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Contributions of U.S. Crop Subsidies to Biofuel and Related Markets

Stephen Devadoss and Jude Bayham

The U.S. crop subsidies provide incentives for farmers to expand feedstock production, which benefits the biofuel producers by lowering input costs. This study develops a general equilibrium model to analyze the effects of a reduction in the U.S. crop subsidy on biofuel industries and social welfare. The impacts of feedstock policies on the biofuel market are marginal. In contrast, the biofuel mandate has a larger impact and counteracts the effects of the crop subsidy reduction. The mandate increases the demand for feedstock and causes not only grain ethanol, but also cellulosic ethanol production to rise. The mandate exacerbates the distortion, and government spending increases significantly, leading to greater welfare loss.

Key Words: biofuel, environmental impacts, farm supports, welfare analysis

JEL Classifications: Q18, Q27

The U.S. government has supported the development of biofuel production not only to solve the energy crisis, but also to increase the income of agricultural producers (Hayes et al., 2009). Farmers benefit from growing feedstocks such as corn and oilseed, which are inputs in biofuel production, because the higher demand for these crops increases prices and incomes. As the biofuel refining process has become more specialized, corn and soybeans have emerged as the dominant feedstock because of a well-established infrastructure for processing them and historically low prices until recently. Currently, there are five federal policies that have significant impacts on biofuel and related industries: biofuel tax credit, biofuel mandate, ethanol import tariff, gasoline excise tax, and crop subsidies.[1]

The literature on biofuels in the past decade has been rich and voluminous. In a recent study, Kim, Schlaible, and Daberkow (2010) present a rigorous theoretical analysis to examine the effects of tax credits and binding mandates on blended gasoline, conventional gasoline, and ethanol prices. Their results show that an increase in tax credits lowers all three fuel prices, but a larger blending mandate puts an upward pressure on all three fuel prices. Harrison (2009) observes that growth in biofuel production contributed to higher corn prices, which led to price inflation of corn-based food items such as eggs, poultry, pork, beef, and milk.[2] Several other

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[1] Duffield and Collins (2006) provide a comprehensive summary of these policies.

[2] Ethanolization has caused a sharp increase in corn and feed prices, and as a result, the livestock industry has borne the brunt of the adverse impacts of these high prices (Anderson, Anderson, and Sawyer, 2008; Herndon, 2008).

studies analyzed the effects of the ethanol tax credit and mandate (de Gorter and Just, 2009b; Eidman, 2007), import tariffs and tax credits (de Gorter and Just, 2008; Elobeid and Tokgoz, 2008), tax credit and farm subsidy interaction (de Gorter and Just, 2009a; de Gorter, Just, and Tan, 2009; Gardner, 2003; Hochman, Sexton, and Zilberman, 2008). de Gorter, Just, and Tan (2009) also emphasize the need to isolate the effects of the farm policy on ethanol and gasoline markets. This study incorporates all of the five biofuel-related policies in a general equilibrium model and focuses on the contribution of the farm subsidy by analyzing its impacts on biofuel and allied industries and social welfare. In doing so, this study internalizes the externality by incorporating the environmental damage of fuel use into the utility function. Because fuel is widely used in almost all sectors of the economy, a general equilibrium analysis is undertaken to capture the interlinkages and policy repercussions on various markets.[3]

There are many complex farm support programs designed to provide aid to agricultural producers. Since the Uruguay Round in 1994, the U.S. has adjusted farm support programs to comply with World Trade Organization (WTO) rules by limiting the price distorting subsidies that affect producers' planting decisions. The 1996 Federal Agricultural Improvement and Reform Act decoupled farm subsidies, thereby disconnecting government payments from market prices in any given year (Lamb and Henderson, 2000). The agricultural economics literature has focused on whether decoupled payment programs do in fact impact commodity prices and production decisions. Bhaskar and Beghin (2009) summarized an array of literature that focuses on the empirical evidence from the past 15 years and concluded that decoupled payment programs do affect producers' planting and acreage decisions. Moreover, the 2008 Farm Bill, in contrast to the goal of the Doha Round, expanded the farm supports, which was one of the causes for the continued breakdown in the negotiations as the developing countries and also some developed counties (e.g., Canada) insist that the U.S. lower its agricultural subsidies for successful completion of the Doha Round. Given the importance of agricultural subsidies to augment production, it is worth examining the effects of crop subsidy reduction on feedstock, biofuel, and related markets and the overall social welfare.

Numerous studies across a variety of disciplines have extensively examined the environmental impacts and economic feasibility of biofuels. Studies such as Patzek et al. (2005) and Pimentel (1991, 2003) contend that despite improvements in biofuel refining efficiency, the energy expended to produce biofuel exceeds the energy derived from biofuel. Liska et al. (2009) and Shapouri, Duffield, and Wang (2002) argue that earlier studies use outdated data and do not consider emerging technologies in biofuel production. The most recent environmental literature focuses on the inclusion of global land use impacts in the calculation of net emissions (Naylor and Mendelsohn, 2007; Searchinger et al., 2008). The estimates reported in these papers are used by other studies to determine externality and welfare impacts. The significant variation in these estimates results in a wide range of conclusions. The current study accounts for the variation in the estimates by considering three pollution assumptions (biofuels reduce greenhouse gas [GHG] emissions, biofuels emit less GHG than petroleum, and biofuels emit more GHG than petroleum).

Theoretical Analysis

This section describes the structure of the general equilibrium model consisting of a representative household, production markets, a government sector, and a trade sector (see Taheripour, Khanna, and Nelson, 2008 for a similar structure of a general equilibrium model). The model also incorporates biofuel-related policies and environmental damages of fuel pollution. Then, the model is used to derive the analytical results.

Household Sector

The representative household derives utility from the consumption of final fuel (G_D), which

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[3] Goulder and Williams (2003) note that the use of a partial equilibrium model may underestimate the social cost of government policies because they neglect tax interaction effects.

is the blended biofuel and fossil fuel, food/feedstock (F_D), and a composite good (Y_D). The pollution (Z) generated from the use of fuel causes disutility. The utility function is given by

$$U=u(G_D,F_D,Y_D,Z(G_D)).$$

The representative household receives income from the endowments of land ($\bar{R}$), capital ($\bar{K}$), and labor ($\bar{L}$), and government transfers (GT), and all the income is spent on consumption goods. Thus, the budget constraint is

$$r_R\bar{R}+r_K\bar{K}+w\bar{L}+GT=P_G^CG_D+P_F^CF_D+Y_D,$$

where r_R is the land rental rate, r_K is the capital rental rate, w is the wage rate, P_G^C is the consumer price of final fuel, and P_F^C is the feedstock price paid by consumers or biofuel producers. The composite good is considered as the numeraire, and hence, all other prices are measured in terms of the composite good price. The representative household maximizes utility subject to the budget constraint and considers pollution as given. The first-order conditions are

$$\frac{\partial u}{\partial G_D}=\lambda P_G^C,$$
$$\frac{\partial u}{\partial F_D}=\lambda P_F^C,$$
$$\frac{\partial u}{\partial Y_D}=\lambda, \quad \text{and}$$
$$r_R\bar{R}+r_K\bar{K}+w\bar{L}+GT=P_G^CG_D+P_F^CF_D+Y_D,$$

where the Lagrange multiplier λ represents the marginal utility of income.

Production Sector

The production sector is comprised of the feedstock, biofuel, petroleum, final fuel, and composite good markets. Production functions for all these goods are assumed to be constant returns to scale. The feedstock is produced using land (R_F), capital (K_F), and labor (L_F). The government subsidizes feedstock production and the per-unit subsidy is S_O. The profit maximization condition with the inclusion of farm subsidy is:

$$(1) \qquad P_F^C=MC_F(r_R,r_K,w)-S_O,$$

where MC stands for marginal cost. Producers receive a price $\left(P_F^P\right)$, which is equal to MC and thus to the consumer/market price plus the subsidy. This representation of price relationship incorporating U.S. crop subsidies follows the studies by Devadoss and Luckstead (2010) and Luckstead, Devadoss, and Rodriguez (2010). The feedstock market-clearing condition states that feedstock supply (F_S) is equal to feedstock used for food consumption (F_D), biofuel production (F_B), and exports (F_X):

$$(2) \qquad F_S=F_D+F_B+F_X.$$

The biofuel producers use feedstock, labor (L_B), and capital (K_B) to produce biofuel. The result of their profit maximization is:

$$(3) \qquad P_B^P=MC_B\left(P_F^C,r_K,w\right),$$

where P_B^P is the producer price of biofuel. Blenders receive a tax credit (tc_B) for using biofuel with petroleum to produce the final fuel and pass along part of the tax credit to biofuel producers, which causes a price wedge between the biofuel purchase price $\left(P_B^C\right)$ and producer price. This price relationship is:

$$(4) \qquad P_B^C=P_B^P-tc_B.$$

Imported biofuel also avails this tax credit. Because the U.S. government's policy aims to subsidize only domestic biofuel production, it imposes a tariff (t_B) to counteract the tax credit. The spatial price arbitration is given by:

$$(5) \qquad P_B^P=P_B^W+t_B,$$

where P_B^W is the world price of biofuel. The market clearing condition for biofuel is:

$$(6) \qquad B_S+B_M=B_D,$$

where B_S is domestic supply of biofuel, B_M is imports of biofuel, and B_D is domestic use of biofuel.

Petroleum/fossil fuel is produced using capital (K_O) and labor (L_O). The profit maximization yields:

$$(7) \qquad P_O=MC_O(r_K,w),$$

where P_O is the petroleum price. The petroleum market equilibrium is given by the identity supply (O_S) plus imports (O_M) equal demand (O_D):

$$(8) \qquad O_S+O_M=O_D.$$

The final fuel is produced by blending biofuel with petroleum. The first-order condition of the profit maximization is:

$$(9)\qquad P_G^P = MC_G(P_O, P_B^C),$$

where P_G^P is the producer price of the final fuel. The fuel tax (t_G) causes the consumer price $\left(P_G^C\right)$ to differ from the producer price by t_G:

$$(10)\qquad P_G^C = P_G^P + t_G.$$

The final fuel is not traded[4] and thus the market clearing condition is:

$$(11)\qquad G_S = G_D.$$

The final market of the production sector is the composite-good market (Y), which is produced using land (R_Y), capital (K_Y), and labor (L_Y). The profit maximization leads to:

$$(12)\qquad P_Y = MC_Y(r_R, r_K, w),$$

where P_Y is the price of the composite good and equal to one because the composite good is the numeraire. The composite-good market equilibrium states that supply (Y_S) is equal to the sum of domestic demand (Y_D) and exports (Y_X):

$$(13)\qquad Y_S = Y_D + Y_X.$$

The factor-market equilibriums for land, capital, and labor are given by the identity that the endowments are equal to uses in the production of various goods:

$$(14)\qquad \bar{R} = R_F + R_Y$$

$$(15)\qquad \bar{K} = K_F + K_B + K_O + K_Y$$

$$(16)\qquad \bar{L} = L_F + L_B + L_O + L_Y.$$

Government Sector

The government collects revenues from the fuel tax and import tariff and spends them on farm subsidies, biofuel tax credits, and transfers.[5] Thus, the government budget constraint is:

$$(17)\qquad t_G G_D + t_B B_M = S_O F_S + tc_B B_D + GT.$$

The government balances the budget by adjusting the transfers in response to changes in the revenues and expenditures.

Trade Balance

The trade balance constraint is given by the identity that the value of exports of feedstock and composite good is equal to the value of biofuel and petroleum imports:

$$(18)\qquad P_F^C F_X + Y_X = P_B^W B_M + P_O O_M.$$

Analytical Results

To analyze the effects of feedstock subsidies, totally differentiate the utility function with respect to subsidy and incorporate the first-order conditions to obtain:

$$(19)\qquad \begin{aligned} \frac{1}{\lambda}\frac{du}{dS_O} = \bar{R}\frac{dr_R}{dS_O} + \bar{K}\frac{dr_K}{dS_O} + \bar{L}\frac{dw}{dS_O} + \frac{dGT}{dS_O} \\ - G_D\frac{dP_G^C}{dS_O} - F_D\frac{dP_C^C}{dS_O} + \frac{u_Z}{\lambda}\frac{dZ}{dS_O}. \end{aligned}$$

Before the current recession, high fuel consumption had stimulated the demand for biofuel and the mandate requirement was nonbinding. However, as a result of the recession, fuel demand declined, resulting in reduced demand for biofuel also. Yet, domestic fuel blenders were subject to the same volumetric requirement and the biofuel use may not exceed this mandated volume. In this case, the mandate becomes binding. Because the mandate has differing impacts and policy implications, it is important to analyze the effects of farm subsidies under both the binding and nonbinding mandates.

Nonbinding Mandate. To analyze the effects of an agricultural subsidy reduction on welfare, the price relationships (Equations [1], [3], [4], [5], [7], [9], [10], and [12]), market equilibrium conditions (Equations [2], [6], [8], [11], and [13]), full employment conditions (Equations [14], [15], and [16]), government budget (Equation [17]), and trade balance (Equation [18]) are incorporated into Equation (19), and Shepherd's lemma is applied to obtain:

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[4] This assumption is applicable to the U.S. because the trade in the final fuel that contains the biofuel is not very significant.

[5] Other government revenues and expenditures are held constant in the theoretical analysis and thus excluded from the government budget constraint.

$$\frac{1}{\lambda}\frac{du}{dS_O} =$$

$$\overbrace{\overbrace{\left(\frac{u_Z}{\lambda}\frac{\partial Z}{\partial G_D}\frac{\partial G_D}{\partial O_D} + t_G\frac{\partial G_S}{\partial O_D}\right)\frac{dO_D}{dS_O}}^{\textit{Petroleum}} + \overbrace{\left(\frac{u_Z}{\lambda}\frac{\partial Z}{\partial G_D}\frac{\partial G_D}{\partial B_D} + t_G\frac{\partial G_S}{\partial B_D} - tc_B\right)\frac{dB_D}{dS_O}}^{\textit{Biofuel}}}^{\text{Pigouvian Effect}} + \overbrace{t_B\frac{dB_M}{dS_O}}^{\text{Tariff Effect}} - \overbrace{S_O\frac{dF_S}{dS_O}}^{\text{Subsidy Effect}} \tag{20}$$

$$\overbrace{\overbrace{-(1-\varepsilon_O)O_M\frac{dP_O^W}{dS_O} - P_O^W\frac{dO_M}{dS_O}}^{\text{Petroleum}}\overbrace{-(1-\varepsilon_B)B_M\frac{dP_B^W}{dS_O} - P_B^W\frac{dB_M}{dS_O}}^{\text{Biofuel}}\overbrace{+(1-\varepsilon_F)F_X\frac{dP_F^W}{dS_O} - P_F^W\frac{dF_X}{dS_O}}^{\text{Feedstock}}}^{\text{Trade Effects}},$$

where ε_O, ε_B, and ε_F are, respectively, elasticity of the rest of the world excess supply of petroleum, excess supply of biofuel, and excess demand of feedstock. A decrease in the subsidy curtails feedstock production and raises the feedstock price. As a result, the cost of biofuel production increases, which reduces biofuel supply and increases biofuel price. The higher biofuel price discourages biofuel use, and petroleum is substituted for biofuel in fuel production, which impacts the final fuel supply. Because the general equilibrium framework is used in the analysis, the repercussions of agricultural support reductions flow through all the markets, trade, and the government sector of the economy to eventually impact utility. All of these effects finally influence consumption and utility as captured in Equation (20). Each term in this equation is either welfare enhancing or reducing, and the net effect is an empirical question.

The first term is the Pigouvian effect, which internalizes the externality arising from the pollution and thus measures the environmental efficiency. The Pigouvian effect is comprised of petroleum and biofuel components. In the "first-best" case where no other distortions exist, the optimal value of the fuel tax is a pure Pigouvian tax. The petroleum component indicates that the adverse environmental effects associated with increased use of fossil fuel resulting from the farm subsidy reduction is equal to the fuel tax weighted by the petroleum content in the blend. The biofuel component reveals that the beneficial or detrimental (depending on whether biofuel reduces or augments pollution) environmental effects of a decrease in biofuel, as a result of the cut in the farm subsidy, are equal to the fuel tax weighted by the biofuel content in the blend minus the tax credit. In the "second-best" case, the environmental loss in the petroleum component reflects the incremental use of fossil fuel times the difference between marginal social benefit and marginal social cost. Similar interpretations of environmental gain/loss also hold for the biofuel component.

The tariff effect captures the impacts of a change in biofuel tariff revenues on utility. Because domestic biofuel production decreases in response to the cut in farm subsidy, biofuel imports and tariff revenues rise, which enhances welfare. The subsidy effect reflects the impacts of a change in farm payments on utility. Lower subsidy payments reduce feedstock production, which leads to a decline in government farm program payments, reduces distortions, improves production efficiency, and augments welfare. The trade effects have three components: petroleum, biofuel, and feedstock. The effects of these terms on utility depend on the elasticity of excess supply/demand, which are generally inelastic. The petroleum trade effect has two subcomponents. The first subcomponent indicates that the increased demand for petroleum raises the world price and increases the value of imports, both of which diminish welfare. The second subcomponent also has a negative effect on utility because increased use of petroleum leads to more imports. The explanation for biofuel trade effects is similar to that of petroleum trade effects. The first part of the feedstock component has a positive effect on welfare because the cut in the farm subsidy increases the world price and the export value of feedstocks. The second part of the feedstock component is also welfare-enhancing as exports are diverted to domestic use.

Binding Mandate. In the U.S., the mandated use of biofuel is formulated as a consumption mandate, i.e., fixed volume of biofuel has to be blended with fossil fuel. However, the Environmental Protection Agency implements it as a blend mandate, i.e., biofuel and fossil fuel are combined based on a specified blend ratio. The analysis of farm subsidy effects was conducted under both consumption and blend mandates and the results were similar. Consequently, in the interest of space limitation, only the analysis and the results of the consumption mandate are presented.

When the biofuel mandate is binding, $\bar{B}_D$ is predetermined and exogenous to the model. The fuel blending industry is required to blend this predetermined volume of biofuel into the fuel supply. Thus, fuel blenders vary blend rates by mixing the petroleum and biofuel to meet the biofuel mandate as well as total fuel demand. For example, if fuel demand decreases, blenders would reduce petroleum content, whereas biofuel use remained constant in the fuel supply. Because biofuel demand $(\bar{B}_D)$ is exogenous, the biofuel component of the Pigouvian effect in these equations drops out, which leads to the following equation:

$$\begin{aligned}\frac{1}{\lambda}\frac{du}{dS_O} &= \overbrace{\left(\frac{u_Z}{\lambda}\frac{\partial Z}{\partial G_D}\frac{\partial G_D}{\partial O_D} + t_G\frac{\partial G_S}{\partial O_D}\right)\frac{dO_D}{dS_O}}^{\text{Pigouvian Effect}} + \overbrace{t_B\frac{dB_M}{dS_O}}^{\text{Tariff Effect}} - \overbrace{S_O\frac{dF_S}{dS_O}}^{\text{Subsidy Effect}} \\ & \overbrace{\overbrace{-(1-\varepsilon_O)O_M\frac{dP_O^W}{dS_O} - P_O^W\frac{dO_M}{dS_O}}^{\text{Petroleum}} \overbrace{-(1-\varepsilon_B)B_M\frac{dP_B^W}{dS_O} - P_B^W\frac{dB_M}{dS_O}}^{\text{Biofuel}} \overbrace{+(1-\varepsilon_F)F_X\frac{dP_F^W}{dS_O} - P_F^W\frac{dF_X}{dS_O}}^{\text{Feedstock}}}^{\text{Trade Effect}}.\end{aligned} \tag{21}$$

In the event that the biofuel mandate remains binding, even with a lower feedstock subsidy, fuel producers are forced to blend the mandated volume of biofuel. Thus, fuel production could be nonoptimal, i.e., isocost line is not tangent to isoquant. Because a mandated volume of biofuel limits the ability of fuel producers to blend biofuel and petroleum optimally, less petroleum will be used although biofuel price increases. The increased petroleum use worsens the environmental efficiency as represented in the petroleum component of the Pigouvian effect. The tariff effect shows that biofuel imports increase as the marginal cost of domestic production rises as a result of the reduction in the feedstock subsidy, and the greater tariff revenue augments utility. The subsidy effect indicates that lower farm payments improve the production efficiency and thus enhance welfare. The interpretation of the three components of the trade effect is similar to that provided in the nonbinding mandate analysis.

In this analysis of the binding mandate, the effect of subsidy reduction is carried out at the pre-existing level of the consumption mandate, which is similar to the analysis by de Gorter and Just (2009b). That is why, unlike in Equation (20), $d\bar{B}_D$ is zero in Equation (21). However, the effect of an exogenous increase in the mandate $\bar{B}_D$ is also relevant because the U.S. government has formulated a schedule of higher volumes of biofuel in the fuel mix through 2022. The effect of this increase in the mandated volume of biofuel is carried out in the empirical analysis.

The Empirical Model

In the theoretical model, many of the commodities, except for the feedstock, biofuel, petroleum, and final fuel, are lumped under the composite good. To fully capture the impacts of policy changes on important sectors of the economy, the composite-good market needs to be disaggregated. In addition, the feedstock market must be expanded to cover all of the crops and vegetations used in biofuel production, and the biofuel market needs to be separated to include various forms of biofuel. The government collects revenues through various forms of taxes and spends the revenues on various economic activities, and thus, all public income and expenditure channels must be accounted for in the model. The rest of the world sector should cover the exports and imports of all goods. This section identifies important markets and components of the empirical model and presents functional forms of key equations.[6]

The empirical model includes 36 commodity markets.[7] The key agricultural commodity markets covered are corn, grains, oilseed, sugar, switch grass, crop residue, forest residue, and livestock. Major ingredients used in the production of grain ethanol are corn and other grains, of sugar ethanol are sugarcane[8] and sugarbeet, and of cellulosic ethanol are switch grass,[9] crop residue, and forest residue. Three forms of ethanol—grain, sugar, and cellulosic—are combined to produce composite ethanol. Composite ethanol and fossil fuel are blended to produce composite gasoline. Oilseeds and animal waste are major ingredients in biodiesel production. Biodiesel and diesel are blended to produce composite diesel. Composite gasoline and composite diesel are called final fuels, which are used in various production sectors and by consumers. The remaining commodity markets cover other agricultural and manufacturing goods.

Commodities are produced using intermediate inputs (e.g., seed, fertilizer, processing inputs) and primary factors (land, labor, and capital). Following Löfgren, Harris, and Robinson (2002), a two-level production function is used (also see Perroni and Rutherford, 1998). At the first level, the aggregate intermediate input and the quantity of value added of primary inputs are obtained. Producers use various intermediate inputs (*QINT*) in fixed proportions to form the aggregate intermediate input (*QINTA*) as given by the Leontief function:

$$QINT_{ca} = ica_{ca} \cdot QINTA_a$$

where ica_{ca} is the constant input requirement of commodity c used in the production of commodity a. The constant elasticity of substitution function defines the value added, i.e., the aggregated quantity of the primary factors:

$$QVA_a = \alpha_a^{va} \cdot \left(\sum_f \delta_{fa}^{va} \cdot QF_{fa}^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}}$$

where f is the set of factors (land, labor, and capital), α_a^{va} is the scale parameter, δ_{fa}^{va} are the share parameters, which sum to 1, ρ_a^{va} is related to the elasticity of substitution, QVA is the quantity of value added in commodity a, and QF_{fa} is the quantity of each factor.

At the second level, intermediate inputs and primary factors are combined in fixed proportion using the Leontief function to produce the final output (Löfgren, Harris, and Robinson, 2002). The equation used for determining the demand for aggregate intermediate inputs is:

$$QINTA_a = inta_a \cdot QA_a$$

where QA_a is the quantity of commodity a produced and $inta_a$ is the amount of aggregate intermediate inputs required per unit of output. The demand for the aggregated quantity of primary factors (land, labor, and capital) is determined by the equation:

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[6] Detailed documentation of the model including mathematical equations, variable definitions, and parameter specifications for all commodity markets, factor markets, institutions, and the rest of the world sector are available on request.

[7] These markets include: oilseeds, grains, corn, sugar, switchgrass, livestock, other agriculture, crop residues, forest residues, manufactured byproducts, distilled dry grain products, glycerin, oil and natural gas, grain ethanol, cellulosic ethanol, sugar ethanol, composite ethanol, gasoline, composite gasoline, biodiesel, diesel, composite diesel, mining, utility, construction, wet corn milling, soybean and other oilseed processing, food manufacturing, fertilizers and pesticides, motor vehicle related manufacturing, other manufacturing, wholesale and retail trade, transportation, pipelines, services, and government industries.

[8] See Outlaw et al. (2007) for viability of sugarcane in ethanol production in the U.S.

[9] See Popp (2007) and Walsh et al. (2007) for the viability of switch grass and cellulose feedstocks in ethanol production.

$$QVA_a = iva_a \cdot QA_a$$

where iva_a is the amount of value added input required per unit of output. Household consumption is characterized by a Stone-Geary utility function.

Data

The data for the base year 2007 was collected from several sources. The majority of the data were based on the input–output database from IMPLAN. The rest of the data are from the U.S. Department of Commerce (2007) and U.S. Department of Agriculture (USDA, 2007). Policy information was assembled from the Economic Research Service of the USDA. The data on various energy sources was obtained from the Energy Information Administration. In addition to these data, various elasticity parameters were collected from the literature. The elasticities of substitution came from the GTAP-E model developed by Burniaux and Truong (2002). Export supply and import demand elasticities were obtained from Holland, Devadoss, and Stodick (2005). The pollution emission data from the GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model developed by the Argone National Labs and Unnasch and Pont (2007) were used to compute the marginal external damage of pollution.

Results

The lack of progress in the Doha round negotiations is largely the result of the disagreement between the developing countries and the developed countries over the unwillingness of the latter to reduce farm supports. In particular, poor countries (generally known as group of 20, i.e., G-20) led by India and Brazil insist that the U.S. reduce agricultural subsidies for successful completion of the Doha Round.[10] Furthermore, Canada filed a request for consultation with the WTO regarding the increase in the U.S. corn subsidy in the 2008 Farm Bill and accused the U.S. of selling subsidized corn at a lower price in the Canadian markets (Canada, 2007). More recently, biofuel proponents have argued that the additional demand for corn created by biofuel production will ensure that prices remain higher than historical averages. These arguments would call for a reduction in farm subsidies. However, well-entrenched farm lobbyists will not let the agricultural subsidy drop too low because it provides a safety net to farmers. Therefore, only a modest reduction of agricultural subsidies is a realistic outcome to meet the demand of the WTO members. In this study, an analysis of a 15% reduction in the agricultural subsidy was conducted under nonbinding and binding mandates. The results of this scenario are presented in Table 1.

Nonbinding Mandate

As crop subsidies are reduced by 15%, total corn production falls by 0.66%, which drives up the consumer price by 0.91%.[11,12] Because corn is also consumed by households and is the primary input in grain ethanol production, the agricultural subsidy reduction impacts the economy through two principal avenues. First, household consumption falls by 0.90% and exports also decline by 0.51%. Second, because of the higher corn price, less corn is used in grain ethanol production, which results in a 0.86% decrease in output and a 0.31% increase in grain ethanol price.

The higher grain ethanol production costs cause composite ethanol blenders to substitute away from grain ethanol in favor of cellulosic and sugar ethanol. Although cellulosic ethanol production increases by 0.11% and sugar ethanol production increases by 2.27%, these gains are nevertheless overshadowed by the decrease in grain ethanol output because

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[10] The G-20 countries insist that the U.S. limits its trade-distorting farm supports to U.S. $13 billion, but the U.S. wants to cap its support at U.S. $17 billion (ICTSD, 2007).

[11] Gardner (2003) also finds impacts of farm programs on corn production and prices are relatively small.

[12] The impacts of 15% reduction in farm subsidy in our general equilibrium analysis range from modest to insignificant because the size of the biofuel relative to the total fuel supply is small and even more so relative to the overall economy.

Table 1. Impacts of Reduction in Farm Subsidy and Mandate Scenarios[a]

		Mandate	
	Base	Nonbinding	Binding
Feedstock Industries		(percent change)	
Corn			
Producer price	1.00	0.92	1.63
Production	26,916.69	–0.66	9.83
Consumer price	1.00	0.91	3.89
Consumption	16,459.22	–0.74	14.67
World price	1.00	1.03	–2.39
Exports	9,524.26	–0.51	1.22
Oilseed			
Producer price	1.00	–0.03	0.93
Production	21,886.92	0.02	3.56
Consumer price	1.00	–0.02	3.16
Consumption	22,604.38	0.01	3.66
World price	1.00	–0.02	4.24
Imports	10,597.51	0.00	1.04
Fuel industries			
Cellulose ethanol			
Price	1.00	0.21	7.10
Output	19.34	0.11	11.83
Sugar ethanol			
Price	1.00	0.00	–0.01
Output	3.99	2.27	122.32
Grain ethanol			
Price	1.00	0.31	2.97
Output	10,907.44	–0.86	65.73
Composite ethanol			
Price	1.00	0.28	4.28
Output	11,666.62	–0.81	61.54
World price	0.68	0.15	28.47
Imports	735.84	0.03	6.46
Petroleum			
Price	1.00	0.00	–0.27
Output	224,964.35	0.03	–2.21
World price	1.00	0.02	–1.27
Imports	11,160.68	0.00	–0.32
Composite gasoline			
Price	1.00	0.01	–1.05
Output	266,298.50	–0.01	0.13
Biodiesel			
Price	1.00	–0.02	2.43
Output	1,249.04	0.06	100.00
Diesel			
Price	1.00	0.00	–0.27
Output	120,226.02	0.00	–0.44
World price	1.00	0.00	–0.44
Imports	8,230.80	0.00	–0.11
Composite diesel			
Price	1.00	0.00	–0.48
Output	128,842.72	0.00	0.18

Table 1. Continued

		Mandate	
	Base	Nonbinding	Binding
Feedstock Industries		(percent change)	
Welfare			
Household consumption			
Corn	9.79	–0.90	–3.77
Livestock	8,949.41	0.01	–0.63
Manufactured food	509,061.42	–0.01	–0.26
Composite gasoline	102,168.20	–0.01	1.03
Composite diesel	9,770.72	0.00	0.45
Factor wages			
Labor	1.00	0.00	0.01
Capital	1.00	0.00	0.01
Land	1.00	0.01	4.35
Government cost(–)/revenue(+)		($ millions)	
Fuel tax	48,049.00	3.00	–342.00
Tax credit	2,690.00	–12.00	–1,988.00
Import tariff	237.00	0.00	87.00
Corn subsidy	1,685.00	–249.00	86.00
Equivalent variation ($ millions)		98.89	2,708.53

[a] Prices are measured in real terms and quantities are in million real dollars.

the former two industries are not as large as the latter. Consequently, composite ethanol output declines by 0.81%, resulting in a price increase of 0.28%. As the ethanol price increases, composite gasoline blenders substitute petroleum for ethanol, thus marginally increasing petroleum use. This leads to a small increase in the composite gasoline price and a slight decrease in the output. A decrease in corn production makes land available for other agricultural production. As a result, oilseed production rises, which in turn increases the biodiesel production and lowers the biodiesel price. These changes, however, are too small to impact diesel and composite diesel markets.

The lower farm supports lead to a $249 million reduction in corn subsidy payments. Also, the tax credit payments decline by $12 million as blenders reduce the biofuel in the fuel mix. The reduction of the distortionary agricultural crop subsidies has a limited impact on the economy because of the relatively minor share of ethanol in the total fuel supply. A 15% reduction in crop subsidies causes overall welfare to increase by $99 million as measured by the equivalent variation. In the first two pollution options (biofuel (a) reduces GHG and (b) emits less GHG than fossil fuel), utility declines (not reported in Table 1) because biofuel in the fuel mix is reduced as a result of the cut in crop subsidies. In contrast, in the third pollution option (biofuel emits more GHG than fossil fuel), utility increases because the biofuel use is reduced.

Binding Mandate

Simulation is also run to analyze the biofuel mandate[13] in addition to changes in crop subsidies. Specifically, the model is calibrated to examine the 2009 ethanol requirement of 10.5 billion gallons and biodiesel requirement of

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[13] A computable general equilibrium analysis by Dicks et al. (2009) showed that the renewable fuel standard mandates of 36 billion gallons of ethanol production in 2022 would require 10.9 billion bushels of grain, 71 million tons of corn stover, and 56,200 tons of switchgrass. Because of this increase in these feedstock productions, land price would increase by 17.2%. Kenkel and Holcomb (2009) found that to meet the mandate of 36 billion gallons of ethanol, a capital investment of more than $100 billion in production facilities would be needed.

0.6 billion gallons. Under the binding mandate, blenders are forced to blend more biofuel into the fuel supply, thus artificially increasing the demand for ethanol and feedstock inputs, which counteracts the agricultural subsidy reduction impacts discussed in the previous analysis. When the mandate and a 15% reduction in crop subsidies are implemented simultaneously, the impacts of the subsidy reduction are overshadowed by the increased biofuel demand caused by the mandate. This point is immediately evident when comparing the 9.83% increase of corn production in the binding mandate case vs. the 0.66% decrease in the nonbinding case. Furthermore, the consumer price of corn increases by 3.89%, which is caused by the increased corn demand for ethanol production. Both of these results support the claims that biofuel policies will provide much more support than the existing corn subsidy does (Gardner, 2003). Hochman, Sexton, and Zilberman (2008) also found that biofuel policies are economically feasible alternatives to deficiency payments because they sufficiently increase the demand for feedstock crops, raising the price above the target price. The binding mandate also increases the biodiesel demand, which augments oilseed production (3.56%).

The subsidy reduction and mandate impact the composite ethanol market most directly because it gives the composite ethanol blenders the option to use the least costly form of ethanol because the three types (cellulosic, sugar, and grain) of ethanol are chemically identical at the point of blending. As discussed in the nonbinding mandate analysis, the reduction in the agricultural subsidy increases the production cost of grain ethanol. Consequently, composite ethanol blenders substitute cellulosic and sugar ethanol for grain ethanol. However, the impact of the ethanol mandate is so large, this substitution effect is almost negligible as consumption of all three forms of ethanol increase (61.54% for grain ethanol, 11.83% for cellulosic ethanol, and 122.32% for sugar ethanol).[14] Ethanol imports also rise by 6.46% to meet the higher demand for ethanol under the mandate. The mandate causes the ethanol content in the composite gasoline supply to increase to 7.89% and petroleum content declines to 92.11% (not reported in Table 1). The mandate also expands the biodiesel output by 100%, resulting in a modest decline in diesel use in the composite diesel mix. Yet, the large increase in biodiesel supply offsets the fall in diesel use, leading to a small increase in composite diesel output. As a result, the biodiesel content in the composite diesel increases to 2.04% and diesel content decreases to 97.96% (not reported in Table 1).

Because the increased biofuel used in the fuel supply receives a tax credit, the price of composite gasoline falls by 1.05% and price of composite diesel falls by 0.48%. As fuel becomes relatively less expensive, consumers use more fuel. The mandate leads to greater demand for corn for biofuel production, which results in an increase in the consumer price of corn and a decline in the household consumption of corn by 3.77%. Although the 15% cut in the agricultural subsidy reduces market distortions, the consumption mandate dramatically increases distortions by forcing the reallocation of resources. The 4.35% rise in land values illustrates increased demand for land to augment feedstock production to meet biofuel demands and also the need for reallocating the farmland from other food crops.[15] Because of the greater use of biofuel in the fuel mix, the government spends an additional $1.99 billion in tax credit. Furthermore, overall welfare decreases by $2.7 billion as measured by the equivalent variation. Finally, increased biofuel use raises utility in the first pollution option but significantly reduces utility (25.19% for composite gasoline and 43.36% for composite diesel) in the third pollution option (not reported in Table 1).

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[14] The large increase in sugar ethanol is the result of the small magnitude of the sugar ethanol production of the U.S.

[15] This result is consistent with the findings by Herndon (2008) and Susanto, Rosson, and Hudson (2008) that ethanolization expanded corn acreage at the expense of other crops such as wheat, soybean, and cotton.

Conclusions

The U.S. farm subsidies provide incentives for farmers to expand feedstock production, which lowers input costs to the biofuel producers. The biofuel tax credits and mandates increase the biofuel production, which provides additional support for farmers by ensuring that demand for their feedstock crops remain high. Furthermore, biofuel production raises the price of land values, which augments the wealth of farmers. The problem with the greater demand for feedstock became apparent during the food shortage around the world in 2008 when high food prices were causing hunger and starvation, especially in developing nations (de Gorter, Just, and Tan, 2009).

Although U.S. crop subsidies, by inducing overproduction of feedstock, benefit both the farmers and biofuel producers, the WTO member countries are insisting that the U.S. drastically reduce its farm supports for successful completion of the Doha Round. However, the U.S. is willing to reduce its farm subsidy by only a modest amount. Consequently, this study examines the effects of a 15% reduction in the U.S. farm subsidy on biofuel, gasoline, feedstock, food, and factor markets, government costs, pollution, and welfare. The impact of the cut in subsidies on the feedstock market is to decrease production and increase price. The increase in feedstock prices would make first-generation biofuels less competitive, providing a further incentive for advanced biofuels such as cellulosic ethanol. The decline in subsidy payments leads to less distortion and a welfare increase. However, the impacts of feedstock policies on fuel prices are very small, which is a direct result of the relative size of the industry, i.e., the biofuel component of the final fuel is relatively small, and in relation to the overall economy, it is insignificant.

The mandate requires the blenders to use more biofuel, which results in more pronounced impacts. Furthermore, the effects of the mandate counteract and dominate the effects of the crop subsidy reduction. Under the mandate scenario, demand for feedstock increases, which causes production to rise. In addition, other ethanol production also increases. Unlike the farm subsidy reduction scenario, the mandate exacerbates the distortion, and government spending increases significantly, leading to greater welfare loss.

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