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Assessing the Welfare Effects of US Biofuel Policies

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This article assesses the main welfare implications of US policies to support biofuels, with an emphasis on corn-based ethanol. The analysis relies on an open economy, multimarket equilibrium model that links world and domestic energy and agricultural markets and explicitly accounts for the externalities of carbon emissions. The first-best policy in our context entails a carbon tax (implemented with a tax on fuel and a subsidy for ethanol), an import tariff on oil, and an export tax on corn. Although this policy is likely not feasible, we show that a second-best policy with an optimally chosen fuel tax and ethanol subsidy can approximate fairly closely the welfare gains associated with the first-best policy. The largest welfare gains to the US economy from first- and second-best policies arise from their impact on the terms of trade, particularly in the oil market.

Key words: biofuel policies, carbon tax, ethanol subsidy, gasoline tax, greenhouse gas emissions, mandates, renewable fuel standard, second best, welfare.

Introduction

The dramatic expansion of the corn-ethanol industry constitutes one of the most significant developments affecting US agriculture in the 21st Century. US fuel-ethanol production has increased from 1.65 billion gallons in 2000 to 10.6 billion gallons in 2009. Indeed, the United States has emerged as the largest world producer of ethanol, surpassing Brazil, which was an early large developer and user of ethanol as transportation fuel. Arguably, the rapid growth of this industry is largely due to critical support policies implemented by the United States. Three sets of policies clearly matter. First, the US ethanol industry benefits from a $0.45/gallon subsidy in the form of an excise tax credit for blending ethanol with gasoline. Second, to prevent this subsidy from being available to foreign ethanol producers, the United States imposes a $0.54/gallon duty on ethanol imports (a secondary tariff, which adds to the normal 2.5% ad valorem tariff). Finally, the renewable fuel standard, introduced by the Energy Policy Act of 2005 and expanded by the Energy Independence and Security Act of 2007, effectively specifies ambitious production "mandates" for the overall use of biofuels in transportation (Yacobucci, 2008). In particular, the annual use of renewable fuel is set to reach 36 billion gallons by 2022, with the corn-ethanol portion of this mandate capped at 15 billion gallons by 2015.

Because of the apparent extensive impact of ethanol-support policies, an interesting set of questions concerns the assessment of their welfare effects. Are the impacts consistent with the objectives that are routinely invoked to justify these policies? What would a first-best policy solution look like in this context? What are the effects of the specific policy instruments being used? What are the main distributional consequences of the existing policies? These are the main questions addressed in this article; the material that is discussed is fully elaborated elsewhere, specifically in Lapan and Moschini (2009) and in Cui, Lapan, Moschini, and Cooper (2010). Here, we present a brief synopsis of the underlying research program, touching upon the model structure that we have developed, the theoretical and empirical analyses carried out, and the main results so far.

The growing literature on the economics of biofuels and their social costs and benefits is reviewed by de Gorter and Just (2010). Contributions particularly related to this study include de Gorter and Just (2009a), who focus on the impact of a biofuel-blend mandate on the fuel market and find that, when implemented along with the mandate, the tax credits essentially subsidize fuel consumption. De Gorter and Just (2009b) extend the analysis by studying the interaction effects of the biofuel subsidy with price-contingent farm subsidies. They find that ethanol production would not be commercially viable without government intervention, and that the rectangular deadweight costs due to the ethanol subsidy dwarf in value the traditional triangular deadweight costs of farm subsidies. Other studies that touch upon the welfare consequences of biofuel production include Elobeid and Tokgoz (2008); Khanna, Ando, and Taheripour (2008); and Hertel, Tyner, and Birur (2010). The latter study uses the GTAP (Global Trade Analysis

Project) computable general equilibrium framework to study the indirect land-use effects highlighted by Searchinger et al. (2008).

Modeling Framework

Lapan and Moschini (2009) note that most existing work does not cast welfare analysis in a normative context that explicitly accounts for the market failures that are deemed to play a critical role in this setting. Indeed, US biofuel policies are typically held to pursue a number of objectives, including that of ameliorating the environmental impacts of carbon emissions, especially in view of global climate change concerns, and that of supporting the quest for renewable sources of energy that may reduce the US dependency on foreign oil. These considerations point to two instances of market failures—the externality of greenhouse gas emission and the national "energy security" argument—that ideally should be explicitly addressed in the welfare analysis. The importance of a normative approach is that in principle it could identify the features of the best (and possibly second-best) policies needed to address the market failures that are conjectured, and it would allow the welfare ranking of alternative policy instruments. To that end, Lapan and Moschini (2009) build a simplified general equilibrium (multimarket) model of the United States and the rest-of-the-world economies that links the agricultural and energy sectors to each other and to the world markets. An important feature of the model is that it allows for the endogeneity of world oil and corn prices (thereby relaxing an undesirable feature of many models in this setting that treat the oil price as exogenous).

This framework of analysis is extended by Cui et al. (2010), who construct a tractable empirical model suitable for providing quantitative estimates of the welfare benefits of alternative policies. The model consists of the following basic components: US corn supply equation, US food/feed corn demand equations (exclusive of ethanol use), rest of the world (ROW) demand for corn imports, US oil supply (production) equation, US fuel demand equation, US petroleum by-products demand equation, and ROW oil export supply equation. Furthermore, the model treats the ethanol-producing segment as a competitive industry with free entry, and the process by which corn is converted to ethanol is represented (realistically) by a fixed-proportion technology and also accounts for the valuable by-products of this process (e.g., distillers dried grains with solubles). Similarly, the refining of oil is also represented as a competitive industry where oil is converted (in fixed proportions) into unblended gasoline and other valuable petroleum by-products (e.g., heating oil). The latter has its own demand, whereas gasoline is blended with ethanol to produce "fuel." Apart from the fact that ethanol and gasoline have different energy content per volume unit (one gallon of ethanol is equivalent to 0.69 gallons of gasoline)—which is accounted for in the model—ethanol and gasoline are treated as perfect substitutes to satisfy fuel demand. Note that by not allowing trade in ethanol, the model effectively assumes the presence of a prohibitive import duty on foreign-produced ethanol (which is largely what happens at present).

The welfare function represents the Marshallian surpluses, net government tax/tariff revenue, and the externality costs of carbon emissions from the point of view of the United States. Producer surplus arises in the two increasing-cost industries represented in the model: agricultural (corn) production and oil production. Consumer surplus arises from the consumption of corn (for food and/or feed), of fuel (gasoline and ethanol), and of petroleum by-products. Finally, the welfare function is (negatively) affected by carbon emissions arising from fuel consumption. Here the model explicitly recognizes that ethanol and gasoline may have different carbon emission levels; note that in the baseline we assume that ethanol is less polluting than gasoline. The welfare function is also impacted by the terms-of-trade effects that arise from oil imports (e.g., reducing import demand lowers the world price of oil) and corn exports (e.g., exporting less corn—because of the ethanol industry expansion—raises the world price of corn). The parameters of the model are calibrated to represent a recent benchmark dataset (for the year 2009) and reflect the consensus on engineering production coefficients, as well as the best available econometric evidence on elasticity estimates. In particular, our baseline level for the welfare cost of carbon emissions reflects an average value evinced from a survey of the vast collection of existing literature (e.g., Tol, 2008).

Based on the calibrated model, for any given value of the policy parameters, we can solve for the resulting equilibrium (domestic and world) prices of corn, oil, ethanol, and gasoline. Thus, we are able to evaluate the positive and normative impacts of a variety of policy interventions. In particular, we can calculate the optimal values for the policy instruments (given the constraint on which instruments can be used) and the associated maximum welfare gains. We establish the first-best policy combination, which consists of oil import and corn export tariffs and a carbon tax. In addition to characterizing this first-best policy, we consider a number of second-best interventions involving various partial combinations of the following policy variables: ethanol mandates or subsidies, oil import tariff, fuel tax, corn export tariff, carbon emissions tax.

Results

Our model's structure permits the derivation of a number of interesting results. From a positive perspective, we characterize the market equilibrium effects of the policy tools that are used in the ethanol market. A particularly useful result in this setting—derived and discussed in Lapan and Moschini (2009)—is that an ethanol quantity mandate is fully equivalent to a combination of an ethanol production subsidy and a fuel (gasoline) tax that is revenue neutral. Because of this feature, the equivalence between a price instrument and a quantity instrument that one typically expects in competitive models without uncertainty is not attained in our case. And, more interestingly, when the policy space is restricted to one active policy instrument, it can be shown that an ethanol quantity mandate welfare dominates an ethanol subsidy policy (Lapan & Moschini, 2009).

The normative welfare analysis centers on characterizing "optimal" biofuel policies. Given our welfare function, it is clear that the first-best policy for welfare maximization requires three instruments: a tax on pollution emissions (i.e., a carbon tax), an import tax on oil, and an export tax on corn. The first of these instruments addresses the externality generated by fuel consumption. The latter two instruments are required because of the terms-of-trade effects that are present, owing to the fact that the United States is a "large country" in the oil and corn markets. The first-best policy solution provides an important benchmark for our analysis, although it is easily recognized that such a solution is not feasible (because of likely political unwillingness to increase excise taxes, constraints arising from the need to comply with World Trade Organization commitments, and the fact that taxes on exports are illegal under the US constitution). In addition to the first-best policy case, we explicitly investigate a number of other scenarios.

First, as the basic benchmark, we look at the "laissez-faire" situation of no policy intervention (e.g., zero fuel/carbon tax and no oil import or corn export tariffs). Next, we consider the "no ethanol policy" case where the fuel tax is fixed at the current level ($0.39/gallon), but there are no subsidies or mandates for ethanol production. Also of interest is the "status quo" scenario with a fuel tax of $0.39/gallon and an ethanol subsidy of $0.45/gallon (with the subsidy as the binding policy parameter vis-à-vis mandates). Getting to the likely feasible policies issue, we then look at the "second-best" solution, where the fuel tax and the ethanol subsidy are the two active policy instruments. Finally, we consider two constrained second-best scenarios: in one constrained scenario, the ethanol subsidy is the only active policy instrument (with the fuel tax fixed at the current $0.39/gallon level); in the other constrained second-best scenario, the ethanol mandate is the only active policy instrument (again with the fuel tax fixed at the current $0.39/gallon level).

In the baseline solution we find that the optimal carbon tax is equivalent to a tax on fuel of $0.37/gallon coupled with a subsidy on ethanol of $0.18/gallon. (Recall that "fuel" here is the mixture of gasoline and ethanol, and that the carbon tax treats the two products differentially because of two distinct elements: ethanol is assumed to pollute less than gasoline for the same level of energy output, and ethanol possesses less energy content per volume unit so that, effectively, a volumetric fuel tax penalizes ethanol more than gasoline.) In addition, the first-best policy requires an oil import tariff of approximately 33% of the world price and a corn export tax of approximately 42% of the world price (at the equilibrium solution values). With our baseline parameters, it is estimated that the first-best solution would increase US welfare by about $15 billion per year relative to the laissez-faire solution of no market intervention.

One of the main objectives of our analysis is to consider the effectiveness of the various policies with respect to the welfare maximization objective. Specifically, the question is how much of the maximum welfare gain of the first-best solution can be achieved by the various scenarios that we considered. It turns out that, for the baseline parameters of our model, the second-best solution where the fuel tax and ethanol subsidies are chosen optimally does remarkably well, achieving 89% of the welfare gains of the first-best policy. When the only active possible policy instruments relate to the ethanol market (with the fuel tax fixed at the current level of $0.39), we find that the optimal mandate outperforms the optimal ethanol subsidy. This numerical solution validates the theoretical welfare-ranking result derived and discussed in Lapan and Moschini (2009). It is also noteworthy that the status quo with the ethanol subsidy fixed at $0.45/gallon (and the fuel tax fixed at $0.39/gallon) achieves approximately half of the potential gains from the (arguably unfeasible) first-best policies. Also, the status quo policy scenario does considerably better than the "no ethanol policy" scenario, which provides some support for the desirability of the policies that have led to the expansion of the ethanol industry (at least from the perspective of US welfare).

One of the alleged objectives of US biofuel policies is to lessen dependence on foreign oil supply. To assess this objective, we find that the first-best solution reduces oil imports by about 24% relative to the laissez-faire benchmark. Again, the second-best solution with an optimal fuel tax and an ethanol subsidy is very close to the first-best solution, whereas the status quo (with an oil import reduction of less than 8% relative to laissez-faire) is not very effective relative to the "energy security" objective.

Another main stated objective of existing biofuel policies is the desire to ameliorate the environmental effects of carbon pollution that arise from energy consumption. The effectiveness of the various policy scenarios in pursuing this objective can be illustrated in terms of the annual carbon emissions (e.g., millions of tons of CO_2) associated with each of the policy scenarios that we consider. We find that, when measured in terms of this pollution reduction standard, first- and second-best policies are essentially equivalent, both reducing carbon emission by about 10% of the emission level of the laissez-faire scenario. Interestingly, the status quo situation with the current biofuel policies actually leads to more emissions than the "no ethanol policy" scenario. As discussed by de Gorter and Just (2009b), the current ethanol subsidy has a consumption subsidy effect for final consumers, which, *ceteris paribus*, leads to an expansion of fuel consumption that translates into higher (not lower) carbon emission levels. Of course, as illustrated earlier, the status quo does improve upon the "no ethanol policy" in terms of overall aggregate welfare, but the mechanism by which this happens is not by reducing pollution. Instead, ethanol policies are mostly useful because of their terms-of-trade effects.

One of the implications of the analysis carried out is that the ethanol industry would essentially not exist were it not for the current policies supporting ethanol production. But we also find that the laissez-faire scenario does entail a fairly sizeable ethanol production. The reason for these apparent contradictory findings is that in the laissez-faire scenario there is no tax on fuel, whereas in the "no ethanol policy" scenario, the tax on fuel is fixed at the current level of $0.39/gallon (with no subsidy for ethanol). Because the fuel tax is on a volumetric basis, and because (as discussed earlier) ethanol has considerably lower energy content than gasoline, the $0.39/gallon fuel tax disproportionally penalizes ethanol vis-à-vis gasoline (specifically, the $0.39/gallon fuel tax is equivalent to a $0.39/gallon tax on gasoline and a $0.57/gallon tax on ethanol).

The discussion of the welfare impacts of the alternative policy scenarios provided earlier did not address the distributional effects associated with ethanol support policies. One way to look at this issue is to compare two of the scenarios that we considered—the status quo and the no ethanol policy scenarios. As noted earlier, the introduction of the current ethanol subsidy policy contributes positively to national welfare (as compared to the case with the pre-existing fuel tax but no ethanol support). But, not surprisingly, it turns out that there are clear winners and losers from these policies. Corn producers and fuel consumers are the biggest beneficiaries. Corn producers benefit from the increased price of corn, which in turn penalizes users of corn for food and feed, and fuel consumers benefit from the reduced equilibrium gasoline/fuel price induced by the ethanol subsidy. But the price of petroleum byproducts increases with the subsidized increase in ethanol use (because less oil is refined, which, owing to the fixed proportion technology, tightens the supply of these byproducts), and this price increase leads to a consumer surplus loss for petroleum byproduct consumers. Parenthetically, it also emerges that subsidizing ethanol production at its current level actually worsens the externality of carbon emission, as discussed earlier.

Conclusion

This article highlighted some results of a research program that was discussed at the 2010 International Consortium of Applied Bioeconomy Research (ICABR) conference, the model and results of which are reported elsewhere (Cui et al., 2010; Lapan & Moschini, 2009). We have shown that, from the point of view of the United States, there is considerable scope for biofuel support policies to increase national welfare. In the logic of our model, the first-best policy would entail a carbon tax (which can be implemented by differentially taxing gasoline and ethanol, or by taxing fuel and subsidizing ethanol), as well as (large) tariffs on imported oil and exported corn. The inability to use first-best policies, of course, reduces the potential welfare gain from policy intervention. However, when the ethanol subsidy and the fuel tax can be chosen optimally, we argue that this second-best policy combination comes surprisingly close to matching the first-best policy in terms of welfare gains and carbon emission reductions. When the policy space is constrained further to consist of only one active policy instrument—the ethanol subsidy or the ethanol mandate—the possible welfare gain declines even more. In either of these cases, because fuel taxes (or oil import tariffs) are not choice variables, it is desirable to increase ethanol consumption (and price), with the larger increase coming under the mandate because raising the mandate increases the effective tax on fuel. Because of this effective tax, the ethanol mandate yields higher welfare and higher ethanol production than does the ethanol subsidy. In any event, a clear lesson is that fuel taxes are a more powerful instrument for reducing carbon dioxide emissions and increasing welfare than are ethanol support policies per se.

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