# The Social Cost and Benefits of US Biofuel Policies

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The most salient set of recent criticisms of biofuels relate to their impact on food prices and the environment. Rapidly escalating food prices have stressed many developing countries and poor households while recent studies argue that indirect land-use changes due to biofuels may enhance greenhouse-gas emissions (Runge and Senauer, 2007; Searchinger *et al.*, 2008). The potential misalignment of policy effects and stated objectives means it is important to understand the economic-efficiency and income-distribution effects of government biofuel policies on agricultural, biofuel and gasoline markets.

This paper summarizes the key aspects affecting the social costs and benefits of US biofuel policies. We first outline the various public-policy goals and categorize the concomitant policies adopted. We then analyze the social costs/benefits of alternative biofuel policies, determine who benefits and who loses and by how much, and how policy reforms can better achieve policy goals. We show that policies have been counterproductive in several instances and so can be much improved. We highlight the interaction effects between policies. For example, the sole cause of biofuel production in the United States historically, for the most part, was biofuel- and feedstock-production subsidies. Tax credits and mandates by themselves would have generated little if no ethanol production. Oil prices were so low that the intercept of the ethanol supply curve has been well above oil prices historically. This means tax costs were wasted and benefited no group. Tax credits, therefore, had minimal impacts on corn prices at low levels of oil prices. But at higher oil prices, tax credits then can potentially have a larger impact on corn prices.

We also determine that mandates are more efficient than tax credits for the same level of ethanol production because mandates result in higher gasoline prices and lower $CO_2$ emissions and miles traveled. When tax credits are used in conjunction with mandates,

the effects of biofuel tax credits are reversed. By themselves, tax credits subsidize biofuel consumption, but with mandates the same tax credit subsidizes gasoline consumption. This has major implications for countries worldwide that also use both tax credits and mandates.

This paper is outlined as follows. After defining policy categories and objectives, we show how a tax credit affects the market. We assess historical data and determine that the United States ethanol policy was very uncompetitive unless substantial subsidies were forthcoming. We then explain how mandates work and compare their effects to tax credits. The key result that the effects of a tax credit are reversed when used in conjunction with mandates is then explained. After explaining how ethanol-import tariffs affect the market, we conclude with the lessons learned for future policy adjustments.

## Policy Objectives and Instruments

The policy objectives are threefold:

- to reduce dependence on oil,
- to improve the environment (reduce local air pollution and mitigate global climate change), and
- to improve farm incomes, reduce tax costs of farm-subsidy programs and stimulate rural development (Rajagopal and Zilberman 2007).

Given the plethora of policy objectives, governments have implemented myriad policies. Biofuel policies generally promote biofuel production and substitution for petroleum fuels in consumption. The most important of these policies are fourfold:

- tax credits,
- mandates,
- import tariffs, and
- production subsidies for ethanol and corn.

It is difficult to determine *a priori* which of the tax credits (totaling $0.57 per gallon if we include both state and federal credits) or the mandates (several state and federal mandates exist, either explicit or *de facto* via environmental regulations) are more important. According to de Gorter and Just (2008b), over 65% of total fuel consumption is affected by tax exemptions for biofuels. Meanwhile, a recent FAO bulletin concluded that "virtually all existing laws to promote…biofuels set blending requirements, meaning the percentages of biofuels that should be mixed with conventional fuels" (Jull *et al.*, 2007). Most countries have huge import tariffs on biofuels while production subsidies for biofuels and biofuel feedstocks are very significant (Steenblik, 2007). We will, therefore, also touch upon the effects of production subsidies for biofuels and biofuel feedstocks and of biofuel import tariffs.[1]

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[1]For a comprehensive documentation of all types of US ethanol policies including import tariffs and ethanol production subsidies, see Koplow (2007). A complete exposition of the welfare effects of US biofuel policy discussed in this paper is given in de Gorter and Just (2007a,b; 2008a,b,c).

## How Tax Credits Affect the Corn, Ethanol and Gasoline Markets

The federal government offers a $0.51 per gallon tax credit for the use of ethanol. State tax credits of about $0.06 per gallon need to be added. The economic incentive of a tax credit is to have the ethanol price bid up above the gasoline price by the amount of the tax credit. Otherwise, blenders would be foregoing money represented in the tax credit. The tax credit is an ethanol-consumption subsidy, but because ethanol is a perfect substitute for gasoline and gasoline prices are assumed to be invariant to ethanol production, the incidence of the subsidy is such that ethanol producers get the full benefit. The market price of ethanol is, therefore, determined by the following equation (see de Gorter and Just 2008a for details):

$$P_E = \lambda P_G - (1-\lambda)t + t_c \qquad (1)$$

where $P_E$ is the market price of ethanol, $P_G$ is the price of gasoline, $\lambda$ is the ratio of miles per gallon of ethanol relative to gasoline and equals 0.70 when adjusted to an E100 basis, and $t_c$ is the tax credit (higher than the fuel tax $t$ in the United States). If the tax credit is eliminated, then the market price is equal to $\lambda P_G - (1-\lambda)t$. It is interesting to note in this situation that $t$ is a disproportionate tax on ethanol because it is levied on a volume basis. Increasing the fuel tax reduces the market price for ethanol. Note that domestic and foreign producers of ethanol benefit alike from this tax credit.

### The Link Between the Corn and Ethanol Markets

The corn price is directly linked to the ethanol price. Denote $\beta$ as the gallons of ethanol produced from one bushel of corn and denote $\delta$ as the proportion of the value of corn returned to the market in the form of byproducts, then the price of corn (equal to $P_{Eb}$, the price of ethanol in $/bu$) is given by:

$$P_{Eb} = \left(\frac{\beta}{1-\delta}\right)(\lambda P_G - (1-\lambda)t + t_c) - c_o \qquad (2)$$

where $c_o$ is the processing cost. Estimates from Eidman (2007) indicate that $\beta$ equals 2.8 and $\delta$ equals 0.31. The resulting value of $\beta/(1-\delta)$ is 4. A tax credit of $0.51 per gallon translates into approximately a $2.04 per bushel subsidy to corn farmers. This means that the corn price is very sensitive to a change in the price of ethanol (induced by either a change in the tax credit or world oil price). However, farmers historically have not been able to take advantage of such a large subsidy, because the intercept of the ethanol-supply curve is above the oil price. This means a significant part of the tax credit has been redundant. We call this "water" in the tax credit.

Because the intercept of the ethanol supply curve in the United States has been far above the price of oil, the resulting "water" in the tax credit generates "rectangular" deadweight costs. Rectangular deadweight costs are defined as that part of the tax cost of the tax credit that is not a transfer to domestic producers or any other domestic or foreign interest group. This exacerbates the social costs of ethanol policies compared to standard analysis.

## Historical Price Relationships for Ethanol in the United States

There are several important conclusions when analyzing the historical experience of biofuel policies in the United States. First, the price premium for ethanol over gasoline has exceeded the tax credit for the past 25 years. This is shown in Fig. 1 where the actual ethanol price is higher than the price that otherwise would be if only a tax credit affected ethanol prices and consumers purchased ethanol only for its contribution to mileage. This means that because the "actual ethanol price" line in Fig. 1 is above the "ethanol price if tax credit only" line, the tax credit was dormant.[2] How can one explain the fact that the ethanol price premium was above the tax credit in these years? Mandates at local, state and federal levels always

[2]Not exactly "dormant" because as we show below, when the ethanol premium exceeds the tax credit, a *de facto* mandate or ethanol purchased on the basis of its additive value necessarily implies that the effects of the tax credit are reversed: it subsidizes oil consumption!
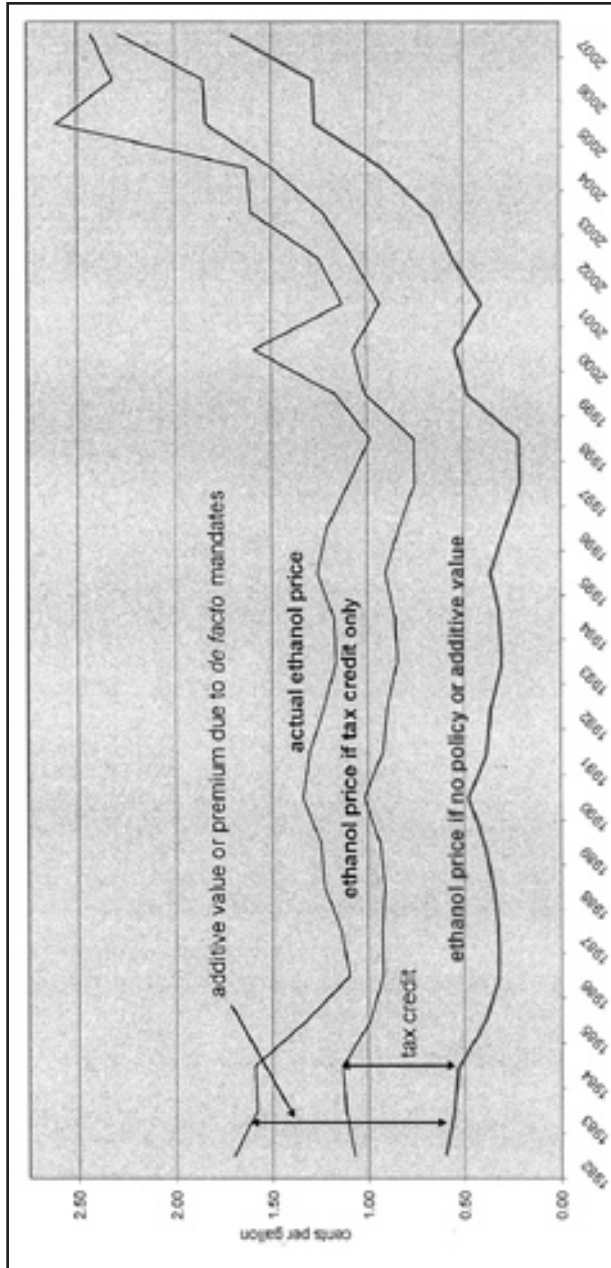


Figure 1. Ethanol prices: actual; with tax credit only; if no policy.

existed, but were never binding. Two explanations are plausible (Tyner 2007). One is that there were *de facto* mandates due to environmental regulations (the Clean Air Act in the 1990s and the implicit ban on MTBE in this decade). Another explanation is that blenders purchased ethanol for its additive value as an octane enhancer/oxygenate. This means ethanol was purchased in fixed proportions to gasoline, implying a blend-consumption-mandate model.

Another important finding is that the actual observed corn price was always below the ethanol price premium until 2007/08 (Fig. 2). In fact, the corn price is observed to be lower than the tax credit itself in 9 of the 25 years! This is, at first glance, puzzling—how can the implied subsidy of the tax credit be greater than the corn price itself? We explained earlier that the corn price is to increase by the amount of the tax credit or ethanol price premium due to its additive value or *de facto* mandates.

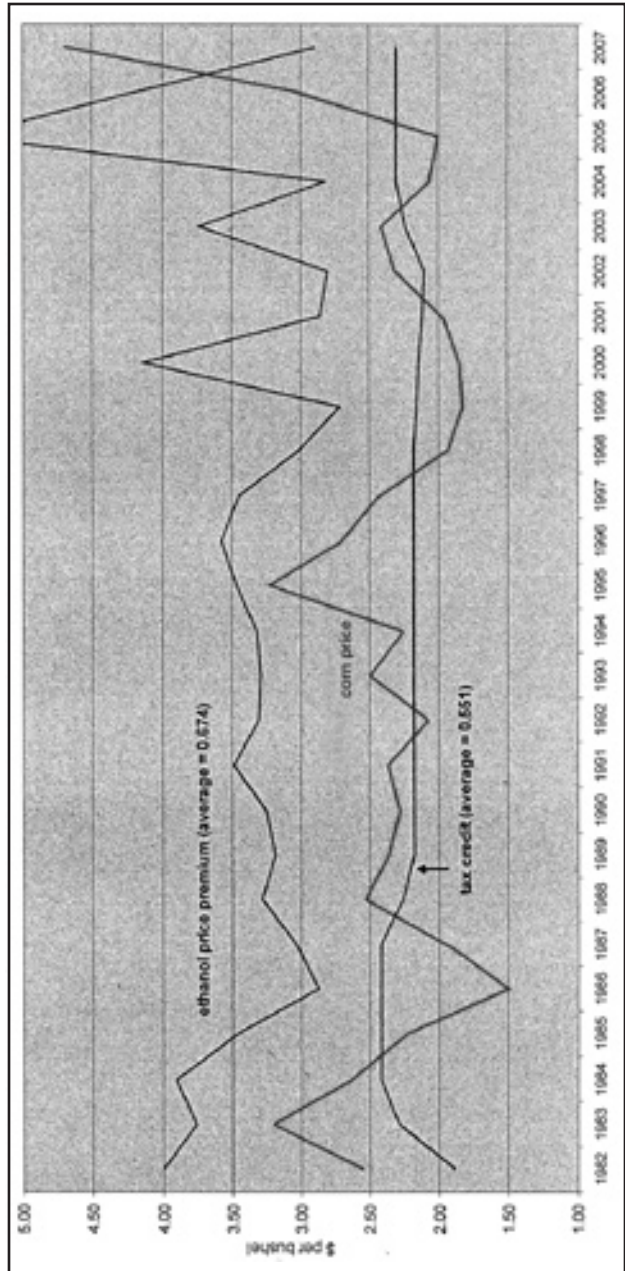The key to understanding this is twofold (see de



Figure 2. Ethanol price premium, corn price and tax credit in dollars per bushel.

Gorter and Just 2008b for complete details). First, one has to recognize that the intercept of the ethanol-supply curve was above the gasoline price. In other words, if there were no ethanol price premium due to either its additive value or tax credits, there would be no ethanol production. Costs of production would exceed the price of gasoline. This means that part of the tax costs are what we call rectangular deadweight costs: it costs taxpayers, but nobody benefits as the gap between the gasoline price and intercept of the ethanol supply curve has to be closed first.

Second, not only was the intercept of ethanol supply below the price of gasoline, but it also was above the price of corn. The only way this can happen is with production subsidies for corn and/or ethanol. These subsidies are the only reason for ethanol production in these cases. In other words, even with the tax credit and premiums due to additive value, there would be no ethanol production unless there were production subsidies for corn and/or ethanol as well.

## How the Tax Credit Affects the Taxpayer Costs of Farm Subsidies

Proponents of US ethanol policy argue that the tax credit reduces the tax costs of farm subsidy programs. There are two particularly important issues to analyze: the tax credit increases both the tax costs and economic inefficiencies of farm-subsidy programs like the loan rate program, and, *vice versa*, farm subsidies increase the tax costs of the tax credit and increase economic inefficiencies due to the tax credit. There are also increased environmental costs of increased agricultural production and adverse effects on consumers (livestock and poor developing-country consumers). Hence, one does not want to introduce biofuel policy to mitigate the effects of farm subsidy programs.

## Effect of Tax Credits on Gasoline Consumption, $CO_2$ Emissions and Miles Traveled

So far, we have determined the effect of the tax credit on ethanol prices and production. If oil prices are assumed not to change with increased ethanol production, the ethanol production displaces gasoline consumption gallon for gallon. But if the supply curve for oil is upward sloping and so oil prices are affected by ethanol production, then the effects of the tax credit will be to increase fuel supply such that the price of gasoline falls. This means less ethanol production and more fuel consumption. Hence, the reduction in gasoline consumption is less than before with a fixed oil price. But the tax credit always increases fuel consumption (while lowering gasoline consumption). This means that the effect of the tax credit on miles traveled is always positive because consumers buy ethanol on the basis of its contribution to mileage. The impact of the tax credit on $CO_2$ emissions, however, is ambiguous.

## THE ECONOMICS OF BIOFUEL MANDATES

Understanding the effects of mandates is very important. First, many countries have mandates. Second, historical price premiums for ethanol above the tax credit in the United States, as shown in Fig. 1, suggest that a mandate existed (*de facto* due to environmental regulations or due to ethanol purchased for its additive value). Third, the new renewable

fuel standard (RFS) in the recently passed Energy Independence and Security Act (EISA) mandates the use of 36 billion gallons of renewable fuel by 2022 in the United States.

Consider a biofuel-consumption mandate of the level $Q_E$. Because no tax costs are involved with a mandate, the consumer has to pay the weighted average price of the biofuel and gasoline where the weights are formed by the required consumption of biofuels:

$$P_F = P_E Q_E + P_G (C_F - Q_E) \qquad (3)$$

where $P_F$ is the weighted average fuel price for consumers, $C_F$ is the consumption of fuel, $P_E$ is the market price of ethanol and $Q_E$ is the mandated level of ethanol consumption.

If we assume that oil prices do not vary with ethanol production, the transfer to ethanol producers is completely financed by an implicit consumer tax on gasoline. For the same level of ethanol production, this necessarily implies that gasoline consumption is lower with a mandate compared to tax credit. Recall in the analysis of a tax credit there is no effect on total fuel consumption with a tax credit and fixed oil price. Total fuel consumption remains the same, but gasoline consumption declines by the level of ethanol production $Q_E$. But with a mandate, total fuel consumption declines, necessarily resulting in a lower level of gasoline consumption compared to a tax credit.

Now consider the case where the supply curve for gasoline is upward sloping. With a tax credit, total fuel consumption increases and world oil price declines. But in the case of a mandate, an upward-sloping supply curve for oil will now result in the mandate acting as a tax on oil producers but not always a tax on consumers, depending on market parameters. Sometimes a mandate will be a tax on consumers, but in other cases it will subsidize fuel consumers even though there are no taxpayer costs. In this case, oil producers are transferring income to both ethanol producers and fuel consumers.

Nevertheless, regardless of market conditions, compared to tax credits that achieve the same level of ethanol consumption, a mandate results in higher fuel prices and lower fuel consumption (even though a mandate can generate an increase in fuel consumption). This means a mandate is preferred to a tax credit when there is a sub-optimal gasoline tax like in the United States. A mandate also saves taxpayer costs and does not incur the inefficiency costs of taxation.

## The Economics of a Biofuel Mandate and Tax Credit Combined

So far, we have determined the equilibrium with a blend mandate and compared the efficiency of a mandate to that of taxes and subsidies under different policy goals. But policymakers seem intent on using mandates and tax credits in concert.

President Bush signed into law the EISA on 19 December 2007, which established the largest increase in a biofuels mandate in history. The new mandate, known as the RFS, requires the use of at least 36 billion gallons of biofuels in 2022, a fivefold increase over current RFS levels. By 2022, biofuels could represent over 20% of US automobile fuel consumption.

Meanwhile, the new legislation calls for the continuation of the federal biofuel tax credit of $0.51 per gallon which, when combined with state tax credits, will potentially

cost taxpayers over $26 billion by 2022.[3] Tax credits by themselves encourage ethanol production as a replacement for oil-based gasoline consumption. But with mandates in place, the tax credits will unintentionally subsidize gasoline consumption instead. This contradicts the new energy bill's stated objectives of reducing dependency on oil, improving the environment and enhancing rural prosperity. This result is independent of the issues related to indirect land use and $CO_2$ life-cycle analysis that is currently in the forefront of the public debate over biofuels.

The effects of current policies are mind-boggling. The billions of tax dollars to be spent will be a pure waste and will have profound consequences beyond that. Transfers of wealth to the Middle East will increase, leading to even more dependence on oil and energy insecurity. Air quality will decline while $CO_2$ emissions will increase. Meanwhile, the resulting rise in oil prices hurts farmers through higher input costs, while ethanol prices are unchanged as ethanol consumption remains at mandated levels.

The unintended result of a tax credit switching to a gasoline subsidy in the presence of a government mandate is easily explained. Consider first how the tax credit would work by itself. To take advantage of the government subsidy offered them, blenders of ethanol and gasoline will bid up the price of ethanol until it is above the market price of gasoline by the amount of the tax credit. If the price premium over gasoline is less than the tax credit, then blenders will be making windfall profits from the government subsidy by pocketing the difference. But competition among blenders will ensure that there will be no "free money left on the table," and the price of ethanol will, therefore, exceed that of gasoline by the full $0.57 per gallon tax credit.

Now consider the case where the ethanol price is determined by the binding mandate—36 billion gallons by 2022—and there is no tax credit. The consumer "fuel" price is a weighted average of the ethanol and gasoline prices. Implicitly, consumers pay a higher price for gasoline to finance the same ethanol production as before, when only the tax credit was in place. Now introduce a tax credit alongside the mandate. Because the ethanol price premium due to the mandate exceeds the tax credit, there is no incentive for blenders to bid up the price of ethanol as before. Instead, blenders will offer a lower fuel price to consumers to take advantage of the tax credit offered to them by the government. Because market prices of ethanol cannot decline due to the mandate, blenders will compete for the government subsidy by reducing the implicit price paid by consumers for gasoline in their fuel price. This increases gasoline consumption and, thus, increases the market price of gasoline and oil. The price of gasoline paid by consumers declines until the per-unit subsidy on ethanol is exactly exhausted on an adjusted per-unit basis of gasoline consumption—hence the reversal of the intended policy effects.

The expected social costs of having a tax credit when a mandate could have done the same thing for the year 2022 ranges from $28.7 billion in the short run to $48.5 billion

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[3]The federal tax credit is $0.51 per gallon and national average state tax credit is about $0.06 per gallon (Koplow 2007; Steenblik 2007). Babcock (2008) predicts that corn-based ethanol production will exceed the 15 billion gallon mandate by 11 billion gallons in 2022. This means a projected tax cost of biofuels for 2022 of $26.5 billion.

in the long run (de Gorter and Just 2008c). Due to the unique way in which mandates reverse the market effects of a tax credit, the intentions of policymakers cannot necessarily be faulted. There is no other example in the economics literature of the interaction between a price-based and quantity-based policy measure that generates such a unique result as that of a biofuel tax credit and mandate (de Gorter and Just 2007b, 2008c). Furthermore, this policy mistake is not unique to the United States, but is a worldwide error of judgment as most countries use both mandates and tax credits simultaneously. The policy implication is clear: allow the mandate to work by itself, eliminate the tax credit and save billions in taxpayer monies. This involves only a modest change in biofuel policy while dramatically improving policy achievements.

## Import Tariffs on Ethanol

Many controversies surround US biofuels policy, not least of which is the import tariff on ethanol of $0.54 per gallon. Congress implemented this import tariff to offset the tax credit. The key reasons why the United States and the world have increased their focus on biofuels include global climate change, 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 greenhouse gases than ethanol derived from corn in the United States, many commentators have remarked on how an ethanol tariff contradicts these goals (Doornbosch and Steenblik, 2007; Howse *et al.*, 2006; Jank *et al.*, 2007; Kojima *et al.*, 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).

Total US imports of ethanol in calendar year 2006 were 653.3 million gallons, almost all from Brazil of which approximately a third was routed through the Caribbean to avoid the import tariff. Through the Caribbean Basin Initiative, an import quota of 7% of domestic US ethanol consumption is tariff free. Brazil exports ethanol with 5% water content to the Caribbean, which is reprocessed so that the water content is 1% 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% of the maximum allowed so, apparently, the costs of obtaining tariff-free status through the Caribbean are significant.

## Concluding Remarks

It is beyond the scope of this paper to analyze the many policies directly impacting the ethanol market and the efficacy of the associated multiple policy objectives. Nevertheless, this paper provides important insights into the social costs and benefits of key policy instruments. One key insight is how a change in the price of ethanol affects the corn price. Because one bushel of corn produces 2.8 gallons of ethanol and 31% of the value of corn is returned to the market in the form of feed byproducts, every one cent per gallon increase in the price of ethanol translates into a 4.06 cent per bushel increase in the price of corn. This means a tax credit of $0.57 per gallon (including state credits of $0.06 per

gallon) that generates a price premium for ethanol of $0.57 per gallon translates into $2.31 per bushel for corn. The same outcome occurs if a consumption mandate is used instead to generate the same price premium. Because the corn market is now directly linked to the ethanol price, which is directly linked to gasoline prices, any change in oil prices that affects gasoline prices is now directly transmitted to the price of corn for a given level of the tax credit. On the other hand, once a consumption mandate is in place, any changes in oil prices will not directly affect the corn price (only indirectly affecting costs of production). Hence, a mandate will not transmit instability from the oil market to the corn market unlike a tax credit.

An immediate question is why the tax credit or mandates have not impacted corn prices that much until only recently. In fact, the corn price in the past has often been lower than this implied subsidy to corn farmers! The reason for why the price of corn was rarely affected by the tax credit in the past is either gasoline prices were too low, corn prices too high or costs of ethanol production too high for the tax credit to have any impact. Low oil prices or high corn prices and processing costs mean that the intercept of the ethanol supply curve was far above the price of oil. This "water" in the tax credit means the taxpayer costs were mostly wasted in rectangular deadweight costs—no transfers were made to any group in society. In fact, we show that the sole reason for ethanol and biodiesel production was for the most part due to production subsidies for either corn or ethanol. The tax credits by themselves would have generated little if any ethanol production. The historical data show how uncompetitive the US ethanol industry has been even with tax credits and mandates.

Because the per-unit tax credits are fixed, a spike in oil prices led to a spike in corn prices (with a lag because it took some time to get ethanol processing facilities online). Clearly then, fixed per-unit tax credits in the face of oil price spikes causes instability in the corn market. Because the corn market is linked to other markets through substitution in both demand and for land in supply, this price spike in corn markets is quickly transmitted to other crop prices. This is partially responsible for the current food crisis (Runge and Senauer 2007).

Careful inspection of the data, however, shows that the price premium for ethanol exceeded the tax credits. This means ethanol was purchased historically for other reasons. Because mandates at the local, state and federal levels do not appear to bind historically, we interpret the data to indicate that either *de facto* mandates in the form of environmental regulations (the Clean Air Act of the 1990s or the implicit ban in MTBE in this decade) were responsible for this excessive price premium or that ethanol was purchased for its additive value as an oxygenate/octane enhancer. This means refiners and blenders purchase ethanol in fixed proportions to gasoline. This necessarily implies a mandate model is appropriate to characterize such a situation and appears to be the case for US ethanol until at least 2007/08. More recently, the tax credit is binding, but the expanded federal RFS in recent energy legislation (in conjunction with continuing local and state mandates) may result in an ethanol price premium above the tax credit again in the future.

We also determine that mandates are more efficient than tax credits for the same level of ethanol production because mandates result in relatively higher gasoline prices and lower

$CO_2$ emissions and miles traveled. New US energy legislation mandates the use of renewable fuel but calls for continuing current biofuel subsidies that will cost taxpayers billions of dollars. The subsidies—tax credits—by themselves encourage ethanol production as a replacement for oil-based gasoline consumption. But when used with mandates, the tax credits will instead unintentionally subsidize gasoline consumption. This contradicts the new energy bill's stated objectives of reducing dependency on oil, improving the environment and enhancing rural prosperity. This also has major implications for countries worldwide that also use both tax credits and mandates.

Although tax costs of farm subsidy programs decline, farm subsidies increase both the tax cost and inefficiency costs of the ethanol policies while the latter increase the inefficiency costs of the farm-subsidy programs. Ethanol policies can, therefore, not be justified on the grounds of mitigating the effects of farm-subsidy programs. We also conclude that the US ethanol industry requires oil prices of at least $70 per barrel to be able to produce any ethanol without government support.

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