Abstract

The U.S. Renewable Fuel Standard program (RFS), which involves mandates for various biofuels, is complex and has been often misinterpreted or oversimplified in previous studies. In this paper we analyze the implications of the RFS for the U.S. domestic and international ethanol markets. We demonstrate the vital role of the advanced biofuel mandate within the RFS. Impacts of changes in tariffs on imported fuel ethanol and subsidies for U.S. domestic ethanol production are examined. One of our important findings is that the RFS could result in serious misallocation of resources in both a national and international context. There is a possibility that the United States could be required to import sugarcane-based ethanol to meet the advanced biofuel mandate, simultaneously exporting corn-based ethanol, while satisfying the national overall mandate. Since the provision of subsidies for domestic ethanol production can stimulate exports of corn-based ethanol, they are equivalent to export subsidies in this situation. The removal of tariffs can reduce the burden imposed on consumers in the United States from the operation of the RFS. Our analysis shows that it is extremely important to understand the potential impact of the RFS on agricultural and energy markets.

Keywords: Ethanol, trade liberalization, Renewable Fuel Standard, mandate, subsidies

JEL codes: F13, Q18, Q42, Q48
**Introduction**

The use of first generation biofuels has increased rapidly around the world as countries pursue a range of goals, such as reducing greenhouse gas emissions and enhancing energy security. In particular, the growth of the biofuel industry in the United States and Brazil has been explosive. According to OECD (2008), these two countries account for roughly 73 percent of world biofuel production and a large percentage of ethanol (about 75 percent) in 2007. The United States uses corn as the primary feedstock for ethanol production and Brazil produces ethanol from sugarcane. An increase in the feedstock demand for biofuel production, which is generally policy driven, has strengthened the linkage between agricultural commodity markets and energy markets (Tyner and Taheripour, 2008). There has been a great deal of debate on the design of biofuel policies and their impact on agricultural markets and the environment.\(^2\)

Currently the volume of fuel ethanol traded among countries represents a small percentage of world consumption (about 10 percent). According to Gallagher (2007), ethanol trade volume was about 1.46 billion gallons in 2006. The major exporters are Brazil, China, and the Caribbean countries and Brazil has been the dominant exporter (more than 85 percent), whereas the major importers are the United States, the European Union, and Japan, and the United States has been the dominant importer. Allowing imports from developing countries that have a comparative advantage in the production of biofuel feedstock (e.g., cane sugar and palm oil) could allow the United States to diversify its sources of energy supply and reduce greenhouse gas emissions at a lower cost than relying exclusively on domestic supplies of biofuel.\(^3\) With a reduced tariff, fuel ethanol is likely to be imported from Brazil,

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\(^2\) Several studies have concluded that biofuel policies can have unintended economic consequences (Vedenov and Wetzstein, 2008; Khanna et al., 2008). Despite such criticisms it seems inevitable that biofuels will play an important role in future energy policies in many countries.

\(^3\) In many developing countries there is significant potential for biofuel production (Jank et al., 2007). This is because tropical and subtropical feedstocks for biofuels usually have more favorable energy and environmental balances than crops grown in temperate latitudes.
which can produce ethanol from sugarcane at lower costs than the corn feedstock used in the United States\textsuperscript{4}. Therefore, changes in domestic and trade policies for biofuels in the United States and Brazil could have a large impact on the world ethanol market.

In addition, changes in their policies are expected to affect the feedstock (for ethanol production) markets and other agricultural commodity markets. If, for example, changes in the U.S. ethanol trade policies affect the corn price, the prices of other agricultural commodities, such as wheat and soybeans, could be affected (primarily through land reallocation). Because of the role of the United States in global markets, ethanol trade liberalization could also have an impact on world crop and feed markets (Elobeid and Hart, 2007; Muhammad and Kebede, 2009). Hence, it is important to examine how changes in trade policies affect the level and variability of U.S. domestic ethanol supply price (linked to the corn price) and world ethanol price (linked to the sugar price).

Although a number of studies have evaluated the impact of biofuel programmes on agricultural and fuel markets and on social welfare, using either partial or general equilibrium analysis (Lundgren, 2008), the implications of U.S. trade policies for biofuels in the presence of domestic biofuel policies, such as subsidies and mandates, have received limited attention. Martinez-Gonzalez et al. (2007) calculate the impact of ethanol trade distortions for the U.S. and Brazil. A partial equilibrium trade model is estimated using two-stage least squares. The results support their hypothesis that the removal of distortions in the U.S. ethanol market would be beneficial for both countries. de Gorter and Just (2008b) investigate the static effects of U.S. ethanol tariffs with or without the biofuel mandate and/or a tax credit. Elobeid and Tokgoz (2008) develop an international ethanol model to examine the effect of removing trade and domestic distortions in the U.S. on the world ethanol market. Since the United States is expected to be a large importer, the world ethanol price will be affected by ethanol

\textsuperscript{4} According to Jank et al. (2007), there is a large potential for sugarcane ethanol production in other developing countries such as Colombia.
trade liberalization. Under free trade, the world ethanol price increases as U.S. ethanol imports increases. Brazil would benefit from the tariff elimination. The U.S. ethanol market is less susceptible to price volatility arising from demand and supply shocks.

Current U.S. biofuels policy is a combination of mandates, tax credits, and tariffs. A key component is the U.S. Renewable Fuel Standard program (RFS), which was revised in the Energy Independence and Security Act 2007. The RFS, which involves mandates for various biofuels, is complex and has been misinterpreted or oversimplified in many previous studies. It is extremely important to understand the complicated requirements of the RFS mandate in order to examine the impact of potential changes in U.S. domestic and trade policies for biofuels accurately (Thompson et al., 2009).

In this paper we formally analyze the implications of the RFS for U.S. domestic and international ethanol markets. We emphasize the vital role of the advanced biofuel mandate within the RFS. In addition, the impacts of changes in the level of tariffs and subsidies are examined. We primarily focus on the consequences in the U.S. ethanol market and the linkage with the corn market.

In terms of the federal government support for ethanol, we assume that if the import tariff were reduced, the current mechanism would be modified such that the tax credit paid to blenders would apply only to domestically produced ethanol or alternatively a production subsidy would be paid directly to domestic ethanol refiners. This would be necessary to avoid the politically unattractive option of subsidizing the use of imported ethanol (Styles, 2008).

The paper is organized as follows. The next section summarizes the U.S. domestic and trade policies for biofuels, with focus on the Renewable Fuel Standard programme and the possible subsidy reform. An ethanol trade model incorporating the U.S. RFS and subsidies for domestic ethanol production is presented in section 3. The implications of import tariffs are discussed in the penultimate section. The final section provides concluding remarks.
U.S. Domestic and Trade Policies

In this section we discuss the U.S. Renewable Fuel Standard (biofuel mandate) in detail and the subsidy reform that would be required if the tariffs were reduced or eliminated.

Renewable Fuel Standard (U.S. Biofuel Mandate)

The Renewable Fuel Standard was created by the Energy Policy Act of 2005 (EPAct) and amended by the Energy Independence and Security Act of 2007 (EISA). It requires that transportation fuel in the United States contain at a minimum specified volumes of renewable fuel, advanced biofuel, cellulosic biofuel, and biomass-based diesel (EISA. H.R.6 Title XV, Subtitle A, Sec. 202). Table 1 shows the renewable fuel volume requirements (taken from EPA 2009).

In the table “applicable volume of renewable fuel” is interpreted as the overall mandate requiring blenders to incorporate 12.95 billion gallons of renewable fuels with gasoline and other transportation fuels in 2010, increasing to 36 billion gallons by 2022. There are also “sub-mandates” (secondary mandates) which are part of the overall mandate. “Applicable volume of advanced biofuel” is the largest sub-mandate (advanced biofuel mandate) and embraces other two sub-mandates: applicable volume of cellulosic biofuel and biomass-based diesel. The cellulosic biofuel mandate has to be met by renewable fuel, derived from any cellulose, hemicelluloses, or lignin, which achieves a 60 percent greenhouse gas (GHG) emission reduction requirement. The applicable volume of biomass-based diesel is determined only for the calendar years 2009 through 2012 in EISA.

The advanced biofuel mandate has to be met by renewable fuel other than ethanol derived from corn starch, including sugarcane-based ethanol from foreign countries (most likely sourced from Brazil), biomass-based diesel, and cellulosic biofuel. Sugarcane-based ethanol

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5 According to Thompson et al. (2009), forecasts suggest that conventional ethanol will be cheaper to produce than “advanced” non-cellulosic ethanol in the United States. Cellulosic ethanol is expected to be more expensive. The feasibility of ethanol from sugarcane or sugar beets will depend on the U.S. policies for sugar. Currently,
<table>
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<th>Year</th>
<th>Total renewable fuel requirement</th>
<th>Advanced biofuel requirement</th>
<th>Cellulosic biofuel requirement</th>
<th>Biomass-based diesel requirement</th>
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<td>2008</td>
<td>9</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>2009</td>
<td>11.1</td>
<td>0.6</td>
<td>n/a</td>
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<tr>
<td>2010</td>
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<tr>
<td>2011</td>
<td>13.95</td>
<td>1.35</td>
<td>0.25</td>
<td>0.8</td>
</tr>
<tr>
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<td>15.2</td>
<td>2</td>
<td>0.5</td>
<td>1</td>
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<td>16.55</td>
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<td>b</td>
<td>b</td>
<td>b</td>
<td>b</td>
</tr>
</tbody>
</table>

* To be determined by the Environmental Protection Agency through a future rulemaking, but no less than 1.0 billion gallons.

*b To be determined by EPA through a future rulemaking.

can be used to fill the gap between the advanced biofuel mandate and other two sub-mandates (the advanced mandate less the cellulosic mandate less the biomass-based diesel mandate). If no cheap alternative other than foreign sugarcane-based ethanol is available, the United States must import this to meet the advanced biofuel mandate unless the mandate is waived.

high domestic sugar prices make it more profitable to convert sugarcane and sugar beets to sugar than to convert it to ethanol (Jacobs, 2006).
This has significant implications for ethanol trade because the United States has to import regardless of the situation of the world sugar and ethanol markets.

The difference between the overall mandate and the advanced mandate can be filled by any combinations of renewable fuels. The U.S. domestic corn-based ethanol (conventional biofuel) can be used for this purpose. If conventional biofuel, which is defined as ethanol derived from corn starch, is relatively costly, sugarcane-based ethanol (or other biofuels if available) can be used to make up for conventional biofuel (corn-based ethanol). It is particularly important to note that there is no mandate for conventional biofuel (corn-based ethanol). Conventional biofuel does not count against the overall mandate above the difference between the overall mandate and advanced mandate. The maximum volume of conventional biofuel that can count against the overall mandate is 15 billion gallons from 2015 to 2022.

Non-Prohibitive Tariffs and Subsidy Reform

For political reasons, reducing or eliminating the import tariff on ethanol would require changes in the mechanism through which the federal government supports the use of domestic ethanol. The U.S. government currently provides a tax credit of 46 cents per gallon to companies that blend ethanol with gasoline. All ethanol imported into the U.S. (except for imports under the Caribbean Basin Initiative) is subject to an import tariff (a 2.5 percent ad valorem tariff) and a “secondary duty” (specific tariff of 54 cents per gallon) amounting to a combined total of roughly 60 cents per gallon. If the import tariff were reduced or eliminated under the current mechanism, taxpayers could end up subsidizing foreign (Brazilian) ethanol producers. The tariff currently imposed on imported ethanol exists to offset the credit that foreign suppliers would otherwise receive.

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6 Thompson et al. (2008) mention about this fact in their paper.
7 There are also state tax credits. According to de Gorter and Just (2008b), the overall tax credit was 56.93 cents per gallon in 2006.
Two options could be considered to avoid subsidizing foreign ethanol suppliers (Styles, 2008). First, the tax credit could be modified so that it applies only to domestically produced ethanol. However, administering a two-tier ethanol subsidy system could be problematic. A second option would be to shift the point of subsidy from the blender to the ethanol producer by providing an ethanol production subsidy. Although some problems may arise regarding such changes, not least through international obligations through the World Trade Organization, we assume that if the import tariff were to become non-prohibitive, the subsidy mechanism would be modified so that American tax dollars would not subsidize the use of foreign ethanol.

**Ethanol Trade Model**

Consider a competitive world ethanol market with an aggregate excess supply $ES$ (mainly from Brazil) and an aggregate excess demand for sugarcane-based ethanol $ED_0$ (excluding U.S. excess demand). The right side of the partial-equilibrium diagrams in figure 1 illustrates the world ethanol market. The initial international equilibrium (without the U.S. demand) is given by the price $p_{WE}$, with the quantity of ethanol traded $Q_{TE}$. Since producers (Brazilian mills) determine what portion of sugarcane goes to ethanol production or sugar production flexibly, depending on the relative prices of these commodities, sugar and ethanol prices tend to move together (Elobeid and Tokgoz, 2008). For example, an increase in the demand for ethanol shifts sugarcane from sugar production to ethanol, resulting in tightened sugar supplies and increased world sugar prices (Brazil is also a large exporter of sugar).

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8 de Gorter and Just (2008b) assume that the tax credit is applicable to both domestic and import supplies. If the aim is solely to increase the use of ethanol in preference to gasoline this could be a cheaper alternative than subsidizing domestic production. However, it is unlikely to be feasible politically.
Figure 1: Ethanol trade with the U.S. RFS: ethanol use exceeds the overall mandate

For simplicity we assume that:

a) Three types of ethanol are available for the United States: i) domestically produced corn-based ethanol (conventional biofuel); ii) imported sugarcane-based ethanol (regarded as advanced biofuel); and iii) cellulosic ethanol. We ignore other biofuels.

b) The U.S. mandates (overall, advanced and cellulosic mandates) are legally enforced through monitoring and high penalties for violation (in reality, any mandates can be waived\(^9\)). The biomass-based biofuel mandate is ignored because it will be small compared to other mandates.

c) The mandates require a minimum volume of ethanol to be consumed. Hence, all mandates are consumption mandates. In reality, the mandate is likely to be implemented through the use of an annual minimum blending requirement (de Gorter and Just 2009).

d) Subsidies in the United States are only applied to domestically produced ethanol.

e) There is no technical constraint on the use of ethanol. If an increase in the blend ratio is limited technically and/or the number of flex-fuel vehicles is limited, the potential

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\(^9\) The U.S. Environmental Protection Agency (EPA) is authorized to waive all or portions of the RFS mandates if EPA determines that implementation of the mandate would severely harm the economy of a state, region, or the United States.
maximum consumption (or blend ratio) of ethanol is limited. If that is the case, however, the mandates are expected to be waived.

f) There is no difference in fuel efficiency between gasoline and ethanol. Therefore, if the ethanol use exceeds the mandated level, its consumer price equals to the consumer gasoline price including any fuel tax at the equilibrium. In other words, ethanol demand will increase up to the point where these prices are the same. In reality, as the ethanol concentration in the blended fuel increases, ethanol’s lower heat content will start to offset the octane and oxygen benefits, and its retail price will be lower than the retail price of gasoline (Xavier, 2007; Gallagher, 2007). Even so, both prices are expected to move together (co-move).

g) Transportation costs are ignored. According to Tokgoz and Elobeid (2006), they are about 16 cents per gallon.

First, consider the case in which the U.S. import tariff on fuel ethanol is eliminated and (all types of) cellulosic ethanol will be too costly to be supplied beyond the volume required by the cellulosic mandate. The cellulosic mandate is binding and the price of this biofuel is high. In this case, sugarcane-based ethanol, which is less costly than the cellulosic ethanol, has to be used to meet the difference between the advanced biofuel mandate and the cellulosic mandate. Given the quantity of imported ethanol that fills the difference (the excess demand curve shifts outward, \( ED_i \)), the world ethanol price will be increased up to \( p_{we}' \), which defines the minimum supply-inducing price for marginal imported ethanol (the intercept of the marginal imported ethanol supply curve \( S_{MIE} \) in the United States). The original domestic (corn-based) ethanol supply curve \( S_{DE} \) is derived from the horizontal difference between an aggregate supply curve for corn and an aggregate non-ethanol demand curve for corn which includes domestic food and livestock feed demand, and foreign demand for corn. Therefore,
the supply price of domestic ethanol is directly linked to the corn price (see de Gorter and Just, 2008a; Yano et al., 2010). The fuel tax and subsidy-inclusive domestic ethanol supply curve is denoted by \( S'_{DE} \) (the subsidy per gallon is greater than the fuel tax per gallon in this case). As the subsidy for domestic ethanol increases, \( S'_{DE} \) shifts downwards. The aggregate ethanol supply curve \( S_{AE} \) is the horizontal sum of \( S'_{DE} \) and \( S_{MIE} \). \( p_{GUS} \) represents the consumer gasoline price, including fuel tax in the United States. The left side of the partial-equilibrium diagram in figure 1 illustrates the U.S. (marginal) ethanol market in which the horizontal axis shows the quantity of ethanol used beyond the volume required by the advanced mandate. \( \hat{Q}_{EDA} \) denotes the ethanol volume required by the overall mandate less that required by the advanced mandate. After the advanced biofuel mandate is met, the United States determines the quantity of domestic corn-based ethanol and/or the additional quantity of foreign sugarcane-based ethanol, depending on their relative costs and the U.S. gasoline price.

Given the advanced biofuel mandate, there are two important cases to be considered: either

\[ p'_{WE} \leq p_{GUS} \quad \text{or} \quad p'_{WE} > p_{GUS}. \]

**CASE 1:** \( p'_{WE} \leq p_{GUS} \)

If \( p'_{WE} < p_{GUS} \) the U.S. always has an incentive to import additional ethanol because the ethanol price is, at the minimum, the U.S. consumer price of gasoline. If the marginal cost of ethanol use (the aggregate supply) is lower than \( p_{GUS} \), total ethanol use exceeds \( \hat{Q}_{EDA} \) since blenders increase ethanol use up to the point at which the marginal cost is equal to the gasoline price in order to maximize their benefits. This situation corresponds to that in figure 1. Total (marginal or additional) ethanol use is \( Q_{AE} \), being composed of domestic ethanol \( Q_{DE} \) and (marginal) imported ethanol \( Q_{MIE} \). The (new) world price of ethanol \( p'_{WE} \) and the demand price of domestic ethanol are equal to the U.S. gasoline price. The supply price of
domestic ethanol (corn price) is determined by the original curve and is the sum of the world oil price and a subsidy (per gallon) whatever the level of domestic ethanol use. Hence, when the mandate is exceeded, the higher the price of petroleum, the higher domestic ethanol demand and the higher the corn price. The use of marginal imported ethanol depends on how changes in the world oil price affect $S_{MIE}$, but the world ethanol price equals to the U.S. gasoline price as discussed above. An increase in the level of subsidy results in increased use of domestic ethanol and a higher corn price, \textit{ceteris paribus}.

If the marginal cost of ethanol is above the gasoline price at the mandated level, the U.S. overall mandate is binding (total marginal ethanol use equals the difference between the overall mandate and the advanced biofuel mandate). Figure 2 illustrates this case.

**Figure 2: Ethanol trade with the U.S. RFS: the overall mandate is binding**

The demand price of ethanol would have to rise above the gasoline price in order to satisfy the mandate; otherwise blenders would be unwilling to use that amount of ethanol. Consumer ethanol prices (both domestic and world prices) are equal to the marginal cost of ethanol use at the required level. The quantities of domestic and imported ethanol are determined according to the positions of their supply curves. The supply price of domestic ethanol is the sum of its demand price and the net subsidy (subsidy less fuel tax). When the mandate is
binding, the oil price affects the price of corn only through its impact on $S_{MIE}$. With a binding mandate, an increase in the subsidy for domestic ethanol has two important effects. First, it reduces the demand price of ethanol, resulting in a reduced mixed fuel price and higher consumption of gasoline. Second, since the supply of domestic ethanol becomes cheaper than before, the demand for domestic ethanol is increased and the use of imported ethanol is reduced (holding $S_{MIE}$ unchanged). Consequently, the price of corn is increased. The price of world ethanol is reduced and so is the world sugar price if sugar mills in Brazil can flexibly determine what proportion of sugarcane goes into ethanol or sugar production.

If $p_{WE}' = p_{GUS}$, marginal (additional) sugarcane-based ethanol imports will occur only when the marginal cost of domestic ethanol production is higher than the gasoline price at $\hat{Q}_{E_{OA}}$ (in which case the overall mandate is binding). If the marginal cost of domestic ethanol is exactly equal to or lower than the gasoline price, domestically produced corn-based ethanol can satisfy the required ethanol use.

**CASE 2: $p_{WE}' > p_{GUS}$**

Given U.S. demand for cane-based ethanol to meet the advanced mandate, the world ethanol price could be forced higher than the U.S. gasoline price even if initially it is lower. Of course, the initial international ethanol price (without U.S. mandates) could be higher than $p_{GUS}$ due, for example, to a sharp rise in world sugar prices (as observed in 2009) or an increase in mandated biofuel use in the rest of the world. In any case, the United States has to import sugarcane-based ethanol from foreign countries (probably from Brazil) unless the advanced mandate is waived or cellulosic ethanol (or other biofuels) becomes commercially viable.
The U.S. imports ethanol if the marginal cost of domestic corn-based ethanol production (including subsidies) at the required level is above $p_{WE}'$. In this case the U.S. overall mandate becomes binding and $p_{WE}^* > p_{WE}'$. Figure 3 depicts this situation.

**Figure 3: Ethanol trade: the overall mandate is binding** $p_{WE}^* > p_{GUS}$

If the marginal cost of domestic ethanol at $\hat{Q}_{EOA}$ is equal to $p_{WE}'$, only domestic ethanol is used to meet the overall mandate, which again becomes binding. But, if the marginal cost of domestic ethanol at $\hat{Q}_{EOA}$ is lower than $p_{WE}'$, what happens? Since the domestic ethanol price is lower than the world ethanol price (there is no demand in the domestic market beyond the mandated use at that higher world price), this will open the door for exports of U.S. corn-based ethanol into markets, such as Europe or Asia (or even northern Brazil), depending on trade policies in other countries. Under this scenario there is a possibility that the United States will import sugarcane-based ethanol to meet the advance biofuel mandate while simultaneously exporting corn-based ethanol, while satisfying the overall mandate! If U.S. becomes a large country exporter, the world ethanol price will be reduced (but will still be higher than the U.S. gasoline price), largely depending on the elasticity of excess demand in the rest of the world. Also, the price of corn will depend on the quantity of corn-based...
ethanol exported. This weird situation could occur if, for example, cellulosic ethanol or other biofuel is not economically viable, world sugar price is high, the demand for ethanol from the rest of the world is high (mandated), the U.S. advanced biofuel mandate is increased and high (strictly speaking, the difference between the advanced mandate and the cellulosic mandate), the world oil price is not so high, and U.S. corn-based ethanol is competitive at prevailing prices. A weak dollar would also make U.S. exports more competitive. Hence, the current mechanism of the U.S. RFS (provided that it is fully enforced) might result in serious misallocation of resources in both a national and international context. Since the provision of subsidies for domestic ethanol production can stimulate exports of corn-based ethanol they are equivalent to export subsidies and distort trade.

Figure 4: U.S. imports cane-based ethanol while simultaneously exporting corn-based ethanol \( p^{WE}_W > p^{GUS}_U \)

Thus far we have assumed that cellulosic ethanol is not viable beyond the mandated level. If cellulosic ethanol becomes competitive beyond the volume required by the cellulosic mandate, (part of) sugarcane-based ethanol can be replaced with it and the quantity of corn-based ethanol will be reduced if the overall mandate is initially binding (because the minimum supply-inducing price for marginal (additional) imported ethanol falls). Also, this
will reduce the possibility that the United States becomes an exporter of corn-based ethanol with the advanced mandate. If the overall mandate is initially exceeded, an increase in the supply of cellulosic ethanol just results in the increased use of total ethanol. Of course, these consequences will hinge on domestic and trade policies for biofuels, such as the level of subsidy and tariffs.

**The Effects of Tariffs**

For simplicity, suppose that a specific tariff, \( t \), is imposed on imported fuel ethanol in the United States. The tariff-inclusive marginal imported ethanol supply is denoted by \( S'_{MIE} \). For CASE 1 in the previous section, with a binding mandate the United States does not use additional imported ethanol if the intercept of \( S'_{MIE} \) is higher than the marginal cost of domestic ethanol, inclusive of a subsidy, at \( \hat{Q}_{EOA} \). Below that point, as the tariff is reduced, the demand price for ethanol (the mixed fuel price) falls due to competition (the aggregate ethanol supply with tariffs, \( S'_{AE} \) shifts downward), the imported ethanol use is increased (the world ethanol price rises), and the quantity of domestic ethanol is reduced (thus the corn price falls). The U.S. demand price of ethanol is the sum of the world ethanol price (supply price) and a tariff. The ethanol trade with U.S. import tariff with a binding overall mandate is described in figure 5. Once the demand price of ethanol reaches to the U.S. consumer gasoline price (i.e., if the overall mandate is exceeded), a reduction in the tariff just increases the quantity of imported ethanol and hence the world ethanol price.

When the advanced biofuel mandate is initially binding (i.e., there are no additional imports), the imposition of a tariff increases the demand price of imported ethanol in the United States by the amount of the tariff, and the burden is completely borne by U.S. consumers because import demand is perfectly inelastic. When the overall mandate is exceeded with imported (and domestic) ethanol, the imposition of a tariff reduces the supply price of imported ethanol by the amount of the tariff, and the tariff revenue is completely paid
by foreign suppliers because they face a perfectly elastic U.S. import demand (at the consumer gasoline price in the United States).

**Figure 5: The ethanol trade with U.S. import tariffs: the overall mandate is binding**

For CASE 2, the imposition of a tariff reduces the likelihood of ethanol imports (the expected quantity of imported ethanol). Additional imports occur only when the marginal cost of domestic ethanol production at \( \hat{Q}_{EOA} \) is greater than \( p_{WE}' + t \). If it lies between \( p_{WE}' \) and \( p_{WE}' + t \), only domestic ethanol is used to meet the overall mandate. But the imposition of a tariff does not affect the possibility that the U.S. exports corn-based ethanol to other countries. This is because the world ethanol price is unchanged by imposing the tariff and the price of corn-based ethanol in the United States depends on the domestic ethanol supply curve and the level of the overall mandate. Since the advanced biofuel mandate is binding when the U.S. exports ethanol, the imposition of the tariff simply increases the U.S. demand price of imported ethanol and (as discussed above) the tariff revenue is paid by consumers in the United States (the mixed fuel price is increased).
Concluding Remarks

The development of first generation biofuels, produced from feedstock such as corn and sugarcane, has been explosive especially in Brazil and the United States. It is essential to investigate how changes in domestic and trade policies for biofuels in these countries affect ethanol prices, feedstock prices, and other agricultural commodity prices.

The U.S. Renewable Fuel Standard (RFS), which is a major domestic biofuel policy and involves mandates for various biofuels, is complex and has been often misinterpreted or oversimplified in previous studies. It is extremely important to understand the complicated requirements of the RFS in order to analyze the implications of domestic and trade policies for biofuels accurately.

This paper examines the impacts of the RFS on the U.S. domestic and world ethanol markets incorporating the advanced biofuel mandate into our model. We emphasize the key role of the advanced biofuel mandate within the RFS. The effects of changes in the level of subsidy for domestic ethanol production and the level of tariffs on imported fuel ethanol are also considered. We mainly focus on the consequences in the U.S. ethanol market and the linkage with the corn market.

An important finding is that the current mechanism of the U.S. RFS could result in serious misallocation of resources in both a national and international context. If cellulosic ethanol or other biofuel is not economically viable, the advanced biofuel mandate will force the United States to import sugarcane-based ethanol regardless of the situation of the world sugar and ethanol markets. As a result, the United States could import sugarcane-based ethanol to meet the advanced mandate while exporting corn-based ethanol to other countries, while satisfying the national overall mandate. Under this situation, subsidies for domestic ethanol are equivalent to export subsidies because they stimulate exports of corn-based ethanol. In addition, the removal of tariffs can reduce their burden borne by consumers in the United
States. Our analysis suggests that policy makers may need to reconsider the present RFS programme, especially the advanced biofuel mandate.
References


