce a surplus amount of biofuel. This system is similar to a cap-and-trade policy, which limits SO_2 and CO_2 emissions (Thompson et al. 2009).

The Energy Policy Act of 2005 initially set the RFS mandate at a total of 4 billion gallons in 2006, with an increase in the mandate to a total of 7.5 billion gallons in 2012. With the adoption of the Energy Independence and Security Act of 2007, the mandated levels were increased from a total of 9 billion gallons in 2008, to a total of 36 billion gallons in 2022. The 2022 mandated level has an implicit cap of 15 billion gallons for corn ethanol, with a minimum of 16 billion gallons from cellulosic biofuels.[4]

The RFS was updated in 2010 to include language that suggests that its goals were to reduce GHG emissions and minimize the contribution of transportation fuel to global climate change (RFS2). The update defined advanced biofuels as those that achieve a reduction to life cycle GHG emissions intensity (including emissions from direct and indirect land use change) by at least 50%, cellulosic biofuels as those that reduce life cycle GHG emissions intensity by at least 60% while conventional biofuels need to achieve a reduction in life cycle GHG emissions by at least 20%. Another stated objective of RFS2 was to decrease gasoline consumption by at least 20% by 2020 and by 30% by 2030 (Sorda et al. 2010).

The implications of the volumetric mandate on fuel prices are a topic of much controversy (Hochman and Zilberman 2016). Because the mandate requires fuel blenders to blend a minimum amount of ethanol in the fuel sold to distributors, a binding mandate may force blenders to bid higher than is economically viable based on the market price for biofuels. That is, the demand for the fuel is not set on the economic market, but by governmental policy (de Gorter and Just 2009a; Thompson et al. 2009). However, others have argued that the introduction of biofuels yields lower crude oil prices (Hochman and Zilberman 2016, and references therein) and thus lowers the price of fuel at the pump.

3.2 The Volumetric Ethanol Excise Tax Credit

The Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 were accompanied by a Volumetric Ethanol Excise Tax Credit (VEETC), or feed in tariff, for blenders to purchase biofuels and an import tariff on foreign biofuels, which incentivized purchase of domestic biofuels to promote the country's infant industry. The VEETC was created by the American Jobs Creation Act of

[4]See U.S. EPA ruling available at http://www.epa.gov/otaq/fuels/renewablefuels/index.htm.

2004 and applied through December 2010. It was extended for one year by the Renewable Fuels Reinvestment Act (RFRA). Initially, the tax credit allowed ethanol blenders the opportunity to claim a $0.51 credit for every gallon of ethanol used in the blending process (Sorda et al. 2010). The 2008 Farm Bill reduced the VEETC from $0.51 to $0.45 per gallon. While the tax credit expired on December 31, 2011, the American Taxpayer Relief Act of 2012 (Pub. L. 112-240) retroactively extended certain fuel tax credits till December 31, 2013, which included biodiesel and renewable biodiesel (Pub. L. 112-240; sec. 405), as well as cellulosic (Pub. L. 112-240; sec. 404).

In general, the use of tax credits to promote biofuels is viewed as being very costly to the taxpayer, and causing negative effects on social welfare (Lapan and Moschini 2012; de Gorter and Just 2009b, 2010; Chen et al. 2012a). The biggest complaint is that a tax credit increases the consumption of fuels by lowering the real cost of the gasoline. This reduction in cost causes a higher consumption rate, making any reduction to GHG emissions difficult to obtain (Khanna et al. 2008). The tax credit is also viewed as an incentive for refineries and blenders to bid up the price of ethanol above that of gasoline. Blenders and refineries are accused of bidding up the price in order to receive the full amount of the tax credit, with a lower price offering a lower credit amount. By bidding the cost higher than the real market value, blenders, and refineries indirectly cause the price of corn to rise throughout its supply chain. Beside the already mentioned increase to corn prices caused by blenders and refiners bidding up the cost of ethanol, the taxpaying public is responsible for providing the tax credit to the fuel producers. It is estimated that the tax credit has cost the United States $2.4 billion in 2006, and $5 billion in 2010. For biodiesel, the credit is estimated to cost taxpayers $1.4 billion in 2008 (Sorda et al. 2010).

3.3 Trade Restrictions

Beginning in the 1980s until 2011, U.S. ethanol producers were protected by a 54 cent per gallon import tariff. Historically, the motivation for the import tariff was to offset the federal tax credit that applied to ethanol regardless of country of origin. These policies together made the purchase of domestic biofuels cheaper than Brazilian sugarcane ethanol. Most of this support was discontinued after 2011, aside from the mandate. A removal of the import tariff was expected to reduce the domestic price for United States ethanol by 13.6%, and reduce the domestic market share for corn ethanol by 3.7%. The removal of the import tariff, along with the biofuel tax credit was expected to reduce ethanol consumption by 2.1% and the price of ethanol by 18.4% (Cui et al. 2011).

On January 1, 2012 the U.S. eliminated the 54 cents per gallon import tariff imposed on ethanol imports followed by the 45 cents per gallon corn ethanol tax credit to blenders. Overall, the two top world producers and exporters of ethanol, the U.S. and Brazil, now provide free access to their conventional biofuel markets.

4 Combining Biofuel Policies

From 2007 to 2022, Chen et al. (2012a) simulated a scenario with only an RFS mandate in the United States and showed that the expected net social welfare gain relative to the business-as-usual would be \$110 billion to \$132 billion. However, if a tax credit is provided then, relative to an RFS alone, social welfare declines to between \$79 billion and \$118 billion over the 2007–2022 period. The incremental gain of a tax credit and RFS regime, relative to the RSF alone, is between 8.45 billion gallons and 26.15 billion gallons across the various scenarios. Put differently, the incremental welfare cost of the tax credit is between \$2.65 and \$9.84 per liter of ethanol.

Hertel et al. (2010) argue that the combination of biofuel mandates, tax credits, and import tariffs have caused a 10% rise in corn prices, which leads to a reduction of food consumption across the world. The rise in corn prices is believed to contribute to a 42% reduction in the amount of corn grown for feed, leading to other crops substituting for corn and higher prices for these competing crops. With an increase in crop prices, the livestock which consume these products also saw an increase in price, contributing to a decrease in demand for livestock by ~31% as a result of higher cost of production.

While food prices are increasing and demand is declining, crop yield increases continue. There has been 0.4% increase in crop yields since the policies have come into effect, leading to a 2.8% increase in agricultural production intensification.[5] This rise in production has resulted in a reduction in coarse grain imports to the United States by 17%, while reducing the countries coarse grain land reserves 4% (Hertel et al. 2010). For more on the benefits of GMO and its impact on yield, see Barrows et al. (2014).

5 Biofuel Policies, Markets, and the Environment

In 2012, CO_2 emissions in the United States accounted for 17.89% of the world's fossil fuel emissions, with 5636.74 mmt emitted (http://www.eia.gov). Biofuels are seen as a way to reduce this number. Although biofuels reduce CO_2 emissions, Nitrous Oxide (NO_x) emissions rise with the use of biofuels, and an increase in NO_x by approximately 10% is expected from pure biodiesel (i.e., B100) and a 2% increase for a 20% biodiesel/80% petrodiesel mix (i.e., B20) (Brown 2008). This has increased the NO_x concentration in the atmosphere from 1.86 to 2.23%, with each pound of NO_x emitted being 300× per pound stronger than each pound of CO_2 emitted [see https://www.epa.gov/climatechange/ghgemissions/gases/n2o.html (viewed: January 12, 2016)]. The U.S. EPA calculates the annual GHG emissions of corn-based ethanol to be 39 gCO_2e/MJ, compared to 92 gCO_2e/MJ annual

[5]See also Bennett et al. (2015).

emissions for gasoline, however these calculations do not account for the market-mediated effect of the introduction of biofuels, such as indirect land use changes.

With the implementation of biofuel policies, the United States expected beneficial outcomes, with energy security being paramount. However, these policies have created numerous economic and environmental side effects. There is an overwhelming consensus that the policies have caused increases in food prices of about $0.61 on average—about 20% at current prices (Hochman and Zilberman 2016). There is also an agreement that these policies have caused a negative effect on current land use, with 40–45% of land being used for the production of corn for biofuel instead of food/feed use (Zilberman et al. 2013).

The most debated unintended consequences of the United States biofuel policy have been adverse land use and an increase in food prices. These two problems have caused researchers to look into the benefits of biofuel policies, and to decide if they are worth promoting in the future, and which changes should be made to ensure the policies have a positive impact rather than a negative one on the social welfare (Zilberman et al. 2012, 2013).

5.1 Indirect Land Use Change

Biofuel policies may cause farmers to change the use of their land by either changing their current cropland for production of energy crops, or by farmers increasing the amount of land used to produce crops for either food or fuel. The introduction of biofuels contributed to increased demand for land, and thus to deforestation, which further increases the cost of reducing CO_2 (Timilsina and Sherestha 2010). Concerns about the effects of biofuels on deforestation led regulators, particularly CARB, to assign biofuels a GHG emissions intensity taking account of the indirect land use changes associated with their production when evaluating their compliance with the biofuel policies.[6]

With the current biofuel policies in place, the United States is expected to increase coarse grain acreage by 10%, representing a 0.8% increase to agricultural land use in 2015 (Cui et al. 2011). This increase will reduce current forest and pasture land by 3.1%. In the European Union, there is an expected 10% increase in oilseed acreage, which will increase the European Union's cropland area by 40% as food crop land increases to make up for energy crop land conversion. The European Union will see a reduction in forest and pasture land by 4.9% (Cui et al. 2011). The demand for feedstock is responsible for 75–80% of this increase in land use (Demirbas 2009).

[6]See U.S. Environmental Protection Agency's website at http://www.epa.gov/otaq/fuels/renewablefuels/regulations.htm.

U.S. coarse grain output has increased by roughly 1.25–2.49%, which is mainly attributed to an increase in land use in the United States assuming 2006 figures and a 1-billion-gallon increase in U.S. ethanol demand (Keeney and Hertel 2009). For every 1 billion gallon increase in the United States ethanol fuel mandate, there has been a 0.35% decrease in forest cover, a 0.53% decrease in pasture cover, and a 0.10% increase to cropland. For the 0.10% increase to cropland, there has been a 1.66% increase in coarse grain land usage, while other crops have decreased in production. Land under oilseed decreased by 1.44%, sugarcane by 0.64%, other grains by 1.31%, and a 0.34% decrease to all other agricultural crops, globally (Keeney and Hertel 2009). The decrease in the supply of these crops caused an increase in their price, resulting in the United States spending more for these crops. The increased demand for imports has also affected land use in other countries, with Canada having a 0.14% increase in crop land, which has caused a 0.105% decrease in forestland, and a 0.17% decrease in pastoral land. The same findings were shown for Latin American countries, Brazil, and Asian Pacific and Oceania (Keeney and Hertel 2009). Chen et al. (2012b) argue that the U.S. biofuel mandate is responsible for a 16% increase in corn acreage in the United States in 2022. This increase is met by a reduction in soybean and other crop production (Chen et al. 2012b). The global harvested area was expected to increase in 2015 by 15.6 Mha because of the EU and U.S. biofuel mandate; the projected increase is much smaller (11.5 Mha) if corn coproducts are incorporated (Taheripour et al. 2009).

In 2004, only 1% of the total world cropland was dedicated to biofuel production. Brazil has led the way among countries dedicating a share of cropland for biofuel crops, with sugarcane being produced on 5.6 million ha, or approximately 10% of the country's cropland. For the world at large, there is approximately 13.5 billion ha of land available, with forest covering 4.2 billion ha, and cropland and pasture covering 5 billion ha. Of the 5 billion ha, only 1.6 billion ha are cropland, 2 billion ha are poor quality land with low crop yield and high degradation, and the rest are urban with too poor quality for agricultural use. These sites provide benefits in the form of biodiversity conservation, carbon sequestration, and natural water filtration, and since these play such an important role in the natural environment, they are likely zoned for protection (Chakravorty et al. 2009).

However, concerns regarding the indirect land use changes are shrouded with uncertainty (Zilberman et al. 2013) and caution need to be applied when applying these methodologies. Koltz et al. (2014) showed that estimates of the change in GHG emissions due to a unit expansion in biofuel varies significantly with the amount of biofuel in the economy and with the policy instituted.

5.2 *Food Versus Fuel Concerns*

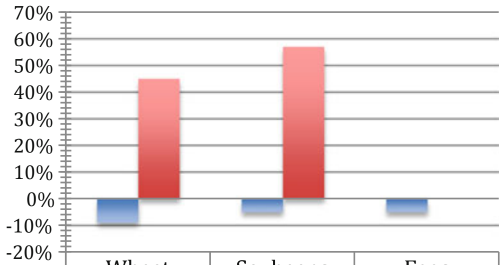
One of the most recognizable complaints about the current biofuel policies has been the relationship between biofuel production and an increase in food commodity prices. From 2000 to 2007, there was an average price increase for food crops of

30% (Rosegrant 2008). This figure is adjusted depending on what factors are being considered; with future expected prices factored into some studies, and the coproducts and inventories being considered in others (Hochman et al. 2011b). There is a wide range of estimates for the increase in food price from 2000 to 2008 is anywhere from 23 to 72%, with biofuel production being the major cause of the increase (Timilisina and Shrestha 2010). Zilberman et al. (2013) argue that there has been an increase of 20–30% in food commodity prices from 2001 to 2008, with factors such as food and feed demand, higher energy prices, a weaker dollar, and increase in biofuel production accounting for about 50% of the increase (see also Hochman et al. 2011a). Hochman and Zilberman's (2016) meta-analysis suggests that the introduction of corn -ethanol contributed on average to an increase of $0.61 in the food commodity price, which at current prices amounts to an increase of about 20%.

There are different ways researchers have estimated how much food prices will change in the future, and how they have changed since the inceptions of various policies. Some look at how price increase will be affected if the biofuel mandates levels are increased the way they are supposed to until 2022. Under this view, corn prices are expected to increase 7.1% per bushel, while soybean prices are expected to increase 2.85% (Babcock 2011). Eggs, beef, poultry, and other food goods have the smallest price increase, with only 1.1%, or $0.02, compared to current policies (Babcock 2011). Other studies argued that rice will increase 39% compared to 1990–2000 policies, while wheat will have a 22% increase compared to these same 1990–2000 policies (Rosegrant 2008).

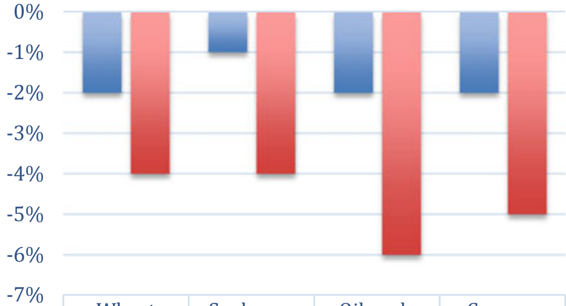
Without an increase in the biofuel mandate levels, and a halt at 2007 mandate levels, food prices were expected to be reduced by 14% by 2015 (Timilsina and Shrestha 2010). Rosegrant (2008) performed a similar exercise and concluded that if the mandates were frozen at 2007 levels, there would be a decrease in food cost by 6% by 2010, and 15% by 2015. For corn, if left at 2004 policy levels, by 2009 there would have been a decrease in prices of 21%. This would also reduce ethanol production approximately 11%, as long as demand for oil and price stay constant up until 2022 (Babcock and Zhou 2013). For other food products, a freeze of the mandate levels would also cause the price to increase at a lower rate than if the subsidies were to increase to 2022 levels (Figs. 5 and 6).

As mentioned before, these findings do not take into consideration the use of corn coproducts, which if taken into consideration, will result in these numbers being less dramatic. By not including coproduct usage in the findings, the United States has a 19.8% increase in food cost, with the EU (11.0%) and Brazil (9.8%), also showing significant food price increases. However, once the coproducts are included, the United States has an increase of food cost of 13.0%, with the EU (5.6%), and Brazil (7.9%) also showing a reduced amount of the increase in food prices (Taheripour et al. 2009).



	Wheat	Soybeans	Eggs
Change in counter-factual prices by 2009	-9%	-5%	-5%
Increase of counter-factual prices from 2004 to 2009	45%	57%	

Fig. 5 If biofuel mandate was left at 2004 level, what are the counterfactual prices in 2009 (Babcock 2011)



	Wheat	Soybeans	Oilseeds	Cassava
Counter-factual prices in 2010	-2%	-1%	-2%	-2%
Counter-factual prices in 2015	-4%	-4%	-6%	-5%

Fig. 6 Counterfactual Prices in 2010 and 2015 if biofuel mandate were frozen at 2007 level (Rosengrant 2008)

5.3 Indirect Fuel Use

Discussions have also looked into the effect indirect fuel use changes have on the amount of GHGs emitted into the atmosphere (Hochman and Zilberman 2016, and references therein). These indirect fuel use changes may increase or decrease greenhouse gas intensity of biofuels, depending on the various factors. These factors include policy attributes, current and future market conditions in fuel markets, and direct greenhouse gas intensity of biofuel related to oil (Rajagopal et al. 2011).

5.4 The Organization of Petroleum Exporting Countries (OPEC) Effect

The behavior of OPEC, a cartel of nations, is different from that of a standard cartel or competitive markets, and this leads to differences in predictions of the OPEC response to changes in supply and demand of crude oil. These different conclusions regarding indirect fuel effect depend on the industrial organization of the fuel markets. Hochman et al. (2011) showed that when computing change in GHG emissions due to the introduction of biofuels, the cartel-of-nations model results in the largest decrease in emissions compared with the standard cartel and the competitive models. That paper shows that the differences are large and that the rebound effect (whereby substituting gasoline with biofuels yields a reduction in fuel prices and thus more fuel consumption) is more than 7% larger under the competitive model.

The cartel-of-firms model (Hochman et al. 2011b) also affects the calculations of the impact of biofuels on food commodity prices. Hochman et al. (2010) analyzed the multiple contributions of biofuels to the increase in food commodity prices within a multimarket framework that includes the OPEC effect, namely, OPEC is modeled as a cartel of nations. These authors show that the introduction of alternatives such as biofuels affects OPEC choices, and that OPEC stabilizes prices and mitigates the upward pressure biofuel created on food commodity prices. The paper concludes that while cartel and competitive models overestimate the effect of biofuels on fuel prices, they underestimate the effect of the introduction of biofuels on the environment.

5.5 The Indirect Coproduct Effect

Barrow et al. (2012) identified an indirect effect of biofuels that results from decreased supply of petroleum coproducts, namely, the indirect coproduct effect (ICE). The ICE represents the change in greenhouse gases associated with the displacement of petroleum coproducts that are eliminated or replaced with reduction in petroleum-based fuels. This study assesses the order of magnitude of the ICE effect and finds that it is likely to reduce the greenhouse gas emissions intensity associated with biofuels and thus serve to offset the negative effect of indirect land use changes. Their numerical analyses suggest that when the ICE is included in the life cycle analysis, corn-based ethanol easily meets minimum requirements for renewable fuel credits under the RFS.

5.6 The Indirect Food Effect

The indirect food effect captures the market-mediated effect from the introduction of biofuels that contribute to the reduction of the GHG emissions from food, as land switches from producing feedstock for food to producing feedstock for fuel. This effect suggests that the life cycle approach that incorporates the indirect land use change recognizes the impact of market-mediated adjustments in an asymmetric manner: while biofuels are credited for market-mediated incremental GHG emissions attributed to land expansion, biofuels are not credited for market-mediated effect that reduced the GHG emissions of food production (Zilberman et al. 2013).

5.7 The Balance of Trade Effect

An important reason for promoting domestic production of biofuels (and natural gas) is the increasing deficit in the United States balance of trade over the last few decades. The introduction of ethanol led the United States to save about US$100 billion (Hochman et al. 2013). Historical data suggests that the increase in ethanol consumption from 2005 to 2011 equaled in volume 67.25% of the decline of finished motor gasoline consumption (Hochman et al. 2013). Both the introduction of biofuels and the new developments in natural gas substantially improved the United States balance of trade.

The primary sources of energy before the promotion of biofuels were, and still are coal, natural gas, and petroleum products. For coal, the United States has been a net exporter since at least 1955. In 1955, the United States imported just 0.008 Q Btu, while exporting 1.465 Q Btu. The trend has continued every year with every year more coal being exported than imported (Fig. 7). The most coal the United States

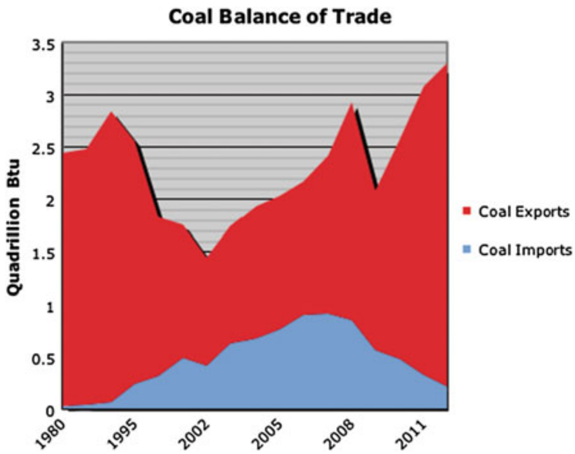


Fig. 7 Coal imports and exports

imported was in 2007, with 0.909 Q Btu purchased from other countries, and 1.507 Q Btu exported. In 2012, the United States exported the greatest quantity in one year at 3.088 Q Btu with 0.212 Q Btu imported [see www.EIA.org (viewed: 447 December 20, 2015)].

For natural gas, the US has consistently imported more than it exported. In 1955, the United States imported 0.011 Q Btu, while exporting 0.049 Q Btu, which is the last time the country has exported more natural gas than imported. This imbalance reached its peak in 2007, which was the year the United States imported the most natural gas at 4.723 Q Btu, while exporting 0.830 Q Btu. The gap has decreased since 2007, with 2012 seeing the United States exporting its highest amount at 1.633 Q Btu, but still importing 3.216 Q Btu (Fig. 8). However, combining coal and natural gas, the U.S. became a net exporter in recent years, with a dramatic break in the existing trend since 2007 (Fig. 9).

Natural gas was 26.9% of U.S. primary energy consumption in 2012, producing 22,902 billion cubic feet, which was 19.74% of the world's total production. The United States was also the world's leading consumer of the product, consuming 24,383 billion cubic feet, or 20.54% of the world's total consumption. Although the

Fig. 8 Natural gas

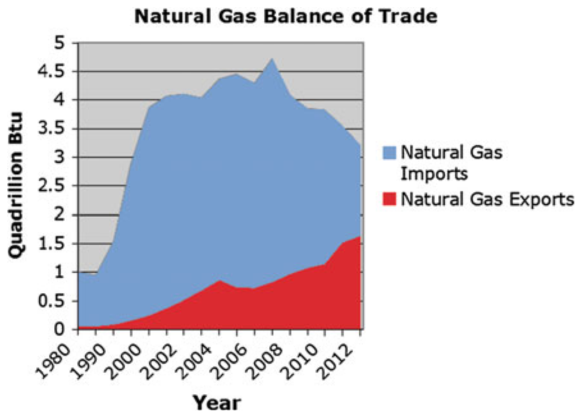
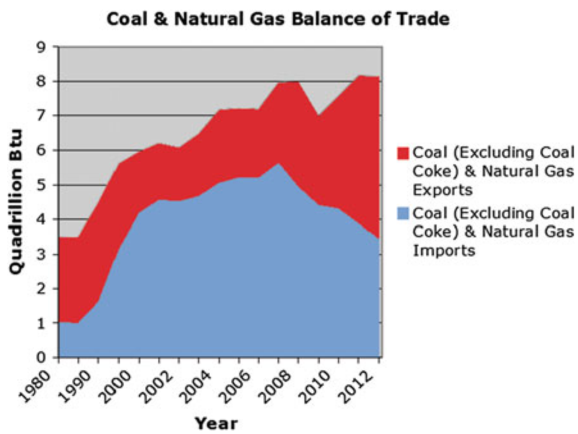


Fig. 9 Net exports of coal and natural gas in B Btu (2007)



industry has been in a recent domestic boom, the United States still has a net trade deficit of 1962 billion cubic feet of natural gas [see www.EIA.org (viewed: December 20, 2015)].

Recent trends indicate that the rise in natural gas will continue for the near future. Proven reserves of U.S. wet natural gas rose by 31.2 trillion cubic feet (Tcf) in 2011, which set a new record for the amount available at 348.8 Tcf. This led the total proven reserves for the U.S., "wet, dry, and shale", to increase by 9.8%, with the states of Texas, Wyoming, Louisiana, Oklahoma, and Pennsylvania having substantial gains in proven reserves. Pennsylvania reserves have increased by roughly 90% in 2011, contributing 41% of the nation's total increase. Texas accounted for an additional 32% of the nation's increase in wet natural gas reserves. For shale gas production, a substantial increase has taken place since 2010, when only 5.4 Tcf were produced, with 97.4 Tcf of reserves. In 2011, there was 8.0 Tcf for production, and an increase in reserves to 131.6 Tcf.[7] Natural gas production is pushing coal into foreign markets, yielding a drastic change in the United States balance of trade. While the introduction of a cleaner energy source results in less GHGs emitted in the U.S., the United States is becoming a major exporter of GHGs.

A similar trend in the energy trade balance of petroleum is observed, albeit for different reasons. The United States has been a net importer of petroleum since at least 1955, when 2.752 Q Btu were imported to only 0.774 Q Btu exported. This gap in imports and exports increased until 2005, when the imports totaled 29.169 Q Btu, which is the most ever imported, while exports for that same year totaled 2.442 Q Btu. The gap has since shrunk, with 2012 United States imports totaling 23.371 Q Btu, while exports were at a record high, at 6.493 Q Btu. At the same time, the United States regulatory environment introduced the Energy Policy Act of 2005 and later of 2007, as well as phased out the use of Methyl Tertiary Butyl Ether (MTBE) and replaced it with ethanol as an oxygenator for reformulated gasoline. While the U.S. is still a net importer of crude oil, it has become a net exporter of petroleum products in 2012 (Fig. 10).

These trends for crude oil and petroleum products, with the import/export gap of petroleum products reversing in 2012, can be seen to correlate with the introduction of biofuel policies (Figs. 11a, b).

This decrease in the net trade gap can be, at least partly, attributed to the biofuel mandate increase, which required a larger percentage of the nation's fuel source to be composed of biofuel products. The United States accounted for nearly 21% of the world's petroleum total use in 2012, with 35.3% of its primary energy source coming from petroleum. The dependence on foreign petroleum was a major deciding factor for policy makers to develop legislation that promoted the production and consumption of biofuels (Lapan and Moschini 2009). Proven reserves of crude oil increased in 2011, mainly because of new discoveries in Texas, Gulf of Mexico, Alaska, California, and North Dakota. For U.S. tight oil reserves, over

[7]The effective recovery factor used to calculate current proven reserves reflects: (i) a probability factor; (ii) prior experience in how production occurs; and (c) current resources in the play.

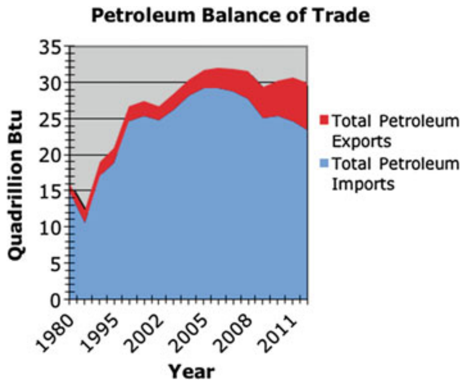


Fig. 10 Crude oil and petroleum products

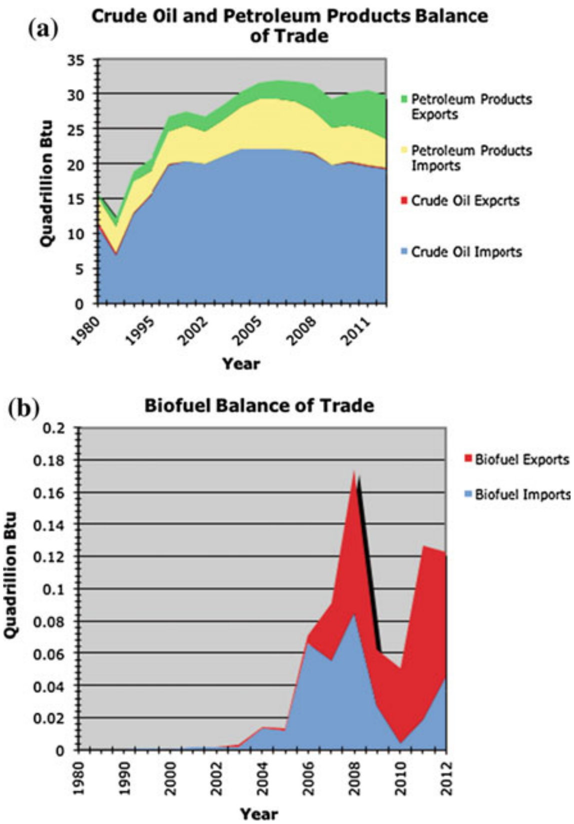


Fig. 11 **a** Crude oil and petroleum. **b** Biofuel production and consumption

90% in 2011 came from four plays, the Bakken Play with 2 billion barrels, Eagle Ford Play reserve which is estimated at almost 1.3 billion barrels, and the Niobrara and Barnett Play, with a combined total of 126 million barrels [www.EIA.org (viewed: December 10, 2015)]. The recent changes in proven reserves are attributed mostly to new discoveries, and to horizontal drilling and hydraulic fracturing—technologies that came into being toward the beginning of the new millennium (Yergin 2006). Although the introduction of current biofuels did not lead to large savings in GHG emissions, it did result in a large impact on the U.S. balance of trade. Similar conclusions can be made for natural gas and shale gas.

6 Demand for Biofuel and the Blend Wall

Currently, any biofuel produced in the U.S. that is above the 10% blend limit needs to be reallocated to a higher blend mixture (e.g., E85), or exported for foreign consumption. However, U.S. demand for flex fuel vehicles does not warrant significant investments in E85 infrastructure. In 2011, the U.S. Energy Information Administration estimated that the U.S. is using nearly all the ethanol it can under the 10% blend wall (U.S. Energy Information Administration 2012). Some see the approaching of the blend wall as a consequence of the infrastructure limitations for higher blend fuels, such as transportation equipment, facilities, the availability of flex fuel vehicle options, and the failure of wholesale distribution systems (Zhang et al. 2010).

The blend wall has become a recent concern due to the decline in demand for gasoline (Snow 2013) and the expansion of the biofuel industry. The ability to export biofuels can serve as a short term option to the blend wall, due to 95% of all ethanol produced having been consumed domestically for the past decade, with the exception of 2006. However, there will still remain a need to increase the demand for higher blend mixtures in the U.S. (Zhang et al. 2010; EIA 2011)

There are 3.24 million flex fuel vehicles currently owned and operated in the United States as of 2015 [see www.EIA.org (viewed: 447 December 20, 2015)]. In the absence of policy, this is not sufficient to justify an increase in investments for flex fuel infrastructure. A station owner would need to invest between $50,000 and $200,000 to add a flex fuel tank to their station (Braeutigam 2009).

As more ethanol is forced into the higher blends of ethanol, ethanol prices will see a decline, relative to gasoline prices (Zhang et al. 2010). Depending on how responsive the blend wall shift is to higher blends, the total petroleum gasoline consumption may increase or decrease with a positive shift in the blend wall (Qiu et al. 2014). The response to the blend wall shift centers around the position of demand curve for ethanol blends above E10.

Due to the small size of the E85 market, some oil companies argue that there is no demand for ethanol beyond the blend wall, while ethanol producers argue that there may be demand, but the limits to the E10 + market have prevented expansion of ethanol consumption (Babcock and Pouliot 2013). The blend wall can serve as an effective constraint on demand for greater ethanol production, however, if producers are able to supply higher blend levels then demand will continue to meet supply (Tyner 2010). Consumption of 1 billion gallons of E85 is possible as long as the blended fuel price match a 6% reduction in fuel costs (with the assumption of

E10 price being $3.60/gallon), and costs decrease further as more E85 is consumed (Babcock and Pouliot 2013). The literature expressed several other concerns with extending the blend wall (Qiu et al. 2014). Some have argued that extending the blend wall will cause a deceleration of flex fuel vehicle adoption, and an increase in total petroleum gasoline demand (Zhang et al. 2010; Foster et al. 2011). Automakers are concerned about the lack of durability testing for higher levels of ethanol blends in cars already on the road, and will not provide extended warranties to consumers that consume fuels beyond the E10 limit (Braeutigam 2009). This indicates that the blend wall might not be as much of a physical barrier, as it is a political-economic barrier (Zhang et al. 2010).

7 Biofuels, Risk Management, and the Contractual Environment

Agriculture and energy markets are inherently volatile leading to periods of high profits punctuated with periods of busts. Volatility in the staple food markets can induce periods of boom and bust in the ethanol markets (Hochman et al. 2008). Thus, biofuel policies have caused farmers to be concerned over the availability of insurance for energy crops. Miao and Khanna (2014) argue that farmers are reluctant to switch over to energy crops because they believe the risk associated with them is not worth the reward of production. Insurance programs could decrease the risk premium that refineries need to pay farmers to grow energy crops, thus reducing production costs and increasing biofuel competitiveness with gasoline and other fossil fuels. However, Miao and Khanna (2014) show that subsidizing crop insurance is less effective at promoting miscanthus in the U.S. than an establishment of cost sharing subsidy. The authors show that the cost-effective energy crop insurance subsidy rate is 0% while the cost-effective establishment subsidy rate is 100%. Comparing these outcomes to the no policy intervention, crop insurance reduces the total costs of meeting the 1 billion gallon mandate by only 0.3% yet the establishment of cost-share subsidy reduces the cost by 34% albeit at the cost of growing miscanthus in less productive counties (because of incentives to diversify the crop portfolio).

Du et al. (2014) argue that when the supply of the contracted feedstock (in our case, energy crop) is uncertain, the supply of biofuel to the biorefineries will be less than under certainty and more capital will be allocated to internal production of the feedstock. Yang et al. (2015) show that the best contract arrangements are very different for farmers in different circumstances

- For a farmer with lower land quality, and a higher degree of risk aversion, farmers will be more willing to lease their land to the refinery for biomass production. This means the farmer who owns the land is guaranteed to earn a reasonable income, and the refinery who signs the lease to grow on the land takes the risk associated with growing energy crops.

- A farmer with low land quality and a low degree of risk aversion is more willing to grow energy crops themselves with a revenue sharing contract signed with the refinery.

Yang et al. (2015) show that biorefineries are more likely to prefer a more vertically integrated system, and grow its own energy crop when biomass yield and price risks are high to avoid paying high risk premiums to a risk averse farmer. Refineries are also likely to prefer to be more vertically integrated when variability in returns to crop production is high and risk averse farmers are more willing to choose leasing land for energy crop production. The biorefinery is likely to have the biggest risk for loss if they only offer a revenue sharing contract. Yang et al. (2015) assume that the choices for refineries are to offer

- a long-term lease with the landowner at a fixed rental rate per acre,
- a fixed price contract for a given quantity of biomass delivery by independent producers, and
- a price indexed to profitability of biofuel production for refineries.

The authors then show that the best choice for the refinery is to lease the land and undertake vertically integrated production.

8 Concluding Remarks

The calculation of GHG emissions of biofuels is based on life cycle analysis, which accounts for emissions throughout the biofuel supply chain. But because biofuel policies impact markets in subtle ways, they result in numerous indirect effects and thus question the current use of lifecycle analysis in regulating biofuels (Khanna and Crago 2012; Zilberman et al. 2013). Because energy is ubiquitous, introducing alternatives to fossil fuels (i.e., biofuels) results in myriad indirect effects that impact numerous markets. A noncompetitive energy market that is very capital intensive further convolutes the effect of the introduction of biofuels on markets. Regulation should either account for the various effects, or disregard them and simply require that biofuels meet a stricter standard than fossil fuels and that the standard becomes stricter with time.

A second conclusion that emerges from our analysis is that current generation biofuels failed to deliver in key areas: the emission benefits are much more limited than initially expected, and the cost of advanced biofuels much higher than many hoped. However, current biofuels did contribute to rural development and substantially affected the U.S. balance of trade—helping the U.S. become less energy dependent and reducing the U.S. trade deficit. This suggests much potential for advanced biofuels, which can potentially result in significant contribution to GHG savings. The challenge, however, remains to reduce their cost, which currently is prohibitively high.

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