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Abstract

This paper analyzes the impact of an ethanol import tariff in conjunction with a consumption mandate and tax credit. A tax credit alone acts as a subsidy to ethanol producers, equally benefiting exporters like Brazil. If an import tariff is imposed to offset the tax credit, world prices of ethanol decline by less than the tariff (unless oil prices are unaffected). Eliminating the tariff with a tax credit in place results in a significant gain to exporters like Brazil but eliminating the tax credit too reduces the initial benefits to Brazil of the tariff reduction substantially. The results change however if there is "water" in the tax credit. Then exporters benefit much more with the elimination of both the tariff and tax credit compared to a situation of both policies in place.

If only a mandate was in place, exporters like Brazil again benefit as much as domestic ethanol producers do. Eliminating the tariff with a mandate results in an increase in domestic ethanol prices (even if oil prices do not change) because more domestic supply is required to maintain the mandate. The tariff therefore has a smaller negative impact on world ethanol prices with a mandate compared to a tax credit.

A tax credit with a binding mandate is a subsidy to fuel consumers and only indirectly benefits ethanol producers if ethanol prices increase due to increased demand for ethanol with the increase in fuel consumption). Therefore, eliminating the tax credit with a binding mandate has little effect on market prices of ethanol – domestic and foreign producers alike benefit very little with a tax credit in this situation. Brazil would much prefer the elimination of the tax credit and the so-called offsetting import tariff when a mandate is binding. Hence, the protective effects of an import tariff are not additive with either a tax credit or the price premium due to a mandate.

Key words: biofuels, mandate, tax credit, ethanol

JEL: F13, Q17, Q18, Q42

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The Economics of U.S. Ethanol Import Tariffs with a Consumption Mandate and Tax Credit

"*Perhaps the most outrageous example is America's $0.54 per gallon import tariff on ethanol… This contrasts with the $0.51 per gallon subsidy that US companies…receive on ethanol. Thus, foreign producers can't compete unless their costs are $1.05 per gallon lower than those of American producers…*" Joseph E. Stiglitz (2006).

1. Introduction[1]

Many controversies surround U.S. biofuels policy, not least of which is the import tariff on ethanol of 54 cents per gallon. The key reasons why the United States and the world have increased their focus on biofuels include global climate change, local air pollution, increasing oil prices with dwindling reserves, political instability in oil-exporting countries and the desire for energy security. Because the import tariff affects exports from Brazil where ethanol from sugar cane contributes far more to reducing green house gases than ethanol derived from corn in the United States, many commentators have remarked on how an ethanol tariff contradicts the goals of improving the environment, reducing reliance on oil and oil imports and diversifying energy sources (Johnson and Runge 2007; Jank et al. 2007; Kojima et al. 2007; Howse et al 2007; Doornbosch and Steenblik 2007). Clearly, other political goals such as enhancing farm incomes, reducing the tax costs of farm subsidy programs and promoting rural development are also very important (Rajagopal and Zilberman 2007; Tyner 2007; Runge and Senauer 2007).

In analyzing the effects of the import tariff, it is however important to understand that countries worldwide have also adopted a number of other policies to encourage the production and use of biofuels as an alternative to fossil fuels (Kojima and Johnson 2006; UNCTAD 2006). Two particularly important policies are biofuel excise-tax exemptions and mandates on biofuel consumption.[2] The focus of this paper is to analyze the impact of an import tariff on ethanol in conjunction with a consumer excise-tax exemption and/or ethanol consumption mandate. Because of key policy interaction effects, we show the standard analysis of an import tariff is not adequate. Indeed, the impacts of a tariff depend not only depend on whether a mandate or tax exemption is in place but also if both policies are in place simultaneously (while the tax exemption itself affects the likelihood that a mandate is binding). In contrast to other analyses, a significant finding is that the benefits to U.S. corn producers from ethanol policies are not additive. The benefits of a tax exemption with a mandate binding are different than if the mandate is binding. Likewise, the costs of a tariff to exporters depend on the tax exemption and whether or not the mandate is binding.

It is difficult to ascertain whether mandates or tax exemptions are used more pervasively. According to de Gorter and Just (2007a), at least 65% of total world fuel consumption is affected by tax exemptions for biofuels while a recent FAO study concludes that "virtually all existing laws …set blending requirements" (Jull et al. 2007, p. 21). Either way, this paper develops a general theory to evaluate the economic effects an import tariff with or without biofuel mandates and/or tax exemptions. To this end, we develop an analytical model that shows how the tax exemption alone increases the market price of ethanol above the gasoline price by the level of the tax. It acts as a taxpayer transfer to biofuel producers, domestic and foreign. Consumers of fuel are only affected indirectly by the reduction in the average price of fuel due to the increased supply of ethanol. Total fuel consumption rises and oil prices fall as a result.

Imposing an ethanol import tariff equal to the tax exemption results in ethanol exporters losing much of the benefits of the tax exemption and will lose all of it if oil prices do no change. One very important finding is that if the import tariff is to offset the benefit of the tax exemption, and there is "water" in the tax exemption,[3] then exporters like Brazil are overtaxed and can be significantly worse off than a policy of neither a tax exemption nor an import tariff.[4] Because water in the tax exemption has been very high historically, this represents a significant penalty on ethanol exporters.[5]

On the other hand, a mandate alone results in an increase in both the producer and consumer price of ethanol.[6] This reduces total consumption of fuel. Imposing an import tariff results in a larger increase in domestic prices compared to the case of a tax exemption because domestic supplies have to increase in order to maintain the mandate. The tariff in the presence of a mandate therefore has a smaller negative impact in world ethanol prices.

However, when both polices operate simultaneously (i.e., the mandate is binding), a tax exemption acts as a subsidy to fuel consumers instead, resulting in a lower price of fuel to consumers compared to a mandate only. Again, domestic and foreign ethanol producers gain from a tax exemption in this situation but only indirectly with the increased ethanol demand resulting from the increase in total fuel consumption. Eliminating the tariff and the tax exemption is much preferred by ethanol exporters when a mandate is binding while water in the tax exemption is not relevant. The results of this paper have several important implications for the design of ethanol policies, including trade policy.

This paper is organized as follows. The next section provides background on tariff policy while Section 3 develops the general theoretical model of import tariffs with or without a fuel tax exemption and/or mandate. Section 4 presents the empirical results while the last section provides some concluding remarks.

2. Background

In addition to the longstanding 2.5 percent import tariff on ethanol, Congress implemented a "secondary" import tariff of 40 cents per gallon in 1980 to offset the 40 cent per gallon excise-tax exemption granted in 1978. The specific import tariff has varied and is now 54 cents per gallon, above the 51 cent per gallon tax exemption established in 2005. The tariff therefore more than offsets the tax exemption; even though the ethanol lobby group RFA (2005) states the tariff was established "to negate the benefit of the tax credit for imported ethanol".[7]

In 2004, the "tax exemption" was changed to a "tax credit" as the Highway Trust Fund was losing funds from what otherwise would have been tax receipts from ethanol. The federal government now reimburses refiners from general tax revenues for ethanol use whereas prior to 2004, it was funds foregone for the Highway Trust Fund to maintain roads (Rask 2004; Steenblik 2007). The overall tax (federal and state) on gasoline is 41 cents per gallon. Hence, the taxpayer is now paying 10 cents per gallon more under the tax credit than it implicitly was paying with the tax exemption system up to 2004. This means the import tariff of 54 cents per gallon up to 2005 was offsetting an effective tax exemption of 41 cents per gallon, not the reported 51 cents per gallon.

Instead of being exempt from the 41 cents per gallon tax, revenues from ethanol sales now go into the Highway Trust Fund. If the government maintained the tax exemption system, taxpayers would have saved the 51 cents per gallon tax now being disbursed to refiners on ethanol production and there would have been pressure to increase gasoline taxes to compensate for the foregone revenues to the Highway Trust Fund because of ethanol. This would have reduced gasoline consumption, pollution and traffic congestion related costs, while at the same time making it easier to achieve the biofuel mandate. There are now deadweight costs with the taxpayer costs because of the 51 cents per gallon credit and the lower fuel taxes as the pressure to compensate for the tax exemption is now gone.

In addition to the 51 cents per gallon federal tax credit, several states provide tax exemptions as well (Koplow 2006). This adds up to an overall tax credit of 0.5693 cents per gallon. If one adds the *ad valorem* equivalent of the 2.5 percent tariff to the 54 cents per gallon tariff, then the overall tariff is about 0.5845 cents per gallon in 2006. Hence, one can assume in the theoretical analysis to follow that the tariff and tax credit are essentially equal.[8] This simplifies the exposition of the theory substantially. However, it should be noted that the actual tax on ethanol and gasoline is 41 cents per gallon (so a tax exemption policy would have a substantially lower level of implicit subsidy to ethanol producers than the current tax credit, and the tariff would be more than offsetting the tax exemption by about 16 cents per gallon – this further discriminated against exporters like Brazil).

Total U.S. imports of ethanol in calendar year 2006 were 653.3 mil. gallons, almost all from Brazil of which approximately 1/3rd was routed through the Caribbean to avoid the import tariff. Through the Caribbean Basin Initiative, an import quota of 7 percent of domestic U.S. ethanol consumption is tariff free. Brazil exports ethanol with 5 percent water content to the Caribbean and then is reprocessed so that the water content is only 1 percent and then exported to the United States as a different product, thereby overcoming any problems with rules of origin in preferential trading agreements (Yacobucci 2005). Imports from the Caribbean were only 65 percent of the maximum allowed so apparently the costs of obtaining tariff free status through the Caribbean are significant.

The literature to date on the welfare economics of biofuel import tariffs is sparse. Unlike in this paper, no paper analyzes tariffs along with mandates and tax credits simultaneously. Martinez-Gonzalez et al. (2007) analyze the tariff alone while Kruse et al. (2007) analyze the simultaneous removal of the tax credit and tariff (the mandate is assumed not to be binding). Elobeid and Togkoz (2007) model the elimination of the tariff alone and then the elimination of the tariff and tax credit simultaneously (the possibility of a mandate is not mentioned).

3. The Economics of a Tax Credit

Assume a competitive market with a supply curve for oil S_O and a supply curve for domestic and imported supplies of ethanol $S_E(P_E)$ and $S_E^M(P_E - t_m)$, respectively, where t_m is the import tariff. The domestic demand for liquid transportation fuel inclusive of the consumer tax t is denoted by D'_F.[9] In Figure 1, equating aggregate fuel supply S_F with demand generates P_O, the consumer and producer price of oil and ethanol (ethanol production is zero and consumption of fuel is C_F).[10] Introducing a tax credit for ethanol effectively shifts the supply curve for ethanol S_E down by the tax to S'_E (because refiners and blenders bid up the price of ethanol to the consumer price of oil because gasoline and ethanol are assumed to be perfect substitutes in demand).[11] The new total fuel supply curve is denoted by S'_F, causing market prices of oil to fall to P'_O. The gap between the new market price for ethanol P'_E and the new price of oil is the tax credit t_c. As noted earlier, for convenience we assume $t = t_c = t_m$. Ethanol production is Q'_E which displaces gasoline consumption and total fuel consumption increases to C'_F. Empirically, oil prices are not expected to fall very far because historically ethanol constitutes a small share of total world oil consumption.

The equilibrium conditions can thus be written as:

(1) $$P_E - t_c - P_O = 0$$

(2) $$D_F\left(P_O + t\right) - S_O\left(P_O\right) - S_E\left(P_E\right) - S_E^M\left(P_E - t_m\right) = 0$$

Totally differentiating and solving obtains:

(3) $$\frac{dP_E}{dt_c} = \frac{\eta_F^D \frac{D_F}{P_N} - \eta_O^S \frac{S_O}{P_O}}{\eta_F^D \frac{D_F}{P_N} - \eta_O^S \frac{S_O}{P_O} - \eta_E^S \frac{S_E}{P_E} - \eta_E^M \frac{S_E^M}{P_E - t_m}} > 0 \text{ and } < 1$$

From equation (3), the tax credit has a larger impact in increasing ethanol prices with higher elasticities of fuel demand and oil supply, and with a lower supply elasticity of ethanol (both domestic and import).

In the limit, if oil prices are fixed (invariant to ethanol production), then $\eta_O^S = \infty$ and both domestic and world prices increase by the amount of the tax credit:

(4) $$\frac{dP_E}{dt_c} = 1 \quad \text{and} \quad \frac{dP_E - t_m}{dt_c} = 1$$

Two important implications emerge. First, the tax credit is an ethanol consumption subsidy that raises the market price of ethanol by the full amount of the credit if oil prices are exogenous. In this case, the tax credit operates like a direct subsidy to ethanol (corn) producers because it results in an increase in market prices by the full amount of the credit. Second, exporters of ethanol would benefit equally with the price increase. Although U.S corn producers benefit from the tax credit, Brazil's sugar cane producers gain equally as well. Hence, the so-called "subsidy" is not specific (Howse et al. 2007) nor does it discriminate against trade (Kojima et al. 2007). Consequently, the U.S. tax credit would appear not to be challengeable under the ACSM of the WTO, applying traditional definitions of specific subsidies that discriminate against trade. We draw this conclusion even though the United States reports the revenues foregone from the tax exemption to the ASCM of the WTO (Howse et al. 2006) and news reports indicate Brazil is considering to contest ethanol subsidies as well (Klapper 2007).[12]

Effect of an import tariff

Let us now consider an import tariff. We therefore decompose total supply of ethanol into domestic supply S_E and import supply S_E^M (Figure 2). The tax credit is applicable to both domestic and import supplies. Assume initially that the import tariff is zero. The market equilibrium is given by the intersection of total fuel supply S_F (the horizontal sum of S'^M_E, S'_E and S_O) and the tax inclusive demand curve D'_F. Domestic ethanol production, imports, oil supply and total fuel consumption are given by Q_E, M_E, Q_O and C_F, respectively.

Now add an import tariff on ethanol equal to the tax credit. The import supply curve for ethanol shifts up by the amount of the tariff, resulting in an upward shift in total fuel supply. Reduced imports causes a higher price for ethanol and consumer fuel, thereby increasing domestic ethanol and oil supply, and reducing total fuel consumption. Exporters of ethanol now face a much lower ethanol price, equal to the new oil price P'_O, but the reduction is lower than the amount of the tariff because of the oil price increase. The net loss to Brazil's ethanol producers is $P_E - P'_O$. Imposing an import tariff on ethanol generates an increase in the world price of oil because it reduces the supply of ethanol from Brazil who can no longer take advantage of the tax credit. U.S. ethanol production and oil supplies increase but less than the decrease in ethanol imports.

From the mathematical model, we can show the impacts of an import tariff:

(5) $$\frac{dP_E}{dt_m} = \frac{-\eta_E^M \frac{S_E^M}{P_E - t_m}}{\eta_F^D \frac{D_F}{P_N} - \eta_O^S \frac{S_O}{P_O} - \eta_E^S \frac{S_E}{P_E} - \eta_E^M \frac{S_E^M}{P_E - t_m}} > 0$$

(6) $$\frac{dP_E - t_m}{dt_m} = \frac{-\eta_F^D \frac{D_F}{P_N} + \eta_O^S \frac{S_O}{P_O} + \eta_E^S \frac{S_E}{P_E}}{\eta_F^D \frac{D_F}{P_N} - \eta_O^S \frac{S_O}{P_O} - \eta_E^S \frac{S_E}{P_E} - \eta_E^M \frac{S_E^M}{P_E - t_m}} < 0$$

From equation (5), the tax credit has a larger impact in increasing domestic ethanol prices with a higher level of imports, tariffs and elasticity of import supply (and is lower with a more elastic fuel demand, oil supply or domestic ethanol supply). Conversely, from equation (6), the import tariff causes a larger decline in world ethanol prices with a more elastic fuel demand, oil supply or domestic ethanol supply.

In the limit, if oil prices are fixed (invariant to ethanol production) where $\eta_O^S = \infty$, then the tariff has no impact on the domestic price of ethanol and full impact in reducing world prices:

$$(7) \qquad \frac{dP_E}{dt_m} = 0 \quad \text{and} \quad \frac{dP_E - t_m}{dt_m} = -1$$

We can now make the following conclusions from Figure 2. First, without a tax credit and tariff, the world price of ethanol (oil) would be P^ in Figure 2 (the fuel supply curve in bold is the horizontal sum of S_E^M, S_E and S_O). Clearly, Brazil would be better off with the tax credit as the only policy intervention because $P_E > P$^. But Brazil is better off with no policy than a tax credit and an import tariff (P^ $> P'_O$). Stiglitz (2006) misinterprets the effect of the tax credit when adding the tariff of 54 cents a gallon to the tax credit of 51 cents a gallon. Instead of $1.05 per gallon disadvantage, exporters like Brazil only suffer a 3 cent per gallon disadvantage from the tax credit and import tariff (assuming for the moment the price of oil is exogenous). However, if only the tariff was removed, then Brazil would reap a 51 cent per gallon benefit compared to free trade and no tax credit. Allowing for endogenous oil prices only modifies the results, the extent to which depends on the proportion ethanol in total fuel consumption and supply demand parameters in the corn-ethanol-oil market complex.

Second, the elimination of an import tariff with a tax credit will result in a very large gain to exporters like Brazil because imports of ethanol are a small share of U.S. ethanol production and of total fuel consumption. Eliminating the tax credit would offset a great part of the initial benefits from removing the tariff. But an important factor in all of this is water in the tax credit. If there is substantial water in the tax credit, then removing the tax credit would effectively be less than the level of the "offsetting" tariff. Hence, any true offsetting tariff should be adjusted for water in the tax credit; otherwise exporters like Brazil are unfairly penalized.

3. The Economics of a Mandate

Consider a mandatory biofuel blend where there must be a minimum share of biofuel α in all fuel sold, where $0 < \alpha < 1$. Because the cost for producing biofuels is higher than that for oil, market prices for biofuels diverge from that for oil. Because no tax costs are involved with a mandate, the consumer has to pay the weighted average price of the biofuel and oil where the weights are formed by the required share of biofuels:

(8) $$P_N = \alpha P_E + (1-\alpha) P_O$$

where P_N is the consumer weighted average price, P_E is the corresponding market supply price of biofuel and P_O is the price of oil. The market equilibrium with a mandatory blend requirement α is depicted in Figure 3.[13] The intersection of D_F and S_F generates an equilibrium consumer price P_N that requires a mandated production of ethanol Q_E that can only be achieved with a market price for ethanol of P_E. Total consumption of fuel is C_F.

The equilibrium conditions can then be written as

(9) $$P_N = \alpha\left(P_E + t - t_c\right) + \left(1-\alpha\right)\left(P_O + t\right),$$

(10) $$D_F\left(P_N\right) = S_O\left(P_O\right) + S_E\left(P_E\right) + S_E^M\left(P_E - t_m\right),$$

(11) $$\alpha D_F\left(P_N\right)=S_E\left(P_E\right)+S_E^M\left(P_E-t_m\right).$$

By totally differentiating (9) to (11) and solving, we can examine the comparative static changes in prices resulting from changes in the mandate or tax credit.

The effect of a tariff with a binding mandate is to shift the import supply curve up by the amount of the tariff (see panel (b) in Figure 3). This shifts the fuel supply curve up to S'_F, generating a higher ethanol and hence fuel price. As shown in Figure 3, if the elasticity of oil supply is flat, i.e., $\eta_O^S=\infty$, then equations (A.1) and (A.2) in the Appendix reduce to:

(13) $$\frac{dP_E}{dt_m}=\frac{\eta_E^M\dfrac{S_E^M}{P_E-t_m}}{\eta_E^M\dfrac{S_E^M}{P_E-t_m}+\eta_E^S\dfrac{S_E}{P_E}+\alpha\eta_F^D\dfrac{\left(S_E+S_E^M\right)}{P_N}}$$

(14) $$\frac{dP_E-t_m}{dt_m}=\frac{-\eta_E^S\dfrac{S_E}{P_E}-\alpha\eta_F^D\dfrac{\left(S_E+S_E^M\right)}{P_N}}{\eta_E^M\dfrac{S_E^M}{P_E-t_m}+\eta_E^S\dfrac{S_E}{P_E}+\alpha\eta_F^D\dfrac{\left(S_E+S_E^M\right)}{P_N}}$$

We showed before that without a mandate, a tariff had no effect on domestic ethanol prices, provided oil prices were exogenous implying $\eta_O^S=\infty$. But with a mandate in place, domestic ethanol prices rise with a tariff even if oil prices are fixed. This is because imports decline with a tariff, requiring an increase in domestic supply to fulfill the mandate. The only way to achieve this is for domestic prices to rise. Hence, the tariff has a bigger impact in increasing domestic ethanol prices with a mandate *versus* a tax credit only. The implication is that world prices are higher also. Hence, exporters like Brazil would prefer mandates over tax credits for a given tariff level.

We are now in a position to analyze the effects of a tax credit with a binding mandate (assume the tariff is zero for the moment). A tax credit for biofuel results in a downward shift in the supply of fuel to S'_F as shown in Figure 4, generating a lower consumer price P''_N and a slightly higher ethanol market price P''_E. Ethanol prices are slightly higher because total fuel consumption increases as the consumer price for ethanol declines sharply due to the tax credit. But with a mandate binding, the tax credit is a transfer from taxpayers to consumers of fuel. Ethanol producers benefit only indirectly through the increased demand for ethanol and so the increase in the price of ethanol is much lower than with a tax credit and no binding mandate.

Compare this to a situation where the mandate is not binding in Figure 1.[14] A fuel consumption tax t results in the consumer price of fuel P_N to rise above the oil price P_O by the tax t while the market price of ethanol P_E equals the market price of oil. Therefore, exempting ethanol from the consumer excise tax leads to refiners and blenders bidding up the price of ethanol to $P'_E = P_N$. This leads to ethanol production of Q'_E which displaces gasoline consumption (by assumption, total fuel consumption C_F remains unchanged).[15] With a non-binding mandate, the tax credit substantially raised the market price of ethanol equally to producers and consumers. The tax credit alone acts as a taxpayer financed subsidy directly to ethanol production.

The effect of a tax credit with a binding mandate depends on many parameters (see equations (A.3) – (A.4) in the Appendix). The impacts of a tax credit with a binding mandate differ sharply from before with a non-binding mandate. If oil prices are fixed; i.e., $\eta_O^S = \infty$, then equations (A.3) and (A.4) in the Appendix reduce to:

(15) $$\frac{dP_E}{dt_c} = \frac{\alpha \frac{\eta_F^D}{P_N}\left(S_E + S_E^M\right)}{-\left(\eta_E^S \frac{S_E}{P_E} + \eta_E^M \frac{S_E^M}{P_E - t_m}\right) + \alpha \frac{\eta_F^D}{P_N}\left(S_E + S_E^M\right)} \;>\; 0 \text{ and } <\; 1$$

(16) $$\frac{dP_E - t_m}{dt_c} = \frac{\alpha \frac{\eta_F^D}{P_N}\left(S_E + S_E^M\right)}{-\left(\eta_E^S \frac{S_E}{P_E} + \eta_E^M \frac{S_E^M}{P_E - t_m}\right) + \alpha \frac{\eta_F^D}{P_N}\left(S_E + S_E^M\right)}$$

Recall that domestic ethanol prices increased by the full amount of the tax credit if oil prices were exogenous. With a mandate, equation (15) shows the effect is also positive with a perfectly elastic supply curve for oil but less than one. On the other hand, if the supply elasticities for ethanol are zero, then $dP_E / dt_c = 1$. Inspection of equation (15) indicates that the effect of the tax credit will be low if the weighted sum of the supply elasticities for ethanol is high relative to the demand elasticity for fuel. This is expected empirically. The implication is that the tax credit is likely not to be very helpful to either domestic producers or exporting countries in the presence of a binding mandate. It actually acts as a subsidy to fuel consumers, resulting in lower fuel prices and higher consumption of fuels.

4. Empirical Illustration

To illustrate the theoretical findings, we calibrate a stylized model of the U.S. corn-ethanol-gasoline markets for the years 2006 and 2015 (the latter based on USDA and EIA baseline projections). For assumptions, elasticities, details on the derivation of parameters and data sources, see de Gorter and Just (2007a,b).[16]

We first simulate the case where the mandate is not binding. Table 1 presents the results for each of the years 2006 and 2015. In each year, removing the tariff alone has significant impacts only in raising world ethanol prices and ethanol imports. Removing both the tax credit and import tariff, however, results in a huge decrease in domestic ethanol and corn prices, and in domestic production of ethanol. Indeed, because of water in the tax credit, domestic ethanol production goes to zero in 2006. The reduction in ethanol and corn prices are about 50 percent higher in 2015 than in 2006 because there is no water in the tax credit in 2015, and because ethanol is a larger share of corn production in 2015. This spreads to the gasoline market as the percentage increase in gasoline supply in 2015 is twice that in 2006, as well as for gasoline market price and consumer fuel price increases. In both years, though, domestic ethanol production collapses.

A very important result from the second line in Table 1 is that Brazil keeps about ½ of the benefits derived from the elimination of the tariff only compared to when both the tariff and tax credit are eliminated. This is a surprising result because it was shown in the theory section earlier that Brazil would lose the benefits of a tariff reduction after both the tariff and tax are eliminated (assuming fixed world oil prices and that the tariff equals the tax credit, the latter of which is the case in this empirical example). Brazil keeps about ½ of the benefits of a tariff reduction in 2006 because of water in the tax credit. Of the 51 cent per gallon tax credit, 0.202 cents is water. In other words, the effective tax credit is only 0.308 cents per gallon but the entire tariff of 0.51 cents was removed. This explains why about ½ of the benefits of the tariff reduction are maintained. Because there was significant water in the tax credit historically for the United States (see de Gorter 2007a,b for a detailed analysis), the tariff more than offsets the effective tax credit and so not only discriminated against Brazil even more but also resulted in higher tax costs and social welfare losses in the United States.

Table 2 present the results when a mandate is binding. The mandate requirement is increased 50 and 25 percent in 2006 and 2015, respectively (resulting in an extra 3 billion gallons of ethanol consumption in each year). In 2006, an increase in the mandate has the expected result of increasing domestic and world ethanol prices by 8 and 10 percent, respectively. Removing the tariff only reduces domestic ethanol prices by 1.5 percent but increases world prices by 24 percent.

Eliminating both the tariff and tax credit makes very little difference. Results for 2015 are very similar.

The empirical results confirm the theoretical results obtained earlier that removing the tax credits with a binding mandate has minimal effects. Indeed, the largest change in any variable is the consumer price of fuel, increasing 1.43 percent in 2006. This is because the tax credit acts as a consumer subsidy when the mandate is binding (*versus* an ethanol production subsidy with a non-binding mandate). One implication is that exporters like Brazil prefer mandates over tax credits. We showed above that tax credits alone with water and an offsetting tariff discriminates against Brazil.

5. Concluding Remarks

With regard to the tax credit alone:

- A tax credit acts as a subsidy to ethanol producers (and only indirectly benefits fuel consumers if oil prices decline with increased ethanol production – because ethanol is a low share of total world fuel consumption, the decline in oil prices is expected to be small).
- Exporters like Brazil benefit as much from a tax credit as U.S. ethanol producers. If an import tariff is imposed to offset the tax credit, world prices decline by less than the tariff (unless oil prices are unaffected).
- Eliminating the tariff with a tax credit in place results in a significant gain to exporters like Brazil but eliminating the tax credit as well reduces the initial benefits to Brazil of the tariff reduction substantially (entirely if oil prices do not change).
- The results change however if there is “water” in the tax credit. Then exporters benefit much more with the elimination of both the tariff and tax credit compared to a situation of both policies in place.

With regard to a binding mandate:

- If only a mandate was in place, exporters like Brazil again benefit as much as domestic ethanol producers do.
- Eliminating the tariff with a mandate results in an increase in domestic ethanol prices (even if oil prices do not change) because more domestic supply is required to maintain the mandate. The tariff therefore has a smaller negative impact on world ethanol prices with a mandate compared to a tax credit.
- A tax credit with a binding mandate is a subsidy to fuel consumers (and only indirectly benefits ethanol producers if ethanol prices increase due to increased demand for ethanol with the increase in fuel consumption – because ethanol is a small share of fuel consumption, the price increase is expected to be small).
- Eliminating the tax credit with a binding mandate has little effect on market prices of ethanol – therefore, domestic and foreign producers alike benefit very little with a tax credit in this situation. Brazil would much prefer the elimination of the tax credit and the so-called offsetting import tariff when a mandate is binding.

In general, the protective effects of an import tariff are not additive with either a tax credit or the price premium due to a mandate. Hence, one cannot add the tariff to the tax credit to determine the protective effect against exporters. Furthermore, the tax credit and premium due to the mandate are by themselves non-additive – see de Gorter and Just (2007b).

Figure 1: The Economics of an Ethanol Tax Exemption

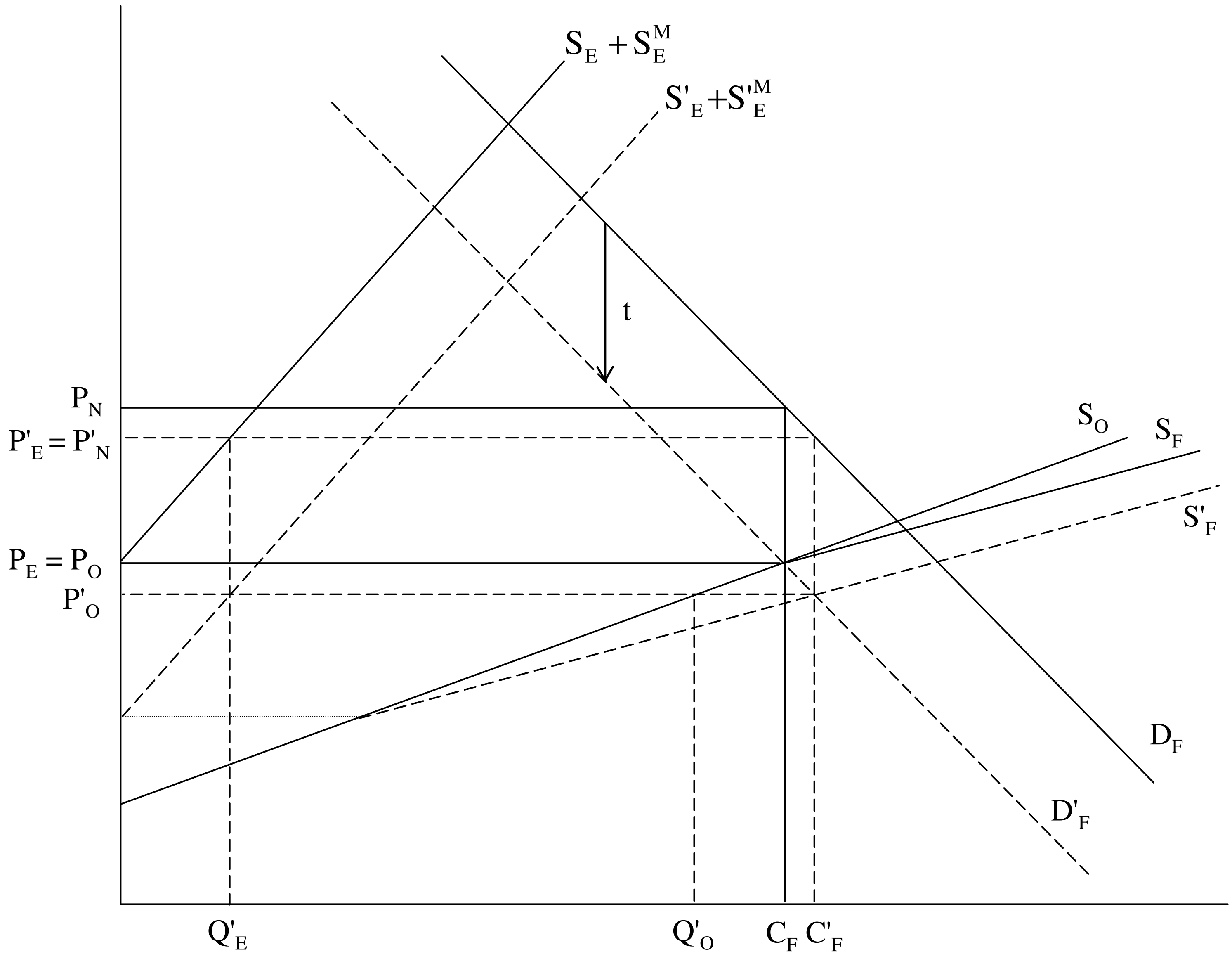

Figure 2: The Economics of an Ethanol Tax Exemption and Import Tariff

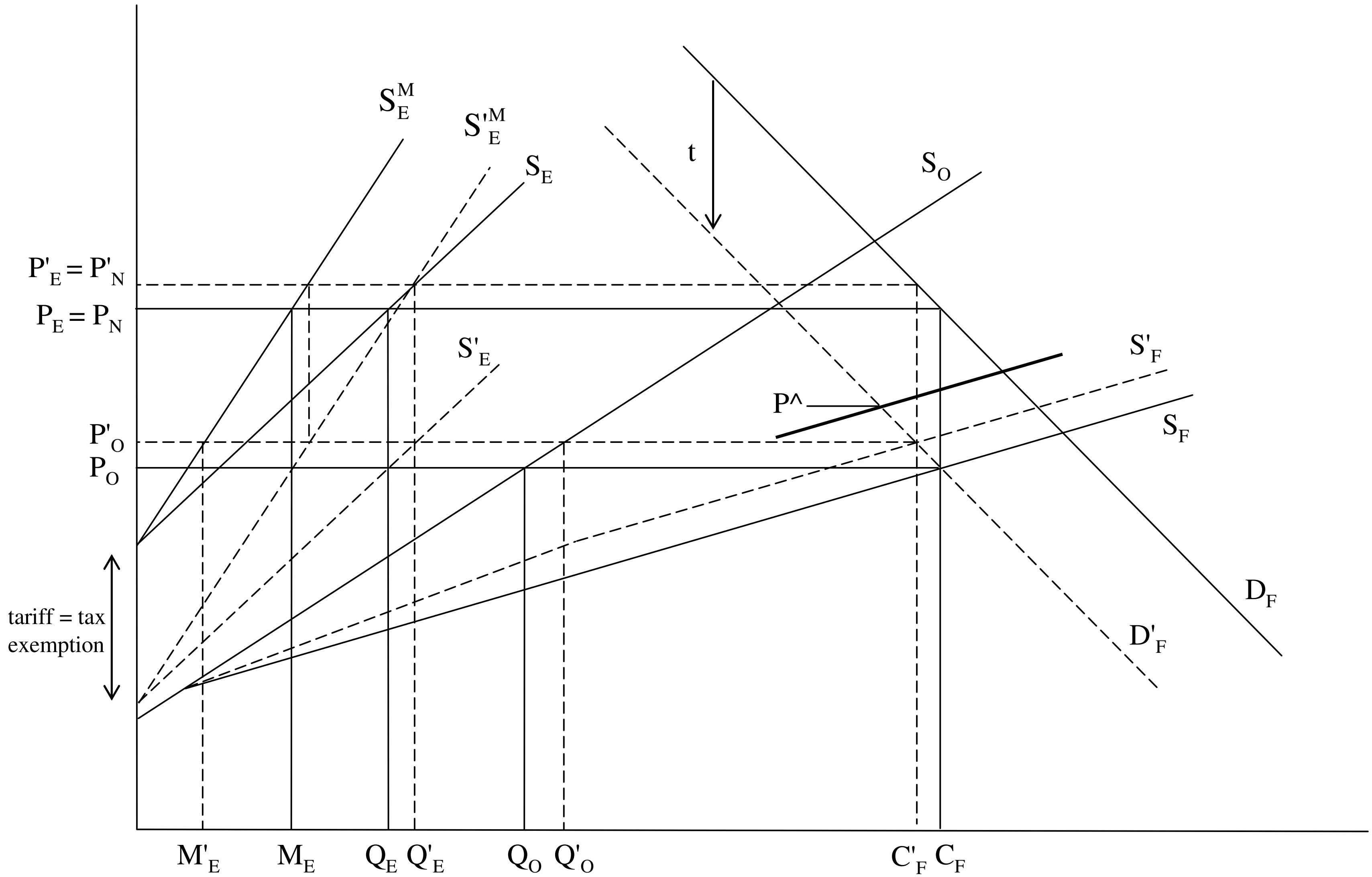

Figure 3: The Economics of an Ethanol Mandate and Import Tariff

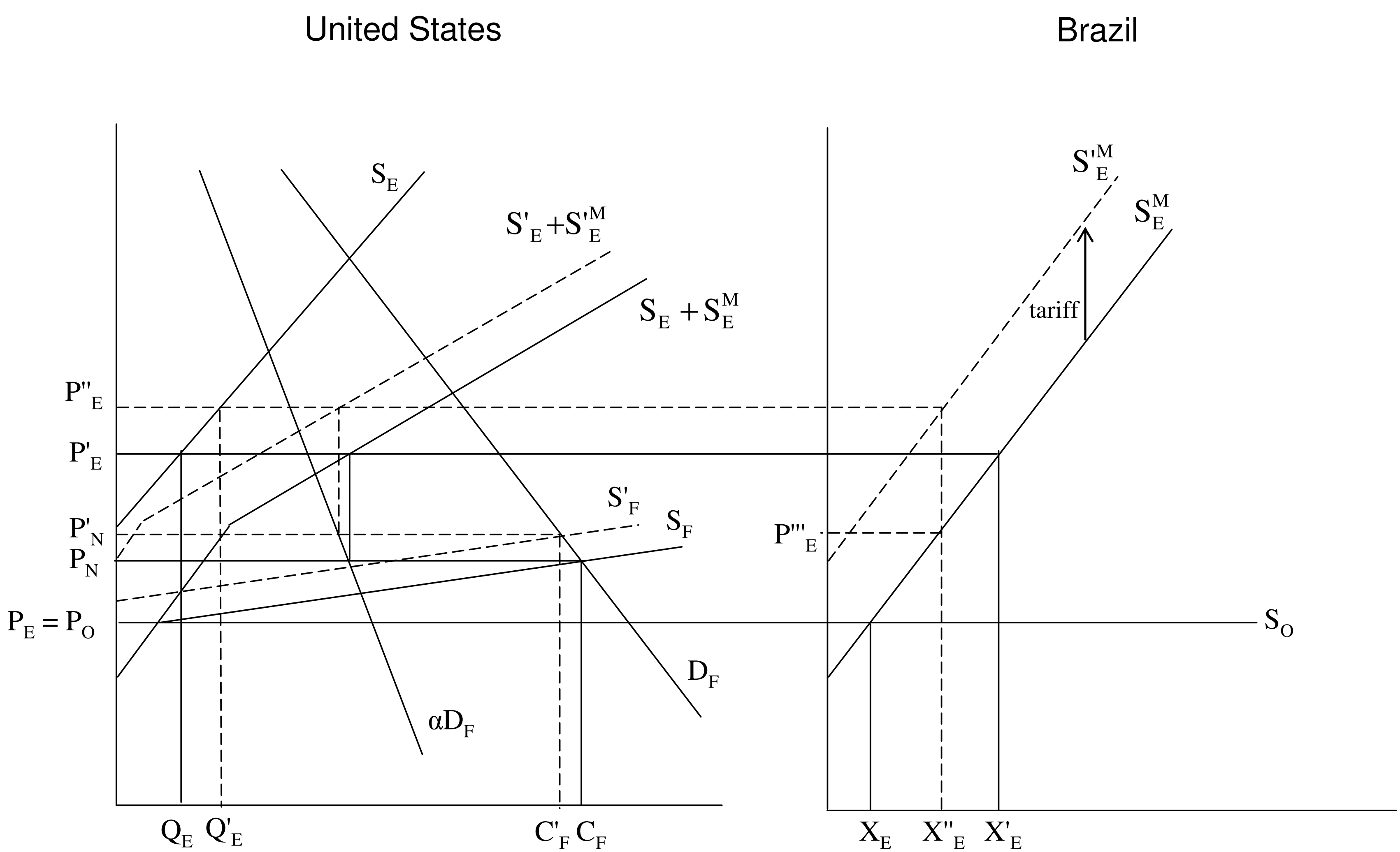

Figure 4: The Economics of an Ethanol Mandate and Tax Exemption with Imports

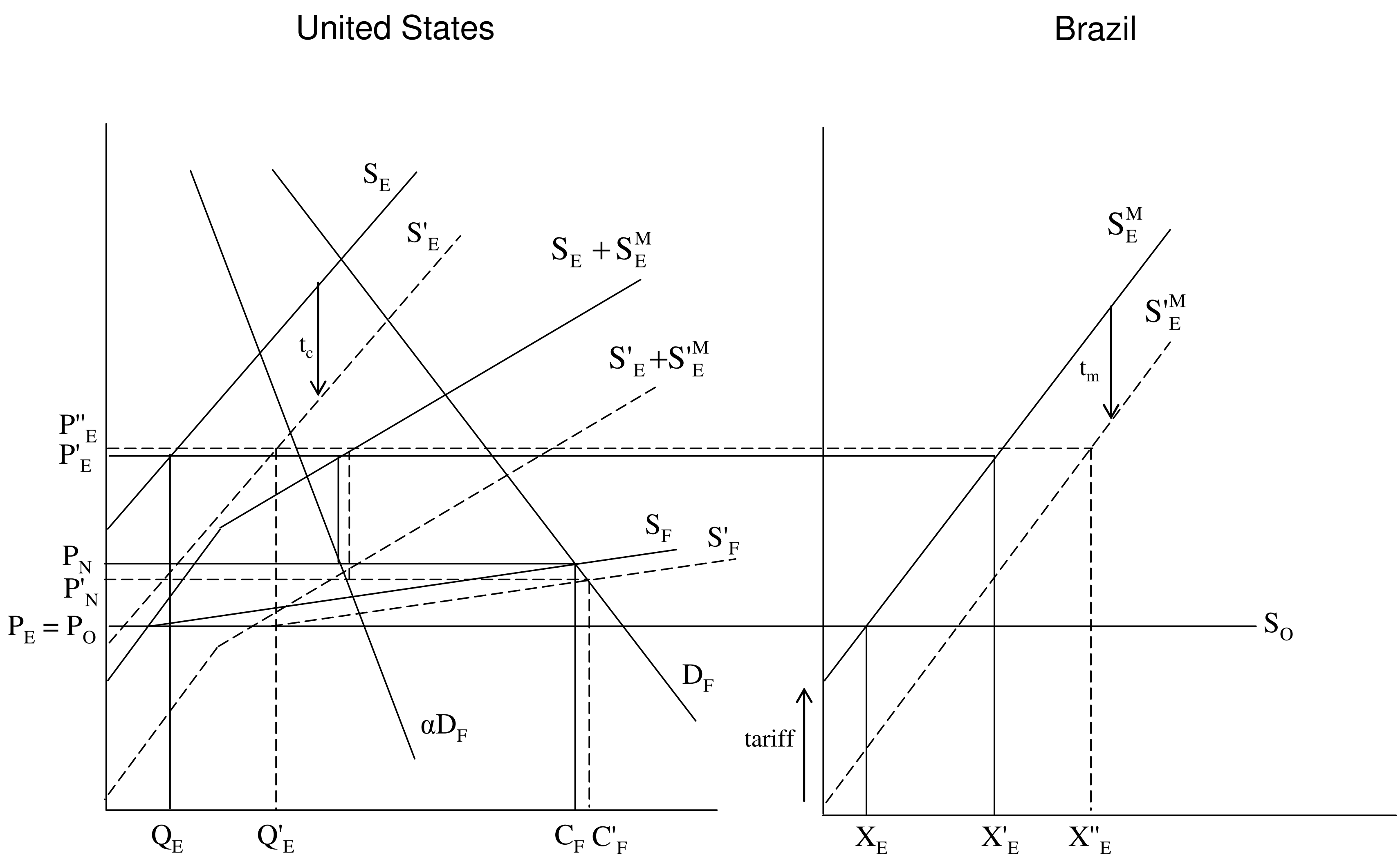

Table 1: Effect of Removing Tax Credit and Import Tariffs for Ethanol (Mandate not binding in baseline)

	2006					2015				
	Baseline[1]	Remove tariff only		Remove tax credit & tariff		Baseline[1]	Remove tariff only		Remove tax credit & tariff	
		value	% change	value	% change		value	% change	value	% change
Price										
Ethanol ($/gal.)										
U.S.	2.32	2.316	-0.170%	2.057	-11.3%	2.434	2.427	-0.318%	2.005	-17.6%
Brazil	1.81	2.316	28.0%	2.057	13.6%	1.924	2.427	26.1%	2.005	4.2%
Gasoline ($/gal.)	1.81	1.8061	-0.22%	1.8515	2.3%	3.178	3.167	-0.37%	3.301	4%
Corn ($/bu)	3.03	3.019	-0.36%	2.294	-24%	3.35	3.328	-0.65%	2.15	-36%
Corn										
Production	10,535	10,520	-0.15%	9,425	-11%	12,450	12,418	-0.26%	10,424	-16%
Ethanol use*	2,150	2,122	-1.29%	0	-100%	4,300	4,246	-1.26%	491	-89%
Fuel										
Ethanol										
Total	6,673	7,210	8.0%	921	-86%	13,346	14,325	7.3%	2,834	-79%
Imports	653	1,267	94.1%	921	41%	1,306	2,437	87%	1,459	12%
Gasoline	135,727	135,238	-0.36%	140,975	3.87%	144,006	143,127	-0.61%	153,492	6.6%
Price	2.32	2.316	-0.17%	2.36	1.87%	3.582	3.571	-0.32%	3.701	3.3%
Consumption										
Nominal	142,400	142,448	0.03%	141,896	-0.35%	157,352	157,452	0.06%	156,326	-0.65%
BTU	140,198	140,069	-0.09%	141,592	0.99%	152,948	152,725	-0.15%	155,391	1.60%

[1] Because the baseline assumes a non-binding mandate, 2006 was calibrated on a non-BTU basis.

* Because of water in the tax credit, ethanol production is zero when the tax credit reaches 0.202 cents per gallon.

Table 2: Effect of Removing Tax Credit and Import Tariffs for Ethanol with a Binding Mandate

	2006						
	Baseline[1]	Increase mandate[2]		Remove tariff only		Remove tax credit & tariff	
		value	% change	value	% change	value	% change
Price							
Ethanol ($/gal.)							
U.S.	2.32	2.49	8%	2.457	-1.5%	2.455	-0.06%
Brazil	1.81	1.98	10%	2.457	23.8%	2.455	-0.06%
Gasoline ($/gal.)	1.81	1.784	-1.4%	1.7842	0.013%	1.7811	-0.17%
Corn ($/bu)	3.03	3.52	16%	3.4129	-3.02%	3.4087	-0.12%
Corn							
Production	10,535	11,185	6%	11,049	-1.2%	11,043	-0.05%
Ethanol use[4]	2,150	3,280	53%	3,049	-7%	3,040	-0.30%
Fuel							
Ethanol							
Total	6,673	10,020	50%	10,022	0.0%	9,994	-0.28%
Imports	653	837	28%	1,485	78%	1,483	-0.16%
Gasoline	135,727	132,527	-2.4%	132,555	0.021%	132,180	-0.28%
Price	2.32	2.308	-0.5%	2.306	-0.106%	2.339	1.43%
Consumption							
Nominal	142,400	142,547	0.1%	142,577	0.021%	142,174	-0.28%
BTU	140,198	139,240	-0.7%	139,270	0.021%	138,876	-0.28%

	2015						
	Baseline	Increase mandate[3]		Remove tariff only		Remove tax credit & tariff	
		value	% change	value	% change	value	% change
Price							
Ethanol ($/gal.)							
U.S.	2.434	2.43	-0.14%	2.38	-2.1%	2.38	-0.08%
Brazil	1.9243	1.92	-0.17%	2.38	23.9%	2.38	-0.08%
Gasoline ($/gal.)	3.178	3.17	-0.32%	3.17	0.019%	3.16	-0.19%
Corn ($/bu)	3.350	3.34	-0.28%	3.20	-4.2%	3.19	-0.16%
Corn							
Production	12,450	12,436	-0.11%	12,224	-1.7%	12,216	-0.06%
Ethanol use[4]	4,300	4,277	-0.54%	3,916	-8.4%	3,902	-0.35%
Fuel							
Ethanol							
Total	144,006	13,275	-90.78%	13,279	0.03%	13,237	-0.32%
Imports	1,306	1,300	-0.46%	2,315	78.1%	2,310	-0.21%
Gasoline	144,006	143,242	-0.53%	143,288	0.03%	142,827	-0.32%
Price	3.69	3.68	-0.26%	3.67	-0.16%	3.73	1.62%
Consumption							
Nominal	157,352	156,517	-0.53%	156,567	0.03%	156,063	-0.32%
BTU	109,830	152,136	38.52%	152,185	0.03%	151,695	-0.32%

[1] Because the baseline assumes a non-binding mandate, 2006 was calibrated on a non-BTU basis.

[2] The mandate requirment increases 50 percent in 2006 [add 3 bil gals with α times 1.5]

[3] The mandate requirment increases 25 percent in 2015 [add 3 bil gals with α times 1.25]

[4] Because of water in the tax credit, ethanol production is zero when the tax credit reaches 0.202 cents per gallon.

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Appendix

Totally differentiating equations (9) – (11), we can solve for:

(A.1) $$\frac{dP_E}{dt_m}=\frac{\left(\frac{\eta_O^S}{P_O}-(1-\alpha)S_O\frac{\eta_F^D}{P_N}\right)\eta_E^M\frac{S_E^M}{P_E-t_m}}{\left(\frac{\eta_O^S}{P_O}-(1-\alpha)S_O\frac{\eta_F^D}{P_N}\right)\left(\eta_E^M\frac{S_E^M}{P_E-t_m}+\eta_E^S\frac{S_E}{P_E}\right)+\alpha\frac{\eta_O^S}{P_O}\eta_F^D\frac{\left(S_E+S_E^M\right)}{P_N}}$$

(A.2) $$\frac{dP_E-t_m}{dt_m}=\frac{-\left(\frac{\eta_O^S}{P_O}-(1-\alpha)S_O\frac{\eta_F^D}{P_N}\right)\eta_E^S\frac{S_E}{P_E}-\alpha\frac{\eta_O^S}{P_O}\eta_F^D\frac{\left(S_E+S_E^M\right)}{P_N}}{\left(\frac{\eta_O^S}{P_O}-(1-\alpha)S_O\frac{\eta_F^D}{P_N}\right)\left(\eta_E^M\frac{S_E^M}{P_E-t_m}+\eta_E^S\frac{S_E}{P_E}\right)+\alpha\frac{\eta_O^S}{P_O}\eta_F^D\frac{\left(S_E+S_E^M\right)}{P_N}}$$

(A.3) $$\frac{dP_E}{dt_c}=\frac{\alpha\frac{\eta_O^S}{P_O}\eta_F^D\frac{\left(S_E+S_E^M\right)}{P_N}}{\left[(1-\alpha)\frac{\eta_F^D}{P_N}-\frac{\eta_O^S}{P_O}\right]\left(\eta_E^S\frac{S_E}{P_E}+\eta_E^M\frac{S_E^M}{P_E-t_m}\right)+\alpha\frac{\eta_O^S}{P_O}\eta_F^D\frac{\left(S_E+S_E^M\right)}{P_N}}$$

(A.4) $$\frac{dP_E-t_m}{dt_c}=\frac{\alpha\frac{\eta_O^S}{P_O}\eta_F^D\frac{\left(S_E+S_E^M\right)}{P_N}}{\left[(1-\alpha)\frac{\eta_F^D}{P_N}-\frac{\eta_O^S}{P_O}\right]\left(\eta_E^S\frac{S_E}{P_E}+\eta_E^M\frac{S_E^M}{P_E-t_m}\right)+\alpha\frac{\eta_O^S}{P_O}\eta_F^D\frac{\left(S_E+S_E^M\right)}{P_N}}$$

Endnotes

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[1] This paper should be read in conjunction with Cornell University Department of Applied Economics and Management Working Papers #13 and #20 by the same authors entitled, respectively, "The Welfare Economics of an Excise-Tax Exemption for Biofuels" and "The Economics of a Biofuel Consumption Mandate and Excise-Tax Exemption: An Empirical Example of U.S. Ethanol Policy". These papers can be accessed at:
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1015542
http://aem.cornell.edu/research/researchpdf/wp0720.pdf

[2] This paper omits to analyze several important biofuel subsidies for production (e.g., grants, loan guarantees and tax related incentives), R&D of new production technologies, new vehicles and infrastructure, and feedstocks.

[3] "Water" in the tax exemption refers to the case where the intercept of the ethanol supply curve is above the price of oil. See de Gorter and Just (2007a) and the discussion of Table 1 in de Gorter and Just (2007b) for a comprehensive discussion on the importance of water in the tax exemption.

[4] It should be noted that Brazil is unfairly taxed even without water in the tax credit because the national treatment principle in the WTO requires both domestic and imported products to have the same consumption tax/subsidy treatment. Hence, a tariff to offset a tax credit is not justifiable under WTO rules and is therefore illegal. As explained in the next section, the U.S. Congress implemented the tariff in 1980 to offset the tax exemption and was not contested when this ethanol tariff was part of the U.S. tariff schedule in the Uruguay Round.

[5] See the discussion of Table 1 in de Gorter and Just (2007b) where the ethanol price premiums in the United States have even exceeded the price of corn.

[6] There is one exception where the mandate reduces fuel prices and increases fuel consumption (see de Gorter and Just 2007b).

[7] Furthermore, the tariff is levied on the full volume of any denatured alcohol, unlike the tax credit for ethyl alcohol content only (Koplow 2006). This further magnifies the tariff relative to the tax credit.

[8] Since 2006, several states have announced new tax credits or expanded existing ones, closing this small gap between the tariff and overall tax credit.

[9] For now, we ignore the distinction between domestic and import supply and assume no ethanol imports. We also assume constant returns to scale in ethanol production.

[10] Ethanol and gasoline are assumed to be perfect substitutes in consumption.

[11] For ease of exposition, the intercept of the ethanol supply curve S_E is arbitrarily set to coincide with the price of oil. Historically, the intercept is found to be above the price of oil - for more details, see de Gorter and Just (2007a,b).

[12] Although one can argue the support to corn farmers from the tax credit could be part of the AMS under the Agreement on Agriculture in that it provides a "favour to producers", "the effect of providing price support to producers" or "support provided through direct payments (including revenue foregone…".

[13] Please refer to de Gorter and Just (2007b) for a full derivation and intuitive explanation of the economics of a mandate.

[14] A non-binding mandate in Figure 4 implies the P_N under the mandate is less than $P_O + t$.

[15] Even if ethanol production lowers oil prices, the effect of the tax credit for ethanol is to increase the market price of ethanol to the price of oil plus the tax t. The only difference would be that the benefits of the tax credit is shared

between fuel consumers and ethanol producers while oil producers would now lose (and ethanol producers gain less than the tax *t*, the extent to which depends on the effect of increased ethanol production on oil prices).

[16] The import supply elasticity of ethanol is estimated to be 2.69 and is calibrated form the equation $\eta_E^M = \eta^S \left(\frac{Q}{X}\right) - \eta^D \left(\frac{C}{X}\right)$ using stylized supply and demand parameters for ethanol in Brazil. Our estimate is very close to 2.76 implied by Tokgoz and Elobeid (2007) but significantly higher than 0.24 estimated by Martinez-Gonzalez et al. (2007). The latter estimate may very well be accurate, given the sudden growth in demand for ethanol in markets like Japan and EU where ambitious mandates have been approved, but we use the higher elasticity to be conservative.

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