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Biofuels: Potential Production Capacity, Effects on Grain and Livestock Sectors, and Implications for Food Prices and Consumers

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We examined four evolution paths of the biofuel sector using a partial equilibrium world agricultural sector model in CARD that includes the new RFS in the 2007 EISA, a two-way relationship between fossil energy and biofuel markets, and a new trend toward corn oil extraction in ethanol plants. At one extreme, one scenario eliminates all support to the biofuel sector when the energy price is low, while the other extreme assumes no distribution bottleneck in ethanol demand growth when the energy price is high. The third scenario considers a pure market force driving ethanol demand growth because of the high energy price, while the last is a policy-induced shock with removal of the biofuel tax credit when the energy price is high. Standard results hold where the biofuel sector expands with higher energy price, raising the prices of most agricultural commodities through demand side adjustment channels for primary feedstocks and supply side adjustment channels for substitute crops and livestock. On the other hand, the biofuel sector shrinks coupled with opposite impacts on agricultural commodities with the removal of all support including the tax credit. Also, we find that given distribution bottlenecks, cellulosic ethanol crowds marketing channels resulting in a corn-based ethanol price that is discounted. The blenders' credit and consumption mandates provide a price floor for ethanol and for corn. Finally, the tight linkage between the energy and agricultural sectors resulting from the expanding biofuel sector may raise the possibility of spillover effects of OPEC's market power on the agricultural sector.

Key Words: biofuel, EISA, ethanol, tax credit, world agricultural sector model

JEL Classifications: Q13, Q18, Q38

The biofuels industry experienced a period of enormous change in 2007 and 2008. World energy prices soared in the summer of 2008, as did grain prices and food prices in general. These market changes attracted attention to biofuel policies and eroded some of the political support that the sector had received. The 2008 farm bill reduced the size of the blenders' credit from \$0.51 per gallon to \$0.45 per gallon for corn-based ethanol and introduced a new

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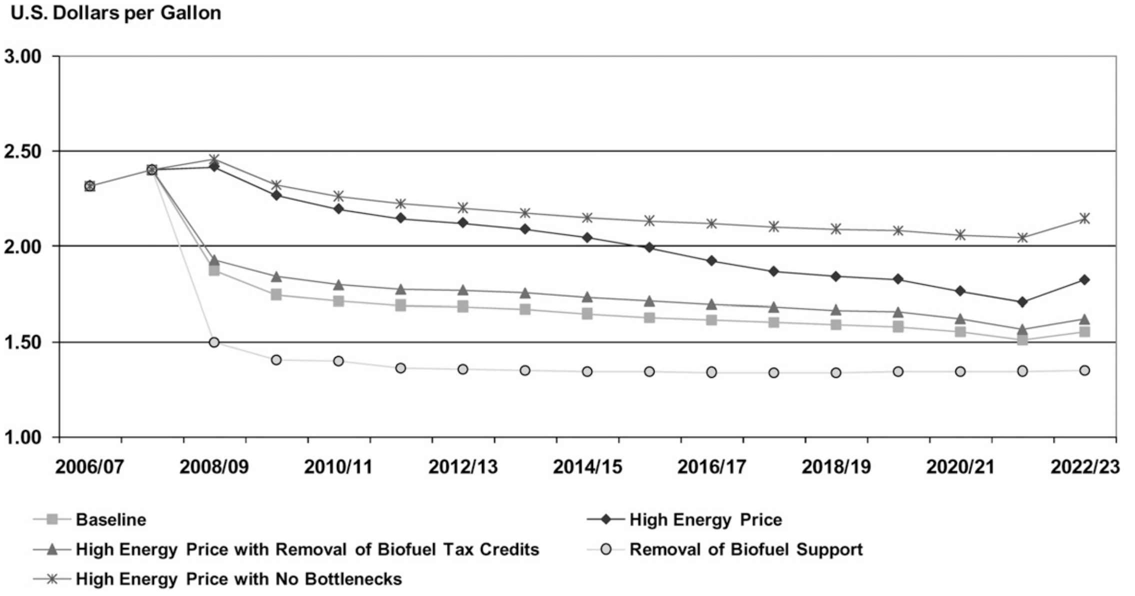

Figure 1. U.S. Ethanol Price, Crop Year

$1.01 per gallon blenders' credit for cellulosic ethanol. It also created a transportation subsidy for cellulosic ethanol producers. The Renewable Fuels Standard (RFS) of the 2007 Energy Independence and Security Act (EISA) mandated large quantities of starch-based ethanol and other advanced biofuels. With lower energy prices and a slightly reduced credit, the provisions of this act may become very important because it now appears unlikely that market forces will be sufficient to generate the use of ethanol required under the act.[1] In other related developments, the rapid production of ethanol in the U.S. is estimated to have a modest impact on U.S. gasoline prices (Du and Hayes, 2008). Also, high energy prices in general would increase farm-level production costs even as they increased output prices through biofuel production.

Tokgoz et al. (2007) analyzed the likely impact of the growing biofuel sector on the grain and livestock sectors and on consumer prices. This report updates that earlier paper to allow for the economic and policy changes previously described. The analysis in this article introduces the provisions of the EISA, endogenizes gasoline and ethanol prices, adjusts for the new blenders' credits, and increases international farm-level production costs when energy prices rise.

Specifically, this article examines four scenarios in the evolution of the biofuel sector. At one extreme, one scenario eliminates all support to the biofuel sector when the energy price is low, while the other extreme assumes no bottleneck (e.g., E85 [85% ethanol and 15% gasoline blend] distribution infrastructure constraint) in ethanol demand growth when the energy price is high. The remaining two scenarios are in-between cases: one scenario considers a pure market force driving ethanol demand growth because of the high energy price, while the remaining scenario is a policy-induced shock with removal of the biofuel tax credit when the energy price is high.

Model and Assumptions

The model and procedures used here are similar to those used in the earlier paper by Tokgoz et al. (2007) (and also documented in Tokgoz

[1] The RFS requires blenders to use a minimum of 9 billion gallons of renewable fuels in 2008. This mandated amount increases gradually to 36 billion gallons in 2022.

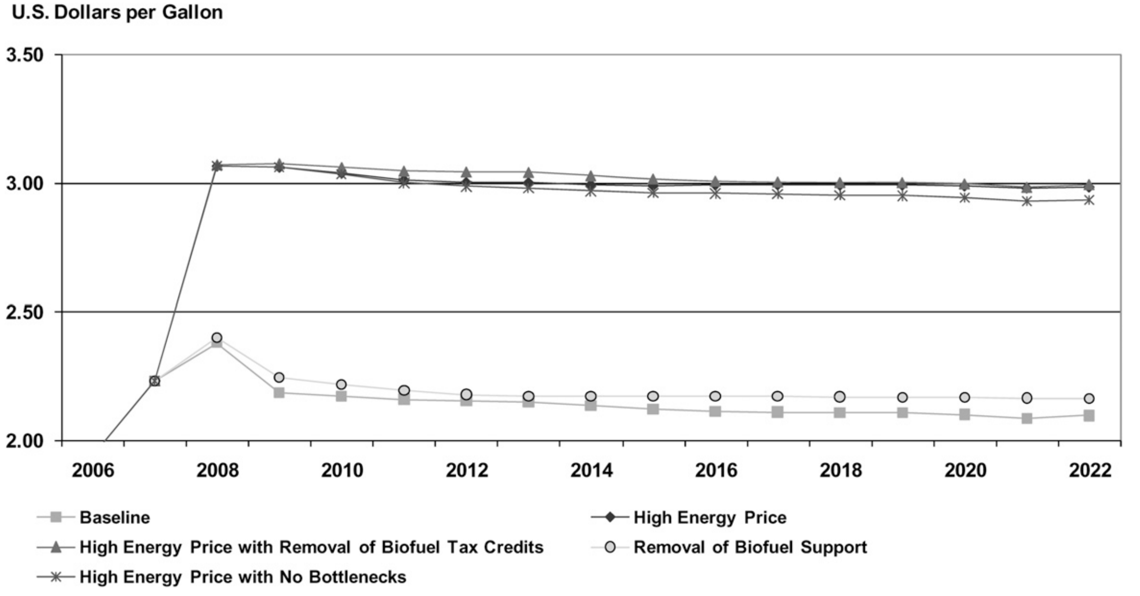

Figure 2. U.S. Gasoline Price, Calendar Year

et al., 2008); however, the list of authors is different. Specifically, a broad partial equilibrium model of the world agricultural economy is used to develop a baseline, and then energy prices and energy policies are changed in a series of scenarios. The model used in this analysis is called the FAPRI model, developed and maintained by the Food and Agricultural Policy Research Institute. The international component is performed by Iowa State, and its partner institution at the University of Missouri performs the U.S. agricultural and biofuel market and policy representations as well as calculations of government and consumer costs. The FAPRI model is used to explore the market effects and costs of actual and proposed

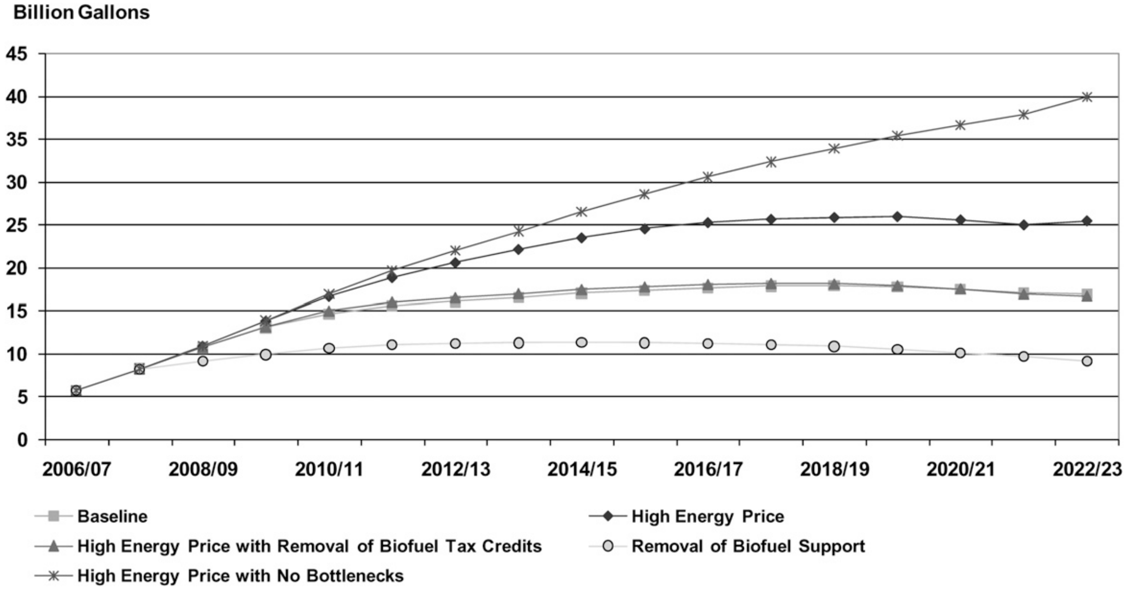

Figure 3. U.S. Ethanol Production from Corn

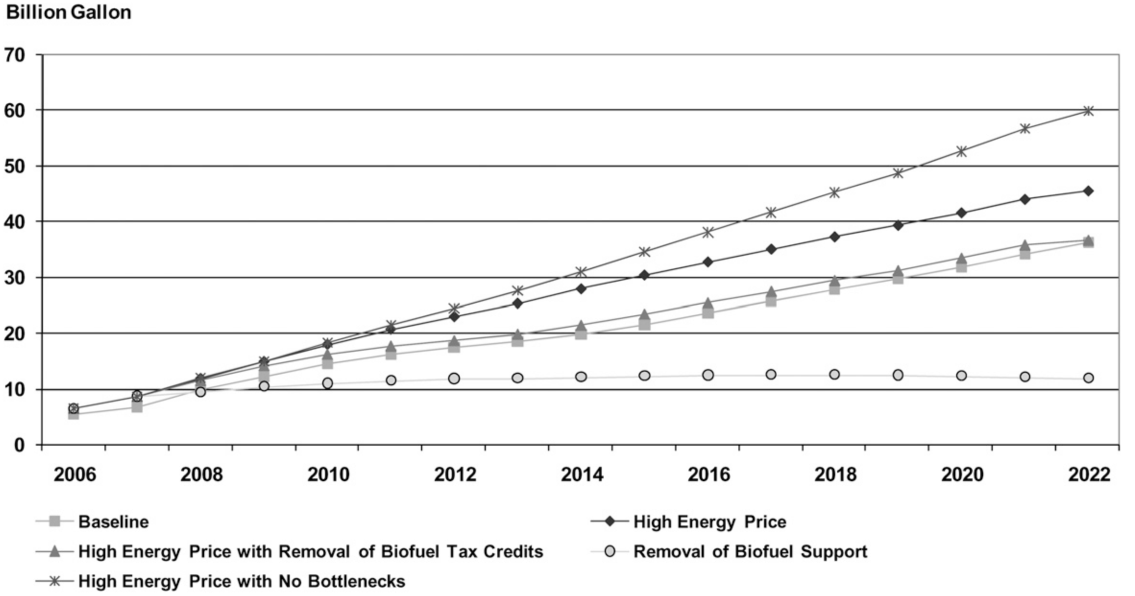

Figure 4. U.S. Ethanol Disappearance, Calendar Year

policies over a 10-year forward-looking period (FAPRI 2008). When Iowa State runs the model on its own at the Center for Agricultural and Rural Development, as was true in the Tokgoz et al. (2007) report, then the modeling system is called the CARD model.

The structure used is a modeling system that contains models of supply and demand and cross-commodity interactions for important temperate agricultural products, including ethanol and biodiesel, in all major producing and consuming countries.[2] This model has often been at the center of the "food versus fuel" debate and the "fuel versus carbon" debate because it can provide year-by-year projections of the impact of major agricultural developments in all of the important countries (see, for example, Searchinger et al., 2008).[3]

The individual agricultural sector models used are partial equilibrium, structural, non-spatial policy models. Parameters in the model are estimated, surveyed from the literature, or obtained from consensus of expert opinion. Two-way trade between countries is not projected. The FAPRI models include existing policy instruments such as price supports and border policies.

The baseline is set up using U.S. and international commodity models calibrated on data available as of January 2008. For any crude oil price, we calculate the price of unleaded gasoline through a price transmission mechanism.[4] This gasoline price in turn impacts ethanol demand and, together with the capacity of the ethanol industry, determines the price of ethanol (adjusted for the tax credit that gasoline blenders receive) and the incentive to invest in additional ethanol production capacity. Ethanol production is driven by the market price of ethanol or the mandated amount of ethanol, which then determines the demand for corn.

[2] The biofuel sector model structure is described at length in Thompson, Westhoff, and Meyer (2008).

[3] The computations for changes in greenhouse gas emissions from indirect land use changes in Searchinger et al. (2008) were based on a CARD study, Tokgoz et al. (2007), which included a scenario of a higher crude oil price in the U.S. and its consequent impacts on the U.S. and international ethanol, crop, and livestock markets.

[4] In the model, the refiners' petroleum product price index (RPPPI) is a function of the crude oil price (with an elasticity of 0.86), and the wholesale unleaded gasoline price is a function of the RPPPI (with an elasticity of 1).

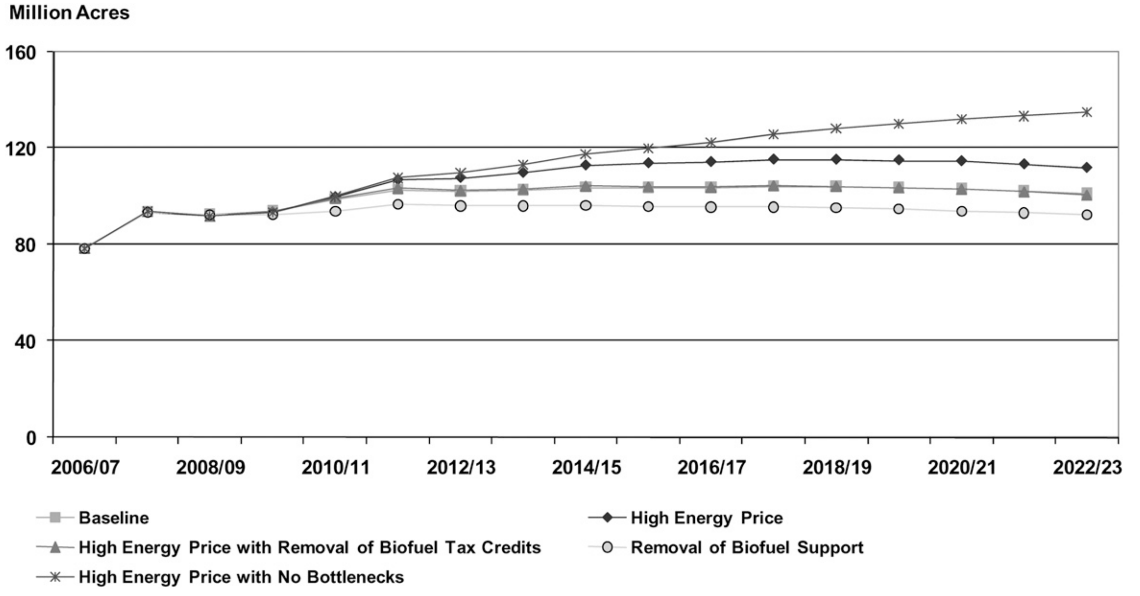

Figure 5. U.S. Corn Area

Investment in new biofuel plants will take place if the market price of corn allows a prospective plant to cover all the costs of ownership and operation.[5] The model is revised to allow for the impact of ethanol production on gasoline prices, a feature that was not included in Tokgoz et al. (2007). In this study, a two-way link between the U.S. ethanol and gasoline sectors is introduced. The gasoline price in the US is impacted by a change in the U.S. ethanol supply at a rate of $0.03 per billion gallons (Du and Hayes, 2008). When a higher crude oil price is introduced in the scenario, both U.S. ethanol production and consumption increase. The increase in ethanol production reduces the U.S. gasoline price, which in turn reduces E85 consumption since E85 is a substitute for gasoline as a fuel. With lower gasoline prices, consumers switch back to gasoline from E85. Thus, in this study, we have less U.S. ethanol expansion per unit change in the crude oil price and therefore a less dramatic shift in crop prices per unit change in the crude oil price. Lower crop price increases mean less crop area expansion in the U.S. and international countries.

Substantial revisions are made to the U.S. FAPRI model with a view to exploring how petroleum prices and biofuel policies affect the long-run equilibrium rather than the immediate effects that are addressed elsewhere (Westhoff, Thompson, and Meyer, 2008). Long-run equilibrium prices for ethanol, crops, and livestock are achieved when there is no incentive to construct new plants and no incentive to expand or contract livestock and dairy production in comparison with the incentives in the baseline. Here, in contrast to the normal approach with this model, the markets are pushed to a set of outcomes that are broadly consistent with such long-run expectations. There are some exceptions. For example, trends in crop yields are subject to small or no price effects even though changing trends could have important effects (see Kalaitzandonakes et al., 2008). Other long-run relationships, such as a zero crush margin in ethanol and feed markets and the elimination of transportation

[5] For wet mills, the capital costs total $0.34 per gallon (calculated at 8% interest amortized over 10 years for an average ethanol plant). Similarly, capital costs for dry mills are $0.24 per gallon. In addition to the value of corn, operating costs also include the cost of electricity, fuel, labor, and other operating costs, which average $0.78 per gallon for wet mills and $0.65 per gallon for dry mills over the projection period.

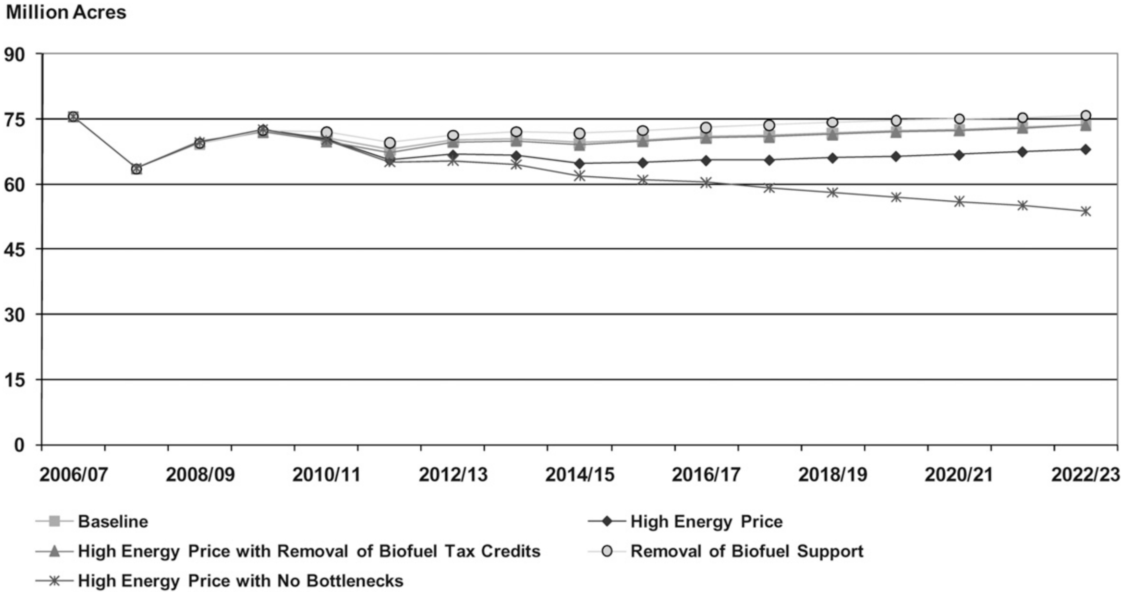

Figure 6. U.S. Soybean Area

bottlenecks, are imposed only in one scenario. While the intention is to represent the long-run equilibrium, it is nevertheless a partial one, as noted earlier. These models do not extend to represent equilibria in input markets, such as land, or in certain closely related markets.

Perhaps a more directly relevant exception, the long-run equilibrium in ethanol markets in most scenarios is one that incorporates bottlenecks in ethanol distribution or adoption. As usual, the model measures demand for ethanol based on relative prices, but also on the availability of E85 pumps and flex-fuel cars. In the

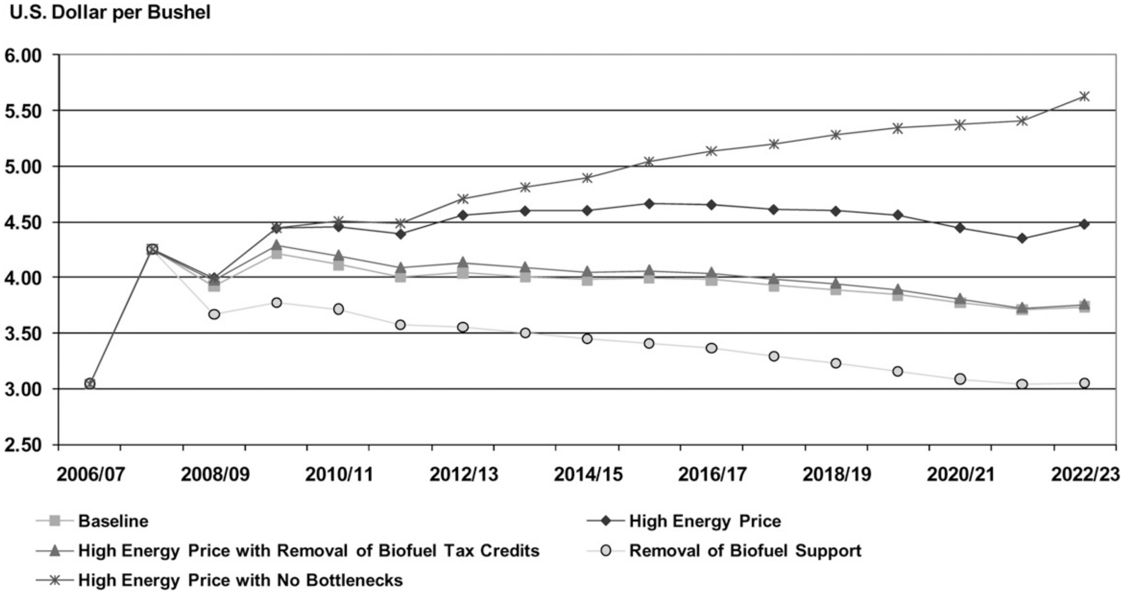

Figure 7. U.S. Corn Prices

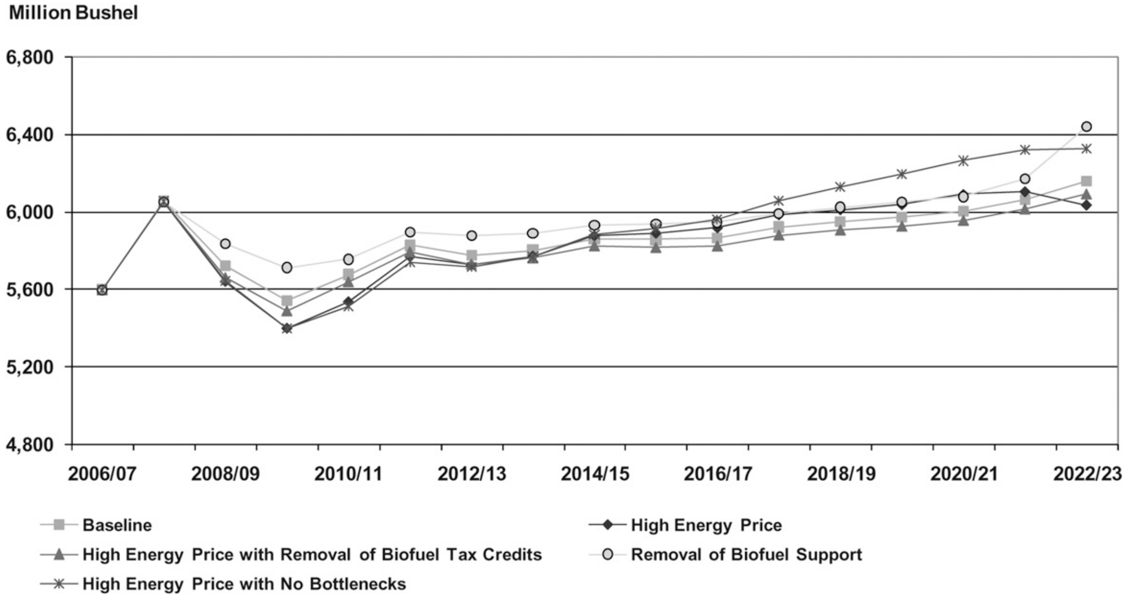

Figure 8. Feed Utilization of Corn in the United States

baseline and three of the scenarios described below we use this feature of the model to estimate the equilibrium ethanol price. In the "no bottleneck, high energy price" scenario we turn off this model and assume that ethanol sells at its energy value relative to gasoline. This scenario implicitly assumes that all bottlenecks in the ethanol sector are solved by the end of the projection period. Other changes in the ethanol market representation relative to the Thompson, Westhoff, and Meyer (2008) study include some simplifications to reduce the complexity required to solve for an implicit retail ethanol price as well as the prices of ethanol associated with different mandates. The determination of the long-run equilibrium relationship between gasoline and ethanol prices is by no means clear. Some states subsidize ethanol production and others do not, so the gasoline-to-ethanol price relationship differs across states. This makes it difficult to find a weighted average national markup because we do not yet know the consumption weights to apply to each state.

In the high energy price scenario, "bottlenecks" in the adoption and distribution of ethanol are assumed to still exist. Thus, ethanol demand did not increase as much as it could have in response to a crude oil price increase, if these infrastructure problems were solved. Therefore, even though the crude oil price shock is higher relative to the Tokgoz et al. (2007) analysis, ethanol demand does not increase as much as a "no bottleneck" scenario. In this scenario, the wholesale price of ethanol ($1.75 per gallon) minus the tax credit ($0.51 per gallon) was $1.24 per gallon. The wholesale price of gasoline was $2.98 per gallon. Thus, ethanol is selling much lower than its energy value of $1.99 per gallon (2.98 $\times$ 0.667) because of bottlenecks. In addition, there is a separate specification for ethanol demand by blenders, and the profit margin for ethanol blenders is still positive. If there were no bottlenecks, this profit margin would have approached zero in equilibrium.

In Tokgoz et al. (2007), there was no differentiation between ethanol demand by blenders and ethanol demand by final consumers. Furthermore, when the crude oil price was increased $10 per barrel, it was assumed that there is "no bottleneck" in the adoption and distribution of ethanol in the U.S. Thus, ethanol demand expanded more relative to a case in which there is a bottleneck. In this scenario, the wholesale price of ethanol ($1.92 per gallon) minus the tax credit ($0.51 per gallon) was $1.41 per gallon. The wholesale price of gasoline was $2.13 per gallon. Thus, ethanol was selling very close to its energy value of $1.42 per gallon (2.13 × 0.667).

For the purposes of the "no bottleneck" scenario discussed here, the basic calculations of the breakeven ethanol price follow the Elobeid et al. (2007) report. In the other scenarios conducted here, the long-run relationship is not imposed so as to allow for bottlenecks in ethanol distribution.

Specific Changes Made to the Model for This Analysis

In order to differentiate the results presented below from earlier work by Tokgoz et al. (2007) and Elobeid et al. (2007), we provide additional detail on the changes made to the model structure.

Model Structure

First, the projection period is extended to the 2022 calendar year or the 2022/23 marketing year. Second, ethanol production capacity is fixed in 2008/09 and 2009/10 based on construction reports. Beyond that, the model solves for all endogenous variables, including the ethanol production capacity. Third, net revenue of dry mills is revised relative to the base model used to include corn oil sold as a separate coproduct equivalent to edible corn oil (1.6 lbs per bushel of corn). Separating corn oil causes revisions as well to the representation of distillers grains in terms of yield, which falls to 15.4 lbs of distillers grains per bushel of corn, and prices. All of the dry mill plants are assumed to have adopted this procedure by 2022. Based on an analysis of the feed value of these low-oil distillers grains, this product is assumed to sell at a 20% discount relative to traditional distillers grains. The additional corn oil supply dampens vegetable oil prices in U.S. and world markets, relative to Tokgoz et al. (2007), and may explain the muted response of soybean area in Brazil.

Furthermore, international cotton and rice models, which were not included in the Tokgoz et al. (2007) study, are also run. This also changes the scenario results, since it allows more cross-price impacts for crop area allocation. International crop area models were improved as well. Specifically, in area equations for each crop, cross-price impacts from other crops were reevaluated, and many crops were added. For example, Brazilian soybean area harvested is a function of the soybean price, wheat price, corn price, sugarcane price, lagged area, and the fertilizer cost index. In Tokgoz et al. (2007), Brazilian soybean area harvested is a function of the soybean price, wheat price, and a positive trend. That is one of the reasons why Brazilian soybean area expanded less in the present study relative to Tokgoz et al. (2007).

Energy Prices

The results depend heavily on assumptions made about energy prices. In Tokgoz et al. (2007), it was assumed that ethanol prices and, by extension, corn prices were proportional to crude oil prices. Tokgoz et al. (2007) did not endogenize gasoline prices relative to crude oil prices, natural gas prices, or farm-level production costs. In the scenarios reported here, the wholesale price of gasoline is responsive to the changes in ethanol supply at the rate of $0.03 per billion gallons based on a linear extrapolation of the parameter estimated by Du and Hayes (2008). Crude oil price projections were taken from NYMEX and were extended to 2022 using a simple linear trend. A regression was used to express the price of natural gas as a function of the crude oil price so as to generate updated natural gas prices. Variable costs (e.g., fertilizer) in the U.S. and the world adjust to changes in energy prices based on standard approaches used in other work (Westhoff, Thompson, and Meyer, 2008). The reports by Tokgoz et al. (2007) and Elobeid et al. (2007) ignored the impact of higher crude oil prices on international grain production costs. In the present study, higher crude oil prices in the U.S. increase costs of production for all crops. Thus, for a given crude oil price increase and the associated expansion in ethanol production, there will be less of an increase in the U.S. crop area or reallocation among crops. The increase in fertilizer costs caused by a crude oil price increase is also introduced in the international crop models for major producers (Argentina, Australia, Brazil, China, EU-27, India, Canada, Russia, Ukraine, and Commonwealth of Independent States [CIS]).[6] These revisions lead to effects that can offset some of the indirect effects on crop area in these countries, so area expansion is dampened when U.S. biofuel use causes crop prices to increase. Our findings in the present study are also based on the expectation that higher crude oil prices also increase nonfeed costs in the U.S. livestock and dairy sectors, reducing supply as a result, and relieving part of the feed demand pressure on corn. This effect reduces some of the original increase in crop prices. In the Tokgoz et al. (2007) study, livestock supply was maintained with changes in the crude oil price.

Renewable Fuels Standard

The new RFS establishes targets for biofuel use, of which up to 15 billion gallons can be met by conventional biofuels by 2015. Corn-based ethanol is the most likely source of conventional biofuels in the RFS. The RFS also mandates 16 billion gallons of cellulosic biofuel by 2022 and 1 billion gallons of biodiesel by 2012. The FAPRI model allows corn-based ethanol to expand beyond the mandates when it is profitable to do so. When economic conditions indicate that the ethanol producers are losing money, we reduce the proportion of ethanol production capacity that is utilized so that the remaining facilities are at least covering their variable costs.

The RFS mandates enormous quantities of cellulosic ethanol, which we assume not to be waived in these experiments, but it also imposes thresholds for net carbon emission reductions. For this exercise, we assume that cellulosic ethanol from traditional crop ground will not meet the standards. This is assumed because the EISA specifies that indirect land use impacts be taken into account in calculating net carbon emissions. Searchinger et al. (2008) estimated that the cellulosic ethanol produced from crop ground does not meet net carbon emission standards once indirect land use impacts are accounted for. In this sense, the EISA appears to have contradictory provisions. We get around this contradiction by assuming that the cellulosic provisions of the act do not result in the removal of land from crop production, even though it is difficult to imagine that potentially large changes in the value of output from land, even from forest area, will have no consequences for the amount of land devoted to the crops included in this study.

The cellulosic provisions do, however, have an important impact on the model. This is true because cellulosic ethanol exacerbates the bottlenecks in the ethanol distribution system in the event that such factors exist even in the long run. This additional ethanol production therefore forces down ethanol and corn prices without any offsetting positive impact on crop prices that would have occurred had we assumed that cellulosic ethanol competed for cropland. This assumption, which may or may not reflect how the policy will be implemented, coupled with the negative impact of ethanol production on gasoline prices (and by extension on ethanol prices), means that the RFS is more likely to have a negative effect on crop prices than may previously have been expected.

Scenarios

We ran a baseline scenario and four other scenarios. We chose scenarios that cover a wide range of issues that are of interest to significant stakeholders in the evolution of the biofuel sector. One extreme scenario considers sustainability of the biofuel sector with all forms of support eliminated when the energy price is at $75 per barrel. Two scenarios consider a purely market driven expansion of the biofuel sector due to the high energy price, at $105 per barrel, with one of the scenarios further assuming that there is no bottleneck in the growth

[6] The U.S. crude oil price is used as a proxy for the world crude oil price. Therefore, an increase in the U.S. crude oil price means higher crude oil prices in these countries and higher costs of production for farmers.

of ethanol demand. The remaining scenario considers policy effects with a pure policy shock of removing the biofuel tax credit when market incentives are already in place in the form of a high energy price

For the baseline, we used the provisions of the EISA and the energy provisions of the farm bill of 2008, coupled with a crude oil price of approximately $75 per barrel. In our "High Energy Price" scenario, we increased crude oil prices by 40%, to $105, and increased natural gas prices by 19%. These had follow-on impacts on fertilizer prices and other farm-level production costs. Further effects, such as on transportation and processing costs or wider economic impacts in the U.S. and abroad, are ignored. This high energy price scenario resulted in large market-driven expansion of ethanol production relative to the baseline. Our "High Energy Price with Removal of Biofuel Tax Credits" scenario helps determine the impact of the credits on ethanol production at this high energy price. For this scenario, we ran the high energy price scenario without biofuel tax credits. In our third scenario, labeled "Removal of Biofuel Support," we ran the baseline $75 crude oil price scenario with the elimination of the tax credits, the RFS mandate, and the import tariffs and duties. The "No Bottleneck" scenario explores a case in which the energy price is high and there are absolutely no bottlenecks in the delivery mechanism for ethanol. This means that ethanol sells at its energy value, which might be viewed as a long-run equilibrium in this market. This assumption allows comparison with the results of Tokgoz et al. (2007).

Results

Impacts of high energy prices and policies on agricultural markets are shown as percent changes of results from four scenarios compared with those from the baseline. All scenarios are summarized in Table 1. The country- and crop-specific results are available on request and contain hundreds of tables of data. Figures 1 through 8 present the key results graphically. Appendix 1 shows only the results for 2022 for the U.S. crop, biofuel, and livestock sectors.

Baseline

In the baseline scenario with crude oil at $75 per barrel, ethanol production from corn reaches 16.9 billion gallons by 2022 and uses 5.9 billion bushels of corn. Total ethanol production is 32.9 billion gallons. The ethanol price (wholesale) is at $1.55 per gallon, and ethanol disappearance is 36.9 billion gallons. The price of corn reaches $3.73 per bushel, while corn area planted is 101.2 million acres (93.6 million acres harvested). Soybean area planted reaches 73.6 million acres, and the projected soybean price is $9.79 per bushel. Biodiesel production is 1.2 billion gallons, and the equilibrium biodiesel price is $5.47 per gallon.

High Energy Price Scenario

With a crude oil price of $105 per barrel, total ethanol production from corn increases by 50% relative to the baseline. The ethanol price increases by roughly 18%, and ethanol disappearance increases by 23%. The price of corn increases by almost 20%, and corn net exports decline by 23%. Soybean area planted decreases by 7%, and the soybean price increases by 9%. In response to the higher corn prices, countries such as Brazil, Argentina, and China increase their corn area. Soybean area increases in Brazil and China but decreases slightly in Argentina, as corn bids area away from soybeans. Total crop area in Canada, Argentina, Brazil, and China increases by 0.003%, 0.12%, 1.92%, and 0.34%, respectively.

High Energy Price with Removal of Biofuel Tax Credits Scenario

When we remove the biofuel tax credits from the high crude oil price scenario, total ethanol production from corn declines by 35% relative to the case of a high petroleum price and a continuation of biofuel support policies. The ethanol price declines by 11%, ethanol disappearance declines by 19%, and the corn price falls by 16%. High crude oil prices, coupled with a removal of the biofuel tax credits, make ethanol more expensive, thus reducing the

Table 1. Summary Impact on Production, Trade, and Prices (%)

	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Production				
Wheat	−2.33	0.10	2.60	−6.98
Corn	11.03	−0.82	−8.69	35.02
Ethanol	25.85	−0.72	−72.05	69.96
Soybean	−8.24	0.09	3.51	−29.14
Soybean meal	−4.20	−0.26	1.06	−11.44
Soybean oil	−4.20	−0.26	1.06	−11.44
Beef	3.14	0.39	−1.62	
Pork	−8.64	−0.35	8.85	
Broiler	−6.04	−0.46	1.63	
Turkey	−5.28	−0.36	1.94	
Butter	−1.36	−0.49	0.84	
American cheese	−0.84	−0.29	0.51	
Nonfat dry milk	−2.59	−0.93	1.58	
Trade				
Wheat	−6.79	0.60	7.11	−21.20
Corn	−23.36	0.56	23.91	−56.10
Ethyl alcohol	0.00	0.00	−33.85	0.00
Soybean	−19.57	0.93	10.17	−76.81
Soybean meal	0.00	0.00	0.00	0.00
Soybean oil	20.65	15.56	50.99	57.95
Beef	−24.50	−2.56	15.17	
Pork	−61.39	−1.96	66.48	
Broiler	−17.08	−1.52	1.65	
Turkey	−17.47	−1.57	1.64	
Butter	0.00	0.00	0.00	
American cheese	0.00	0.00	0.00	
Nonfat dry milk	−5.28	−1.95	3.17	
Prices				
Wheat, farm price	9.36	0.93	−8.98	20.73
Corn, farm price	19.56	0.65	−18.39	50.72
Ethanol, FOB Omaha	17.59	4.34	−12.96	38.40
Soybean, farm price	8.87	−0.47	−9.87	22.71
Soybean meal, 48% meal price	15.06	1.22	3.99	32.01
Soybean oil price	−4.28	−2.35	−16.77	−3.42
Cotton, farm price	4.09	1.62	−5.68	7.75
Beef, wholesale price	3.16	−0.09	−2.86	
Pork, wholesale price	12.45	0.39	−9.99	
Broiler, 12-city wholesale	10.27	0.54	−4.95	
Turkey, east region, wholesale	10.47	0.52	−5.80	
Egg, NY grade A lg wholesale	11.17	0.46	−7.54	
Butter, CME wholesale price	15.99	5.72	−9.26	
Cheese, Am., 40#, CME wholesale price	3.63	1.30	−2.10	
Nonfat dry milk, AA wholesale price	1.57	0.52	−0.99	

demand. Consequently, demand for corn for ethanol use declines and the price of corn falls. This means less area for corn, which frees up land for other crops such as wheat and soybeans. With less corn going into ethanol, corn used for exports and feed increases. Without the tax credit, biodiesel is no longer competitive in the world market and biodiesel export demand drops, and therefore production declines. The remaining biodiesel production is enough to meet the domestic demand, which is mandated and binding in the assumed absence of any imports. In response to the lower corn prices, Brazil, Argentina, and China decrease their corn area. Soybean area also declines, by 1% in Brazil and by 0.2% in Argentina.

Removal of Biofuel Support Scenario

In this scenario, the energy price is low (at $75) and there is no political support of any kind. As a result, ethanol production from corn declines by 72% from baseline levels, and there is assumed to be zero production of cellulosic ethanol. The ethanol price increases by 13%, and ethanol disappearance declines by 68%. The corn price falls by 18%, whereas corn area planted decreases by 9%, and corn exports rise by 24%. Corn used for exports and for feed increases. Less area going into corn means more area is available for other crops such as wheat and soybeans. Without the biofuel support, biodiesel exports increase because of the decline in domestic demand.

High Energy Price with No Bottlenecks Scenario

We conclude with a more speculative scenario that is intended for comparison with the findings of Tokgoz et al. (2007). This scenario assumes that the U.S. market can absorb all of the ethanol that is mandated by the RFS plus any additional ethanol that is produced in response to market forces. This ethanol sells for its energy value relative to gasoline. The $0.45-per-gallon tax credit is added to the retail price to determine the price corn-based ethanol producers receive. It also assumes a high energy price and the continuation of existing support levels.

Corn-based ethanol production reaches 39.8 billion gallons, and ethanol disappearance reaches 59.8 billion gallons, or approximately 40% of gasoline use. The ethanol sector uses more than 13 billion bushels of corn, and the market price of corn is $5.63. But this magnitude of market effects calls into question some of the structural elements of this representation, such as the lack of a yield response to the very high prices observed in this scenario.

Food Price Inflation

As previously described, changes in energy prices or biofuel policies lead to changes in corn prices and the prices of other crops that compete with corn for land. In equilibrium, part of these price impacts is transferred to consumers through changes in prices for livestock, dairy, and bakery products. The model used here does allow us to measure the direct impact of these price changes on the Consumer Price Index (CPI) for food. The mechanism used to accomplish this is an accounting identity that measures livestock production costs under each scenario and then assumes that the livestock producer passes along these costs in full. Similarly, we assume that the retailer passes along these extra production costs on a dollar-for-dollar basis since the model does not allow us to measure second-round costs such as might happen if individuals in service sector jobs increased prices in response to higher food costs. The model also does not allow retailers or processors to increase their markup in dollar terms. The absence of these two possible responses means that the food price changes shown below represent a minimum impact. These price impacts would be substantially higher if we assumed a percentage markup rather than a dollar-for-dollar markup.[7]

[7] Light and Shevlin (1998) suggested that a 100-point increase in the feed grain price index transferred a 4.1-point increase in the CPI for food and beverage based on monthly data from 1967 through 1997, which supports our findings and suggestions.

The list below shows the percent change in the prices of various food products in response to each dollar increase in the cost of corn, coupled with equilibrium changes in the prices of other grains and in livestock products.

Percent of Changes of CIP Food Indices Resulting from a $1/bu Increase in Price of Corn

FOOD (Total)	0.8%
Food at Home	1.0%
Cereal and Bakery	0.4%
Meat	2.9%
Beef	3.7%
Pork	3.2%
Poultry	3.5%
Eggs	5.5%
Fish	0.0%
Dairy	1.7%
Milk	2.1%
Cheese	1.8%
Ice Cream	0.6%
Fruit and Vegetables	0.0%
Other Food at Home	0.2%
Sugar and Sweets	0.7%
Fats and Oils	0.7%
Other Prepared Items	0.0%
Nonalc. Beverages	0.3%
Food Away From Home	0.7%

The results indicate that the price impacts are greatest for grain-intensive products such as eggs and poultry and that impacts on value-added products such as dairy and beverages are much smaller. In general, the price impacts are very modest when one considers the relatively large percentage impact on feed costs that are represented by a one-dollar increase in corn prices.

Discussion of the Difference in Results between the Two Studies

We compare the high energy price scenarios of this study and Tokgoz et al. (2007). Below are the percent changes in scenario results for the two studies for the higher crude oil price scenario scaled by the change in U.S. corn-based ethanol production in billion gallons for each case. For this study, percent changes are divided by the change in ethanol production of 8.5 billion gallons. For Tokgoz et al. (2007), percent changes are divided by the change in ethanol production of 14.5 billion gallons.

In the present analysis, the U.S. corn price increased by 2.3%, corn area planted increased by 1.22%, and corn exports declined by 2.74%. In response to higher corn prices, soybean area planted decreased by 0.88%. This increased the soybean price by 1.04% and decreased soybean exports by 2.29%. Wheat area planted also declined by 0.25%, leading to a wheat price increase of 1.1%. U.S. wheat exports declined by 0.67%. Higher U.S. crop prices and lower U.S. crop exports lead to higher crop prices in the world markets and changes in crop area allocation as seen in Table 2.

Table 2. Difference Area in Results Between the Two Studies (%)

	Present Analysis	Tokgoz et al. (2007)
Brazil		
Corn	0.42	0.40
Soybean	0.29	0.44
Wheat	−0.17	−0.04
Rice	−0.02	
Argentina		
Corn	0.50	0.91
Soybean	−0.02	−0.08
Wheat	−0.08	−0.06
Rice		
China		
Corn	0.27	0.19
Soybean	0.02	0.03
Wheat	0.09	0.09
Rice	−0.14	
India		
Corn	0.30	0.48
Soybean	0.13	0.17
Wheat	0.01	0.15
Rice	−0.05	
Indonesia		
Corn	0.47	0.61
Soybean		
Wheat		
Rice	0.02	
Philippines		
Corn	0.28	0.66
Soybean		
Wheat		
Rice	0.18	
Mexico		
Corn	0.13	0.15
Soybean	0.13	
Wheat	0.19	0.37
Rice	0.13	

In Tokgoz et al. (2007), the U.S. corn price increased by 2.78%, corn planted area increased by 1.52%, and corn exports declined by 4.27%. Soybean planted area decreased by 0.97%, and the soybean price increased by 1.36%. Soybean exports declined by 1.97%. Wheat planted area declined by 0.64% and the wheat price increased by 1.21%. U.S. wheat exports declined by 2.13%. In response to these changes in the U.S. crop markets, world crop prices increased and crop area changed, as shown in Table 2.

The international crop area responses are muted in the present analysis relative to Tokgoz et al. (2007) because of the changes in model structure and scenario assumptions discussed above. Table 2 compares the international crop area changes between the two studies scaled by the change in U.S. corn-based ethanol production in billion gallons for each case.

Conclusions

This report represents a single iteration in the ongoing attempt to understand the interaction between biofuels and world agriculture. When compared against other similar reports released recently, the key contributions of this report are to include the Renewable Fuels Standard of the Energy Independence and Security Act of 2007, to allow for a two-way relationship between fossil energy markets and biofuel markets, to incorporate the recent trend toward corn oil extraction in ethanol plants, and to allow for the demand-side impacts of cellulosic ethanol production.

One result that stands out is the likely impact of mandated ethanol production on corn-based ethanol prices. The ethanol sector has serious and long-term problems with bottlenecks in the distribution system, and these problems are exacerbated by large consumption mandates. If the provisions of the EISA are followed in the way that we assume here, then corn-based ethanol prices will be heavily discounted as cellulosic ethanol crowds marketing channels. One might normally have expected these bottlenecks to be solved by market forces, but the companies that are in the best position to solve these problems are the refiners and petroleum retailers that sometimes benefit from low ethanol prices.

A second result that stands out in the scenarios is that the ethanol blenders' credit and the biofuel consumption mandate offer a very effective support to the corn ethanol sector. When energy prices are high such that the RFS is exceeded, then corn ethanol expands to higher energy prices; when energy prices are low then corn ethanol production responds to corn ethanol mandates.[8] The combination of these two supports effectively provides a price floor for ethanol and for corn.

It is very obvious from the results that the size and impact of the biofuel sector is extremely dependant on energy prices and support policies. Because there is so much uncertainty about these exogenous forces, the real value of the scenario results presented here is to compare results across energy price and policy scenarios rather than to use any one scenario as a projection.

Finally, this study shows strong evidence of the increasingly tight linkage between the energy and agricultural sectors as a result of the expanding biofuel sector. That is, to a large degree, energy price determines biofuel price and thus the prices of agricultural commodities as well. There are significant implications of this study that have not been fully explored. For example, on the one hand, although the agricultural sector is often cited as a classic case of a competitive market, to the extent that the energy price is influenced by OPEC's market power, will the exercise of this market power have direct spillover effects on the market performance of the agricultural sector? On the other hand, can the biofuel sector grow to a size that is considerable enough to erode OPEC's market power when a significant portion of the energy market is outside OPEC's control and discipline?

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Appendix 1. Numerical Results for U.S. Crop and Livestock Sectors in 2022

U.S. Wheat Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Planted area (million acres)	60.7	59.4	60.8	62.1	56.9
Yield (bushels/acre)	47.1	47.1	47.1	47.1	47.0
Production (million bushels)	2,403	2,345	2,405	2,465	2,235
Imports (million bushels)	107	112	107	101	119
Exports (million bushels)	1,137	1,073	1,143	1,205	931
Domestic use (million bushels)	1,370	1,386	1,366	1,358	1,433
Feed, residual (million bushels)	200	225	197	178	284
Seed (million bushels)	86	84	86	88	80
Food, other (million bushels)	1,085	1,077	1,084	1,092	1,069
Farm price (U.S. dollars/bushel)	5.35	5.87	5.40	4.87	6.46
Net returns (U.S. dollars/acre)	120.56	136.75	114.63	97.97	164.07

* Long-run equilibrium

U.S. Rice Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Planted area (million acres)	3.38	3.27	3.29	3.38	3.14
Yield (pounds/acres)	7,965	7,970	7,969	7,965	7,978
Production (million cwt.)	255.9	247.7	249.3	256.2	237.8
Imports (million cwt.)	27.6	27.6	27.6	27.6	27.5
Exports (million cwt.)	138.8	131.5	132.5	138.5	121.9
Domestic use (million cwt.)	144.5	143.5	144.1	145.1	143.3
Farm price (U.S. dollars/cwt.)	12.75	13.45	13.00	12.26	13.57
Net returns (U.S. dollars/acre)	371.82	373.45	337.22	332.77	383.92

* Long-run equilibrium

U.S. Corn Supply and Utilization *

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Planted area (million acres)	101.2	111.9	100.4	92.5	134.8
Yield (bushels/acre)	183.7	183.9	183.8	184.0	184.1
Production (million bushels)	17,190	19,106	17,049	15,696	23,209
Imports (million bushels)	15	15	15	15	15
Exports (million bushels)	3,626	2,780	3,647	4,490	1,600
Domestic use (million bushels)	13,598	16,443	13,447	11,218	21,706
Feed, residual (million bushels)	6,154	6,032	6,091	6,438	6,322
Fuel alcohol (million bushels)	5,886	8,871	5,801	3,210	13,872
HFCS (million bushels)	592	584	590	594	570
Seed (million bushels)	25	28	25	23	35
Food, other (million bushels)	940	927	940	953	908
Farm price (U.S. dollars/bushel)	3.73	4.48	3.76	3.05	5.63
Net returns (U.S. dollars/acre)	381.43	501.32	368.32	256.33	713.67

* Long-run equilibrium

U.S. Ethanol and Coproduct Supply and Use*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Ethanol					
Production (million gallons, crop year)	32,890	41,489	32,653	9,194	55,901
From corn (million gallons, crop year)	16,878	25,456	16,630	9,184	39,838
From other feedstocks (million gallons, crop year)	12	34	23	10	63
Cellulosic (million gallons, crop year)	16,000	16,000	16,000	0	16,000

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Net imports (ethyl alcohol) (million gallons, crop year)	4,000	4,000	4,000	2,646	4,000
Disappearance (million gallons, crop year)	36,856	45,428	36,624	11,865	59,761
Conventional (million gallons, crop year)	16,847	25,403	16,606	9,211	39,714
Cellulosic (million gallons, crop year)	16,000	16,000	16,000	0	16,000
Other advanced ethanol (million gallons, crop year)	4,009	4,025	4,017	2,654	4,047
Ending stocks (million gallons, crop year)	1,826	2,242	1,811	652	2,945
Fuel prices					
Petroleum, ref. acquisition (dollars/barrel, crop year)	74.91	104.91	104.91	74.91	104.91
Unleaded gasoline, retail (dollars/gallon, crop year)	2.75	3.62	3.64	2.78	3.57
Ethanol, FOB Omaha* (dollars/gallon, crop year)	1.55	1.82	1.62	1.35	2.15
Cellulosic* (dollars/gallon, crop year)	3.32	2.72	2.49	3.09	3.09
Other advanced* (dollars/gallon, crop year)	1.55	1.82	1.62	1.35	2.15
Ethanol, implied retail (dollars/gallon, crop year)	1.73	2.07	2.28	1.96	2.39
Distillers grains					
Production (dry equivalent) (thousand tons, Sept.–Aug. year)	43,020	65,481	42,252	22,640	103,951
Domestic use (thousand tons, Sept.–Aug. year)	36,521	37,338	37,936	21,943	37,191
Net exports (thousand tons, Sept.–Aug. year)	6,499	28,143	4,316	696	66,761
Price, Lawrenceburg, IN (U.S. dollars/tons, Sept.–Aug. year)	133.39	155.00	129.91	109.47	194.63
Com gluten feed					
Production (thousand tons, Sept.–Aug. year)	9,071	9,353	9,138	8,969	9,218
Domestic use (thousand tons, Sept.–Aug. year)	7,898	8,249	7,945	7,694	8,275
Net exports (thousand tons, Sept.–Aug. year)	1,173	1,104	1,193	1,275	943
Price, 21%, IL points (U.S. dollars/tons, Sept.–Aug. year)	93.70	110.15	92.72	78.06	139.23
Com, gluten meal					
Production (thousand tons, Sept.–Aug. year)	2,387	2,461	2,405	2,360	2,426
Domestic use (thousand tons, Sept.–Aug. year)	1,151	1,232	1,169	1,128	1,209
Net exports (thousand tons, Sept.–Aug. year)	1,236	1,230	1,236	1,233	1,217
Price, 60%, IL points (U.S. dollars/tons, Sept.–Aug. year)	327.96	357.72	330.56	337.85	403.06

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Corn oil					
Production (million pounds, Oct.–Sept. year)	11,514	16,271	11,375	7,244	24,228
Domestic use (million pounds, Oct.–Sept. year)	10,696	15,421	10,556	6,426	23,319
Net exports (million pounds, Oct.–Sept. year)	823	838	826	833	854
Ending stocks (million pounds, Oct.–Sept. year)	546	791	543	356	1,194
Chicago price (U.S. cents/pound, Oct.–Sept. year)	60.29	57.95	58.93	51.81	55.91

* Long-run equilibrium

U.S. Corn Processing*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Corn food, industrial use					
Fuel alcohol (million bushels)	5,886	8,871	5,801	3,210	13,872
HFCS (million bushels)	592	584	590	594	570
Glucose and dextrose (million bushels)	254	250	254	258	245
Starch (million bushels)	315	311	315	319	304
Beverage alcohol (million bushels)	153	151	153	155	148
Cereals and other (million bushels)	218	215	218	221	210
Total (million bushels)	7,419	10,382	7,331	4,757	15,350
Corn dry milling					
Corn dry milled for ethanol (million bushels)	5,456	8,375	5,357	2,807	13,375
Share of total ethanol (percent)	92.7%	94.4%	92.3%	87.5%	96.4%
Yields per bushel of corn					
Ethanol (gallons) (units/bushel)	2.88	2.88	2.88	2.88	2.88
Distillers grains (pounds) (units/bushel)	17.00	17.00	17.00	17.00	17.00
Costs and returns					
Ethanol value (dollars/gallon)	1.55	1.82	1.62	1.35	2.15
Distillers grains value (dollars/gallon)	0.29	0.33	0.28	0.23	0.42
Corn cost (dollars/gallon)	−1.30	−1.56	−1.31	−1.06	−1.96
Fuel and electricity cost (dollars/gallon)	−0.27	−0.31	−0.31	−0.27	−0.31
Other operating costs (dollars/gallon)	−0.37	−0.37	−0.37	−0.37	−0.37
Net operating return (dollars/gallon)	0.23	0.23	0.23	0.17	0.23

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Corn wet milling					
Corn wet milled for ethanol (million bushels)	430.09	496.08	444.12	402.64	497.63
Share of total ethanol (percent)	7.3%	5.6%	7.7%	12.5%	3.6%
Other corn wet milling (million bushels)	1,161	1,145	1,159	1,171	1,120
Total corn wet milling (million bushels)	1,591	1,641	1,603	1,574	1,617
Yields per bushel of corn					
Ethanol (gallons) (units/bushel)	2.76	2.76	2.76	2.76	2.76
Gluten feed (pounds) (units/bushel)	11.40	11.40	11.40	11.40	11.40
Gluten meal (pounds) (units/bushel)	3.00	3.00	3.00	3.00	3.00
Corn oil (pounds) (units/bushel)	1.75	1.75	1.75	1.75	1.75
Costs and returns					
Ethanol value (dollars/gallon)	1.55	1.82	1.62	1.35	2.15
Gluten feed value (dollars/gallon)	0.19	0.23	0.19	0.16	0.29
Gluten meal value (dollars/gallon)	0.18	0.19	0.18	0.18	0.22
Corn oil value (dollars/gallon)	0.38	0.37	0.37	0.33	0.35
Corn cost (dollars/gallon)	−1.35	−1.62	−1.36	−1.10	−2.04
Fuel and electricity cost (dollars/gallon)	−0.21	−0.24	−0.24	−0.21	−0.24
Other operating costs (dollars/gallon)	−0.59	−0.59	−0.59	−0.59	−0.59
Net operating return (dollars/gallon)	0.16	0.16	0.17	0.12	0.14

* Long-run equilibrium

U.S. Sorghum Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Planted area (million acres)	6.93	6.83	6.77	6.86	6.93
Yield (bushels/acre)	67.6	67.5	67.7	67.8	67.3
Production (million bushels)	385	379	378	384	380
Imports (million bushels)	0	0	0	0	0
Exports (million bushels)	239	214	235	257	176
Domestic use (million bushels)	146	166	143	127	206
Feed, residual (million bushels)	130	148	125	109	185
Food, seed, Ind. (million bushels)	16	18	18	18	20
Farm price (U.S. dollars/bushel)	3.63	4.20	3.67	3.13	4.91
Net returns (U.S. dollars/acre)	77.19	101.02	65.97	44.27	147.27

* Long-run equilibrium

U.S. Barley Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Planted area (million acres)	3.82	3.95	3.79	3.63	4.22
Yield (bushels/acre)	72.3	72.0	72.4	72.7	71.5
Production (million bushels)	241	248	240	231	264
Imports (million bushels)	7	5	7	9	2
Exports (million bushels)	48	51	47	44	55
Domestic use (million bushels)	200	203	199	195	211
Feed, residual (million bushels)	56	61	55	49	72
Food, seed, Ind. (million bushels)	145	142	144	146	140
All barley farm price (U.S. dollars/bushel)	3.47	4.04	3.50	2.93	4.83
Feed barley price (U.S. dollars/bushel)	3.17	3.75	3.19	2.63	4.60
Net returns (U.S. dollars/bushel)	112.16	142.69	105.49	74.28	197.68

* Long-run equilibrium

U.S. Oat Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Planted area (million acres)	3.46	3.31	3.43	3.58	3.12
Yield (bushels/acre)	66.6	66.5	66.6	66.7	66.4
Production (million bushels)	87	81	87	93	73
Imports (million bushels)	104	109	104	99	115
Exports (million bushels)	2	2	2	2	2
Domestic use (million bushels)	189	188	188	189	188
Feed, residual (million bushels)	107	107	107	107	108
Food, seed, Ind. (million bushels)	82	81	82	82	80
Farm price (U.S. dollars/bushel)	2.36	2.71	2.38	2.00	3.18
Net returns (U.S. dollars/acre)	15.34	29.15	3.78	−8.49	60.17

* Long-run equilibrium

U.S. Soybean Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Planted area (million acres)	73.6	68.1	73.6	75.8	53.8
Yield (bushels/acre)	48.6	48.3	48.7	48.9	47.2
Production (million bushels)	3,533	3,242	3,536	3,657	2,503
Imports (million bushels)	6	6	6	6	6
Exports (million bushels)	917	737	925	1,009	217
Domestic use (million bushels)	2,623	2,504	2,617	2,658	2,284
Crush (million bushels)	2,404	2,304	2,398	2,429	2,129
Seed, residual (million bushels)	219	199	219	229	155
Farm price (U.S. dollars/bushel)	9.79	10.70	9.74	8.82	12.01
Illinois processor price (U.S. dollars/bushel)	10.12	11.01	10.08	9.19	12.28
Net returns (U.S. dollars/acre)	329.67	362.71	320.41	284.74	413.74
Bean/corn ratio (U.S. dollars)	2.62	2.39	2.59	2.89	2.13
Crushing margin (U.S. dollars/bushel)	1.41	1.00	1.35	1.39	0.52

* Long-run equilibrium

U.S. Soybean Meal Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Production (thousand tons)	57,265	54,899	57,177	57,874	50,713
Imports (thousand tons)	165	165	165	165	165
Exports (thousand tons)	12,354	13,671	12,450	11,237	9,677
Domestic use (thousand tons)	45,074	41,388	44,830	46,805	41,198
48% Meal price (U.S. dollars/ton)	198.08	224.01	200.51	205.98	261.49

* Long-run equilibrium

U.S. Soybean Oil Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Production (million pounds)	27,432	26,298	27,361	27,723	24,293
Imports (million pounds)	38	38	38	38	38
Exports (million pounds)	6,919	8,366	7,990	10,428	10,907
Domestic use (million pounds)	20,567	18,003	19,428	17,331	13,458
Food use (million pounds)	12,545	9,820	12,755	16,010	5,148
Biodiesel use (million pounds)	8,022	8,183	6,674	1,321	8,309
Oil price (U.S. cents/pound)	59.69	58.44	58.29	49.67	57.65

* Long-run equilibrium

U.S. Biodiesel Sector*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Biodiesel supply and use					
Production (million gallons, Oct.–Sep. year)	1,179.26	1,204.61	1,000.00	258.02	1,222.02
From soybean oil (million gallons, Oct.–Sep. year)	1,041.79	1,062.73	866.70	171.62	1,079.13
From other fats and oils (million gallons, Oct.–Sep. year)	137.47	141.88	133.30	86.40	142.89
Net exports (million gallons, Oct.–Sep. year)	179.26	204.61	0.00	258.02	222.02
Domestic use (million gallons, Oct.–Sep. year)	1,000.00	1,000.00	1,000.00	0.00	1,000.00
Fuel prices*					
Biodiesel rack (dollars/gallon, calendar year)	5.47	5.38	5.36	3.99	5.32
#2 Diesel, refiner sales (dollars/gallon, calendar year)	2.41	3.28	3.28	2.41	3.28
#2 Diesel retail (dollars/gallon, calendar year)	3.19	4.04	4.04	3.14	4.04
Tax credit, virgin oil (dollars/gallon, calendar year)	1.00	1.00	0.00	0.00	1.00
Tax credit, other feedstocks (dollars/gallon, calendar year)	0.50	0.50	0.00	0.00	0.50
Costs and returns					
Biodiesel value (dollars/gallon, Oct.–Sep. year)	5.47	5.38	5.36	3.99	5.32
Glycerin value (dollars/gallon, Oct.–Sep. year)	0.05	0.05	0.05	0.05	0.05
Soy oil cost (dollars/gallon, Oct.–Sep. year)	−4.60	−4.50	−4.49	−3.82	−4.44
Other operating costs (dollars/gallon, Oct.–Sep. year)	−0.62	−0.62	−0.62	−0.62	−0.62
Net operating return (dollars/gallon, Oct.–Sep. year)	0.30	0.30	0.30	−0.41	0.31

* Long-run equilibrium

U.S. Vegetable Oil Consumption*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Per capita consumption (pounds)	78.59	83.61	78.45	76.81	92.02
Soy oil (exc. biodiesel) (pounds)	36.23	28.36	36.83	46.23	14.87
Corn oil (pounds)	30.89	44.53	30.48	18.56	67.34
Canola oil (exc. biodiesel) (pounds)	6.92	6.46	6.63	7.12	6.01
Cottonseed oil (pounds)	1.44	1.28	1.46	1.76	0.97
Sunflower oil (pounds)	2.11	2.00	2.05	2.14	1.88
Peanut oil (pounds)	1.01	0.99	1.00	1.00	0.96

* Long-run equilibrium

U.S. Upland Cotton Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support	High Energy No Bottleneck
Planted area (million acres)	9.67	9.51	9.72	10.33	9.03
Yield (pounds/acre)	941	939	940	944	937
Production (million bales)	17.12	16.77	17.18	18.37	15.85
Imports (million bales)	0.01	0.01	0.01	0.01	0.01
Exports (million bales)	13.58	13.32	13.60	14.53	12.57
Domestic use (million bales)					
Mill use (million bales)	3.75	3.36	3.54	4.02	3.23
Farm price (U.S. dollars/pound)	0.609	0.637	0.619	0.575	0.656
Net returns (U.S. dollars/acre)	105.71	112.44	87.71	56.81	141.40

* Long-run equilibrium

U.S. Beef Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support
Beef cows (Jan. 1) (million head)	32.6	32.8	32.7	32.5
Dairy cows (Jan. 1) (million head)	9.0	8.9	9.0	9.1
Cattle and calves (Jan. 1) (million head)	93.1	95.1	93.4	91.9
Calf crop (million head)	37.7	37.8	37.7	37.6
Calf death loss (million head)	2.2	2.2	2.2	2.2
Steer and heifer slaughter (million head)	28.0	28.8	28.1	27.4
Total slaughter (million head)	35.3	36.2	35.4	34.8
Cattle imports (million head)	3.2	3.3	3.2	3.1
Cattle exports (million head)	0.5	0.5	0.5	0.5
Cattle death loss (million head)	2.3	2.3	2.3	2.3
Residual (million head)	0.2	0.2	0.2	0.2
Cattle and calves (Dec. 31) (million head)	93.9	95.2	94.1	93.2
Cattle on feed (Jan. 1) (million head)	13.6	14.0	13.6	13.4
Supply				
Imports (million pounds)	3,814	3,868	3,811	3,764
Production (million pounds)	28,254	29,066	28,364	27,797
Disappearance				
Domestic use (million pounds)	30,653	30,929	30,700	30,563
Exports (million pounds)	1,412	1,996	1,470	997
Prices				
1100–1300 #, Nebraska direct steers (U.S. dollars/cwt.)	102.21	105.42	102.12	99.28
600–650 #, Oklahoma City feeder steers (U.S. dollars/cwt.)	134.73	135.77	134.69	134.21
Boxed beef cutout (U.S. dollars/cwt.)	176.51	181.53	176.46	172.18
Beef retail (U.S. dollars/pound)	5.24	5.33	5.24	5.16
Net returns				
Cow–Calf (U.S. dollar/cow)	68.44	68.44	68.44	68.44

* Long-run equilibrium

U.S. Pork Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support
Breading herd (Dec. 1**) (million head)	4.76	4.49	4.73	4.98
Gilts added (million head)	3.68	2.50	3.67	5.01
Sows slaughter (million head)	2.64	2.50	2.63	2.77
Sows farrowed (million head)	11.24	9.56	11.19	13.02
Pigs/litter (head) (million head)	9.81	9.81	9.81	9.81
Market hogs (Dec. 1**) (million head)	51.9	49.5	51.7	54.0
Pig crop (million head)	110.3	93.8	109.8	127.7
Barrow and Gilt slaughter (million head)	105.5	96.2	105.2	114.9
Hog imports (million head)	11.4	11.9	11.5	10.9
Hog exports (million head)	0.1	0.1	0.1	0.2
Death loss/residual (million head)	10.9	9.6	10.9	12.2
Market hogs (Nov. 30) (million head)	57.0	49.3	56.8	65.3
Supply			0	0
Imports (million pounds)	1,605	1,615	1,601	1,586
Production (million pounds)	23,094	21,073	23,013	25,138
Disappearance				
Domestic use (million pounds)	20,647	20,165	20,613	21,050
Exports (million pounds)	4,015	2,520	3.964	5,599
Prices				
Barrows & Gilts, Natl. Base 51–52% lean equiv. (U.S. dollars/cwt)	51.39	57.75	51.59	46.25
Sows, IA-S. Minn. #1–2, 300–400 lb (U.S. dollars/cwt)	46.01	51.48	46.29	42.01
Pork cutout value (U.S. dollars/cwt)	83.74	88.96	83.98	79.86
Pork retail (U.S. dollars/pound)	3.36	3.47	3.37	3.28
Net returns				
Farrow–Finish (U.S. dollars/cwt)	1.47	1.47	1.47	1.47

* Long-run equilibrium** Preceding year.

U.S. Broiler Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support
Production (million pounds)	45,104	42,559	44,898	45,839
Imports (million pounds)	108	108	108	108
Exports (million pounds)	8,945	7,560	8,810	9,090
Domestic use (million pounds)	36,225	35,095	36,156	36,819
Prices				
12-City wholesale (cents/pound)	82.86	91.02	83.31	78.76
Bnls. breast wholesale, NE (cents/pound)	0.00	0.00	0.00	0.00
Whole leg wholesale, NE (cents/pound)	0.00	0.00	0.00	0.00
Broiler retail (cents/pound)	195.01	213.45	196.23	184.56
Broiler–Feed ratio	6.2	6.2	6.2	6.2

* Long-run equilibrium

U.S. Turkey Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support
Production (million pounds)	6,463	6,141	6,440	6,589
Imports (million pounds)	26	26	26	26
Exports (million pounds)	936	790	922	951
Domestic use (million pounds)	5,551	5,371	5,541	5,667
Prices				
East. region, wholesale (U.S. cents/pound)	94.11	103.63	94.60	88.65
Turkey retail (U.S. cents/pound)	130.32	147.97	131.77	119.65
Net returns	7.3	7.3	7.4	7.3

* Long-run equilibrium

U.S. Egg Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support
Production (million dozen)	8,352	8,241	8,345	8,410
Imports (million dozen)	18	18	18	18
Exports (million dozen)	380	380	380	380
Disappearance				
Civilian disappearance (million dozen)				
Shell egg (million dozen)	4,560	4,524	4,558	4,588
Breaking egg (million dozen)	2,327	2,308	2,326	2,341
Hatching egg (million dozen)	1,104	1,048	1,099	1,120
Prices				
NY Grade A lg wholesale (U.S. cents/dozen)	111.97	124.24	112.49	103.53
Shell egg retail (U.S. cents/dozen)	189.78	203.53	190.45	180.16
Net returns	9.7	9.7	9.7	9.7

* Long-run equilibrium

U.S. Milk Component Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support
Milk-fat basis				
Fluid use (million pounds)	1,833	1,822	1,829	1,840
Whole milk (million pounds)	400	398	399	401
2% Milk (million pounds)	455	453	454	456
1% and skim milk (million pounds)	79	79	79	79
Other (million pounds)	900	893	897	904
Product use (million pounds)	5,697	5,653	5,681	5,724
merican cheese (million pounds)	1,557	1,544	1,553	1,565
Other cheese (million pounds)	1,960	1,950	1,956	1,966

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support
Butter (million pounds)	1,296	1,279	1,290	1,307
Nonfat dry (million pounds)	4	4	4	5
Evap. and condensed (million pounds)	53	53	53	53
Frozen products (million pounds)	729	726	728	731
Whey products (million pounds)	11	11	11	11
Other (million pounds)	86	85	86	86
Farm use (million pounds)	42	42	42	42
Milk production (million pounds)	221,054	219,317	220,439	222,105
% Fat (million pounds)	3.57%	3.57%	3.57%	3.57%
Total fat supply (million pounds)	7,892	7,830	7,870	7,929
Residual fat (million pounds)	319	313	317	323
Solids-not-fat basis				
Fluid use (million pounds)	4,995	4,972	4,987	5,009
Whole milk (million pounds)	1,060	1,056	1,059	1,063
2% Milk (million pounds)	2,078	2,070	2,075	2,084
1% and skim milk (million pounds)	1,397	1,391	1,395	1,400
Other (million pounds)	460	456	458	462
Product use (million pounds)	9,036	8,944	9,004	9,093
American cheese (million pounds)	1,447	1,435	1,443	1,454
Other cheese (million pounds)	2,054	2,044	2,050	2,060
Butter (million pounds)	48	48	48	49
Nonfat dry (million pounds)	1,577	1,517	1,556	1,614
Total nonfat dry (million pounds)	2,432	2,369	2,409	2,470
Nonfat dry in other (million pounds)	−854	−852	−853	−856
Evap. and condensed (million pounds)	451	449	450	453
Frozen products (million pounds)	1,008	1,004	1,007	1,010
Whey products (million pounds)	1,879	1,880	1,879	1,878
Other (million pounds)	572	568	571	575
Farm use (million pounds)	99	99	99	100
Milk production (million pounds)	221,054	219,317	220,439	222,105
% SNF (million pounds)	8.70%	8.70%	8.70%	8.70%
Total SNF supply (million pounds)	19,232	19,081	19,178	19,323
Residual whey (million pounds)	3,635	3,618	3,629	3,645
Residual SNF (million pounds)	1,466	1,447	1,460	1,478
Min. FMMO class prices				
Class I mover (U.S. dollars/cwt)	16.93	17.75	17.22	16.46
Class II (U.S. dollars/cwt)	16.30	17.49	16.72	15.60
Class III (U.S. dollars/cwt)	17.16	17.97	17.45	16.68
Class IV (U.S. dollars/cwt)	16.30	17.49	16.72	15.60
All milk price (U.S. dollars/cwt)	17.92	18.80	18.16	17.33

* Long-run equilibrium

U.S. Dairy Product Supply and Utilization*

	Baseline	High Energy Price	High Energy Price and No Biofuel Tax Credit	Low Energy Price and No Biofuel Support
Butter				
Production (million pounds)	1,598	1,576	1,590	1,612
Imports (million pounds)	52	52	52	52
Domestic use (million pounds)	1,621	1,599	1,613	1,634
American cheese				
Production (million pounds)	4,841	4,800	4,826	4,865
Imports (million pounds)	51	51	51	51
Domestic use (million pounds)	4,822	4,780	4,806	4,846
Other cheese				
Production (million pounds)	7,990	7,949	7,976	8,015
Imports (million pounds)	466	466	466	466
Domestic use (million pounds)	8,295	8,254	8,281	8,320
Nonfat dry milk				
Production (million pounds)	2,541	2,475	2,517	2,581
Imports (million pounds)	5	5	5	5
Domestic use (million pounds)	1,437	1,428	1,434	1,442
Evap. and condensed milk				
Production (million pounds)	599	596	598	601
Imports (million pounds)	12	12	12	12
Domestic use (million pounds)	555	551	554	557
Wholesale prices				
Butter, CME (cents/pound)	147.7	171.3	156.1	134.0
Cheese, Am., 40#, CME (cents/pound)	172.8	179.1	175.1	169.2
Nonfat dry milk, AA (cents/pound)	148.8	151.1	149.6	147.3
Evaporated (cents/pound)	187.2	188.9	187.8	186.3
Retail prices				
Butter, salted, AA, stick (dollars/pound)	3.66	3.93	3.76	3.51
Cheese, natural cheddar (dollars/pound)	4.88	5.01	4.93	4.81
Milk, fresh, whole fortified (dollars/pound)	3.78	3.89	3.82	3.71

* Long-run equilibrium