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On blending mandates, border tax adjustment and import standards for biofuels

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Abstract

The transport sector is a major contributor to green house gas (GHG) emissions and its share is increasing. Biofuels may provide an option to replace fossil fuels and generate an increasing worldwide interest. Rich countries like the US and the European Union ha idies for domestic producers, while applying tariffs for some of the foreign producers. Mid income and poor countries do not have binding restrictions on carbon emissions in the Kyoto treaty, but may have great potential for producing biofuels both for domestic and foreign use. In this paper we study trade policies for biofuels. We find that only by combining an import standard with border tax adjustment the government can ensure cost efficient production of biofuels from a global point of view. We also consider a blending mandate. This fundamentally alters the way the market works. For instance, if domestic biofuels production is subsidized, the optimal BTA may be negative.

Key words: Biofuels, Border tax adjustment,
Carbon Leakage, Trade policy
JEL Classification: F1, H2, Q5

1 Introduction

There is an established consensus that green house gas (GHG) emissions caused by human activities are warming the globe (IPCC 2007; Oreskes

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2004). The transport sector is a major contributor of GHG emissions where the total share of emissions in EU 25 during 1990-2004 grew from 17% to 24% in 2004 (EEA, 2006). On a global scale more than 20 % of the world GHG emissions come from transports (UNFCCC, 2009). These numbers are expected to grow in the years to come, partly because there are currently few alternative technologies available to the conventional internal combustion engine based on fossil fuels, and partly because of the expected increase in the number of vehicles, which in turn is the result of increasing income (Chow, Kopp and Portney, 2003). Hence, there is a great demand for low carbon fuels to replace the currently dominating fossil fuels. Biofuels, provide an interesting set of opportunities to combat GHG emissions, and generate an increasing interest worldwide.

The European Union (EU) has stated an ambition to take a lead in biofuels deployment and common goals for consumption have been made within the framework of the EU biofuels policy. The Biofuels Directive (EC, 2003) sets a target value of 5.75 percent biofuels of total energy consumption in transport by 2010, and in the Renewable Energy Road Map (EC, 2006) the member states agreed on a minimum binding target of 10 percent market share for biofuels by 2020. However, if targets are reached through imports, carbon leakage may become a problem. While the EU can control their own production of biofuels, they cannot regulate GHG emissions from their imports as long as these are connected to the production of the imported biofuels. In other words, as the EU increases their use of biofuels, GHG emissions from EU territory decrease, while it may increase due to the same policy elsewhere. Today, the EU has a tariff on biofuel imports from some countries[1], and further, in order to maximize the GHG emission reductions from the replacement of fossil fuels by biofuels, the EU is considering a certification scheme for biofuels.

In this paper we look at the potential option of reducing GHG emissions using biofuels from an international perspective. Biofuels refer to either ethanol made from fermenting sugar or starch, or biodiesel diesel made from oily plants. While ethanol replaces gasoline, biodiesel replaces conventional diesel. Given proper land use (Fargione et al, 2008; Searchinger et al., 2008) net GHG emissions can be reduced as biofuels replace fossil fuels. Biofuels are interesting to industrialized countries since the technology is nearly ripe. Ethanol made from sugarcane has from time to time been able to compete with gasoline depending on oil-

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[1] For example, undenaturated ethanol from e.g. Brazil has a tariff of €0.192/litre while ethanol from a number of low developing countries is exempted (IISD, 2007). American B99 biodiesel can be exposed to tariffs of up to 41% (NewEnergyFocus, March 13, 2009),

and sugar prices (Kojima et al., 2007). Moreover, the industry is optimistic about producing ethanol from cellulose competitively where the costs of producing ethanol may be reduced by more than 50% within 20 years (Hamelinck and Faaij, 2006). This would greatly enhance the potential for biofuels to replace fossil fuels on a larger scale in the future. At the same time many countries without binding restrictions on carbon emissions according to the Kyoto protocol have great potential for production of biofuels, which raises concern about carbon leakage.

Our focus is on trade policies for biofuels. The problem of using trade policies for preventing carbon leakage in general has been treated in papers by Hoel (1996), Mæstad (1998) and Mæstad (2001). Our analysis confirms some of the central results from this literature. First, it is efficiency enhancing from a global point of view to use border tax adjustment (BTA) on biofuels to the extent that production entails GHG emissions and these emissions are not subject to any climate policy in the country of origin. Second, supporting local biofuel industry either by production subsidies or by less stringent environmental regulation in order to "levy the playing field" is not advisable.

We then take the analysis further in order to investigate some special features of the biofuel market. Contrary to the above mentioned contributions, we include the possibility for GHG emissions abatement. This allows us to look at biofuels import standards which currently are much debated in the EU. We find that the government should introduce a flexible standard accompanied by a BTA schedule making the BTA dependent on the actual emission per unit of output relationship. In fact, such a policy will yield the first best.

Finally, we analyze the effect of introducing a blending mandate for biofuels usage in addition to the other instruments. We show that a blending mandate is equivalent with an additional tax on conventional fuels and a general subsidy to all biofuels. Hence, if the only purpose of introducing biofuels is to reduce GHG emissions, a blending mandate will always reduce global welfare. Our simulations also indicate that given the current subsidy to biofuels production in the EU, the tariff on imported biofuels should be negative! The reason is that a blending mandate amplifies the distortive effects of all domestic policies, and thus, requires a far more drastic change in the tarifrate than in the case without a blending mandate.

2 The model

Our intention is to illustrate some important principles that should guide biofuel policy. We have chosen to model both the demand and supply side of the market for transport fuel using straightforward functional forms. This enables us to derive explicit solutions that are easy to interpret, and can be used for numerical illustrations.

We assume that there are two jurisdictions. Production of biofuels takes place in both jurisdictions by a representative producer of biofuels in each region. Region 1 has introduced a GHG emission tax, while in Region 2 there is no climate policy. There is only one way trade in the model, and Region 2 exports to Region 1. We compare the welfare effects of different instruments.

2.1 The market for transportation fuels

In order to facilitate the analysis we assume that all transportation fuels; gasoline, diesel, biodiesel and ethanol are perfect substitutes, and thus, that the demand for transportation fuels is given by a single demand function:

$$P_i = M_i - N_i Q_i, \ i = 1, 2, \tag{1}$$

where P_i is the price of transportation fuel, M_i, N_i are parameters and the number i denotes the region i.e. Region 1 and Region 2. Total quantity of transportation fuel Q_i is measured in energy equivalents like ton oil equivalents (TOE), to adjust for the fact that different fuels have different energy content per liter.

Further, we assume that the supply of conventional fuels (gasoline and diesel) is completely elastic, and that all production of conventional fuels take place outside the two regions in our model. Clearly, this is also a simplification, but to the extent that OPEC regulates its oil production with point of departure in a target price of oil it is likely not too far away from reality.

Next, we normalize the import price of conventional fuels to zero, and thus, the marginal cost of conventional fuels in Region 1 is T_C, where T_C is a Region 1 specific GHG tax on conventional fuels. In equilibrium the price of transportation fuels must be equal to the constant marginal cost of conventional fuels, that is, we have $P_1 = T_C$. Demand is then given by $Q_1 = \frac{M_1 - T_C}{N_1}$. Whether there will be just conventional fuels in the market, or both conventional and biofuels depends on T_C.

Consumer surplus is derived from (1):

$$CS_1 = \int_0^{Q_1} (M_1 - N_1 Q_1) dQ_1 - P_1 Q_1 = \frac{(M_1 - T_C)^2}{2N_1}, \tag{2}$$

that is, consumers surplus is decreasing in the tax on conventional fuels. In Region 2 there is no tax on conventional fuels, and hence $Q_2 = M_2/N_2$, and $CS_2 = \frac{(M_2)^2}{2N_2}$.

We assume that the target for biofuels usage in Region 2 is given, and hence, that the supply of biofuels from the producers in Region 2 to the domestic market is given, for instance a certain share of Q_2. Hence, we can concentrate on the supply of biofuels to Region 1.

2.2 The supply of biofuels to Region 1

We assume that production costs are convex in output. This is to capture that availability of land is limited, and the more land being allocated to biofuel crops, the higher the marginal value of land in its alternative usage. The cost function is then approximated by the following polynomial:

$$c_i(y_i) = \theta_i y_i + \theta_{ii}(y_i)^2 \tag{3}$$

where $\theta_i, \theta_{ii} \geq 0$ are region specific parameters.

In addition to production costs, producers in Region 1 incur environmental taxes and abatement costs as growing and processing biofuels imply GHG emissions. First, energy crops must be grown and harvested. Possible inputs are then land, labor and fertilizer. GHG emissions from this part of the process is connected to land-use change and fertilizer usage. In both cases emissions can be reduced by careful consideration of the choice of land and crop (Fargione et al, 2008).

For ethanol the next step in the process is fermenting the crops and distilling the fuel. Inputs in this process are energy and capital. Energy may come from the grid, and hence, may involve GHG emissions that are not regulated by any GHG policy. Other ethanol production processes utilizes parts of the energy crop for energy production, and hence GHG emissions is of less concern. Biodiesel processing also requires the use of energy and capital although the production method is very different.

We define a variable $A =$ "abatement" which measures the costs of avoiding GHG emissions. Moreover, we approximate emissions from biofuels production by the following polynomial:

$$\varepsilon_i^B = \lambda_i y_i + \lambda_{ii}(y_i)^2(A_i)^{-1}, \tag{4}$$

where y_i is the supply of producer i to Region 1, and $\lambda_i, \lambda_{ii} \geq 0$ are region specific parameters. The emission function is assumed to be convex in output due to the emissions that follow from land use change, and the need for converting virgin land to crop land as production expands.

In Region 2 there is no climate policy, and hence, the representative biofuel industry in Region 2 will not do any GHG abatement or incur any abatement costs.[2] In Region 1 there is a tax T_B on GHG emissions from

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[2] Emissions are then given by (4) with $A_2 = 1$.

biofuel production. Thus, the representative biofuel producer minimizes the sum of emission tax payments and abatement cost with respect to abatement effort. This yields the following first-order condition:

$$-T_B\lambda_{11}(y_1)^2(A_1)^{-2}+1=0, \tag{5}$$

where the price of abatement is 1. Hence, the level of abatement is given from: $A_1=\sqrt{\lambda_{11}T_B}y_1$. Moreover, emissions will be equal to $(\lambda_1+\sqrt{\lambda_{11}}/\sqrt{T_B})y_1$.

While the cost function for the producers in Region 2 is still given by (3), the cost function for the producers in Region 1 can be written:

$$c_1(y_1,T_B)=\theta_1y_1+\theta_{11}(y_1)^2+\left(\lambda_1T_B+2\sqrt{\lambda_{11}T_B}\right)y_1, \tag{6}$$

which includes both abatement costs and emission tax payments through the term $\left(\lambda_1T_B+2\sqrt{\lambda_{11}T_B}\right)y_1$.

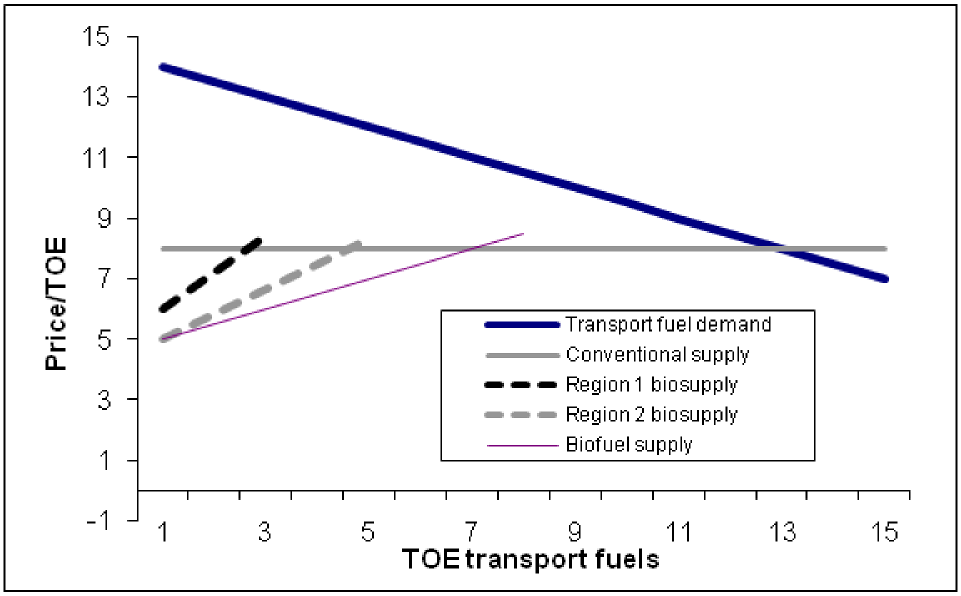
The linear terms θ_1y_1, θ_2y_2, λ_1y_1 and λ_2y_2 do not add anything to the results from the analytical part of the paper. Thus, from now on and until the section with the numerical illustrations, we set $\theta_1,\theta_2,\lambda_1,\lambda_2=0$. We also normalize $\lambda_{11}=1$.

Denoting the price on biofuels in Region 1 by ρ_1, the supply of biofuels to Region 1 from the representative producers are given by:

$$y_1=\frac{\rho_1+s_1-2\sqrt{T_B}}{2\theta_{11}},\ y_2=\frac{\rho_1-t_1}{2\theta_{22}}. \tag{7}$$

In equilibrium the price on biofuels must be equal to the price on conventional fuels: $\rho_1=T_C$. Thus, the sales of biofuels from Region 1 are not influenced by the tariff t_1, while the sales of biofuels from Region 2 do not depend on the subsidy s_1. The market solution can be shown in the following diagram:

Figure 1: The market solution without a blending mandate



Notice that the total sales of transportation fuel only depends on T_C, that is, total sales is given where the transport fuel demand schedule crosses the conventional fuel supply curve. Adding the two supply curves for biofuels gives total biofuel supply for any transportation fuel price. The sales of conventional fuel is then equal to the residual demand, which in Figure 1 for practical reasons is approximately half of the transportation fuel demand. In reality current biofuels sales in the EU is below 2%.

2.3 Welfare and environmental costs

Global environmental damages is a function of total GHG emissions. We assume that damages D can be expressed by an ordinary linear damage function $D = \delta \sum_i (\varepsilon_i^C + \varepsilon_i^B)$, where ε_i^C is emissions from conventional fuel consumption in country i and ε_i^B is emissions from biofuel production in country i. Further, we assume that each region receives a share ψ_i of the damages with $\psi_1 + \psi_2 = 1$.

The welfare of Region 1 is then given by:

$$w_1 = CS_1 + \pi_1 - \psi_1 \delta \sum_i (\varepsilon_i^C + \varepsilon_i^B) + T_C \varepsilon_1^C + T_B \varepsilon_1^B + t_1 y_2 - s_1 y_1, \quad (8)$$

where $T_C\varepsilon_1^C$ is income from taxing conventional fuels, $T_B\varepsilon_1^B$ is income from taxing emissions in biofuels production, t_1 is BTA on biofuel imports, and s_1 is a subsidy to local production of biofuels. Moreover, total emissions of GHG gasses from the use of conventional fuels is given by: $\varepsilon_1^C = \left[\frac{M_1-T_C}{N_1} - y_1 - y_2\right]$ and ε_2^C, which is exogenously given. Emissions from the processing of biofuels ε_i^B in both regions is given from (4), with abatement in Region 1 given by (5).

Likewise, for the welfare of Region 2 we have:

$$w_2 = CS_2 + \pi_2 - \psi_2\delta\sum_i(\varepsilon_i^C + \varepsilon_i^B). \tag{9}$$

3 Use of BTA

3.1 Global second best

Since, Region 1 cannot enforce emission taxes in Region 2, we will look at the use of BTA and subsidies in order to reach the global optimum. We start by considering the most ordinary case without a blending mandate and without an import standard.

Producer surplus can simply be written: $\theta_{11}(y_1)^2$ and $\theta_{22}(y_2)^2$. These expressions can together with (2), (4) and (5) be inserted into the welfare functions (8) and (9), and after a great deal of rearranging we have for total welfare W:

$$W = w_1 + w_2 = \frac{(M_1-T_C)^2}{2N_1} + \theta_{11}(y_1)^2 + (T_C-\delta)\frac{M_1-T_C}{N_1} \tag{10}$$

$$+\left[\delta - T_C - \frac{\delta - T_B}{\sqrt{T_B}} - s_1\right]y_1 + \left[\delta - T_C + t_1\right]y_2 + \left[\theta_{22} - \delta\lambda_{22}\right](y_2)^2,$$

where we have only included terms that depend on the policy instrument; for instance in Region 2, neither consumer surplus, nor the level of conventional fuel usage depend on the tax rates. The first term in (10) is consumer surplus in Region 1, the second term is producer surplus in Region 1, and the third term is tax income subtracted environmental damages from the use of conventional fuels. The fourth term is the external effects of Region 1 biofuel production, that is, domestic biofuel production reduces GHG emissions, decreases conventional fuel tax income and leads to subsidy outlays. Then, the fifth term is the gross effect of foreign biofuel production, which do not include emissions from the production in Region 2. These are included in the last term as a correction of Region 2 producer surplus.

The first order conditions are given by:

$$\frac{\partial W}{\partial T_C} = -\frac{T_C - \delta}{N_1} + \left[\delta - T_C - \frac{\delta - T_B}{\sqrt{T_B}} - s_1\right]\frac{1}{2\theta_{11}} = 0 \tag{11}$$

$$\frac{\partial W}{\partial t_1} = -\left[\delta - T_C + t_1\right] + 2\delta\lambda_{22}y_2 = 0 \tag{12}$$

$$\frac{\partial W}{\partial s_1} = \left[\delta - T_C - \frac{\delta - T_B}{\sqrt{T_B}} - s_1\right] = 0 \tag{13}$$

$$\frac{\partial W}{\partial T_B} = -\left[\delta - T_C - \frac{\delta - T_B}{\sqrt{T_B}} - s_1\right]\frac{1}{\theta_{11}} + \left[\frac{\delta - T_B}{T_B}\right]y_1 = 0 \tag{14}$$

First, note the optimal BTA t_1^*, is independent of the optimal subsidy s_1 and the GHG tax on domestic biofuel production T_B. Notice also that the subsidy is independent of the tariff. Thus, the instrument used to regulate the supply of biofuels from Region 2 to Region 1 and instruments used for regulating domestic biofuels supply should be set independently of each other. In other words policies should not be guided by intentions to "level the playing field".

The solution is: $T_C = \delta$, $T_B = \delta$, $s_1 = 0$ and $t_1 = 2\delta\lambda_{22}y_2$. The BTA is positive, and we can see that it equals *the global marginal environmental damage from a marginal increase in imports.* Our results are summarized in the following proposition:

Proposition 1 *In a global second-best solution domestic biofuel production should be subject to the same GHG emission taxes as other sectors and should receive no subsidies. Import of foreign biofuels should be subject to BTA depending on the emission output coefficient in the source country and the volume of imports.*

The BTA is increasing in the import volume. The intuition is that GHG emissions per unit of biofuels likely are increasing when output is increasing and virgin land is converted to crop land unchecked.

Further, as long as $T_C = T_B = \delta$ i.e. the environmental damage resulting from both conventional fuel use and domestic production of biofuels is fully internalized, the subsidy to biofuels s_1 should be zero. On the other hand, if for instance $T_B < \delta$, the subsidy should be negative.

In the second best the BTA is not conditioned on the emissions of the exporter, but follows from the import volume and a fixed parameter. Hence, the BTA does not give an incentive to invest in GHG abatement in Region 2. We will return to this when we look at an optimal import standard.

3.2 Domestic second best

BTAs and subsidies may be misused. In order to investigate the scope of such misuse, we look at the optimal BTA and subsidy when Region 1 only maximizes its own welfare. In this case, we assume that Region 1 only cares about their part of environmental damages; $\psi_1\delta(\varepsilon_1+\varepsilon_2)$. Secondly, for the tax on conventional fuel, and domestic tax on biofuel production we assume $T_c=\psi_1\delta$, $T_B=\psi_1\delta$. Thus, the welfare of Region 1 is given by:

$$w_1=\frac{(M_1-T_C)^2}{2N_1}+\theta_{11}(y_1)^2-s_1y_1+t_1y_2-\psi_1\delta\lambda_{22}(y_2)^2 \tag{15}$$

From the first order condition for the optimal BTA we obtain:

$$t_1=2\left(\psi_1\delta\lambda_{22}+\theta_{22}\right)y_2, \tag{16}$$

There are two effects: The BTA will reduce emissions from biofuel production in Region 2 and it will yield an income for Region 1. Note that the difference between the unilateral BTA and the second best BTA is given by: $2(\psi_1-1)\delta\lambda_{22}y_2+\theta_{22}y_2$. Defining misuse of BTA as setting a too high BTA, we obtain:

Proposition 2 *Region 1 will have an incentive to misuse the BTA, however, potential misuse become less prominent as the share of environmental damages belonging to Region 1 decreases.*

Clearly, it may be of great risk to the international trading system allowing individual regions to decide the level of the BTA. Rather, setting BTAs in order to reduce carbon leakage should follow a fixed scheme negotiated and agreed upon by the partners of future climate treaties. It should also be considered whether the countries introducing GHG emission based BTAs should be the recipient of the income from the BTAs.

For the optimal subsidy we have:

$$\frac{\partial W}{\partial s_1}=-\frac{s_1}{2\theta_1}<0. \tag{17}$$

Again, we note the optimal subsidy is zero.

4 Use of import standard

4.1 Absolute standard

The EU is considering setting an abosolute standard for biofuels import, that is, all biofuels not fulfilling the standard will be denied at the boarder. Clearly, a standard could take many forms i.e. specify everything from GHG emissions per unit of production to working conditions and the effect on biodiversity conservation. If the desire is to include standards that cover a wide spectre of "externalities" from the use of local inputs, one should logically not only limit the standard to biofuels, but include all imported goods. In this paper we will only consider a standard on GHG emissions per unit of output γ. Thus, in order to be able to export the producer in Region 2 must buy abatement according to:

$$\lambda_{22} y_2 (A_2)^{-1} = \gamma,$$

which yield the following abatement cost function:

$$A_2 = \frac{\lambda_{22}}{\gamma} y_2. \tag{18}$$

The cost function for the representative producer in Region 2 is then : $c_2(y_2, \gamma) = \frac{\lambda_{22}}{\gamma} y_2 + \theta_{22}(y_2)^2$. We also have for the supply of Producer 2: $y_2 = \frac{T_c - \lambda_{22}/\gamma - t_1}{2\theta_{22}}$, and moreover, the profits is still given by: $\pi_2 = \theta_{22}(y_2)^2$. Assume $T_C = \delta$, $T_B = \delta$ and $s_1 = 0$. The global optimal standard and BTA can then be found from:

$$\max_{\gamma, t_1} \left\{ \theta_{22}(y_2)^2 - \delta\gamma y_2 + t_1 y_2 \right\},$$

where the first term is the profit of the foreign industry, the second term is global environmental damage resulting from land clearing and process emissions given the standard, and the third term is income from the BTA. Note that it is only the profit of the foreign industry, and the emissions of the foreign industry from its factor input usage that enters the maximum expression. Hence, when setting the standard, Region 1 should not look at the emissions of its own industry.

After inserting for y_2 and some rearranging, the two first order conditions write:

$$\frac{\partial W}{\partial \gamma} = -\delta^2 \gamma^3 + \delta \lambda_{22} \gamma - (\lambda_{22})^2 + \delta t_1 \gamma^3 = 0. \tag{19}$$

$$\frac{\partial W}{\partial t_1} = \delta\gamma - t_1 = 0. \tag{20}$$

Hence, the optimal BTA given the standard is $\delta\gamma$. Note that it is no longer dependent on import volume as in the plain BTA case covered in Subsection 3.1.

Seemingly, the equation for γ will be hard to solve. However, from Subsection 2.2 we know that given $T_B = \delta$, emissions per unit of output from the domestic industry will be equal to $\sqrt{\lambda_{11}}/\sqrt{\delta}$. Inserting $\gamma = \sqrt{\lambda_{22}}/\sqrt{\delta}$ shows that this indeed solves the equation for γ. Thus, we have the following proposition:

Proposition 3 *The optimal standard should be set such that the emissions per unit of output is as if the foreign producer were subject to an emission tax δ. Moreover, the BTA should be positive and equal to $\sqrt{\delta\lambda_{22}}$. Hence, the marginal cost of the foreign producer will also be as if the foreign producer were subject to an emission tax δ.*

A standard cannot replace BTA fully. The reason is that the optimal standard leads to too high production of foreign biofuels when the foreign biofuels producers are not forced to pay emission taxes for their residual emissions.

4.2 Flexible standard

Governments will seldom have enough information to set the optimal standard by (19). However, they can then instead offer a schedule of BTAs based on the emission/output relationship γ described by (20)[3]. Given this schedule the foreign producer will minimize costs with respect to γ in the following manner:

$$\min_{\gamma} \left\{ \delta\gamma y_2 + \frac{\lambda_{22}}{\gamma} y_2 \right\},$$

where the first term is BTA payments and the second term is the part of the costs being dependent of γ.

Inserting $\gamma = \lambda_{22} y_2 (A_2)^{-1}$ we obtain:

$$\min_{A_2} \left\{ \delta\lambda_{22}(y_2)^2(A_2)^{-1} + A_2 \right\},$$

which will yield the optimal level of abatement. Hence, we have:

Proposition 4 *Introducing a flexible standard connected to a BTA schedule will yield the first best.*

Of course, the government in Region 1 would need to find a way to verify that the foreign producers is acting according to the standard γ.

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[3] Thanks to Henrik Horn for pointing this out.

5 Blending mandate

5.1 The market solution

We now consider the case in which the government in Region 1 regulates the usage of biofuels by a blending mandate $\eta_1 = (y_1 + y_2)/Q_1$ in addition to the already mentioned instruments[4]. As we will see that this changes the way the market for transportation fuels works in a fundamental way. Given the biofuels blending mandate, the cost of one unit of transportation fuel is then:

$$(1 - \eta_1)T_C + \eta_1 \rho_1, \tag{21}$$

where ρ_1 is the Region 1 equilibrium price of biofuels. Since biofuels is guaranteed some sales, we may now have $T_C < \rho_1$. By adding the two supply functions for biofuels given in (7), and using that $y_1 + y_2 = \eta_1 Q_1$, we obtain the following relationship between the price on biofuels and total sales of transportation fuel:

$$\rho_1 = \frac{2\theta_{11}\theta_{22}\eta_1}{\theta_{11} + \theta_{22}} Q_1 - \frac{\theta_{22}(s_1 - 2\sqrt{T_B}) - \theta_{11}t_1}{\theta_{11} + \theta_{22}}. \tag{22}$$

Notice that the equilibrium price of biofuels is increasing in the total sales of transportation fuels Q_1. The reason is off course the increasing marginal cost of biofuels. By inserting (22) into (21) we obtain the supply of transportation fuels which can be plotted in a diagram:

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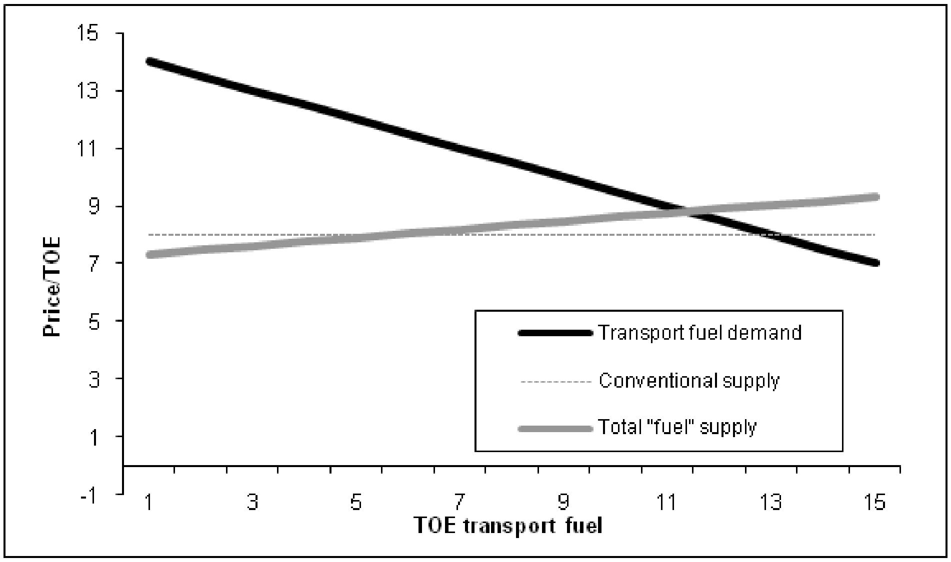
[4] For instance, the blending mandate is implemented in Region 1 by requiring the retailers of conventional fuels to sell a fraction η_1 of their total fuel sales as biofuels.

Figure 2: The market solution with a blending mandate



Notice that the total sales of transportation fuel no longer depends solely on T_C, that is, total sales is given where the transport fuel demand schedule crosses the total "fuel" supply curve. As long as the blending mandate is binding, this will happen to the left of the original equilibrium i.e. with lower total sales of transportation fuel. Total biofuel supply is then equal to a η_1-share of total supply, while sales of conventional fuel is equal to to a $(1-\eta_1)$-share of total supply.

From (22) and (21) we see that the total sales of transportation fuel now depends on all the instruments s_1, t_1 and T_B in addition to T_C. In particular, the sales of biofuels from Region 1 now depend positively on the tariff t_1, that is, an increase in the tariff, will increase the equilibrium price of biofuels, and lead to more sales of domestic biofuels, although total sales of transportation fuels will decrease. *Vice-versa*, the sales of biofuels from Region 2 now depend on the subsidy s_1, that is, an increase in the subsidy, will decrease the equilibrium price of biofuels, and lead to less sales of foreign biofuels.

6 Welfare properties

At once we know the new market equilibrium Q_1, it is easy to calculate the respective market shares. The sales of conventional fuels is equal to $(1-\eta_1)Q_1$, and the price of biofuels is given by (22). This price can then be inserted into the equations given in (7). We then obtain for the supply of biofuels:

$$y_1 = \frac{(s_1 + t_1 - 2\sqrt{T_B})N_1 + 2\eta_1\theta_{22}\left[M_1 + \eta_1 s_1 - 2\eta_1\sqrt{T_B} - (1-\eta_1)T_C\right]}{\Delta}, \tag{23}$$

$$y_2 = \frac{-(s_1 + t_1 - 2\sqrt{T_B})N_1 + 2\eta_1\theta_{11}\left[M_1 - \eta_1 t_1 - (1-\eta_1)T_C\right]}{\Delta} \tag{24}$$

where $\Delta = 2(\theta_{11} + \theta_{22})N_1 + 4\theta_{11}\theta_{22}(\eta_1)^2$.

Our conjectures above are easily verified: Given the blending mandate η_1, the instruments s_1, T_B and t_1 now have more wide ranging effects. For instance, by increasing t_1 the government of Region 1, not only increases its tariff income, but also the production of the representative firm in Region 1.

We can also show that any binding blending mandate η_1 is equivalent with introducing an extra tax on conventional fuels T_1 and a general subsidy S_1 to all biofuels with the additional constraint that the income from the tax and the outlay for the subsidy should balance: $T_1(1-\eta_1)Q_1 = S_1\eta_1 Q_1$. Hence, we have:

Proposition 5 *Any binding blending mandate can be reached by an extra tax on conventional fuels and a general subsidy to all biofuels. Since the subsidy should be zero and the tax on conventional fuel should equal marginal damages from GHG emissions δ, it is not optimal to introduce a binding blending mandate.*
Proof. *See Appendix* ■

The reason for introducing the blending mandate cannot be to obtain additional reductions in current emissions of GHG as these reductions will necessarily come at a cost in excess of δ.

6.1 BTA given a blending mandate

We now turn to look at the optimal BTA. With $T_C, T_B = \delta$, global welfare is given:

$$W = \frac{N_1}{2(\eta_1)^2}(y_1 + y_2)^2 + \theta_{11}(y_1)^2 + \theta_{22}(y_2)^2 + t_1 y_2 - s_1 y_1 - \delta\lambda_{22}(y_2)^2,$$

where the first term is consumer surplus, the second and third terms are producer surplus, the fourth and the fifth terms are tariff income and subsidy outlay and finally, the last term is environmental damage resulting from production in the other region[5]. The output quantities of biofuels y_1 and y_2 are given from (23) and (24). Hence, for the derivatives we have $\frac{\partial y_1}{\partial t_1} = \frac{N_1}{\Delta}$ and $\frac{\partial y_2}{\partial t_1} = \frac{-N_1 - 2\theta_{11}(\eta_1)^2}{\Delta}$. The first order condition is then given:

$$\frac{\partial W}{\partial t_1} = -\frac{2N_1\theta_{11}}{\Delta}(y_1 + y_2) + 2\theta_{11}(y_1)\frac{N_1}{\Delta} - 2\theta_{22}(y_2)\frac{N_1 + 2\theta_{11}(\eta_1)^2}{\Delta}$$

$$+y_2 - t_1\frac{N_1 + 2\theta_{11}(\eta_1)^2}{\Delta} - s_1\frac{N_1}{\Delta} + 2\delta\lambda_{22}(y_2)\frac{N_1 + 2\theta_{11}(\eta_1)^2}{\Delta} = 0$$

The four first terms cancel, hence, simplifying yields:

$$(2\delta\lambda_{22}y_2 - t_1)\frac{N_1 + 2\theta_{11}(\eta_1)^2}{\Delta} = s_1\frac{N_1}{\Delta} \tag{25}$$

In the second-best we had $t_1^* = 2\delta\lambda_{22}y_2^*$, see (12). Thus, we have the following proposition:

Proposition 6 *The rule for setting the BTA now includes the subsidy rate s_1. The BTA should be lower the higher the subsidy rate.*

The blending mandate does not rule out BTA, however, if subsidies to domestic biofuel production are extensive, the BTA could turn negative.

7 Numerical illustration

In order to illustrate the effects of a blending mandate we have calibrated the model to data from 2004 covering the transport market in the European Union, European production of biofuels and to Brazilian ethanol production (see Eurostat 2007, Kutas et al. 2007). Since our focus in on the blending mandate and the data with regards to GHG abatement possibilities are limited, we decided not to include possibilities for GHG abatement in biofuels production.[6]

We treat the EU as one market, and convert all fuels to energy equivalents. By weighting consumer prices for gasoline and diesel in each country by their share of total consumption, we computed an average consumer price, exercise tax and carbon tax for conventional fuel. Supply of conventional fuels is then assumed to be completely elastic at the

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[5] Note that the third and fourth term in (8) becomes zero when $T_C, T_B = \delta$.

[6] Still we assume that GHG emissions per unit of output are increasing in output. In the simulations below we have used 10% increase for every doubling of production for both the European and Brazilian biofuels industries. Increasing this figure to 25% does not lead to any significant change in our results.

average consumer price. Given a price elasticity of transportation fuels of -0.4, it is then easy to fit a linear demand schedule to the 2004 data.

Supply of Brazilian ethanol is upward sloping, and average cost is assumed to increase by 5% for every doubling. In 2004 production costs were comparable to the international price on gasoline measured in volume units (Kujima et al, 2007). Then by using production figures from 2004, we were able to specify the Brazilian supply schedule.

We decided to treat European biodiesel and ethanol together. Due to the intricate support scheme for European biofuel production, it is difficult to find cost data. Instead we used the cost of producing biodiesel from soy beans which is available from the US Energy Department. Moreover, for European biofuel production we assumed that average cost increases by 10% for every doubling due to less availability of land. The supply schedule can then be specified using current biofuels production in the EU. Finally, the current European subsidy to biofuels production measured as a fixed per unit subsidy is calculated residually.[7]

Table 1 - Key data for year 2004

Price conventional fuels	1.07 euro/liter
Exercise tax conventional fuel	0.70 euro/liter
Carbon tax conventional fuel	0.05 euro/liter
International price conventional fuel	0.32 euro/liter
Marginal cost EU biofuels	0.56 euro/liter
Unit subsidy EU biofuels	0.31 euro/liter
Marginal cost Brazilian ethanol	0.26 euro/liter[8]
Tariff Brazilian Ethanol	0.19 euro/liter
Net GHG reduction EU biofuels	50%
Net GHG reduction Brazilian ethanol	85%

The carbon tax amounts to 20 euro/ton CO_2. Domestic biofuels is partly exempted from the exercise tax which is reflected in the subsidy.

Below we show results for three scenarios. In the baseline scenario we introduce a 5.75% blending mandate based on the 2004 figures. The implicit tax on conventional fuels and subsidy to both types of biofuels can then be calculated. In the next scenario we look at the optimal

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[7] Due to the high costs of European biofuels, the supply schedule would give zero sales with current conventional fuel prices. The calculated subsidy is then equal to the subsidy that would give 2004 biofuels production as an equilibrium outcome. The per unit subsidy is probably on the low side as European rapeseed based biodiesel likely is more costly than biodiesel based on soy beans. The calibration method is described in more detail in a separate Appendix.

[8] Since ethanol has a lower energy content, cost per energy unit is higher than conventional fuels. Biodiesel also has a higher energy content than ethanol.

tariff from a global point of view given the EU domestic biofuel subsidy. Finally, we look at the optimal combination of the EU subsidy and tariff.

Table 2 - The effect of introducing a 5.75 % blending mandate

Scenarios:	EU Biodiesel	Ethanol	Implicit	Implicit
	subsidy	tariff	tax	subsidy
Baseline	0.31	0.19	0.02	0.32
Optimal tariff	0.31	-0.1	0	0
Optimal subsidy + tariff	0	0.03	0.01	0.12

* All figures in €/liter

In the baseline scenario total subsidies to European biofuels production amounts to 8 billion euro of which more than a half is paid directly by consumers through a higher price on transportation fuels. Consumers also subsidize Brazilian ethanol through the blending mandate, and this subsidy amounts to nearly 4 billion euro. Thus, given current policy the blending mandate implies a transfer of more than 8 billion euro from consumers to biofuel producers which does not show up in the national budgets.

The tariff is non optimal both from a global point of view and from a strict EU perspective. If of some reason the EU cannot remove the European domestic biofuel subsidy, tariffs should be negative as indicated in the third row of Table 2. The blending mandate is then reached by increasing Brazilian ethanol supply alone, and keeping EU biofuels supply fixed. The welfare improvement from such a policy shift is about 3 billion euro for the EU alone. Finally, the hidden transfer from consumers to biofuels producers is eliminated.

From a global welfare point of view the European domestic biofuel subsidy should be completely removed, and the tariff set slightly positive. The reason for not removing the tariff fully is the small, but still significant GHG emissions from Brazilian ethanol production. Finally, notice that the optimal policy does not eliminate the hidden subsidies. Removing the domestic subsidy, implies that in order to reach the blending mandate approximatly 4 billion euro must be transfered from EU consumers to Brazilian biofuel producers. This is also optimal from an EU point of view.

8 Discussion and Conclusion

In this paper we study trade policies for biofuels in the context of reducing GHG emissions. Like any other model ours' use simplifications and any policy conclusion drawn from our results should be taken with a grain of salt. The drivers behind the global interest in biofuels are not solely concern about the climate, but also of energy safety, local environmental pollution particularly in developing countries, and last but not the least, an interest in supporting domestic agriculture related to ongoing trade liberalizing negotiations (Kojima et al., 2007). The current EU policies for biofuels are likely influenced by all of these factors except maybe the concern for local environmental pollution.

The EU is planning to introduce a standard for biofuels imports, and our paper may provide some guidance in that respects. We find that governments should not set absolute standard, but introduce flexible standards accompanied by BTA schedules making the BTA dependent on the actual emission per unit of output relationship. In fact, such a policy will yield the first best.

The EU is also toughening its biofuels blending mandate. We show that a blending mandate fundamentally alters the way the market works. For instance, if domestic biofuels production is subsidized, the optimal BTA may be negative. Clearly, a negative tariff is unrealistic, on the other hand, it stresses the need for the EU to reconsider both its trade policy and subsidy policy with respect to biofuels.

We find that a 5.75% blending mandate implies a transfer from consumers to producers of 8 billion euro. This should not be misinterpreted as a welfare loss since the transfer partly shows up as increased producer surplus. Although our numerical model should not be expected to give exact figures, one may ask if transferring anything in the range of this amount of money to biofuels suppliers is well spent given all the uncertainty regarding biofuels as a long term solution to GHG abatement in the transport sector. A recent study from 2006 estimated the costs to achieve GHG reductions with current subsidies to be in the range €215-800 per tonne of CO_2 equivalent reduction, which can be contrasted to the market prices for the same time period at the Chicago- and the European Climate Exchange ranging from €3-26 (Kutas et al., 2007). Hence, we feel safe to claim that the current EU biofuel policy does not achieve the most ‘bang for the buck’.

Policies for reducing emissions from the transport sector are easily combined with other targets. Both industrialized countries and developing countries are concerned about energy safety. Currently, a large part of the fossil fuels are supplied from the OPEC states and their share of the world market for transportation fuels will likely increase considerably (Aune et al, 2005). If energy safety is another objective for EU’s biofuels policy, the current tariff on ethanol imports from e.g. Brazil is clearly suboptimal. Ethanol from Brazil would reduce dependence on both Russian gas and oil from OPEC, but it is also superior in terms of

GHG reductions compared to EU produced ethanol (See e.g. Kojima et al., 2007) indicating that the optimal tariff in this case would be negative. The empirical application part of this study has focussed on EU, but the American policies bear a lot of resemblance to EU. "The modern U.S. ethanol industry was born subsidized" Koplow and Steenblik (2008) write, and found the 18,5 billion liters of ethanol produced in US during 2006 to be subsidized by about €4 billions.

Clearly, the current EU policy on biofuels is hard to grasp within our model. One additional argument frequently cited for subsidies is the potential for future cost reductions using new cleaner energy technologies (see e.g. Hamelinck and Faaij, 2006). Here, we have not treated induced technological change, which is clearly an area for future research.

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9 Proof of proposition 4

First, by rearranging the budget constraint we have $S_1 = T_1 \frac{(1-\eta_1)}{\eta_1}$. Thus, $T_1 - S_1 = T_1/\eta_1$. We then have for the supply of Producer 1 and Producer 2: $y_1 = \frac{T_C + T_1/\eta_1 + s_1 - 2\sqrt{T_B}}{2\theta_{11}}$ and $y_2 = \frac{T_C + T_1/\eta_1 - t_1}{2\theta_{22}}$ (see (7) and insert $\rho_1 = T_C$). Since total quantity Q_1 with an extra tax on conventional fuels T_1 is given by $Q_1 = \frac{M_1 - T_C - T_1}{N_1}$, we must have:

$\frac{T_C+T_1/\eta_1+s_1-2\sqrt{T_B}}{2\theta_{11}} + \frac{T_C+T_1/\eta_1-t_1}{2\theta_{22}} = \eta_1\left(\frac{M_1-T_C-T_1}{N_1}\right)$. This equation can be solved for T_1:

$$T_1 = \frac{2\theta_{11}\eta_1 N_1(t_1 - s_1 - T_C) + 4\theta_{11}\theta_{22}(\eta_1)^2(M_1 - T_C) + 2\theta_{22}\eta_1 N_1(2\sqrt{T_B} - T_C)}{\Delta},$$

where Δ is defined above. From the budget constraint we get for S_1:

$$S_1 = \frac{1-\eta_1}{\eta_1}T_1.$$

We note that as long as $T_1$is positive, S_1 is positive as well.

10 Numerical model

10.1 Demand

We have taken total diesel sales, total petrol sales, total ethanol sales and total biodiesel sales in the EU-25 and converted it to *tonnes oil eqivalent* (toe). Similarily, we have taken a weighted average of the consumer price in EU-25 and converted it to a euro/toe price. Moreover, we assume that the short run price elasticity of demand in the current equilibrium is $-\varepsilon$. The parameters in the demand function in our numerical model are then given by:

$$N_{eu} = \frac{P_{eu}^{2004}}{\varepsilon Q_{eu}^{2004}},$$

$$M_{eu} = (1+\varepsilon)\frac{P_{eu}^{2004}}{\varepsilon},$$

where Q_{eu}^{2004} is total consumption of transportation fuel in the EU in 2004 measured in toe, and P_{eu}^{2004} is the weighted average price for the same year.

10.2 Supply

The average tax on conventional fuel in EU-25 is approximatly 70%. We say that the GHG tax part of this tax amounts to 20 Euro per ton CO_2. The rest of the tax has either a fiscal motivation and/or some other motivation related to local pollution, traffic congestion etc. To the extent that biofuels enjoy a relif from this part of the tax, it must be considered a subsidy.

Further, in the range of total fuel supply that we are looking at we assume that conventional fuel can be supplied to the EU at a price equal to 30% of the consumer price.

With respect to biofuels supply, the costfunctions are callibrated by looking at the current average cost and by assuming that a doubling in production volume will lead to a Δ_i^c %-increase in average cost. Let current average production cost be given by α_i. We then have:

$$\theta_i = 2\alpha_i - (1 + \Delta_i^c)\alpha_i,$$

$$\theta_{ii} = \frac{\Delta_i^c \alpha_i}{y_i^{2004}},$$

where y_i^{2004} is production of biofuels from region i in the base year. For simplicity, we assume that Brazil only supplies ethanol, and that the EU only has biodiesel production.

10.3 Abatement

For the callibration of the emission functions we use the same approach as for the cost funtion. That is, we know current, production related GHG emissions per unit of toe, and then we look at different assumptions with regards to the increase in emissions per unit of toe implied by a doubling in production volume. Thus, let β_i be the emission per unit of toe coefficient, let Δ_i^e be the %-increase in emissions per toe, and let $A_i = 1$. We then have:

$$\lambda_i = 2\beta_i - (1 + \Delta_i^e)\beta_i,$$

$$\lambda_{ii} = \frac{\Delta_i^e \beta_i}{y_i^{2004}}.$$

Assuming away abatement implies some changes to the biofuel supply functions which we turn to now.

10.4 Output of the domestic and foreign firm

Output of the domestic representative biofuel firm is given by:

$$y_1 = \frac{W_T + T_T + T_C + s_1 - \theta_1 - \lambda_1 T_B}{2\hat{\theta}_{11}},$$

where W_T is the international ex. tax price on conventional fuels, T_T is the non-carbon tax on conventional fuels and $\hat{\theta}_{11} = \theta_{11} + \lambda_{22} T_B$.. Since the EU has a GHG emission ceiling, we assume in the simulations that $T_B = T_C$. Without abatement possibillities GHG emissions from the domestic producer is given by:

$$\varepsilon_1^B = \lambda_1 + \lambda_{22}(y_1)^2.$$

Output of the foreign representative biofuel firm in the case without the import standard is given by:

$$y_2 = \frac{W_T + T_T + T_C - t_1 - \theta_2}{2\theta_{22}}.$$

GHG emissions is then given by:

$$\varepsilon_2^B = \lambda_2 y_2 + \lambda_{22}(y_2)^2$$

Finally, we have for the extra tax T_1 in case of a blending mandate:

$$T_1 = \frac{\frac{1}{2\hat{\theta}_{11}}\left(\theta_1 + \lambda_1 T_B - W_T - T_T - T_C - s_1\right)}{\frac{1}{2\eta_1\hat{\theta}_{11}} + \frac{1}{2\eta_1\theta_{22}} + \frac{\eta_1}{N_1}}$$

$$-\frac{\frac{1}{2\theta_{22}}\left(W_T - t_1 - \theta_2 + T_C + T_T\right) + \frac{\eta_1}{N_1}\left(W_T - M_1 + T_C + T_T\right)}{\frac{1}{2\eta_1\hat{\theta}_{11}} + \frac{1}{2\eta_1\theta_{22}} + \frac{\eta_1}{N_1}},$$

where $\hat{\theta}_{11} = \theta_{11} + \lambda_{22} T_B$.