On biofuels and trade: Tariffs, standards or import subsidies?

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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 have set targets like portfolio standards for the use of biofuels and provide subsidies 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. Real world trade conditions for biofuels are currently far from a first best solution. In this paper we study second best trade policies for biofuels. In particular we find, that standards should be accomanied by tariffs. And moreover, that with a portfolio standard, the government should in some cases provide an import subsidy instead of a tariff.

Key words: Trade policy, Biofuels, Carbon Leakage

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1 Introduction

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

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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 drivers behind this interest 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, Mitchell and Ward, 2007).

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). 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, 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.

Here 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 bio diesel made from oily plants. While ethanol replaces gasoline, bio diesel 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- and sugar prices (World Bank, 2007). Moreover, the industry is optimistic about producing ethanol from cellulose competitively. 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.

In this paper we consider second best trade policies for biofuels. The problem of using trade policies for preventing carbon leakage has been treated in general papers like 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 levy an import tariff on biofuels to the extent that productions entails emissions and these emissions are not subject to 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. Surprisingly, we find that a standard should be accompanied by a tariff, and hence, that a standard cannot replace a tariff in the second best. As expected, we also find that both the standard and the tariff should solely be based on the production technology in the country of origin, and not on the local best available production technology.

Finally, we analyze the effect of setting a proportional target for biofuels usage, i.e. introducing a portfolio standard in addition to the other instruments. We show that the portfolio standard 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 portfolio standard will always reduce global welfare. In other words, the portfolio standard can only be defended to the extent that the introducing biofuels has other purposes for instance diversifying transportation fuel supply. In case such purposes do not exist, we show that increasing the tariff leads to increased global welfare.

2 The model

Our intention is to illustrate some important principles that should guard biofuel policy. We have chosen to model both the demand and supply side of the market for transport fuel using simple functional forms. This allows us to derive explicit solutions which are easy to interpret.

The model is further made as simple as possible: There are two jurisdictions. Production of biofuels takes place in both jurisdictions. Region 1 has committed to a ceiling on green house gasses (GHG), 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 demand for transportation fuels

We assume that demand for transportation fuels (gasoline and/or diesel, bio and/or conventional) is given by the following demand function:

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

where the number i denotes the region i.e. Region 1 and Region 2.

Next, we normalize the marginal production cost 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 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 whether some demand will be covered by 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 $CS_2 = \frac{(M_2)^2}{2N_2}$.

2.2 The supply of biofuels

Each region may have a policy targeting the use of biofuels. We note that the motivation could be i) Environmental, ii) Reduce dependency on fossil fuel imports and iii) Support marginal regions through agriculture. Moreover, we denote the total supply of biofuels by Y_i.

There is a representative producer of biofuels in each region. First, energy crops must be grown and harvested. The essential 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 (Polasky et al.).

The next step in the process is fermenting the crops and distilling the fuel. For this process the essential input is energy and capital. Energy may come from the grid, and hence, may involve GHG emissions. However, some biofuel production processes utilizes parts of the energy crop for energy production, and hence GHG emissions is greatly reduced. Moreover, energy and capital are substitutes in this part of the process, and hence, by using more capital, emissions from energy usage can be brought down.

We define a variable $A =$ "abatement" to be any activity directed towards reducing GHG emissions. Moreover, we assume that all abatement activity has an add-on cost, that is, "abatement" forces the representative producers to produce in a less efficient way in order to reduce emissions. We measure A directly in money. Assume then that emissions from biofuels production are given by the following emission function:

$$\varepsilon_i^B = \lambda_i (y_i)^2 (A_i)^{-1}, \tag{3}$$

where $\lambda_i \geq 0$, is a region specific parameter. 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.

We also assume that costs are convex in output. This is to capture that land has an alternative usage, 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:

$$c_i(y_i, a_i) = \theta_i (y_i)^2 + A_i \tag{4}$$

where θ_i is another region specific parameter.

In Region 2 there is no climate policy. For convenience, we then set $A_2 = 1$. In Region 1 there is a tax T_B on GHG emission from biofuel production. Thus, the representative biofuelproducer minimizes cost with respect to abatement effort. This yields the following first-order condition:

$$-T_B \lambda_1 (y_i)^2 (A_i)^{-2} + 1 = 0,$$

and hence, the level of abatement is given from: $A_1 = \sqrt{\lambda_1 T_B} y_1$. Moreover, emissions will be equal to $(\sqrt{\lambda_1}/\sqrt{T_B})y_1$. The cost function can then be written: $c_1(y_1, T_B) = 2\sqrt{\lambda_1 T_B} y_1 + \theta_1(y_1)^2$, which includes both abatement costs and emission tax payments. From now on we normalize $\lambda_1 = 1$.

2.3 Welfare and environmental costs

Global environmental damages is a function of total GHG emissions. We assume that damages can be expressed by the simple linear damage function $\delta = \delta \sum_i (\varepsilon_i^C + \varepsilon_i^B)$, and moreover, we assume that each region receives a share ψ_i of the damages with $\psi_1 + \psi_2 = 1$.

Total emissions of GHG gasses from the use of conventional fuels is given by: $\varepsilon_i^C = \left[\frac{M_i - T_i}{N_i} - Y_i\right]$ .The welfare of Region 1 is then given by:

$$w_1 = CS_1 + \pi_1 - \psi_1 \delta \sum_i (\varepsilon_i^C + \varepsilon_i^B) + T_C \varepsilon_1^C + T_B \varepsilon_1^B + t_1 y_2 - s_1 y_1 + B_1(\eta_1),$$

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 a tariff on biofuel imports, and s_1 is a subsidy to local production of biofuels. Finally, $\eta_1 = \frac{Y_1}{Q_1}$ and $B_1(\eta_1)$ is a region specific benefit from being less dependent on import of conventional transportation fuels.

Likewise, for the welfare of Region 2 we have:

$$w_2 = CS_2 + \pi_2 - \psi_2 \delta \sum_i (\varepsilon_i^C + \varepsilon_i^B) + B_2(\eta_2).$$

In most of the analysis we will assume that $B_i(\eta_i)$ is $0 \forall \eta$. Hence, we do not give a micro foundation for $B_i(\cdot)$ in the paper.

3 Optimal policies

3.1 Global second best with a simple tariff

Since, Region 1 cannot enforce emission taxes in Region 2, we will look at the use of tariffs and subsidies in order to reach the global optimum. We start by considering the simplest case. We assume that $B_i(\eta_i)$ is zero for all η_i, $i = 1, 2$, and consequently, there will be no domestic use of biofuels in Region 2.

For Region 1, in equilibrium, the marginal cost of biofuels must be equal to the price of conventional fuels T_C. Moreover, the producers have the following cost functions: $c_1(y_1) = (2\sqrt{T_B} - s_1)y_1 + \theta_1(y_1)^2$ and $c_2(y_2) = t_1 y_1 + \theta_2(y_2)^2$. Note that the tariff is fixed per unit of import, and is not indexed to the emission output coefficient of the Region 2 producer. Hence, it provides no incentive for abatement.

For the supply of Producer 1 and Producer 2 we have:

$$y_1 = \frac{T_C + s_1 - 2\sqrt{T_B}}{2\theta_1}, y_2 = \frac{T_C - t_1}{2\theta_2}$$

Total supply of biofuels is then: $Y_1 = \frac{T_C+s_1-2\sqrt{T_B}}{2\theta_1} + \frac{T_C-t_1}{2\theta_2}$. Moreover, producer surplus can simply be written: $\theta_1(y_1)^2$ and $\theta_2(y_2)^2$. This can then be inserted into the welfare functions, and after a great deal of rearranging we have for total welfare W:

$$W = w_1 + w_2 = \frac{(M_1 - T_C)^2}{2N_1} + \theta_1(y_1)^2 + (T_C - \delta)\frac{M_1 - T_C}{N_1} \tag{5}$$

$$+ \left[\delta - T_C - \frac{\delta - T_B}{\sqrt{T_B}} - s_1\right] y_1 + [\delta - T_C + t_1]\, y_2 + [\theta_2 - \delta\lambda_2]\, (y_2)^2,$$

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. Note that the first term in (5) 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 net effect of Region 1 biofuel production, that is, domestic biofuel production reduces GHG emissions by a factor $\frac{\sqrt{T_B}-1}{\sqrt{T_B}}$, 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:

$$\frac{\partial W}{\partial T_C} = -\frac{T_C - \delta}{N_1} + \left[\delta - T_C - \frac{\delta - T_B}{\sqrt{T_B}} - s_1\right] \frac{1}{2\theta_1} = 0 \tag{6}$$

$$\frac{\partial W}{\partial t_1} = -\left[\delta - T_C + t_1\right] + 2\delta\lambda_2 y_2 = 0 \tag{7}$$

$$\frac{\partial W}{\partial s_1} = \left[\delta - T_C - \frac{\delta - T_B}{\sqrt{T_B}} - s_1\right] = 0 \tag{8}$$

$$\frac{\partial W}{\partial T_B} = -\left[\delta - T_C - \frac{\delta - T_B}{\sqrt{T_B}} - s_1\right] \frac{1}{\theta_1} + \left[\frac{\delta - T_B}{T_B}\right] y_1 = 0 \tag{9}$$

Thus, the solution is: $T_C = \delta$, $T_B = \delta$, $s_1 = 0$ and $t_1 = 2\delta\lambda_2 y_2$. The tariff is positive, and we can see that it equals *the global marginal environmental damage from a marginal increase in imports*. The tariff is increasing in the import volume. The intuition is that GHG emissions are increasing when output is increased as long as land is converted unchecked. Further, as long as $T_C = \delta$ i.e. the environmental damage resulting from conventional fuel use is fully internalized, the subsidy to biofuels s_1 should be zero. Note also that if $\lambda_2 = 0$, the tariff should be zero.

Given that the tariff is non-zero, the optimal tariff can also be written:

$$t_1^* = \frac{T_C}{1 + \theta_2/\delta\lambda_2} \tag{10}$$

Hence, the tariff is lower than marginal global environmental damage from conventional fuels, independent of the emission coefficient λ_2. Note that the tariff is increasing in λ_2.

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 a tariff depending on the emission output coefficient in the source country.*

The main weakness of the plain tariff is that it does not lead to abatement investments in Region 2. We will return to this when we look at an optimal import standard.

3.2 Unilateral tariff setting

Tariff and subsidies may be misused. In order to investigate the scope of such misuse, we look at the optimal tariff 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:

$$w_1 = \frac{(M_1 - T_C)^2}{2N_1} + \theta_1(y_1)^2 - s_1 y_1 + t_1 y_2 - \psi_1\delta\lambda_2(y_2)^2 \tag{11}$$

The two first order conditions are given by:

$$\frac{\partial W}{\partial t_1} = -t_1 + 2\theta_2 y_2 + 2\psi_1\delta\lambda_2 y_2 = 0, \tag{12}$$

$$\frac{\partial W}{\partial s_1} = -\frac{s_1}{2\theta_1} < 0. \tag{13}$$

Again, we note the optimal subsidy is zero. Further, we note that even if $\lambda_2 = 0$, the tariff should be non-zero. With $\lambda_2 \neq 0$, the optimal tariff in the unilateral policy case is given by:

$$t_1^U = \delta\psi_1 \left[\frac{\theta_2 + \delta\psi_1\lambda_2}{2\theta_2 + \delta\psi_1\lambda_2} \right]. \tag{14}$$

By comparing with (10) we note that if $\psi_1 = 1$, $t_1^U > t_1^* \forall \lambda_2$. However, since $\frac{\partial t_1^U}{\partial \psi_1} > 0$, we may have for low values on ψ_1 that $t_1^U \leq t_1^*$.We then have:

Proposition 2 *Region 1 will have an incentive to misuse the tariff and apply a "beggar-thy-neighbour" policy. The incentive is weakened the lower the share of environmental damages belonging to Region 1.*

Clearly, it may be of great risk to the international trading system allowing individual regions to decide the level of the tariffs. Rather, tariff setting 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 which country should be the recipient of the tariff income. Of course, it need not be the country in which the tariff is operative.

In Section 5 we compare the optimal tariff for different scenarios in a numerical example.

3.3 Biofuels import standard

In this section we consider a biofuel standard as an addition to a biofuel tariff. 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 of course 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:

$$\lambda_2 y_2 (A_2)^{-1} = \gamma,$$

which yield the following abatement cost function:

$$A_2 = \frac{\lambda_2}{\gamma} y_2. \tag{15}$$

The cost function for the representative producer in Region 2 is then : $c_2(y_2, \gamma) = \frac{\lambda_2}{\gamma} y_2 + \theta_2(y_2)^2$. We also have for the supply of Producer 2: $y_2 = \frac{T_c - \lambda_2/\gamma - t_1}{2\theta_2}$, and moreover, the profits is still given by: $\pi_2 = \theta_2(y_2)^2$. Assume $T_C = \delta$, $T_B = \delta$ and $s_1 = 0$. The global optimal standard and tariff rate can then be found from:

$$\max_{\gamma} \left\{ \theta_2(y_2)^2 - \delta\gamma y_2 + t_1 y_2 \right\},$$

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 tariff. 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:

$$\frac{\partial W}{\partial \gamma} = -\delta^2\gamma^3 + \delta\lambda_2\gamma - (\lambda_2)^2 + \delta t_1 \gamma^3 = 0.$$

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

Hence, the optimal tariff given the standard is $\delta\gamma$. Note that it is no longer dependent on import volume as in the plain tariff 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 $\sqrt{\lambda_1}/\sqrt{\delta}$. Inserting $\gamma = \sqrt{\lambda_2}/\sqrt{\delta}$ 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 tariff should be positive and equal to $\sqrt{\delta\lambda_2}$. 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 a tariff 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 Portfolio standard for biofuels in Region 1

4.1 The market solution

We now consider the case in which the government in Region 1 regulates the usage of biofuels by a portfolio standard η_1 in addition to the already mentioned instruments. In other words, the government in Region 1 does not necessarily remove the taxes T_C and T_B, and might still use a tariff t_1.

Given the proportional biofuels target, the cost of one unit of transportation fuel is:

$$C_1 = T_C + \eta_1 \omega_1,$$

where ω_1 is the Region 1 equilibrium price of biofuels.

Equilibrium in the transportation fuel market requires that price must be equal to marginal cost. By inserting into (1) we obtain:

$$T_C + \eta_1 \omega_1 = M_1 - N_1 Q_1,$$

which may be rearranged to:

$$Q_1 = \frac{M_1 - T_C}{N_1} - \frac{\eta_1}{N_1}\omega_1. \tag{16}$$

The equation (16) gives us the demand for transportation fuel as a function of the price on biofuels ω_1. The demand for biofuels Y_1 must be equal to $\eta_1 Q_1$:

$$Y_1 = \frac{\eta_1(M_1 - T_C)}{N_1} - \frac{(\eta_1)^2}{N_1}\omega_1. \tag{17}$$

Inverting (17) yields: $\omega_1 = \frac{(M_1 - T_C)}{\eta_1} - \frac{N_1}{(\eta_1)^2} Y_1$. We know that the price on biofuels ω_1 must be equal to its marginal cost: $\omega_1 = 2\sqrt{T_B} + 2\theta_1 y_1$ and $\omega_1 = t_1 + 2\theta_2 y_2$. Moreover, we know that demand must be equal to supply i.e. $Y_1 = y_1 + y_2$. Hence, we can solve for y_1 and y_2 as functions of η_1:

$$y_1 = \frac{N_1 t_1 + 2M_1\theta_2\eta_1 - 2T_C\theta_2\eta_1 - 2N_1\sqrt{T_B} - 4\sqrt{T_B}\theta_2(\eta_1)^2}{2\theta_1 N_1 + 2\theta_2 N_1 + 4\theta_1\theta_2(\eta_1)^2}, \tag{18}$$

$$y_2 = \frac{2\theta_1\eta_1 M_1 - 2T_C\theta_1\eta_1 + 2N_1\sqrt{T_B} - N_1 t_1 - 2\theta_1(\eta_1)^2 t_1}{2\theta_1 N_1 + 2\theta_2 N_1 + 4\theta_1\theta_2(\eta_1)^2} \tag{19}$$

Note that the profits are still given: $\theta_1(y_1)^2$ and $\theta_2(y_2)^2$. Thus, given the portfolio standard η_1, the instruments T_B and t_1 now have strategic effects. For instance, by increasing t_1 the government of Region 1, not only increases its tariff income, but also the producer surplus of the representative firm in Region 1.

Proposition 4 *Given a portfolio standard in Region 1, both the tariff and the domestic tax on production related emissions have strategic effects, that is,* $\frac{\partial \pi_2}{\partial T_B} > 0$ *and* $\frac{\partial \pi_1}{\partial t_1} > 0$*.*

Clearly, this could increase the temptation to misuse the tariff.

4.2 Portfolio standard versus taxes and subsidies

We then pose the question whether the market solution with a proportional target can be reached by a combination of an additional tax on conventional fuels T_1 and a general subsidy S_1 to all biofuels. Since a proportional target implies no money transfers, the income from the tax and the outlay for the subsidy should balance:

$$T_1(1-\eta_1)Q_1 = S_1\eta_1 Q_1. \tag{20}$$

With a tax T_1 on conventional fuels, and a subsidy S_1 on biofuels, we have for the supply of Producer 1 and Producer 2: $y_1 = \frac{T_C+T_1+S_1-2\sqrt{T_B}}{2\theta_1}$ and $y_2 = \frac{T_C+T_1+S_1-t_1}{2\theta_2}$. Utilizing (20), we obtain $T_1 + S_1 = T_1/\eta_1$.

It is possible to reach the proportional target by a general subsidy and a tax on conventional fuels for any given values of T_C, T_B and t_1. From (18) and (19)we get two equations in only one unknown T_1, however, both are satisfied at the same time. Thus, for T_1 and S_1 we have:

$$T_1 = \frac{\eta_1\theta_1 N_1 t_1 + 2\theta_1\theta_2(\eta_1)^2(M_1 - T_C) + 2\eta_1\theta_2 N_1\sqrt{T_B}}{\theta_1 N_1 + \theta_2 N_1 + 2\theta_1\theta_2(\eta_1)^2} - \frac{\eta_1 T_C N_1(\theta_1+\theta_2) + 2T_C\theta_1\theta_2(\eta_1)^3}{\theta_1 N_1 + \theta_2 N_1 + 2\theta_1\theta_2(\eta_1)^2},$$

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

We note that as long as $T_1$is positive, S_1 is positive as well. Hence, we have:

Proposition 5 *Any proportional target can be reached by an additional tax on conventional fuels and a general subsidy to all biofuels. On the other hand, since the subsidy should be zero, it is never optimal to use a portfolio standard as long as* $B_1(\eta_1) = 0$, $\forall\eta_1$*.*

The European Union has already set a proportional target for its biofuel usage. Moreover, the target is set to increase in the future. Hence, it makes to analyze optimal policy given a portfolio standard.

4.3 Optimal tariff given a portfolio standard

As shown in the previous subsection, any portfolio standard is equivalent with a tax on conventional fuels and a general subsidy to biofuels. With $T_C, T_B = \delta$ and $s_1 = 0$, and by inserting $y_1 = \frac{\delta + T_1 + S_1 - 2\sqrt{\delta}}{2\theta_1}$ and $y_2 = \frac{\delta + T_1 + S_1 - t_1}{2\theta_2}$, welfare is given:

$$W = \frac{(M_1 - \delta - T_1)^2}{2N_1} + \frac{(\delta + T_1 + S_1 - 2\sqrt{\delta})^2}{4\theta_1} + \frac{(\delta + T_1 + S_1 - t_1)^2}{4\theta_2} \tag{21}$$

$$+t_1 \left(\frac{\delta + T_1 + S_1 - t_1}{2\theta_2} \right) - \delta\lambda_2 \left(\frac{\delta + T_1 + S_1 - t_1}{2\theta_2} \right)^2,$$

where T_1 and S_1 are functions of t_1, and where: $\frac{\partial T_1}{\partial t_1} = \frac{\eta_1 \theta_1 N_1}{\theta_1 N_1 + \theta_2 N_1 + 2\theta_1 \theta_2 (\eta_1)^2} \in \langle 0, 1 \rangle$, $\frac{\partial S_1}{\partial t_1} = \frac{(1-\eta_1)\theta_1 N_1}{\theta_1 N_1 + \theta_2 N_1 + 2\theta_1 \theta_2 (\eta_1)^2} \in \langle 0, 1 \rangle$. The first order condition for a second best tariff is given by:

$$\frac{\partial W}{\partial t_1} = -Q_1 \frac{\partial T_1}{\partial t_1} + (y_1 + y_2) \left(\frac{\partial T_1}{\partial t_1} + \frac{\partial S_1}{\partial t_1} \right) \tag{22}$$

$$+\frac{t_1 - 2\delta\lambda_2}{2\theta_2} \left(\frac{\partial T_1}{\partial t_1} + \frac{\partial S_1}{\partial t_1} - 1 \right) = 0.$$

The sum of the first two terms is likely negative since Q_1 is much greater than $y_1 + y_2$. Moreover, it can be shown that $\left(\frac{\partial T_1}{\partial t_1} + \frac{\partial S_1}{\partial t_1} - 1 \right)$ is negative. Thus we have that the sum $t_1 - 2\delta\lambda_2$ must be negative. In the second-best we had $t_1 = 2\delta\lambda_2 y_2$. Thus, as long as $y_2 > 1$. The tariff should likely be set lower with a portfolio standard. Thus, we have:

Proposition 6 *The existence of a portfolio standard does not rule out a tariff, however, the tariff should likely be lower and could also be negative.*

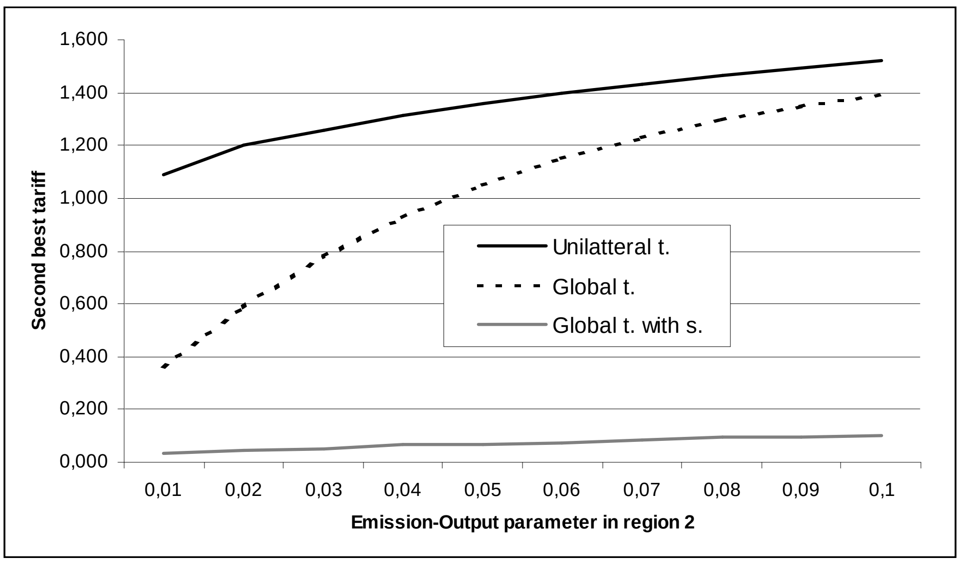
Clearly, the tariff should be negative if $\lambda_2 = 0$. The proposition is illustrated in the next section.

5 Numerical simulations

We have run some simple numerical illustrations of the model in order to give some flavor to our results. The following parameter values are chosen: $M_1 = 100$, $N_1 = 0.025$, $\delta = 0.1$, $\psi_1 = 0.8$, $\theta_1 = 0.01$, $\theta_2 = 0.005$ and $\lambda_1 = 0.01$. We also have a marginal cost of conventional fuels equal to 2.

Firstly, we have looked at the second-best tariff in three scenarios: i) Global second best, ii) Region 1 second best and iii) Global second best with an import standard. The results are given in Figure 1:

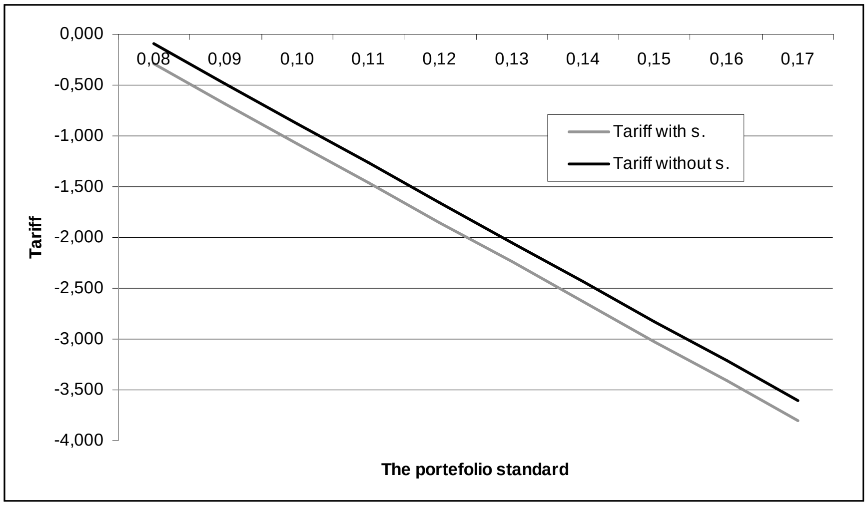
Figure 1 "Second best tariffs"



Along the $x - axis$ the parameter λ_2 increases from 0.01 to 0.1. Note the incentive for applying a "beggar-thy-neighbour" policy especially when GHG emissions from imports are low. Note also that a standard reduces the tariff significantly in our example.

The introduction of a portfolio standard changes everything. In Figure 2 we look at the second best tariff given such a standard.

Figure 2 "Tariffs and portfolio standards"



Along the $x - axis$ the portfolio standard increases from 0.08 to 0.17. Note that the second-best tariff is negative both with an import standard and without an import standard. Hence, in our example, the government should provide an import subsidy. Note further, that the import subsidy is higher with a standard. The reason is that in case of an import standard, there is less GHG emissions from imports, and import should be further encouraged.

6 Discussion and Conclusion

Clearly, the current EU policy on biofuels is hard to grasp within our model. On the other hand, our model has a number of shortcomings. Firstly, we would like to extend the model with biofuels consumption in Region 2. One first shot of this is given in the Appendix, and we aim to build this into the numerical model. Secondly, we would like to test our findings in a calibrated model of the European market for private car transport. In particular, we would like to investigate our finding about the possibility for a negative tariff.

We have not treated induced technological change. One argument frequently cited for subsidies is the potential for cost reductions through experience in new, clean energy technologies, see for instance IEA (2000). However, IEA (2000) seems to conclude that the potential for cost reductions with regards to first generation biofuels are bleak. In our upcoming research we will more explicitly look at the distinction between first and second generation biofuels, and we will then return to this issue.

As long as first generation biofuels receive subsidies alongside second generation biofuels, current EU policy seems hard to defend. Moreover, according to many sources see e.g. Kojima et al. (2007), Brazilian ethanol production implies very low GHG emissions, but is still subject to a tariff. Finally, the EU is considering a certification scheme for imported biofuels. Our finding is then that such a scheme should be based on the possibilities for GHG reductions from biofuel production in the source country and on the global shadow price on GHG emissions.

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7 Foreign portfolio standard

So far region 2 has been a pure export region. We now want to consider the implications of a proportional target in Region 2. The question is to what extent this changes the conclusions we have reached so far. With respect to Region 1 we assume that they have set $T_c = T_B = \delta$ and consider a tariff t_1 on imports.

With respect to Region 2 we assume $\psi_2 = 0$ ($\psi_1 = 1$), and hence Region 2 does not perceive GHG emissions as an environmental problem. However, the region considers diversifying energy supply as a benefit. The marginal cost of the supplier in Region 2 is $2\theta_2(y_2 + y_2^*)$ where y_2^* is the supply to Region 2. This marginal cost should be equalized with the price on biofuels in the two regions given the target η_2:

$$2\theta_2(y_2 + y_2^*) = \frac{M_2}{\eta_2} - \frac{N_2}{(\eta_2)^2} y_2^*$$
$$2\theta_2(y_2 + y_2^*) = \delta - t_1$$

where $\delta - t_1$ is the producer price in Region 1. Note that there is no import to Region 2. We then have:

$$y_2 = \frac{N_2\delta + 2\theta_2(\eta_2)^2\delta + 2\theta_2\eta_2 M_2 - 2\theta_2(\eta_2)^2 t_1 - N_2 t_1}{2\theta_2 N_2}.$$

$$y_2^* = \frac{\eta_2 M_2 + (\eta_2)^2(t_1 - \delta)}{N_2}$$

Total quantity is y_2^*/η_2, and consumer surplus is $\frac{N_2}{2}(\frac{y_2^*}{\eta_2})^2$. The government thus maximizes:

$$\max_{\eta_2} \left\{ \frac{N_2}{2}(\frac{y_2^*}{\eta_2})^2 + \theta_2(y_2^*)^2 + \theta_2(y_2)^2 + b_2\eta_2 \right\},$$

where $b_2\eta_2$ is the benefit of the target. The first-order condition is given by:

$$\frac{\partial w_2}{\partial \eta_2} = \frac{(t_1 - \delta)}{\eta_2} y_2^* + 2\theta_2(y_2^*)(\frac{M_2 + 2\eta_2(t_1 - \delta)}{N_2}) + 2\theta_2(y_2)(\frac{M_2 - 2\eta_2(t_1 - \delta)}{N_2}) + b_2 = 0$$

From the first-order condition we obtain:

$$\frac{\partial^2 w_2}{\partial t_1 \partial \eta_2} = \frac{2y_2^*}{\eta_2} + \frac{10\theta_2(\eta_2)^3(t_1 - \delta)}{(N_2)^2} > 0,$$

and hence, we have:

$$\frac{d\eta_2}{dt_1} > 0, \frac{dy_2}{dt_1} < 0, \frac{dy_2^*}{dt_1} > 0.$$

Thus, the effects of trade policy is not as strong on emissions.