Lobbying and policy inertia: Biofuels policy under uncertainty

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Abstract

The present paper studies the effect of uncertainty about the environmental properties of a good (biofuels) on trade policy, in the presence of lobby groups. We construct a political economy model to explain why the biofuels trade policy does not necessarily respond to new information about the emissions arising from the (domestic) production of biofuels. Thus, while it would be optimal from a general welfare point of view to lower the trade tariff on biofuels when it becomes clear that the production of these leads to increased emissions of greenhouse gases, if the government is susceptible to lobbying and the biofuels sector's lobbying effort is intensive enough, it may be that the tariff rate is raised instead in the face of new information. We further show that if new information is available later, when biofuels production has had time to adjust to other support policies in place, the trade policy revision due to new information about the emissions from biofuels production will lead to a higher level of trade protection being afforded to the biofuels sector than had been the case had the same information been available earlier.

1 Introduction

Some recent studies indicate that greenhouse gas (GHG) emissions from the production of biofuels, especially those produced from food crops, can be considerable. For instance, Searchinger et al. (2008) and Fargione et al. (2008) argue that the land use changes that biofuels production leads to cause considerable, and so far unaccounted for emissions of GHGs. Crutzen et al. (2008) show how emissions of other greenhouse gases than carbon dioxide can increase with increased production of biofuels. Finally, Melillo et al. (2009) calculate that emissions of greenhouse gases from the production and consumption of biofuels can exceed the emissions that would take place if fossil fuels were consumed instead, for at least 20-30 years. Wibe (2010) calculates that in Sweden, this can be the case for up to 50-60 years. These factors should be taken into consideration in the policy making process, which, however, by necessity is quite slow. It is further possible that inertia in policy making can be exaggerated by lobbying.

The present paper uses a political economy framework based on Grossman and Helpman (1994, 1995) to study the effect of lobbying on biofuels trade policy when there is uncertainty about emissions of GHGs from the production of biofuels. We will set up an analytical model to examine whether lobbying can explain policy inertia. We assume that biofuels policy is determined at two different levels, where at the local level, the policy makers attempt to lower the emissions of GHGs from a road transport sector by imposing biofuels mandates, which stipulate that a certain share of fuel use for road transport will have to be of a "biological" origin. Once the biofuels mandate has been determined, a central or federal government (such as the European Union (EU)) determines the tariff applicable to bio- and fossil fuels. At this stage of the game, the biofuels and fossil fuels producing sectors, respectively, lobby the policy-maker for trade protection. We show how a sufficiently intensive lobbying effort by the biofuels sector combined with a government's susceptibility to lobbying may lead to a situation where the government actually raises the tariff rate on biofuels when these turn out to lead to increasing emissions, instead of lowering the tariff, which would be the optimal policy response from a general welfare point of view.

We will not make a difference between different types of biofuels, except to the extent that we assume that biofuels can either be produced abroad for known 'low' emissions, or domestically for unknown emissions. This assumption abstracts from the fact that different types of biofuels have very different emissions profiles. It also ignores the fact that biofuels production in every country faces the same problems of indirect land use change. The reason for making the assumption is the biofuels mandate; if there are no biofuels available that lower the emissions of GHGs at the world market, it would be optimal to have a prohibition against biofuels instead of a mandate. For simplicity, we want to avoid this situation; besides, we deem it irrelevant considering the present policies supporting the production and consumption of biofuels. We also do not consider the differences between the gasoline and diesel markets, nor do we differentiate between the different substitutes to these two fuels. The biofuels mandate in the present paper is common both to the gasoline and diesel markets, and is designed in a cost-effective manner, unlike quite a few real-life examples of such mandates.

The combination of policy instruments assumed in the paper is rather realistic, as many countries combine a biofuels mandate with a trade tariff on imported biofuels (these countries include the United States and many EU Member States). Furthermore, at least in the EU, the tariffs are determined at the EU level, while it is up to the Member States to determine how to support the production and consumption of biofuels (in order to reach the EU's 20-20-20 targets, see Directive 2009/28/EC). In many countries, biofuels mandates and tariffs are complemented by tax excemptions or rebates to biofuels. In the present paper we ignore this last policy instrument in order to keep the model tractable. While a tax credit certainly affects the welfare effects of biofuels policies, adding it to the present model would not provide additional insights.

The present model develops futher the large literature based on Grossman and Helpman (1994, 1995). While these models have been used to study a great range of questions, starting from the determination of environmental policy (see, e.g., Fredriksson (1997), Aidt (1998), Schleich (1999) for small country models and Schleich and Orden (2000), Conconi (2003), McAusland (2005) for large country models) to pollution tax rebates given to declining industries (e.g., Damania (2002)), to our knowledge it has not been applied to the question of how emissions uncertainty affects policy change. A second extension concerns the interdependencies between two (up- and downstream) industries. Thus, in our model the biofuels sector not only competes with the fossil fuels sector on the consumer market, but also uses fossil fuels as an input factor. The only other model of 'lobbying competition' with upstreams and downstreams industries within the tradition of the Grossman-Helpman model that we are aware of is Gawande et al. (2009), who find empirical support for their model. Gawande et al. do not consider environmental externalities in their model, however, and besides, concentrate only on competition between up- and downstream industries without consideration of competition on a consumer market.

We will start by setting up the model. We describe consumer demand and prices, the production of the two non-numeraire goods, policy instruments, lobby groups, and finally, emissions. After having set up the basic model we solve for the tariff rate in the absence of a biofuels mandate. We then continue by solving the political game backwards, with both a biofuels mandate and tariffs. We shortly describe how the production and imports of biofuels and fossil fuels change due to the policies. We then solve for the politically optimal tariff rates, and examine how policy may be time dependent. Finally, we solve for the optimal biofuels mandate assuming that the lobby groups do not affect the mandate's level directly but only through the governments' consideration of their impact on trade policy. The final section concludes.

2 The model

2.1 Consumer demand, prices and production

Consider a large open economy, which means that we assume that domestic policies affect the world market prices, and consequently, the supply of goods. The economy is populated by N individuals residing in m different local jurisdictions, so that $\Sigma_m N_m = N$, with identical, additively separable preferences. Each individual maximizes a utility function of the form $U_{ht} = c_{Ot} + u_R(c_{Rt}) - \pi_t \phi(\underline{\epsilon_t}) - (1-\pi_t)\phi(\overline{\epsilon_t})$.[1] c_{Ot} denotes the consumption of the numeraire good and c_{Rt} consumption of good R, road transport. We consider three time periods so that $t \in \{0,\ 1,\ 2\}$, where the timing of the beginning of period $t+1$ is unknown at t.[2] The sub-utility function $u_R(c_{Rt})$ is differentiable, increasing and strictly concave. $\phi(\epsilon_t)$ measures the external effect arising from the emissions of greenhouse gases, where $\underline{\epsilon_t}$ denotes low expected (domestic) emissions, and $\overline{\epsilon_t}$ denotes high expected (domestic) emissions. ϕ is assumed to be differentiable, increasing and strictly convex. The parameter π_t measures the probability of information indicating either low (with probability π_t) or high (with probability $(1-\pi_t)$) emissions. For simplicity we assume that $\pi_t = \{0,\ 1\}$ and does not take any intermittent values. We assume the individuals to be risk neutral with respect to the level of emissions. The emissions function will be discussed more closely in Section 2.3.

Good O serves as a numeraire with a domestic and world market price equal to one. The domestic price of good R equals p_{Rt}. With these preferences, each consumer demands $d_R(p_{Rt})$ units of good R, where $d_R(p_{Rt})$ is the inverse of the marginal utility function $u'_R(c_{Rt})$. The remainder of a consumer's income, Inc, is devoted to the numeraire good. The consumer then attains indirect utility given by $v(p_{Rt},\ Inc,\ \epsilon_t) = Inc + S(p_{Rt}) - \pi_t\phi(\underline{\epsilon_t}) - (1-\pi_t)\phi(\overline{\epsilon_t})$, where $S(p_{Rt}) = u_R[d_R(p_{Rt})] - p_{Rt}d_R(p_{Rt})$ is consumer surplus arising from the consumption of good R. Consumption of the numeraire good does not create any consumer surplus.

Road transport can be produced either using fossil fuels (F) or biofuels (B). Consequently, demand for it can be written as $d_R(p_{Rt}) = d_F(p_{Ft}) + d_B(p_{Bt})$.[3] Denoting the share of biofuels of the total fuel consumption as

[1] The two last terms of the utility function take the form of a von Neumann-Morgenstern utility function under uncertainty about emissions.

[2] By this we mean that at each period $t = \{0,\ 1\}$, the actors do not know when period $t+1$ begins, and what the policies implemented at that later period will be.

[3] We express demand in terms of energy content, which makes it possible to leave the weights for the different energy contents of different types of fuels away from the model.

$\rho = \frac{d_B(p_{Bt})}{d_R(p_{Rt})}$, it is easy to see that the demand for biofuels equals $d_B(p_{Bt}) = \rho d_R(p_{Rt})$, and demand for fossil fuels equals $d_F(p_{Ft}) = (1-\rho)\, d_R(p_{Rt})$. The value of road transport is given by $p_{Rt} d_R(p_{Rt}) = p_{Bt} d_B(p_{Bt}) + p_F d_F(p_{Ft})$, substituting for $d_B(p_{Bt})$ and $d_F(p_{Ft})$ and simplifying yields the price of road transport as

$$p_{Rt} = \rho p_{Bt} + (1-\rho)\, p_{Ft}. \tag{1}$$

This is a weighted average of the price of fossil fuels and biofuels. In the absence of a biofuels mandate, $p_{Bt} = p_{Ft}$.

The numeraire good O is produced using labour only, with constant returns to scale and an input-output coefficient equal to one. We assume the aggregate labour supply, l, to be large enough to ensure a positive output of this good. It is then possible to normalize the wage rate to one. Biofuels are produced using labour, land and fossil fuels. Fossil fuels are produced using labour and a sector-specific fixed input factor. Production is assumed to exhibit constant returns to scale, the production functions are increasing and convex in the factor inputs, and all the goods are produced under perfect competition. Disregarding of the labour and capital inputs, the profit accruing to sector $j \in \{B,\ F\}$ is given by

$$\begin{aligned}\Pi_j(p_{jt},\ z,\ p_F) = p_{jt} y_j \left[D_B(p_{Bt},\ z,\ p_{Ft}),\ X_B(p_{Bt},\ z,\ p_{Ft})\right] \\ - z D_B(p_{Bt},\ z,\ p_{Ft}) - p_{Ft} X_B(p_{Bt},\ z,\ p_{Ft}) - C_j(\boldsymbol{\theta}_{\mathbf{t}}), \end{aligned} \tag{2}$$

where $y_j(D_{Bt},\ X_{Bt})$ is the production function. D_{Bt} is demand for land and X_{Bt} demand for fossil fuels in the production of biofuels; z and p_{Ft} are the respective prices. $C_j(\boldsymbol{\theta}_{\mathbf{t}})$ is industry j's political contribution.

We assume that factor demand by the biofuels sector does not affect the prices of land, z, and fossil fuels, p_{Ft},[4] but that demand for land and fossil fuels changes in input prices, so that $\frac{\partial D_B}{\partial p_B} > 0$, $\frac{\partial D_B}{\partial z} < 0$, $\frac{\partial X_B}{\partial p_B} > 0$ and $\frac{\partial X_B}{\partial p_F} < 0$.[5] Furthermore, land and fossil fuels can reasonably be either

[4] Thus, even though the country we study is large enough for its policies to affect the world market prices, we assume its biofuels sector to be too small to affect the prices of its imput factors.

[5] That z is taken to be a constant means that even though changes in land use due to

complements or substitutes in the production of biofuels. Then, if land and fossil fuels are substitutes (complements), $\frac{\partial D_B}{\partial p_F} > 0$ ($\frac{\partial D_B}{\partial p_F} < 0$) and $\frac{\partial X_B}{\partial z} > 0$ ($\frac{\partial X_B}{\partial z} < 0$).

2.2 Policy instruments and lobby groups

The governments have two policy instruments at their disposal. First, in order to internalise the external effect arising from the emissions of carbon dioxide from the consumption of fossil fuels in road transport, the local governments in m jurisdictions impose biofuels mandates $\widehat{\rho_m}$, which fix the share of biofuels of the total fuel for road transport as $\widehat{\rho} = \Sigma_m \widehat{\rho_m} = \frac{\widehat{d_B(\widehat{p_{Bt}})}}{d_R(\widehat{p_{Rt}})}$, and yield the price of road transport as

$$\widehat{p_{Rt}} = \widehat{\rho}\widehat{p_{Bt}} + (1 - \widehat{\rho})\,\widehat{p_{Ft}}. \tag{3}$$

The 'hat' here refers to variables affected by the mandate. The biofuels mandate, by forcing consumers to buy a certain amount of (more expensive than fossil fuels) biofuels, allows the biofuels (world market) price to rise above the price of fossil fuels, so that $\widehat{p_{Bt}^w} > p_{Bt}^w = p_{Ft}^w$. Since demand for fossil fuels falls, their price falls so that $\widehat{p_{Ft}^w} \leq p_{Ft}^w$. The total effect of the mandate on the price of road transport, $\widehat{p_{Rt}}$, is thus ambiguous. We assume that the interest groups do not affect the level of the biofuels mandate directly.[6]

The second policy instrument, which is at the central government's disposal is an import tariff on the imports of biofuels and fossil fuels, both of which are assumed to be importables for simplicity.[7] The tariffs are denoted by θ_{jt} for sector $j \in \{B,\ F\}$. The tariffs determine the domestic prices of

increased production of biofuels can be considerable in an emissions perspective, they are not large enough to impact on the equilibrium price of land. This could be the case, for instance, if there was a sufficient supply of 'surplus' or unused land. We study the case where the biofuels sector affects the cost of land in, e.g., Hammes (2009).

[6] In practice, of course, lobbies try to affect the formulation and level of a biofuels mandate as well. As we assume that the mandate is set at a different level of government than the trade tariffs, we argue that different lobby groups influence the mandate-setting game and ignore these.

[7] The analysis would not change even if the goods were exportables, as long as the chosen policy instrument to promote exports was an export subsidy.

goods, which are given as $p_{jt} = (1 + \theta_{jt}) p_{jt}^w$, where p_{jt}^w is the world market price of good j. In order to simplify the analysis we assume the tariff rate always to be non-negative.[8] The interest groups give the government political contributions in order to affect the level of chosen trade tariffs.

The government collects revenue from the tariffs, and distributes these in a lump-sum fashion to the consumers. The tariffs generate the following per capita government revenue:

$$R(\mathbf{p_t}) = \sum_j \theta_{jt} p_j^w \left\{ d_j(p_{jt}) - \frac{1}{N} y_j \left[D_B(p_{Bt},\ z,\ p_{Ft}),\ X_B(p_{Bt},\ z,\ p_{Ft}) \right] \right\}.$$

The biofuels mandate, being a regulation, does not generate any government revenue.

We assume that those owning the sector-specific capital used in the production of fossil fuels, and those producing biofuels, respectively, have similar interests in the trade taxation of their sector and form lobby groups to influence the government's trade policy. The formation of lobby groups is not modeled here; the reader is referred to Olson (1965), or for models of endogenous lobby organization to Mitra (1999), Magee (2002), Le Breton and Salanie (2003) or Bombardini (2008). We assume that at most two lobby groups ($j \in \{B,\ F\}$) overcome the free riding problem inherent to interest group organization and form lobby groups that are small enough not to take into account any other sources of income than the effect of trade policy on their profits in their lobbying decision.[9] The organized groups coordinate their political activities so as to maximize respective lobby group's members welfare. The lobby representing industry j thus submits a contribution schedule $C_j(\boldsymbol{\theta_t})$ that maximizes

$$v_{jt} = W_j(\boldsymbol{\theta_t}) - C_j(\boldsymbol{\theta_t}), \tag{4}$$

where

$$W_j(\boldsymbol{\theta_t}) \equiv \Pi_j(p_{jt},\ z,\ p_{Ft}) \tag{5}$$

[8] With some reinterpretation even import subsidies and export taxes can be accommodated within the framework of the model.

[9] Aidt (1998) calls such lobby groups "functionally specialized".

gives the gross of contribution profits (welfare) of the members of lobby group j, and the lobby group expects to give a campaign contribution only once.

2.3 Emissions

Domestic emissions of greenhouse gases are given by

$$\epsilon_t^d\left(p_{Rt},\ \mathbf{p_t}\right)=\varepsilon\left[Nd_F\left(p_{Ft}\right)+EX_B\left(p_{Bt},\ z,\ p_{Ft}\right)\right]+E\mu^d D_B\left(p_{Bt},\ z,\ p_{Ft}\right). \tag{6}$$

Emissions are thus a function of the consumption of fossil fuels for road transport, and of the use of fossil fuels and land in the production of biofuels. Parameter ε measures emissions per unit use of fossil fuels, and parameter μ^d measures (domestic) emissions from land use for biofuels production. E is an expectations operator.

As was noted in the introduction, uncertainty about the emissions from the production of biofuels can arise from two sources: either from land use change (see, e.g., Fargione et al. (2008), Searchinger et al. (2008) or Crutzen et al. (2008)) or from the fact that the production of biofuels in some areas is rather energy intensive (e.g., due to the required fertilizer input or the energy required for processing certain crops, see, e.g., Soimakallio et al. (2009)). We will consider both sources of uncertainty, in the form of an expectation partly about the fossil fuel use in the production of biofuels, EX_{Bt}, and partly about the emissions from land use, $E\mu^d$. We denote the case with low expected emissions by $\underline{\epsilon_t}(p_{Rt},\ \mathbf{p_t})=\varepsilon\left[Nd_F\left(p_F\right)+\underline{X_{Bt}}\right]+\underline{\mu}^d D_{Bt}+\epsilon_t^w$ and the case with high emissions by $\overline{\epsilon}\left(p_{Rt},\ \mathbf{p_t}\right)=\varepsilon\left[Nd_F\left(p_F\right)+\overline{X_{Bt}}\right]+\overline{\mu}^d D_{Bt}+\epsilon_t^w$, where ϵ_t^w is world emissions, and total emissions (which determine the damages from emission) are $\epsilon_t=\epsilon_t^d+\epsilon_t^w$.[10] For simplicity, we assume that at time periods $t\in\{0,\ 1\}$ the government expects 'low' emissions, i.e., $\pi_0=\pi_1=1$. At period $t=2$ information may come out indicating 'high' emissions. If this happens, the parameter π_2 switches values to $\pi_2=0$. International emissions, ϵ_t^w, are assumed to be known to be 'low'.

[10] It is of course possible that emissions from fossil fuel use for production X_B are low ($\underline{X_B}$) while the emissions from land use are high ($\overline{\mu}$) or vice versa. Both these cases are considered as cases with high emissions, $\overline{\epsilon}$.

Changes in policy affect emissions. Starting with the (total) biofuels mandate, increasing the share of biofuels in road transport has an ambiguous effect on emissions:

$$\frac{d\widehat{\epsilon_t^d}}{d\widehat{\rho}} = \varepsilon N\left[(1-\widehat{\rho})\frac{\partial\widehat{d_{Rt}}}{\partial\widehat{p_R}}\left(\widehat{p_{Bt}}-\widehat{p_{Ft}}+\widehat{\rho}\frac{\partial\widehat{p_B}}{\partial\widehat{\rho}}+(1-\widehat{\rho})\frac{\partial\widehat{p_F}}{\partial\widehat{\rho}}\right)-\widehat{d_{Rt}}\right]$$
$$+\left[\varepsilon E\frac{\partial\widehat{X_B}}{\partial\widehat{p_B}}+E\mu^d\frac{\partial\widehat{D_B}}{\partial\widehat{p_B}}\right]\frac{\partial\widehat{p_B}}{\partial\widehat{\rho}}+\left[\varepsilon E\frac{\partial\widehat{X_B}}{\partial\widehat{p_F}}+E\mu^d\frac{\partial\widehat{D_B}}{\partial\widehat{p_F}}\right]\frac{\partial\widehat{p_F}}{\partial\widehat{\rho}}. \quad (7)$$

The first term in the square brackets on the first line arises from the effect that the mandate has on the price of road transport. The term is negative if the price of road transport, $\widehat{p_{Rt}}$, does not fall when the mandate is introduced: $\frac{\partial\widehat{p_{Rt}}}{\partial\widehat{\rho}} = \widehat{p_{Bt}}-\widehat{p_{Ft}}+\widehat{\rho}\frac{\partial\widehat{p_B}}{\partial\widehat{\rho}}+(1-\widehat{\rho})\frac{\partial\widehat{p_F}}{\partial\widehat{\rho}} \geq 0$. If, however, the price of fossil fuels falls sufficiently, $\widehat{p_{Rt}}$ may fall in the mandate and the term is positive, thus creating a kind of 'Green Paradox' (e.g., Ploeg and Withagen (2010)). The second term in the square brackets on the first line reflects the replacement of fossil fuels with biofuels due to an increase in the mandate, and is unambiguously negative. Thus, it may be that the total effect from the introduction of a biofuels mandate is negative even if the price of road transport falls in the mandate.

The two terms on the second line of (7) arise from the effect that the mandates have on the domestic price of biofuels and fossil fuels, respectively. The mandates allow for the price of biofuels to rise above that of fossil fuels. An increase in the price of biofuels raises demand for fossil fuels and land as input factors as the production of biofuels increases. The term in the first square brackets is thus positive, therefore raising emissions. A fall in the price of fossil fuels, due to the mandates, also raises the demand for fossil fuels. However, the effect of the fossil fuel price on land demand is ambiguous, depending on whether land and fossil fuels are complements ($\frac{\partial\widehat{D_B}}{\partial\widehat{p_F}} > 0$) or substitutes ($\frac{\partial\widehat{D_B}}{\partial\widehat{p_F}} < 0$). In the former case the last term is of ambiguous sign, in the latter case it is positive. The net effect depends on whether the positive or the negative terms dominate (7). This determines whether the imposition of the biofuels mandates lead to a fall or a rise in domestic net emissions. In order for the mandates to be meaningful, however, we assume that the total net effect is to lower emissions, so that $\frac{\partial\left(\widehat{\epsilon_t^d}+\widehat{\epsilon_t^w}\right)}{\partial\widehat{\rho}} < 0$.

An increase in the price of biofuels also has an ambiguous effect on emissions. This is given by

$$\frac{d\epsilon_t^d}{dp_{Bt}} = \varepsilon N\left(1-\widehat{\rho}\right)\widehat{\rho}\frac{\partial d_{Rt}}{\partial p_{Bt}} + \varepsilon E\frac{\partial X_{Bt}}{\partial p_{Bt}} + E\mu^d\frac{\partial D_{Bt}}{\partial p_{Bt}}, \tag{8}$$

where we have assumed that the price of biofuels does not directly affect the price of fossil fuels, i.e., that $\frac{\partial p_F}{\partial p_B} = 0$. The first term on the RHS arises from the effect that an increase in the price of biofuels has on demand for road transport, which falls as the price of road transport increases. The second and the last terms reflect the increased demand for production factors in the production of biofuels as the higher price of biofuels induces more (domestic) production, and are positive. The net effect is determined by whether the first, or the second and third terms dominate (8). If domestic production of biofuels leads to a net fall in emissions, $d\underline{\epsilon}^d/dp_B < 0$. If domestic production of biofuels leads to a net increase in emissions, then $d\overline{\epsilon^d}/dp_B > 0$. This yields price elasticities of emissions as $e_{\underline{\epsilon}^d,\ p_B} = -\left(d\underline{\epsilon}^d/dp_B\right)\left(p_{Bt}/\underline{\epsilon_t^d}\right)$ and $e_{\overline{\epsilon^d},\ p_B} = \left(d\overline{\epsilon^d}/dp_B\right)\left(p_{Bt}/\overline{\epsilon_t^d}\right)$, which are both defined to be positive.

Finally, an increase in the price of fossil fuels, while having an ambiguous effect on emissions, is assumed to lead to a fall in emissions:

$$\begin{aligned}\frac{d\epsilon_t^d}{dp_F} = \varepsilon&\left[N\left(1-\rho\right)^2\frac{\partial d_{Rt}}{dp_F} + E\frac{\partial X_B}{\partial p_F} + E\frac{\partial X_B}{\partial p_B}\frac{\partial p_B}{\partial p_F}\right] \\ &+ E\mu^d\left[\frac{\partial D_B}{\partial p_F} + \frac{\partial D_B}{\partial p_B}\frac{\partial p_B}{\partial p_F}\right] < 0,\end{aligned} \tag{9}$$

where $\frac{\partial p_B}{\partial p_F} \geq 0$, with strict equality applying in the presence of the biofuels mandate. The first and second terms in the first square brackets are negative, since demand both for road transport and for fossil fuels as an input factor to biofuels fall as the price of fossil fuels increases. The third term, however, is positive, reflecting the increasing demand for fossil fuels in the production of biofuels as their price increases. The sign of the first term in the latter square brackets depends on whether land and fossil fuels are substitutes or complements. It is positive if they are substitutes and negative if they are complements. The second term is positive, again because the effect that an increased biofuels price has on land demand.

As was noted above, we assume the emissions from the world production of biofuels to be known for certain. We further assume that it is known that the world production of biofuels leads to a net fall in greenhouse gas emissions.

3 Policy in the absence of a biofuels mandate

At time $t = 0$ there is no biofuels mandate in place. We will neverthelss examine the tariff setting game at this period, in order to show how the economics differ between the case with and without a biofuels mandate. We assume that the tariff rates on biofuels and fossil fuels that prevail before the imposition of a biofuels mandate are set in a similar manner to the tariff-setting game, which is played after the imposition of a biofuels mandate.

Thus, in a similar manner to Grossman and Helpman (1994), the government chooses the vector of tariffs to maximize

$$\max G\left(\boldsymbol{\theta}_{\mathbf{t}}\right) = \sum_j C_j\left(\boldsymbol{\theta}_{\mathbf{t}}\right) + aW\left(\boldsymbol{\theta}_{\mathbf{t}}\right), \tag{10}$$

where $C_j\left(\boldsymbol{\theta}_{\mathbf{t}}\right)$ is industry j's political contribution, and a is the weight that the government gives to general welfare relative to political contributions. If $a \to \infty$, the government only cares about general welfare, and if $a \to 0$, it only cares about the political contributions. Average (gross) welfare is given by

$$W\left(\boldsymbol{\theta}_{\mathbf{t}}\right) = \sum_j \Pi_j\left(p_{jt},\ z,\ p_F\right) + S\left(p_{Rt}\right) + R\left(\mathbf{p}_{\mathbf{t}}\right) - \pi_t \phi\left(\underline{\epsilon_t}\right) - \left(1 - \pi_t\right)\phi\left(\overline{\epsilon_t}\right). \tag{11}$$

The derivation of the equilibrium in differentiable strategies is done in similar fashion to Grossman and Helpman (1994), Dixit (1996) and Fredriksson (1997), alternatively it can be modeled as a Nash-bargaining game in the fashion of Goldberg and Maggi (1999). The derivation is left out from the present paper. We note, however, that (both locally and) globally truthful contribution functions satisfy

$$\nabla C_j(\boldsymbol{\theta}_\mathbf{t}) = \nabla W_j(\boldsymbol{\theta}_\mathbf{t}), \tag{12}$$

i.e., that every lobby group contributes up to the point where their marginal contribution exactly equals the marginal welfare change due to trade policy. The equilibrium domestic prices supported by differentiable contribution functions and general welfare are characterized by the following equation:

$$\sum_j \nabla W_j(\boldsymbol{\theta}_\mathbf{t}) + a\nabla W(\boldsymbol{\theta}_\mathbf{t}) = 0. \tag{13}$$

In the absence of a biofuels mandate, biofuels are consumed up to the point where they are at most as expensive as fossil fuels. This determines the (domestic) price of biofuels as $p_{B0} = p_{F0}$. The tariff rate on biofuels is then determined by the tariff rate on fossil fuels and is given by $\theta_{B0} = (1+\theta_{F0})\frac{p^w_{F0}}{p^w_{B0}} - 1$. Since the prices are equalized even in the world market, this simplifies to $\theta_{B0} = \theta_{F0}$.

Taking the first order conditions of the lobby groups' objective functions (4) with respect to the tariff rate on fossil fuels yields $\frac{\partial W_{F0}}{\partial p_{F0}} = y_{F0}$ for the fossil fuels sector and $\frac{\partial W_{B0}}{\partial p_{F0}} = y_{B0} - X_{B0}$ for the biofuels sector. Substituting in these and the first order condition of the general welfare function (11) with respect to the tariff rate on fossil fuels into (13) yields

$$\begin{aligned} &I_F y_{F0} + I_B(y_{B0} - X_{B0}) \\ &\quad + a\left[-X_{B0} - m_{R0}\frac{\partial p^w_F}{\partial p_F} + \theta_{F0}p^w_{F0}\left(\frac{\partial m_{B0}}{\partial p_F} + \frac{\partial m_{F0}}{\partial p_F}\right) - \phi'\left(\underline{\epsilon_0}\right)\frac{d\underline{\epsilon_0}}{dp_F}\right] = 0. \end{aligned}$$

I_j is an indicator variable taking value 1 if sector $j \in \{B,\ F\}$ gives a positive political contribution and zero otherwise. $m_{jt} = [Nd_{jt} - y_{jt}]$ denotes imports of good $j = \{B,\ F,\ R\}$. Imports fall with a higher import tariff: $\frac{\partial m_{jt}}{\partial p_F} < 0$. Finally, $\pi_0 = 1$, i.e., the government believes that increasing the consumption of biofuels unambiguously lowers emissions, which implies that $\frac{d\epsilon_0}{dp_F} < 0$ in

(9). Simplifying yields the equilibrium tariff rate on fossil (and bio-) fuels in the absence of a biofuels mandate:

$$\theta_{F0} = \frac{I_F y_{F0} + I_B y_{B0} - (a + I_B) X_{B0} + a \left[m_{R0} e_{p_F^w,\ p_F} + \frac{\phi'(\underline{\epsilon_0})\underline{\epsilon_0}}{p_{F0}^w} e_{\underline{\epsilon},\ p_F} \right]}{a \left(m_{B0} e_{m_B,\ p_F} + m_{F0} e_{m_F,\ p_F} \right) + (a + I_B) X_{B0} - I_B y_{B0} - I_F y_{F0}}. \tag{14}$$

Variables e in (14) denote elasticities of the first variable in lower case to the second variable, and are defined so that they are all positive. We assume the elasticities to be constants. The tariff equation yields a modified Ramsay rule, i.e., the higher the elasticities of import demand in the denominator, the lower the tariff rate. This result is in line with Grossman and Helpman (1994) and the literature following that article. The rationale behind the finding hinges on the deadweight loss that the tariff creates; the greater the elasticity of import demand, the greater the deadweight loss from a given tariff rate, and the lower the government will set the tariff rate. Lobbying modifies the rule, however. Firstly, since a higher (domestic) price of fossil fuels has a detrimental effect on the biofuels sector since they use fossil fuels as an input factor, the biofuels sector lobbies for a lower tariff rate on fossil fuels (the term $I_B X_{Bt}$). The effect also affects general welfare (aX_{Bt}). Secondly, both the fossil fuels and the biofuels sectors' lobbying lowers the denominator as a higher tariff increases their output price and therefore profits. Thus, the higher the (domestic) production (due to the adjusted tariff rate) of both fuels, the lower the denominator and the higher the tariff rate. For lobbying not to lead to (from the viewpoint of the interest groups) a perverse effect, it must be that the denominator of (14) is positive; otherwise lobbying promotes an import subsidy. This condition sets a lower bound to the value that the parameter a can take at

$$a > \frac{I_F y_{F0} + I_B (y_{B0} - X_{B0})}{m_{F0} e_{m_F,\ p_F} + m_{B0} e_{m_B,\ p_F} + X_{B0}}.$$

In the numerator of (14), lobbying by both the fuel producing sectors serves to raise the tariff rate. At the same time, the biofuels sector has an incentive to moderate the tariff rate on fossil fuels through term $-(I_B + a) X_{B0}$, which also takes general welfare into account. The first term in the square brackets reflects the change in the terms of trade due to the import tariff, and serves to raise the optimal tariff rate. Finally, considerations of emissions serve to raise the tariff rate. In the absence of a biofuels mandate, in the present model, the tariff on fuels is the only policy instrument available for internalizing the externality from emissions.

The tariff rate in (14) determines the domestic production of both biofuels and fossil fuels for the time remaining before the local governments implement biofuels mandates and the central government readjusts the tariff rate(s) to take the mandates into account. We denote these production levels as $y_{B0}(p_{F0})$ for biofuels and by $y_{F0}(p_{F0})$ for fossil fuels. The world market production of biofuels is given by $y_{B0}^{w}(p_{F0}^{w})$. The tariff drives a wedge between the domestic and the world market prices of bio- (and fossil) fuels, and leads to 'excessive' domestic production of biofuels.

4 Policy in the presence of a biofuels mandate

The previous Section described the tariff-setting game in the absence of a biofuels mandate. In this section we solve a game at time period $t = 1$ ($t = 2$), in four (three) stages. In the first stage in period $t = 1$, the local governments determine their biofuels mandates. In the next stage (in $t = \{1,\ 2\}$), the interest groups for biofuels and fossil fuels take the biofuels mandates for given and offer the central government their menus of contributions $C_i(\boldsymbol{\theta}_{\mathbf{t}})$, which are contingent on the chosen trade policy. The government, taking the political contributions and general welfare into account, determines the vector of domestic prices. At this stage in period $t = 1$ ($t = 2$), the government's information indicates that the emissions from the production of biofuels are 'low' ('high'), i.e., the government assumes that $\pi_1 = 1$ ($\pi_2 = 0$). Once the vector of domestic prices is known, the two fuel producing sectors adjust their factor demands and production.

The biofuels mandates in the game are set only once: we assume that there is no uncertainty about the emissions arising from the consumption of fossil fuels, or about the biofuels ability to substitute for fossil fuels in consumption. Furthermore, imports of biofuels are assumed to lower emissions.

We assume that at time $t = 1$ it is not known that there is uncertainty about the emissions from biofuels. Therefore, the lobby groups expect the tariff rate to be determined once and for all, and in their contribution decision do not take into account emissions uncertainty. The revision of trade policy affects above all the the domestic production of biofuels. We solve the game backwards, starting from the two sectors' production decision once the biofuels mandate and the vector of domestic prices are known.

4.1 Changes in factor demand and production

The introduction of the biofuels mandates, $\widehat{\rho_m}$, which sum up to $\widehat{\rho}$, fix the share of biofuels in the production of road transport. The total mandate is assumed to be set at a level which increases the demand for biofuels. The presence of the mandate allows for the biofuels price to rise above that of the fossil fuels, so that $\widehat{p_{Bt}^w} > p_{Ft}^w$. We formulate the effect of the mandate on the domestic production of biofuels in the following Lemma:

Lemma 1 *As long as the domestic price of biofuels does not fall after the introduction of the biofuels mandates and the adjustment of the trade policy, domestic production of biofuels will not fall after the policy revisions.*

Proof. The production of biofuels is determined by the price of biofuels, even in the presence of biofuels mandates. Binding biofuels mandates lower the world market price of fossil fuels: $\frac{\partial p_{Ft}^w}{\partial \widehat{\rho}} < 0$. Assuming that the tariff on fossil fuels, θ_F, is kept constant, even the domestic price of fossil fuels falls: $\frac{\partial p_F}{\partial \widehat{\rho}} = (1 + \theta_F) \frac{\partial p_F^w}{\partial \widehat{\rho}} < 0$. The world market price of biofuels increases because of the mandates: $\widehat{p_{Bt}^w} \geq p_{F0}^w \left(> \widehat{p_{Ft}^w}\right)$. In order for the domestic production of biofuels not to fall after the imposition of the biofuels mandates and the revision of biofuels trade policy, the domestic price of biofuels will have to be at least as high as the price at period $t = 0$: $\widehat{p_{Bt}} \geq p_{F0} \, (> \widehat{p_{Ft}})$. We will examine when is this likely to be the case.

Under market conditions, biofuels are demanded until their price is at most as high as the domestic price of the fossil fuel alternative. If the tariff on biofuels is set equal to zero ($\widehat{\theta_{Bt}} = 0$), we may have a situation where $p^w_{F0} < p^w_{Bt} = p_{Ft} < p_{F0}$. Then, the domestic price of fossil fuels , p_{Ft}, determines the global production of biofuels, but while the foreign production increases, the domestic production falls as the producer price falls (from p_{F0} to p_{Ft}). This determines the lower bound of binding biofuels mandates.

The biofuels mandates must thus be set at levels, which exclude the market equilibrium (i.e., $\rho < \widehat{\rho}$). With $\widehat{\theta_{Bt}} = 0$ we can either have $\widehat{p_{Ft}} < \widehat{p^w_{Bt}} \leq p_{F0}$, or $\widehat{p^w_{Bt}} > p_{F0}$. In the former case, the domestic production of biofuels falls compared to the situation without a biofuels mandate, while the foreign production increases. In the latter case domestic production with a mandate will exceed domestic production without a mandate.

As will be clear from the analysis in the next section, it is not optimal for the government to set the tariff on biofuels equal to zero, however. Then, regardless of the world market price of biofuels, as long as the tariff is set at a level where $\widehat{p_{Bt}} \geq p_{F0}$, the domestic production of biofuels with a mandate will not fall compared to the situation without a mandate. For instance, at θ_F, $(1 + \theta_F)\, \widehat{p^w_{Bt}} > (1 + \theta_F)\, p_{F0}$. ■

An import tariff leads to the replacement of foreign biofuels with domestic, given the total biofuels mandate. This lowers world market price of biofuels, $\widehat{p^w_{Bt}}$, although not to the same level as during time $t = 0$, except in the special case where the domestic production rises enough to cover the whole increase in demand for biofuels due to the mandate. The effect reflects the change in a large country's terms of trade, as will be seen in the next section.

As production changes, the biofuels sector's factor demand also changes. If $\widehat{p_{Bt}} > p_{B0}$, the production of biofuels increases from $t = 0$ to $t = \{1,\ 2\}$, and demand for both fossil fuels and land in the production of biofuels increases. What happens to emissions was discussed in Section 2.3. Finally, as is clear from Equation (3), the combined policies have an ambiguous effect on the price of road transport, and consequently, on demand for road transport (and the fuels).

4.2 Determination of the equilibrium tariff

Differentiating the lobby groups' objective functions (4) with respect to the tariff rate on biofuels in the presence of a biofuels mandate at time $t = \{1,\ 2\}$ yields $\frac{\partial \widehat{W_{Bt}}}{\partial \widehat{p_{Bt}}} = \widehat{y_{Bt}}$ for the biofuels sector and $\frac{\partial \widehat{W_{Ft}}}{\partial \widehat{p_{Bt}}} = 0$ for the fossil fuels sector. Substituting in these and the first order condition of the general welfare function (11) with respect to the tariff rate on biofuels into (13) yields

$$
\begin{aligned}
& I_B \widehat{y_{Bt}} \\
& + a \left[-\widehat{m_{Bt}} \frac{\partial p_B^w}{\partial \widehat{p_B}} + \theta_{Ft} p_{Ft}^w \frac{\partial \widehat{m_{Ft}}}{\partial \widehat{p_B}} - \pi_t \phi' \left(\underline{\widehat{\epsilon_t}} \right) \frac{d \underline{\widehat{\epsilon_t}}}{d \widehat{p_B}} - (1 - \pi_t)\, \phi' \left(\widehat{\overline{\epsilon_t}} \right) \frac{d \widehat{\overline{\epsilon_t}}}{d \widehat{p_B}} \right] = 0,
\end{aligned}
\tag{15}
$$

Imports of both types of fuels fall with a higher price of biofuels: $\frac{\partial \widehat{m_{Bt}}}{\partial \widehat{p_B}} < 0$ and $\frac{\partial \widehat{m_{Ft}}}{\partial \widehat{p_B}} < 0$. From Equation (8) we further have that if emissions are 'low', then an increase in the price of biofuels lowers emissions ($\frac{d \underline{\widehat{\epsilon_t}}}{d \widehat{p_B}} < 0$), but if they are 'high', an increase raises emissions ($\frac{d \widehat{\overline{\epsilon_t}}}{d \widehat{p_B}} > 0$). Simplifying (15) yields the equilibrium tariff rate on biofuels in the presence of a biofuels mandate:

$$
\begin{aligned}
\widehat{\theta_{Bt}} = & \frac{I_B \widehat{y_{Bt}}}{a \widehat{m_{Bt}} e_{\widehat{m_B},\ \widehat{p_B}} - I_B \widehat{y_{Bt}}} \\
& + a \frac{\widehat{m_{Bt}} e_{p_B^w,\ \widehat{p_B}} - \theta_{Ft} \frac{p_{Ft}^w}{p_B^w} \widehat{m_{Ft}} e_{\widehat{m_F},\ \widehat{p_B}} + \pi_t \frac{\phi'\left(\underline{\widehat{\epsilon_t}}\right) \underline{\widehat{\epsilon_t}}}{p_B^w} e_{\underline{\widehat{\epsilon_t}},\ \widehat{p_B}} - (1 - \pi_t) \frac{\phi'\left(\widehat{\overline{\epsilon_t}}\right) \widehat{\overline{\epsilon_t}}}{p_B^w} e_{\widehat{\overline{\epsilon_t}},\ \widehat{p_B}}}{a \widehat{m_{Bt}} e_{\widehat{m_B},\ \widehat{p_B}} - I_B \widehat{y_{Bt}}}.
\end{aligned}
\tag{16}
$$

As was noted above, we assume that $\widehat{\theta_{Bt}} \geq 0$. The variables e denote elasticities of the first variable in lower case to the second variable, and are defined so that they are all positive. The elasticities are assumed to be constants for simplicity. The tariff equation yields a modified Ramsay rule, with the elasticity of biofuels import demand entering the denominator of (16). The rule is again modified for lobbying by the biofuels sector. Thus, the higher the (domestic) production of biofuels, the lower the denominator and the higher the tariff rate. For lobbying not to lead to (from the viewpoint of the interest group) a perverse effect, the denominator has to be positive; otherwise lobbying promotes an import subsidy. This condition sets a lower bound to the value that the parameter a can take at

$$a > \frac{I_B \widehat{y_{Bt}}}{\widehat{m_{Bt}} e_{\widehat{m_B},\ p_B}}. \tag{17}$$

In the numerator of (16), lobbying by the biofuels sector serves to raise the tariff rate. On the second line of (16), the first term in the numerator denotes the terms-of-trade effect of the biofuels tariff. Thus, it is optimal for a large country to impose a tariff on biofuels in order to benefit from the change in its terms of trade. The second term on the second line in the numerator reflects the effect of a biofuels tariff on the imports of fossil fuels; the more elastic the import demand of fossil fuels to the price of biofuels, the lower should the tariff on biofuels be. The effect is again due to the greater deadweight loss that trade policy creates, the higher is the elasticity of import demand. Finally, even in the presence of a biofuels mandate, the emission term(s) enter the tariff equation.

The biofuels mandate determines the share of biofuels in the production of road transport as $\widehat{\rho}$. An import tariff changes the proportions of domestically and foreign produced biofuels with which the mandate is filled. A higher tariff rate makes a greater domestic production possible thus increasing the share of domestically produced biofuels in the mix, with the consequences to emissions depending on the effects delineated above.We start by examining the socially optimal tariff rates at $\pi_t = \{0,\ 1\}$, respectively. The tariff equation in social optimum (as $a \to \infty$) simplifies to

$$\widehat{\theta^{so}_{Bt}} = \frac{\widehat{m_{Bt}} e_{p^w_B,\ \widehat{p_B}} - \theta_{Ft} \frac{p^w_{Ft}}{p^w_B} \widehat{m_{Ft}} e_{\widehat{m_F},\ \widehat{p_B}} + \pi_t \frac{\phi'\left(\underline{\widehat{\epsilon_t}}\right)\underline{\widehat{\epsilon_t}}}{p^w_B} e_{\underline{\widehat{\epsilon_t}},\ \widehat{p_B}} - (1-\pi_t)\, \frac{\phi'\left(\widehat{\overline{\epsilon_t}}\right)\widehat{\overline{\epsilon_t}}}{p^w_B} e_{\widehat{\overline{\epsilon_t}},\ \widehat{p_B}}}{\widehat{m_{Bt}} e_{\widehat{m_B},\ \widehat{p_B}}}. \tag{18}$$

Examining when the tariff rate with $\pi_t = 0$, i.e., when the domestic production of biofuels leads to increasing emissions, exceeds the tariff rate when $\pi_t = 1$, i.e., when the domestic production of biofuels is believed to lower emissions, we write $\widehat{\theta_{Bt}^{\overline{\epsilon}so}} > \widehat{\theta_{Bt}^{\underline{\epsilon}so}}$, substitute and simplify to obtain

$$\left(\widehat{m_{Bt}^{\overline{\epsilon}}} - \widehat{m_{Bt}^{\underline{\epsilon}}}\right) > \frac{\phi'\left(\widehat{\underline{\epsilon}_t}\right)\widehat{\underline{\epsilon}_t}\widehat{m_{Bt}^{\overline{\epsilon}}}e_{\widehat{\underline{\epsilon}_t},\ \widehat{p_B}} + \phi'\left(\widehat{\overline{\epsilon}_t}\right)\widehat{\overline{\epsilon}_t}\widehat{m_{Bt}^{\underline{\epsilon}}}e_{\widehat{\overline{\epsilon}_t},\ \widehat{p_B}}}{\theta_{Ft}p_{Ft}^{w}\widehat{m_{Ft}}e_{\widehat{m_F},\ \widehat{p_B}}}.$$

If $\widehat{\theta_{Bt}^{\overline{\epsilon}so}} > \widehat{\theta_{Bt}^{\underline{\epsilon}so}}$, the LHS is negative, i.e., $\widehat{m_{Bt}^{\overline{\epsilon}}} - \widehat{m_{Bt}^{\underline{\epsilon}}} < 0$, since a higher tariff rate lowers the imports. The RHS is unambiguously positive. Then, LHS > RHS, and consequently $\widehat{\theta_{Bt}^{\overline{\epsilon}so}} > \widehat{\theta_{Bt}^{\underline{\epsilon}so}}$ are never possible but the socially optimal tariff rate will always be set at a lower level if $\pi_t = 0$ than if $\pi_t = 1$.

We continue by examine whether it is possible for the politically optimal tariff rate at $\pi_t = 0$ to exceed the tariff rate at $\pi_t = 1$. We formulate the following Proposition:

Proposition 2 *At any time period t if 1. the government is susceptible to lobbying, and 2. given that the contribution given by the biofuels sector is large enough, the tariff rate on biofuels can be set at a higher level if the government assumes that the biofuels mandates lead to increasing emissions ($\pi_t = 0$) than if it assumes that the mandates lower emissions ($\pi_t = 1$), i.e., $\widehat{\theta_{Bt}^{\overline{\epsilon}}} > \widehat{\theta_{Bt}^{\underline{\epsilon}}}$ is possible.*

Proof. We examine the tariff level both with $\pi_t = 1$ and with $\pi_t = 0$. As the biofuels sector's contribution is determined by (12), its contribution depends on the chosen tariff level, $\widehat{\theta_{Bt}}$. We denote these by $y_{Bt}^{\underline{\epsilon}}$ for the case where $\pi_t = 1$ and by $y_{Bt}^{\overline{\epsilon}}$ for $\pi_t = 0$. If $\pi_t = 1$, i.e., information indicates low emissions from the (domestic) production of biofuels, the tariff rate from (16) will be

$$\widehat{\theta_{Bt}^{\underline{\epsilon}}} = \frac{I_B\widehat{y_{Bt}^{\underline{\epsilon}}} + a\left[\widehat{m_{Bt}^{\underline{\epsilon}}}e_{p_B^w,\ \widehat{p_B}} - \theta_F\frac{p_F^w}{\widehat{p_B^w}}\widehat{m_{Ft}}e_{\widehat{m_F},\ p_B} + \frac{\phi'\left(\widehat{\underline{\epsilon}_t}\right)}{\widehat{p_B^w}}\widehat{\underline{\epsilon}_t}e_{\widehat{\underline{\epsilon}},\ p_B}\right]}{a\widehat{m_{Bt}^{\underline{\epsilon}}}e_{\widehat{m_B},\ p_B} - I_B\widehat{y_{Bt}^{\underline{\epsilon}}}}. \tag{19}$$

If $\pi_t = 0$, the tariff rate is

$$\widehat{\theta_{Bt}^{\overline{\epsilon}}} = \frac{I_B\widehat{y_{Bt}^{\overline{\epsilon}}} + a\left[\widehat{m_{Bt}^{\overline{\epsilon}}}e_{p_B^w,\ \widehat{p_B}} - \theta_F\frac{p_F^w}{\widehat{p_B^w}}\widehat{m_{Ft}}e_{\widehat{m_F},\ p_B} - \frac{\phi'\left(\widehat{\overline{\epsilon}_t}\right)}{\widehat{p_B^w}}\widehat{\overline{\epsilon}_t}e_{\widehat{\overline{\epsilon}},\ p_B}\right]}{a\widehat{m_{Bt}^{\overline{\epsilon}}}e_{\widehat{m_B},\ p_B} - I_B\widehat{y_{Bt}^{\overline{\epsilon}}}}. \tag{20}$$

Examining when $\widehat{\theta^{\bar{\epsilon}}_{Bt}} > \widehat{\theta^{\epsilon}_{Bt}}$, taking into account that $\widehat{m^{\bar{\epsilon}}_{Ft}} = \widehat{m^{\epsilon}_{Ft}}$ since the share of fossil fuels in road transport is fixed and imports are not affected by the level of emissions from biofuels, and using (17) to simplify the denominator (writing $a = \frac{I_B \widehat{y_{Bt}} + \omega}{\widehat{m_{Bt}} e_{\widehat{m_B},\ p_B}}$), yields

$$I_B \left(\widehat{y^{\bar{\epsilon}}_{Bt}} - \widehat{y^{\epsilon}_{Bt}} \right) > a \left[\left(\widehat{m^{\epsilon}_{Bt}} - \widehat{m^{\bar{\epsilon}}_{Bt}} \right) e_{p^w_B,\ \widehat{p_B}} + \frac{\phi' \left(\widehat{\underline{\epsilon}_t} \right)}{\widehat{p^w_B}} \widehat{\underline{\epsilon}_t} e_{\widehat{\underline{\epsilon}},\ p_B} + \frac{\phi' \left(\widehat{\bar{\epsilon}_t} \right)}{\widehat{p^w_B}} \widehat{\bar{\epsilon}_t} e_{\widehat{\bar{\epsilon}},\ p_B} \right]. \tag{21}$$

$\widehat{\theta^{\bar{\epsilon}}_{Bt}} > \widehat{\theta^{\epsilon}_{Bt}}$ signifies $\widehat{y^{\bar{\epsilon}}_{Bt}} > \widehat{y^{\epsilon}_{Bt}}$ since a higher tariff rate increases domestic production. Furthermore, it indicates that $\widehat{m^{\epsilon}_{Bt}} > \widehat{m^{\bar{\epsilon}}_{Bt}}$ since a higher tariff lowers imports. Thus, both the LHS and the RHS of (21) are positive. $\widehat{\theta^{\bar{\epsilon}}_{Bt}} > \widehat{\theta^{\epsilon}_{Bt}}$ is then possible at a sufficiently low level of a:

$$a < \frac{I_B \left(\widehat{y^{\bar{\epsilon}}_{Bt}} - \widehat{y^{\epsilon}_{Bt}} \right)}{\left(\widehat{m^{\epsilon}_{Bt}} - \widehat{m^{\bar{\epsilon}}_{Bt}} \right) e_{p^w_B,\ \widehat{p_B}} + \frac{\phi' \left(\widehat{\underline{\epsilon}_t} \right)}{\widehat{p^w_B}} \widehat{\underline{\epsilon}_t} e_{\widehat{\underline{\epsilon}},\ p_B} + \frac{\phi' \left(\widehat{\bar{\epsilon}_t} \right)}{\widehat{p^w_B}} \widehat{\bar{\epsilon}_t} e_{\widehat{\bar{\epsilon}},\ p_B}}, \tag{22}$$

i.e., if the government is susceptible to lobbying. ■

As a corollary to Proposition 2 we can examine when the tariff rate set at $t = 2$, when new information about the emissions from the production of biofuels comes out can exceed the tariff rate set at $t = 1$ when emissions are believed to be low.

Corollary 3 *Given that the biofuels sector's contribution at $t = 2$ exceeds the contribution at $t = 1$, and that the government is susceptible to lobbying, it is possible that the government raises the tariff rate on biofuels as new information comes out about the emissions from biofuels production (π_t switches from $\pi_1 = 1$ to $\pi_2 = 0$).*

Proof. We start by examining when the tariff rate at $t = 2$ can exceed the tariff at $t = 1$, given that the parameter π_t switches from $\pi_1 = 1$ to $\pi_2 = 0$, i.e., when is $\widehat{\theta^{\bar\epsilon}_{B2}} > \widehat{\theta^{\underline\epsilon}_{B1}}$? Using (19) and (20), and (17) and simplifying yields

$$I_B \left(\widehat{y^{\bar\epsilon}_{B2}} - \widehat{y^{\underline\epsilon}_{B1}}\right) > a \left[\left(\widehat{m^{\underline\epsilon}_{B1}} - \widehat{m^{\bar\epsilon}_{B2}}\right) e_{p^w_B,\, \widehat{p_B}} + \frac{\phi'\left(\widehat{\epsilon_1}\right)}{\widehat{p^w_B}} \underline{\widehat{\epsilon_1}} e_{\widehat{\underline\epsilon},\, p_B} + \frac{\phi'\left(\widehat{\epsilon_2}\right)}{\widehat{p^w_B}} \widehat{\overline{\epsilon_2}} e_{\widehat{\bar\epsilon},\, p_B}\right], \tag{23}$$

which is similar to (21). If $\widehat{\theta^{\bar\epsilon}_{B2}} > \widehat{\theta^{\underline\epsilon}_{B1}}$, both $\widehat{y^{\bar\epsilon}_{B2}} > \widehat{y^{\underline\epsilon}_{B1}}$ and $\widehat{m^{\underline\epsilon}_{B1}} > \widehat{m^{\bar\epsilon}_{B2}}$, i.e., both the LHS and the RHS of (23) are nonnegative. Consequently, $\widehat{\theta^{\bar\epsilon}_{B2}} > \widehat{\theta^{\underline\epsilon}_{B1}}$ is possible at a sufficiently low level of a:

$$a < \frac{I_B \left(\widehat{y^{\bar\epsilon}_{B2}} - \widehat{y^{\underline\epsilon}_{B1}}\right)}{\left(\widehat{m^{\underline\epsilon}_{B1}} - \widehat{m^{\bar\epsilon}_{B2}}\right) e_{p^w_B,\, \widehat{p_B}} + \frac{\phi'(\widehat{\epsilon_1})}{\widehat{p^w_B}} \underline{\widehat{\epsilon_1}} e_{\widehat{\underline\epsilon},\, p_B} + \frac{\phi'(\widehat{\epsilon_2})}{\widehat{p^w_B}} \widehat{\overline{\epsilon_2}} e_{\widehat{\bar\epsilon},\, p_B}},$$

where $I_B \left(\widehat{y^{\bar\epsilon}_{B2}} - \widehat{y^{\underline\epsilon}_{B1}}\right)$ denotes the difference in sector B's political donation between periods $t = 1$ and $t = 2$.

It remains to show under which circiumstances the tariff rate at $t = 2$ with $\pi_2 = 0$ can be lower than the tariff rate at $t = 1$ with $\pi_1 = 1$, i.e., when is $\widehat{\theta^{\bar\epsilon}_{B2}} < \widehat{\theta^{\underline\epsilon}_{B1}}$. Again using (19) and (20), and (17) yields

$$I_B \left(\widehat{y^{\bar\epsilon}_{B2}} - \widehat{y^{\underline\epsilon}_{B1}}\right) < a \left[\left(\widehat{m^{\underline\epsilon}_{B1}} - \widehat{m^{\bar\epsilon}_{B2}}\right) e_{p^w_B,\, \widehat{p_B}} + \frac{\phi'\left(\widehat{\epsilon_1}\right)}{\widehat{p^w_B}} \underline{\widehat{\epsilon_1}} e_{\widehat{\underline\epsilon},\, p_B} + \frac{\phi'\left(\widehat{\epsilon_2}\right)}{\widehat{p^w_B}} \widehat{\overline{\epsilon_2}} e_{\widehat{\bar\epsilon},\, p_B}\right], \tag{24}$$

where $\widehat{\theta^{\bar\epsilon}_{B2}} < \widehat{\theta^{\underline\epsilon}_{B1}}$ signifies $\widehat{y^{\bar\epsilon}_{B2}} < \widehat{y^{\underline\epsilon}_{B1}}$ and $\widehat{m^{\underline\epsilon}_{B1}} < \widehat{m^{\bar\epsilon}_{B2}}$. $\widehat{\theta^{\bar\epsilon}_{B2}} < \widehat{\theta^{\underline\epsilon}_{B1}}$ is thus possible given that a is sufficiently large:

$$a > -\frac{I_B \left(\widehat{y^{\underline\epsilon}_{B1}} - \widehat{y^{\bar\epsilon}_{B2}}\right)}{\left(\widehat{m^{\underline\epsilon}_{B1}} - \widehat{m^{\bar\epsilon}_{B2}}\right) e_{p^w_B,\, \widehat{p_B}} + \frac{\phi'(\widehat{\epsilon_1})}{\widehat{p^w_B}} \underline{\widehat{\epsilon_1}} e_{\widehat{\underline\epsilon},\, p_B} + \frac{\phi'(\widehat{\epsilon_2})}{\widehat{p^w_B}} \widehat{\overline{\epsilon_2}} e_{\widehat{\bar\epsilon},\, p_B}}$$

where it must be that

$$\frac{\phi'\left(\widehat{\epsilon_1}\right)}{\widehat{p^w_B}} \underline{\widehat{\epsilon_1}} e_{\widehat{\underline\epsilon},\, p_B} + \frac{\phi'\left(\widehat{\epsilon_2}\right)}{\widehat{p^w_B}} \widehat{\overline{\epsilon_2}} e_{\widehat{\bar\epsilon},\, p_B} > -\left(\widehat{m^{\underline\epsilon}_{B1}} - \widehat{m^{\bar\epsilon}_{B2}}\right) e_{p^w_B,\, \widehat{p_B}},$$

i.e., the terms-of-trade effect is low enough. ■

A further consequence of Proposition 2 and Corollary 3 is that if we allow

π_t to be continuous, but assume that at some time period $t = 2$ sufficient information about the (high) emissions from the production of biofuels has been accumulated for the government to decide to revise its trade policy (π_2 passes some threshold value), given the value of a, the RHS of (23) will be smaller than that in (23) because of the lower level of the higher damages function. Then it becomes even more likely that the government in fact raises the tariff rate instead of lowering it, when new information about emissions becomes available.

In the end, the two factors that determine the effect of lobbying on the tariff rate are the government's susceptibility to lobbying, a, and the intensity of lobbying, $I_B\widehat{y_{Bt}}$. If the biofuels sector expects its production to grow in the next period, it will give a greater contribution than if it expects its production to fall. Which is the case is, however, a function of the tariff rate set. We now turn to the lobbies' contribution decision.

4.3 Policy persistence

We end with an examination of the persistence of the policy under the above-delineated results. To this end we add one more feature to the model, namely that the adjustment of production to the new tariff rate takes some time. Thus, at $t = \{1,\ 2\}$, when the tariff rate is determined, the biofuels producers initially produce approximately the same amount as during the last moments of period $t-1$, and then adjust their production. This can be thought of as an adjustment time; while the sector starts to adjust its production directly after the new tariff rate is known, production during the very first sub-period during period t will still be approximately equal to production during $t-1$. In order to take this effect into account we adjust the first derivative of the objective function (4) so that this becomes (including a dicount parameter δ):

$$\frac{\partial\widehat{C_{Bt}}}{\partial\widehat{p_{Bt}}} = \frac{\partial\widehat{W_{Bt}}}{\partial\widehat{p_{Bt}}} = \widehat{y_{Bt-1}} + \delta\widehat{y_{Bt}}. \tag{25}$$

$$\frac{\partial C_{Bt}}{\partial p_F} = \frac{\partial W_{Bt}}{\partial p_F} = (y_{Bt-1} - X_{Bt-1}) + \delta\left(y_{Bt} - X_{Bt}\right), \tag{26}$$

where (25) applies in the presence of the biofuels mandate and (26) in the absence of a mandate. This introduces a backwards looking term into the objective function thus allowing past production to influence lobbying, and consequently future production. We start by stating the effect that the biofuels mandates have on the marginal lobbying effort of the biofuels sector:

Proposition 4 *Given that $\widehat{p_{Bt}} \geq p_{F0}$, the marginal lobbying effort of the biofuels sector in the presence of a biofuels mandate exceeds the effort in the absence of a mandate. If $\widehat{p_{Bt}} < p_{F0}$, it is possible but not certain that this is the case.*

Proof. Starting with the former case ($\widehat{p_{Bt}} \geq p_{F0}$), we prove Proposition 4 by contradiction. We denote a period with a mandate by $t = 1$, and compare it to the previous period $t = 0$, without a mandate. From Lemma 1 we know that as long as $\widehat{p_{B1}} \geq p_{F0}$, the domestic production of biofuels in $t = 1$ is no smaller than the production in $t = 0$: $\widehat{y_{B1}} \geq y_{B0}$. Comparing (25) and (26) to find when is the marginal contribution at $t = 1$ smaller than the marginal contribution at $t = 0$, i.e., $\frac{\partial \widehat{C_{B1}}}{\partial \widehat{p_{B1}}} \leq \frac{\partial C_{B0}}{\partial p_{F0}}$ yields

$$y_{B0} + \delta \widehat{y_{B1}} \leq (y_{B0-1} - X_{B0-1}) + \delta (y_{B0} - X_{B0}),$$

Rearranging yields

$$\widehat{y_{B1}} \leq \frac{1}{\delta}(y_{B0-1} - y_{B0}) + y_{B0} - \frac{1}{\delta} X_{B0-1} - X_{B0}, \tag{27}$$

where $y_{B0} \geq y_{B0-1}$ assuming that the price of biofuels at $t = 0$ is not lower than the price at (the non-modelled period) $t = (0 - 1)$. We start by examining how an increase in y_{B0} affects (27); differentiating w.r.t. y_{B0} yields $-\frac{1}{\delta} + 1 < 0$ since $\frac{1}{\delta} > 0$ as long as $\delta < 1$. The highest value that $\widehat{y_{B1}}$ can take for (27) to be satisfied is thus when y_{B0} is at its lowest, i.e., when $y_{B0} = y_{B0-1}$. Substituting into (27) yields

$$\widehat{y_{B1}} \leq y_{B0-1} - \frac{1}{\delta} X_{B0-1} - X_{B0}. \tag{28}$$

But from Lemma 1 we have that when $\widehat{p_{Bt}} \geq p_{F0}$, $\widehat{y_{B1}} \geq y_{B0} = y_{B0-1}$. Then, given that $X_{Bt} > 0$ $(t = \{0-1,\ 0\})$, the LHS of (28) always exceeds the RHS, and it must be that the marginal contribution in the presence of a biofuels mandate exceeds the marginal contribution in the absence of a mandate, i.e., that $\frac{\partial \widehat{C_{B1}}}{\partial \widehat{p_{B1}}} > \frac{\partial C_{B0}}{\partial p_{F0}}$.

If $\widehat{p_{Bt}} < p_{F0}$, however, $\widehat{y_{Bt}} < y_{B0} = y_{B0-1}$. In this case, we cannot do the last substitution, and while it is possible that the LHS of (27) still exceeds the RHS for certain values of the parameters, it is easy to see that this no longer is always the case. ■

We illustrate the inequality in (27) in Figure 1. In this figure we depict the lowest value that $\widehat{y_{B1}}$ can take for $\widehat{y_{B1}} > \frac{1}{\delta}(y_{B0-1} - y_{B0}) + y_{B0} - \frac{1}{\delta} X_{B0-1} - X_{B0}$ to hold at different values of δ and y_{B0}, given that $y_{B0-1} = 1$ and that $X_{Bt} = 0.1 \times y_{Bt}$. In other words, as long as $\widehat{y_{B1}}$ exceeds the figure given on the vertical axis, the biofuels sector's marginal contribution with biofuels mandates will exceed its contribution without mandates. It is clear from Figure 1 that even if the production of biofuels with mandates falls, the marginal contribution is likely to exceed the marginal contribution in absence of mandates.

For two time periods with a mandate, $t = \{1,\ 2\}$, we examine when the inequality $\frac{\partial \widehat{C_{B2}}}{\partial \widehat{p_{B2}}} < \frac{\partial \widehat{C_{B1}}}{\partial \widehat{p_{B1}}}$ holds, i.e., when is the marginal contribution at a later period lower than the marginal contribution at an earlier period. Substituting in from (25) simplifies to

$$\widehat{y_{B2}} < \frac{1}{\delta}\left(y_{B0} - \widehat{y_{B1}}\right) + \widehat{y_{B1}}. \tag{29}$$

Again, an increase in $\widehat{y_{B1}}$ leads to a fall on the RHS of (29). Assuming again that $\widehat{p_{Bt}} \geq p_{F0}$, we have $\widehat{y_{Bt}} \geq y_{B0}$. Substituting in the lowest possible value of $\widehat{y_{B1}}$: $\widehat{y_{B1}} = y_{B0}$ yields $\widehat{y_{B2}} < \widehat{y_{B1}} = y_{B0}$. But since Lemma 1 with $\widehat{p_{Bt}} \geq p_{F0}$ signifies that $\widehat{y_{B2}} \geq y_{B0}$, even in this case the lobbying effort at $t = 2$ is at least as high as during period $t = 1$. Figure 2 illustrates this

From Figure 2 it is clear that the level of domestic biofuels production required at $t = 2$, $\widehat{y_{B2}}$, for the lobbying effort of the biofuels sector to be at least as high as the lobbying effort at $t = 1$ is below the level of production

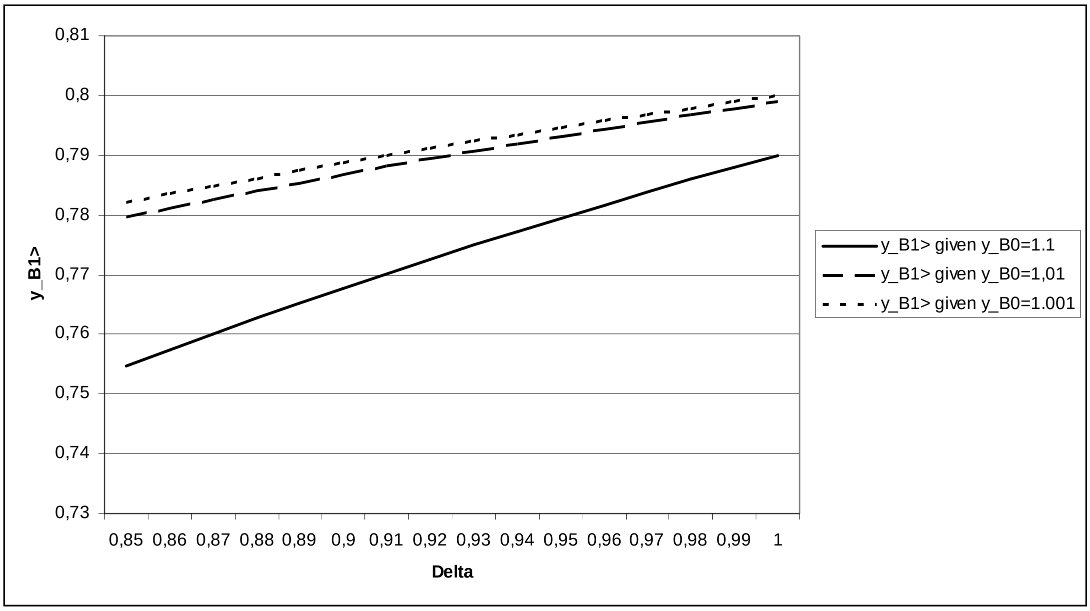

Figure 1: The lowest value that $\widehat{y_{B1}}$ can take for $\widehat{y_{B1}} > \frac{1}{\delta}\left(y_{B0-1} - y_{B0}\right) + y_{B0} - \frac{1}{\delta}X_{B0-1} - X_{B0}$ to hold, given that $\widehat{p_{Bt}} \geq p_{F0}$, and at $0.85 \leq \delta \leq 1$, $y_{B0-1} = 1$, $X_t = 0.1 y_{Bt}$ and at three different values of y_{B0} $(= 1.1;\ 1.01; 1.001)$. Given that the inequality holds, the contribution given by the biofuels sector at $t = 1$ is at least as high as the one given at $t = 0$.

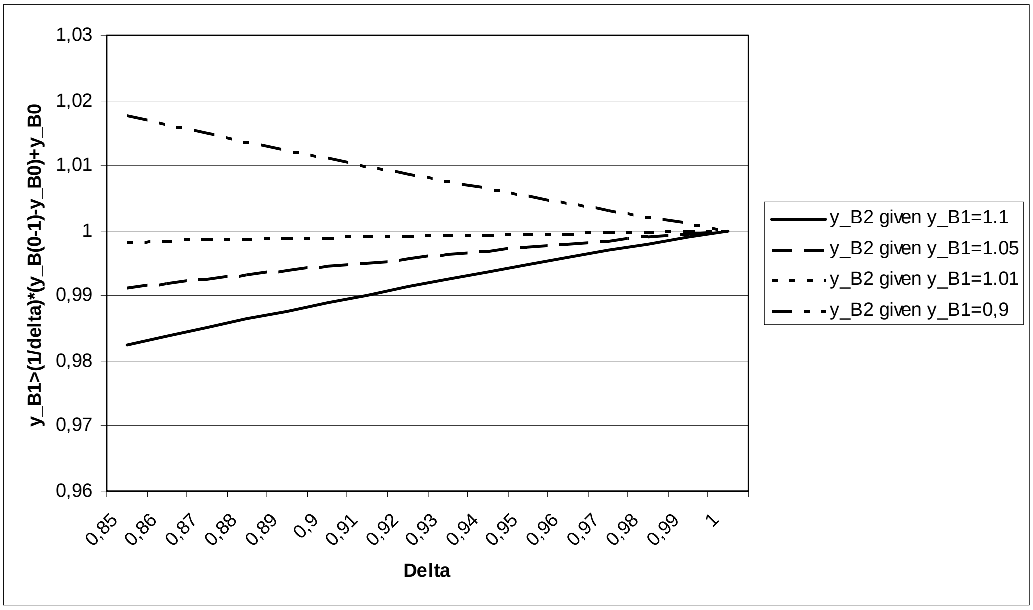

Figure 2: The lowest value that $\widehat{y_{B2}}$ can take for $\widehat{y_{B2}} > \frac{1}{\delta}\left(y_{B0} - \widehat{y_{B1}}\right) + \widehat{y_{B1}}$ at $0.85 \leq \delta \leq 1$ to hold, given that $\widehat{p_{Bt}} \geq p_{F0}$, and $y_{B0} = 1$, and at three different values of $y_{B0}\,(= 1.1;\ 1.05; 1.01)$. Given that the inequality holds, the contribution given by the biofuels sector at $t = 2$ is at least as high as the one given at $t = 1$. However, the figure also includes an example of a situation where $\widehat{p_{B1}} < p_{F0}$, and consequently, $\widehat{y_{B1}} < y_{B0}$. In this case, $\widehat{y_{B2}}$ will have to be greater than 1 for the marginal contribution at $t = 2$ to exceed the marginal contribution at $t = 1$.

at $t = 1$, $\widehat{y_{B1}}$, for all values of $\delta < 1$, given that $\widehat{p_{Bt}} \geq p_{F0}$. The closer $\widehat{y_{B1}}$ is to y_{B0}, the higher will $\widehat{y_{B2}}$ have to be for the lobbying effort at $t = 2$ to exceed the effort at $t = 1$. Relaxing the assumption about the price and allowing for $\widehat{p_{B1}} < p_{F0}$, we note that the lobbying effort at $t = 2$ even in this case may exceed the lobbying effort at $t = 1$, but that if the introduction of the biofuels mandates at $t = 1$ lead to a fall in the domestic production of biofuels compared to the situation without the mandates at $t = 0$, then production at $t = 2$ will have to increase compared to production at $t = 0$ in order for the marginal lobbying effort at the latter period to exceed the marginal lobbying effort at period $t = 1$.

These results can be compared to those in Damania (2002), who finds that a contracting sector gives a larger contribution to affect the level of an emissions tax within the framework of the Grossman-Helpman (1994) model. While our results qualify those in Damania's model, as a (biofuels) sector that contracts sufficiently in period $t = 2$ will give a lower (marginal) contribution than it gives at $t = 1$, for a contraction that is sufficiently small, and at sufficiently high discount rates, the contribution of a contracting sector may well exceed that by a growing sector. While Damania's result is due to a (fairly similar) lag structure combined with a tax function which is falling and concave in contributions, here it is the lag in contributions combined to the discount factor that leads to the result.

The conclusion from Proposition 4 and the discussion above indicates that the biofuels sector's lobbying effort tends to increase (or at least does not fall) as time passes by, regardless of whether its domestic production increases or not. In Proposition 2 we further showed that at any given time period, the tariff rate with $\pi_t = 0$ can be higher than the tariff rate with $\pi_t = 1$ if the government is sufficiently susceptible to lobbying and if the biofuels lobby's marginal contribution is sufficiently high. We end by examining when may policy be 'persistent' in the sense that a tariff rate set at $t = 1$ given $\pi_1 = 0$, $\widehat{\theta_{B1}^{\bar{\epsilon}}}$, is lower than a tariff rate set at $t = 2$ given $\pi_1 = 1$ and $\pi_2 = 0$, $\widehat{\theta_{B2}^{\bar{\epsilon}}}$. If, at $t = 1$ there was information available indicating $\pi_1 = 0$, then policy would not be readjusted at $t = 2$. The only thing different between the two time periods in this case is lobbying by a biofuels sector which, in the case where information about $\pi_t = 0$ becomes available first at $t = 2$, has had time to adjust its production during the first time period, to the biofuels mandate.

Proposition 5 *Biofuels trade policy may be persistent if the government is susceptible to lobbying and given that* $\widehat{p_{Bt}} \geq p_{F0}$.

Proof. We prove Proposition 5 by examining when the tariff rate at $t = 1$, given $\pi_1 = 0$ exceeds or is lower than the tariff rate at $t = 2$ given $\pi_2 = 0$, i.e., when is $\widehat{\theta^{\epsilon}_{B1}} \leq \widehat{\theta^{\epsilon}_{B2}}$. Instead of the marginal welfare change, we insert the marginal contribution, $\widehat{C'^{\epsilon}_{Bt}}$ by the bifuels sector in the numerator of Equation (20). Using (17) and simplifying yields the following condition:

$$\widehat{C'^{\epsilon}_{B1}} - \widehat{C'^{\epsilon}_{B2}} < a\left[\left(\widehat{m^{\epsilon}_{B2}} - \widehat{m^{\epsilon}_{B1}}\right) e_{p^w_B,\ \widehat{p_B}} + \left(\frac{\phi'\left(\widehat{\epsilon_1}\right)}{\widehat{p^w_B}}\widehat{\epsilon_1} - \frac{\phi'\left(\widehat{\epsilon_2}\right)}{\widehat{p^w_B}}\widehat{\epsilon_2}\right) e_{\widehat{\epsilon},\ p_B}\right]. \tag{30}$$

From Proposition 4 and the discussion following that Proposition we know that $\widehat{C'^{\epsilon}_{B1}} - \widehat{C'^{\epsilon}_{B2}} \leq 0$ given that $\widehat{p_{Bt}} \geq p_{F0}$. Furthermore, $\widehat{y^{\epsilon}_{B1}} - \widehat{y^{\epsilon}_{B2}} \leq 0$, which implies that $\widehat{m^{\epsilon}_{B2}} - \widehat{m^{\epsilon}_{B1}} \leq 0$ since higher domestic production lowers imports, and that $\frac{\phi'(\widehat{\epsilon_1})}{\widehat{p^w_B}}\widehat{\epsilon_1} - \frac{\phi'(\widehat{\epsilon_2})}{\widehat{p^w_B}}\widehat{\epsilon_2} \leq 0$ since emissions are determined by the level of domestic production of biofuels, and increase in greater production. Solving (30) for a yields

$$a \leq \frac{\widehat{C'^{\epsilon}_{B1}} - \widehat{C'^{\epsilon}_{B2}}}{\left(\widehat{m^{\epsilon}_{B2}} - \widehat{m^{\epsilon}_{B1}}\right) e_{p^w_B,\ \widehat{p_B}} + \left(\frac{\phi'(\widehat{\epsilon_1})}{\widehat{p^w_B}}\widehat{\epsilon_1} - \frac{\phi'(\widehat{\epsilon_2})}{\widehat{p^w_B}}\widehat{\epsilon_2}\right) e_{\widehat{\epsilon},\ p_B}}. \tag{31}$$

In other words, given that $\widehat{p_{Bt}} \geq p_{F0}$, the result in Proposition 4 and at a 'low' enough a we can have $\widehat{\theta^{\epsilon}_{B1}} < \widehat{\theta^{\epsilon}_{B2}}$. Then the timing of the policy affects the lobbying effort of the biofuels sector and consequently, policy becomes time-dependent and 'persistent'. ■

As was the case in Proposition 4, it is possible that trade policy may be persistent even if $\widehat{p_{Bt}} < p_{F0}$. It is, however, impossible to show at the present level of generality at what parameter values it might hold in this case.

From Corollary 3 we know that if $\pi_1 = 1$ and $\pi_2 = 0$, then a will have to be low for the government to raise the tariff at $t = 2$ compared to $t = 1$.

Thus, when the government is not susceptible to lobbying, there is no 'policy persistence'. However, if the government is susceptible to lobbying, then the government will set a higher tariff rate at $t = 2$ all else given than it would if it had had the same information available at $t = 1$.

4.4 The biofuels mandate

In the first stage of the game, at period $t = 1$ (believing that $\pi_t = 1$) respective local government determines the level of its biofuels mandate. It does this with perfect foresight. For simplicity we assume that the local governments determine the level of their biofuels mandates independently, without the involvement of any (local, non-modelled) lobby groups. They thus maximize general welfare:

$$\max_{\widehat{\rho_m}} W_m\left(\widehat{\rho_m}\right) = \sum_{j \in B,\ F} \frac{N_m}{N} \Pi\left(\widehat{p_{j1}},\ z,\ p_F\right) + S_m\left(\widehat{p_{R1}}\right) + R_m\left(\widehat{\mathbf{p_1}}\right) - \phi_m\left(\widehat{\underline{\epsilon_1}}\right), \tag{32}$$

where the price of road transport is given by (3). Summing over each local government's welfare function yields $\Sigma_m W_m\left(\widehat{\rho_m}\right) = W\left(\widehat{\rho}\right)$, which is identical to (11). Summing over the local solutions, the maximization problem yields

$$\begin{aligned} &- \widehat{m_{B1}} \frac{\partial \widehat{p_{B1}^w}}{\partial \widehat{\rho}} - \widehat{X_{B1}} \left(1 + \widehat{\theta_{F1}}\right) \frac{\partial \widehat{p_{F1}^w}}{\partial \widehat{\rho}} - \widehat{m_{F1}} \frac{\partial \widehat{p_{F1}^w}}{\partial \widehat{\rho}} \\ &- N\widehat{d_{R1}}\left(\widehat{p_{B1}} - \widehat{p_{F1}}\right) + \widehat{\theta_{B1}} \widehat{p_{B1}^w} \frac{\partial \widehat{m_{B1}}}{\partial \widehat{\rho}} + \widehat{\theta_{F1}} \widehat{p_{F1}^w} \frac{\partial \widehat{m_{F1}}}{\partial \widehat{\rho}} - \phi'\left(\widehat{\underline{\epsilon_1}}\right) \frac{\partial \widehat{\underline{\epsilon_1}}}{\partial \widehat{\rho}} = 0, \end{aligned} \tag{33}$$

where we assume that $\frac{\partial \widehat{m_{B1}}}{\partial \widehat{\rho}} = Nd'_{B1} \frac{\partial \widehat{p_{R1}}}{\partial \widehat{\rho}} - \frac{\partial \widehat{y_{B1}}}{\partial \widehat{p_{B1}}} \frac{\partial \widehat{p_{B1}}}{\partial \widehat{\rho}} < 0$ and $\frac{\partial \widehat{m_{F1}}}{\partial \widehat{\rho}} = Nd'_{F1} \frac{\partial \widehat{p_{R1}}}{\partial \widehat{\rho}} - \frac{\partial \widehat{y_{F1}}}{\partial \widehat{p_{F1}}} \frac{\partial \widehat{p_{F1}}}{\partial \widehat{\rho}} > 0$, even though the change in the price of road transport, $\frac{\partial \widehat{p_{R1}}}{\partial \widehat{\rho}} \gtrless 0$, creates an ambiguity since it is not clear whether the biofuels mandates raise or lower $\widehat{p_{R1}}$. Simplifying (33) and solving for the mandate yields

$$\widehat{\rho} = \frac{-\left[e_{\widehat{p^w_B},\, \widehat{\rho}} + \widehat{\theta_{B1}} e_{\widehat{m_{B1}},\, \widehat{\rho}}\right] \widehat{p^w_{B1}} \widehat{m_{B1}} + \widehat{p_{F1}} \widehat{X_{B1}} e_{\widehat{p^w_F},\, \widehat{\rho}}}{N \widehat{d_{R1}} \left(\widehat{p_{B1}} - \widehat{p_{F1}}\right)} + \frac{\left[e_{\widehat{p^w_F},\, \widehat{\rho}} + \widehat{\theta_{F1}} e_{\widehat{m_{F1}},\, \widehat{\rho}}\right] \widehat{p^w_{F1}} \widehat{m_{F1}} + \phi' \left(\underline{\widehat{\epsilon_1}}\right) \underline{\widehat{\epsilon_1}} e_{\underline{\widehat{\epsilon_1}},\, \widehat{\rho}}}{N \widehat{d_{R1}} \left(\widehat{p_{B1}} - \widehat{p_{F1}}\right)}. \quad (34)$$

The import demand elasticities to the mandates, $e_{\widehat{m_j},\, \widehat{\rho}}$, the elasticity of emissions to the mandate, $e_{\epsilon,\, \widehat{\rho}}$, and the elasticities of the world market prices to the mandate, $e_{\widehat{p^w_j},\, \widehat{\rho}}$, have all been defined to be positive.

Thus, for the mandate to be defined in (34), it must be that the price of biofuels rises above that of the price of fossil fuels: $\widehat{p_{B1}} > \widehat{p_{F1}}$. The greater the demand for road transport, Nd_{R1}, the lower the mandate.

In the numerator, the greater the elasticities of the world market price and import demand of biofuels are to the total biofuels mandate, the lower should the total mandate be set. On the other hand, the greater the elasticity of the world market price of fossil fuels, or the import elasticity of fossil fuels, the higher should the mandate be. Finally, while not being the only factor affecting the level of the mandate, the greater the marginal environmental damages from the emissions of GHG, and the greater the elasticity of emissions to the total mandate, the higher should the total biofuels mandate be.

5 Conclusions

In this paper, we have shown how policy making for biofuels can lead to unexpected results when new information about the emissions properties of biofuels comes out. We show that it is possible that the government sets the import tariff on biofuels, when the production of biofuels leads to a net increase in emissions, at a level which is higher than the level which would be chosen were the production of biofuels to lead to a net fall in emissions, given that the government is sufficiently susceptible to lobbying, and given that the biofuels lobby gives a contribution which is sufficiently high. This despite the finding that from a societal point of view it would be optimal to lower the import tariff on biofuels if the domestic production led to increased net emissions of GHG.

We further show that policy may be 'path dependent' in the sense that the time period when a tariff rate is set, all else equal, can matter for the chosen tariff rate if the government is susceptible to lobbying. Thus, if the government had information about the 'high' emissions properties of the domestic production of biofuels already when it revises the tariff rate for the first time after the imposition of the biofuels mandates, it would choose a lower tariff rate than it does when the information about the 'high' emissions comes out later, and it already chose one tariff rate at $t = 1$, assuming that the emissions were 'low'. This result survives up to a point even if the domestic production of biofuels contracts after the imposition of the biofuels mandates, or at $t = 2$, when new information about emissions has come out.

The model in this paper makes one particularly gross simplification, namley the assumption that the world production of biofuels always leads to lower emissions. Within the framework of the present model, however, assuming that the foreign emissions, too, are uncertain would necessitate not only the revision of domestic trade policy in face of new information but would also require the revision of the biofuels mandate; or rather, it would change the optimal biofuels policy from being a mandate to a prohibition of the more-polluting-than-fossil-fuels biofuels. Even then, the balance of domestically and foreign-produced biofuels would be determined by the tariff rate on biofuels after the mandate (or prohibition), however.

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