Path dependence: Biofuels policy under uncertainty about greenhouse gas emissions

Johanna Jussila Hammes
Swedish National Road and Transport Research Institute, VTI, and Centre for Transport Studies Stockholm, CTS
E-mail: johanna.jussila.hammes@vti.se
Tel: +46 (0)8 555 77 035

January 12, 2011

Abstract

We study the effect of uncertainty about the greenhouse gas emissions arising from the production of biofuels on trade policy, in the presence of lobby groups and two policy instruments, trade policy and biofuels mandates. We show that in the presence of biofuels mandates it would be optimal from a societal point of view to lower the trade tariff on biofuels when the emissions from their production are shown to be 'high' as compared to when they are believed to be 'low'. If the government is susceptible to lobbying, the tariff may be raised instead. We further show that at subsequent time periods, the biofuels sector's marginal lobbying effort will not fall compared to previous periods, and that consequently, its political contribution also does not fall. Finally we show how policy may be path dependent, i.e., that earlier tariff rates in part determine future tariff rates if the government is susceptible to lobbying and given that the domestic price of biofuels does not fall. The model can, e.g., shed light on why the EU does not lower the tariffs on Brazilian ethanol in the face of new information.

1 Introduction

A number of recent studies indicate that greenhouse gas (GHG) emissions from the production of biofuels can be considerable.[1] One important motivation for biofuels policy so far has been that these fuels, by replacing fossil fuels, can lower the emissions of GHGs. The aim of this paper is to study how new information about the GHG emissions from the production of biofuels affects biofuels trade policy in a large country, such as the European Union (EU). We show, using as a starting point the model developed in Grossman and Helpman (1994, 1995), where Special Interest Groups (SIGs) affect the policy adjustment process, how lobbying by the SIGs can inhibit policy adjustment and instead, make policy both 'persistent' and 'path dependent'.

The main policy instrument studied in this article is trade tariffs. Standard normative analyses of trade tariffs indicate that it is optimal for a large country to impose an import tariff because of the change in the terms of trade that the tariff induces. Grossman and Helpman (1995), and the literature following them adds to this by showing how SIG influence also serves to give the politicians incentives to implement a trade tariff.

Biofuels mandates of some form are a fairly common policy instrument in Europe.[2] We include biofuels mandates into the model. These allow the domestic price of biofuels to diverge from the price of fossil fuels. A biofuels mandate is a quantitative policy instrument mandating the consumption of

[1]For instance, Searchinger et al. (2008) and Fargione et al. (2008) argue that the (indirect) 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. 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 the same result in Sweden, see Wibe (2010)). Furthermore, there are indications that the production process, at least for some crops and in some countries, can be so energy intensive that it uses up more energy than the final product contains (Soimakallio et al. (2009)).

[2]European countries that have implemented some form of biofuels mandate include Austria, Cyprus, Denmark, Finland, France, Germany, Italy, Latvia, Lithuania, the Netherlands, Poland, Romania, Slovakia, Slovenia and the United Kingdom (Energimyndigheten (2009)). Sweden has considered a biofuels mandate but as to date (December 2010) no definite decisions have been made. The United States has a blend mandate for biofuels.

a certain share of biofuels of the total fuel consumed. It can either be a blend mandate (see de Gorter and Just (2009)) specifying how much biofuels must be blended in a given quantity of fossil fuels, or a more general target for the consumption of biofuels.

We construct a simple, three sector general equilibrium model. Consumers maximize utility derived from the consumption of road transport. Emissions create disutility. Road transport can be produced using either fossil fuels or biofuels, where the consumption of the former is known to lead to emissions, but where even the latter cause emissions from production. We examine two cases of emissions: one where it is believed that the emissions from the production of biofuels are 'low' and the substitution of biofuels for fossil fuels leads to a net fall in emissions, and one where the net emissions are positive instead.

Trade policy is decided at a central (e.g., the EU) level, taking both SIG influence and general welfare into account. We assume that the politicians care about two things: political office, and their career after they quit politics. In order to stay in office as long as possible the politicians must care about general welfare, the level of which impacts on their (non-modeled) probability of being re-elected. Considerations of their career past politics makes them open for lobbying, however. We thus assume that the organized SIGs can credibly commit to offering the politicians lucrative positions after they quit politics, and thus present a 'menu' of 'contributions' tied to the chosen trade policy. The politicians consequently take both SIG profits and general welfare into consideration when making policy decisions (for a similar argument, see Cadot et al. (2006)). This modification of the interpretation allows us to use an objective function à la Grossman and Helpman, but without the US style campaign contributions, which are illegal in most EU countries. We call the resources that the SIGs need to spend to lobby the policy makers 'political contributions'.

In the EU, the Member States determine domestically how to reach the EU's goals for renewable energies. For this reason, besides considering trade policy we also include local-level biofuels mandates in the model. However, to keep things simple, we do not model the political economics behind the design of biofuels mandates but assume that these are set at the optimal level. The model we set up can explain under which circumstances trade policy may not only be 'persistent' but also 'path dependent' in the sense that whether there have been previous political decisions influence consequent revisions of policy. In particular, it may be that a revision of trade policy to take into account new information about the emissions arising from biofuels production is hampered by entrenched SIGs, when the government is susceptible to lobby influence.

In order to keep the model tractable, our study has certain limitations. We do 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 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 reduce the emissions of GHGs, it would be optimal to have a prohibition against biofuels instead of a mandate. We also do not consider the differences between the gasoline and diesel markets. Finally, we ignore all additional policy instruments; for instance, in many countries, biofuels mandates and tariffs are complemented with tax exemptions or rebates to biofuels. Adding more policy instruments to this study would not add to the results, however.

The political economy literature studying SIG influcence on environmental policy-making is large, and not surveyed in the present paper. Those studies most relevant to the present one are by Damania (2002), who explains why greater pollution tax rebates are given to declining industries than to growing ones, and Coate and Morris (1999), who study policy persistence once policy has been implemented. Coate and Morris show how the fact that policy tends to be persistent may hamper future attempts at policy making. Our study differs from these by explaining some circumstances under which policy may not only become persistent, but also path dependent.

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 continue by solving the political game backwards, with both a biofuels mandate and tariffs. We shortly describe how the production of biofuels change due to the policies, before solving for the politically optimal tariff rates, and examine when policy may be persistent and/or path dependent. The final section concludes.

2 The model

2.1 Consumer demand, prices and production

Consider a large open economy. It 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 $U_{ht} = c_{Ot} + u_R(c_{Rt}) - \phi(E\epsilon_t)$. c_{Ot} denotes the consumption of the numeraire good O, and c_{Rt} consumption of good R, road transport. The sub-utility function $u_R(c_{Rt})$ is differentiable, increasing and strictly concave. $\phi(E\epsilon_t)$, where E is an expectations operator, and ϵ_t emissions, is the damage function, which is assumed to be differentiable, increasing and strictly convex. Individuals are assumed to be risk neutral with respect to the level of emissions. The emissions will be discussed more closely in Section 2.3. Subscripts denote sectors and time. 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, and depends on the availability of exogenous information.[3]

Good O has a domestic and world market price equal to one, and does not generate any consumer surplus. 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, I, is devoted to the numeraire good. The consumer then attains indirect utility given by $v(p_{Rt},\ I,\ \epsilon_t) = I + S(p_{Rt}) - \phi(E\epsilon_t)$, where $S(p_{Rt}) = u_R[d_R(p_{Rt})] - p_{Rt}d_R(p_{Rt})$ is consumer surplus from

[3] 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.

good R.

Road transport can be produced either using fossil fuels (F) or biofuels (B). Consequently, demand for it can be written as $d_R(p_{Rt}) = d_F(p_{Ft}) + d_B(p_{Bt})$.[4] The price of road transport is a weighted average of the price of fossil fuels and biofuels:

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

where $\rho = \frac{d_B(p_{Bt})}{d_R(p_{Rt})}$ is the share of biofuels of total fuel demand. In the absence of a biofuels mandate, $p_{Bt} = p_{Ft}$, in the presence of the mandate the two prices (can) differ.

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

$$\begin{aligned} \Pi_j(p_{jt},\ p_D,\ p_F) = p_{jt} y_j(p_{Bt},\ p_D,\ p_{Ft}) - p_D D_B(p_{Bt},\ p_D,\ p_{Ft}) \\ - p_{Ft} F_B(p_{Bt},\ p_D,\ p_{Ft}) - C_j(\boldsymbol{\theta}_\mathbf{t}), \end{aligned} \tag{2}$$

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

We assume that the biofuels sector's factor demand does not affect the prices of land and fossil fuels,[5] but that demand for land and fossil fuels

[4] 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 outside the model.

[5] 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

changes in input prices, so that $\frac{\partial D_B}{\partial p_B} > 0$, $\frac{\partial D_B}{\partial p_D} < 0$, $\frac{\partial F_B}{\partial p_B} > 0$ and $\frac{\partial F_B}{\partial p_F} < 0$.[6] Furthermore, land and fossil fuels can reasonably be either 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 $\frac{\partial F_B}{\partial p_D} > 0$ ($\frac{\partial F_B}{\partial p_D} < 0$).

2.2 Policy instruments and interest groups

Each level of government, local and central, has one policy instrument at its disposal. 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 $\widehat{\rho} = \frac{\Sigma_m \widehat{\rho_m}}{m}$. 'Hats' on variables denote their values in the presence of a biofuels mandate; variables without hats are the market equilibrium values. The biofuels mandates, 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 $\widehat{p^w_{Bt}} > p^w_{Bt} = p^w_{Ft}$. Since demand for fossil fuels falls, their price falls so that $\widehat{p^w_{Ft}} \leq p^w_{Ft}$. The total effect of the mandate on the price of road transport, $\widehat{p_{Rt}}$, is ambiguous (see Appendix 6). To simplify, we assume that interest groups do not affect the levels of the biofuels mandates directly.[7]

The central government imposes an import tariff on the imports of biofuels and fossil fuels, both of which are assumed to be importables for simplicity.[8] The tariffs are denoted by θ_{jt} for sector $j \in \{B,\ F\}$. The tariffs determine the domestic prices of goods, which are given as $p_{jt} = (1 + \theta_{jt})\, p^w_{jt}$, where p^w_{jt} is the world market price of good j. In order to simplify the analysis

its input factors.

[6]That p_D is taken to be a constant means that even though changes in land use due to 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., Jussila Hammes (2009).

[7]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.

[8]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.

we assume the tariff rate always to be non-negative.[9]

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

$$R(\mathbf{p_t}) = \sum_j \theta_{jt} p_j^w \left\{ N d_j (p_{jt}) - y_j (p_{Bt,}\ p_D,\ p_{Ft}) \right\}.$$

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

We assume that those owning the sector-specific capital, respectively land used in the production of fossil- and biofuels have similar interests in the trade taxation of their sector and form special interest groups to influence the government's trade policy. The formation of SIGs is not modelled 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 SIGs ($j \in \{B,\ F\}$) overcome the free riding problem inherent to interest group organization and form functionally specialized interest groups (see Aidt (1998)).[10] The organized groups coordinate their political activities so as to maximize respective lobby group's members' welfare. The lobby representing industry j thus has a political contribution schedule $C_j(\boldsymbol{\theta}_\mathbf{t})$ that maximizes

$$v_{jt} = W_j(\boldsymbol{\theta}_\mathbf{t}) - C_j(\boldsymbol{\theta}_\mathbf{t}), \tag{3}$$

where

$$W_j(\boldsymbol{\theta}_\mathbf{t}) \equiv \Pi_j(p_{jt},\ p_D,\ p_{Ft}) \tag{4}$$

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

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

[10] That an interest group is functionally specialized means that it only cares about its members' profits, not of other sources of income, such as transfers of government revenue.

2.3 Emissions

Expected emissions of greenhouse gases are given by

$$E\epsilon_t(\mathbf{p_t}) = \varepsilon\left[Nd_F(p_{Ft}) + EF_B(p_{Bt},\ p_D,\ p_{Ft})\right] + E\mu^d D_B(p_{Bt},\ p_D,\ p_{Ft}) + \epsilon_t^w(\mathbf{p}_t^w)\,. \tag{5}$$

Emissions are 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. $\epsilon_t^w(\mathbf{p}_t^w)$, where $\mathbf{p}_t^w$ is the vector of prices, denotes emissions from the rest of the world.

Uncertaintly about emissions from the energy required to produce biofuels is reflected in an expectation about the fossil fuel use in the production, EF_{Bt}. Uncertainty about emissions from land use is reflected by the term $E\mu^d$. We denote a case with low expected emissions with $\underline{\epsilon_t}(\mathbf{p_t})$ and a case with high expected emissions with $\overline{\epsilon_t}(\mathbf{p_t})$. We assume that at time periods $t \in \{0,\ 1\}$ the government expects 'low' emissions. At period $t = 2$ information comes out indicating 'high' emissions. World emissions, ϵ_t^w, are assumed to be known to be 'low'.

The (total) biofuels mandate has an ambiguous effect on emissions (see Appendix 6). In order for the mandates to be meaningful we assume that their 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 domestic price of biofuels has an ambiguous effect on emissions (see Appendix 6). Thus, an increase in the domestic biofuels price (and consequently production) may either lead to a net fall in emissions, $d\underline{\epsilon^d}/dp_B < 0$, or to a net increase in emissions, $d\overline{\epsilon^d}/dp_B > 0$. If the increase in domestic emissions is high enough, it may actually raise global emissions, i.e., we may have $\frac{\partial\left(\epsilon_t^d+\epsilon_t^w\right)}{\partial p_B} > 0$. Finally, an increase in the price of fossil fuels, has an ambiguous effect on emissions in the absence of biofuels mandates, and lowers emissions in the presence of mandates (see Appendix 6).

3 Policy in the absence of a biofuels mandate

At time $t = 0$ there are no biofuels mandates. We assume that the tariff rates on biofuels and fossil fuels that prevail before the imposition of biofuels mandates are set in a similar manner to the tariff-setting game, which is played after the imposition of biofuels mandates.

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

$$\max G\left(\boldsymbol{\theta}_{\mathbf{t}}\right) = \sum_{j} C_j\left(\boldsymbol{\theta}_{\mathbf{t}}\right) + aW\left(\boldsymbol{\theta}_{\mathbf{t}}\right), \tag{6}$$

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 SIG interests. Average (gross) welfare is given by

$$W\left(\boldsymbol{\theta}_{\mathbf{t}}\right) = \sum_{j} \Pi_j\left(p_{jt},\ p_D,\ p_F\right) + S\left(p_{Rt}\right) + R\left(\mathbf{p}_{\mathbf{t}}\right) - \phi\left(E\epsilon_t\right). \tag{7}$$

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

$$\nabla C_j\left(\boldsymbol{\theta}_{\mathbf{t}}\right) = \nabla W_j\left(\boldsymbol{\theta}_{\mathbf{t}}\right), \tag{8}$$

i.e., that every SIG spends on lobbying activities up to the point where their marginal expenditure 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:

$$\sum_{j} \nabla W_j\left(\boldsymbol{\theta}_{\mathbf{t}}\right) + a\nabla W\left(\boldsymbol{\theta}_{\mathbf{t}}\right) = 0. \tag{9}$$

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 both the price of biofuels as $p_{B0} = p_{F0}$, and the tariff rate as $\theta_{B0} = \theta_{F0}$.

Maximizing the interest groups' objective functions (3) 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 (7) with respect to the tariff rate on fossil fuels into (9) yields

$$\begin{aligned} & y_{F0} + (y_{B0} - F_{B0}) \\ & + a\left[-F_{B0} - m_{R0}\frac{\partial p_F^w}{\partial p_F} + \theta_{F0} p_{F0}^w \left(\frac{\partial m_{B0}}{\partial p_F} + \frac{\partial m_{F0}}{\partial p_F}\right) - \phi'\left(E\epsilon_0\right)\frac{dE\epsilon_0}{dp_F}\right] = 0. \end{aligned}$$

$m_{jt} = [Nd_{jt} - y_{jt}]$ denotes imports of good $j = \{B,\ F,\ R\}$. Imports fall with a higher import tariff: $\frac{\partial m_{jt}}{\partial p_F} < 0$. The government believes that increasing the consumption of biofuels unambiguously lowers emissions, i.e., $\frac{dE\epsilon_0}{dp_F} < 0$. Simplifying yields the equilibrium tariff rate on fossil (and bio-) fuels in the absence of a biofuels mandate:

$$\theta_{F0} = \frac{y_{F0} + y_{B0} - (a+1) F_{B0} + a\left[m_{R0} e_{p_F^w,\ p_F} + \frac{\phi'\left(\epsilon_0\right)\epsilon_0}{p_{F0}^w} e_{\underline{\epsilon},\ p_F}\right]}{a\left(m_{B0} e_{m_B,\ p_F} + m_{F0} e_{m_F,\ p_F}\right) + (a+1) F_{B0} - y_{B0} - y_{F0}}, \tag{10}$$

where $e_{\underline{\epsilon},\ p_F} = -\frac{\partial E\epsilon_t}{\partial p_F}\frac{p_{Ft}}{E\epsilon_t} > 0$ is the elasticity of expected low emissions to the price of fossil fuels, and the other variables e are elasticities of the first variable in lower case to the second variable. The elasticities are all defined so that they are positive, and they are assumed 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. Lobbying modifies the rule, however. Firstly, since a higher (domestic) price of fossil fuels increases the input cost to the biofuels sector, lobbying along with considerations of general welfare lower the tariff rate (the term $(a+1)\,F_{Bt}$, both in the numerator and the denominator). Secondly, both the fossil fuels and the biofuels sectors' lobbying lowers (raises) the denominator (numerator) 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 (greater) the denominator (numerator) 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 (10) is positive, however; otherwise lobbying would promote an import subsidy.

In the numerator of (10), the three first terms arise from lobbying and were explained above. 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 the tariff on fuels is the only policy instrument available for internalizing the externality from emissions.

The tariff rate in (10) determines the domestic production of both biofuels and fossil fuels for time $t = 0$, i.e., 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 production of biofuels is given by $y^w_{B0}\,(p^w_{F0})$.

4 Policy in the presence of a biofuels mandate

In this section we solve a game at time period $t = 1$ ($t = 2$). In the first (unmodelled) stage in period $t = 1$, the local governments determine their biofuels mandates.[11] 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.

[11] The result from solving for the biofuels mandates is uninteresting. It is available at request from the author.

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 expects emissions from the production of biofuels to be 'low' ('high'). Once the vector of domestic prices is known, the two fuel producing sectors adjust their factor demands and production. The game is solved backwards.

4.1 Changes in factor demand and production

The introduction of the biofuels mandates, $\widehat{\rho} = \frac{\sum_m \widehat{\rho_m}}{m}$, fix the share of biofuels in the production of road transport. The total mandate is assumed to be set at a level which increases 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 trade policy, domestic production of biofuels will not fall after the policy revisions.*

Proof. The domestic production of biofuels is determined by their domestic price. Thus, for production not to fall we must have

$$\widehat{p_{Bt}} \geq p_{F0}. \tag{11}$$

Given that the total biofuels mandate is binding, the world market price of biofuels must increase when the mandates are introduced, i.e., $\widehat{p_{Bt}^w} > p_{F0}^w$. Then, for (11) to hold it is sufficient that $\frac{\widehat{p_{Bt}^w}}{p_{F0}^w} > \frac{1+\theta_{F0}}{1+\widehat{\theta_{Bt}}}$, where the LHS is greater than 1. Then, at all $\widehat{\theta_{Bt}} \geq \theta_{F0}$, and at some $\widehat{\theta_{Bt}} < \theta_{F0}$ where either $\frac{\widehat{p_{Bt}^w}}{p_{F0}^w}$ is large or $\widehat{\theta_{Bt}}$ is not much lower than θ_{F0}, (11) holds. ■

An import tariff leads to the replacement of foreign biofuels with domestic, given the total biofuels mandate. This lowers the world market price of biofuels, $\widehat{p_{Bt}^w}$, 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 production changes, the biofuels sector's factor demand also changes. If $\widehat{p_{Bt}} > p_{F0}$, the production of biofuels increases, 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 Appendix 6, 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

Maximizing the interest groups' objective functions (3) with respect to the tariff rate on biofuels in the presence of a biofuels mandate 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 (7) with respect to the tariff rate on biofuels into (9) yields

$$\widehat{y_{Bt}} + a \left[-\widehat{m_{Bt}} \frac{\partial p_B^w}{\partial \widehat{p_B}} + \theta_{Ft} p_{Ft}^w \frac{\partial \widehat{m_{Ft}}}{\partial \widehat{p_B}} - \phi' \left(E\widehat{\epsilon_t} \right) \frac{dE\widehat{\epsilon_t}}{d\widehat{p_B}} \right] = 0. \tag{12}$$

Imports of both types of fuels fall with a higher price of biofuels: $\frac{\partial \widehat{m_{Bt}}}{\partial \widehat{p_B}} < 0$ and $\frac{\partial \widehat{m_{Ft}}}{\partial \widehat{p_B}} < 0$. Simplifying (12) yields the equilibrium tariff rate on biofuels in the presence of a biofuels mandate:

$$\widehat{\theta_{Bt}} = \frac{\widehat{y_{Bt}} + a \left[\widehat{m_{Bt}} e_{p_B^w,\ \widehat{p_B}} - \theta_{Ft} \frac{p_{Ft}^w}{p_{Bt}^w} \widehat{m_{Ft}} e_{\widehat{m_F},\ \widehat{p_B}} \pm \frac{\phi'(E\widehat{\epsilon_t}) E\widehat{\epsilon_t}}{p_B^w} e_{E\widehat{\epsilon},\ \widehat{p_B}} \right]}{a\widehat{m_{Bt}} e_{\widehat{m_B},\ \widehat{p_B}} - \widehat{y_{Bt}}}. \tag{13}$$

The elasticities of expected emissions to p_B are $e_{\widehat{\underline{\epsilon}},\ p_B} = -\frac{d\widehat{\underline{\epsilon_1}}}{d\widehat{p_B}} \frac{\widehat{p_{B1}}}{\widehat{\underline{\epsilon_1}}} > 0$ at $t = 1$ with expected 'low' emissions, and $e_{\widehat{\overline{\epsilon}},\ p_B} = \frac{d\widehat{\overline{\epsilon_2}}}{d\widehat{p_B}} \frac{\widehat{p_{B2}}}{\widehat{\overline{\epsilon_2}}} > 0$ at $t = 2$ with 'high' emissions. The $\pm$ sign is positive for 'low' emissions and negative for 'high' ones.

Even here the tariff equation yields a modified Ramsay rule (compare with (10)), with the elasticity of biofuels import demand entering the denominator. Biofuels sector's lobbying again serves to decrease the denominator. 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

$$a > \frac{\widehat{y_{Bt}}}{\widehat{m_{Bt}} e_{\widehat{m_B},\ p_B}}. \tag{14}$$

In the numerator of (13), lobbying by the biofuels sector serves to raise the tariff rate. In the square brackets, the first term denotes the terms-of-trade effect of the biofuels tariff, which gives an incentive to impose a tariff on biofuels regardless (see also (10)). The second term 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. This effect was missing from Equation (10). Finally, even in the presence of a biofuels mandate, the emission term enters 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, making a greater domestic production possible and thus increasing the share of domestically produced biofuels in the mix. This has consequences to emissions, which were delineated above. We continue by examining the socially optimal tariff rates. The tariff equation in social optimum (as $a \to \infty$) simplifies to

$$\widehat{\theta_{Bt}^{so}} = \frac{\widehat{m_{Bt}} e_{p_B^w,\ \widehat{p_B}} - \theta_{Ft} \frac{p_{Ft}^w}{p_B^w} \widehat{m_{Ft}} e_{\widehat{m_F},\ \widehat{p_B}} \pm \frac{\phi'(E\widehat{\epsilon_t}) E\widehat{\epsilon_t}}{p_B^w} e_{E\widehat{\epsilon},\ \widehat{p_B}}}{\widehat{m_{Bt}} e_{\widehat{m_B},\ \widehat{p_B}}}. \tag{15}$$

Proposition 2 *The socially optimal tariff rate will always be higher when emissions are expected to be 'low' (at $t = 1$) than when they are 'high' (at $t = 2$).*

Proof. We prove Proposition 2 by contradiction. Therefore, we write $\widehat{\theta_{B2}^{\bar{\epsilon}so}} > \widehat{\theta_{B1}^{\epsilon so}}$, substitute and simplify to obtain

$$\left(\widehat{m_{B2}^{\bar{\epsilon}}} - \widehat{m_{B1}^{\underline{\epsilon}}}\right) > \frac{\phi'\left(\underline{\widehat{\epsilon_1}}\right) \underline{\widehat{\epsilon_1}} \widehat{m_B^{\bar{\epsilon}}} e_{\underline{\widehat{\epsilon}},\ \widehat{p_B}} + \phi'\left(\widehat{\overline{\epsilon_2}}\right) \widehat{\overline{\epsilon_2}} \widehat{m_B^{\underline{\epsilon}}} e_{\widehat{\bar{\epsilon}},\ \widehat{p_B}}}{\theta_F p_F^w \widehat{m_F} e_{\widehat{m_F},\ \widehat{p_B}}}.$$

If $\widehat{\theta^{\overline{\epsilon}so}_{B2}} > \widehat{\theta^{\underline{\epsilon}so}_{B1}}$ as assumed, the LHS is negative, since a higher tariff rate lowers imports. The RHS is unambiguously positive. Then, LHS $<$ RHS, and consequently $\widehat{\theta^{\overline{\epsilon}so}_{Bt}} > \widehat{\theta^{\underline{\epsilon}so}_{Bt}}$ is impossible. ■

We continue by examining whether it is possible for the politically optimal tariff rate with 'high' emissions (at $t = 2$) to exceed the tariff rate at expected 'low' emissions (at $t = 1$). We formulate the following Proposition:

Proposition 3 *If the government is susceptible to lobbying, the tariff rate on biofuels can be set at a higher level if the government assumes 'high' emissions than if it assumes 'low' emissions, i.e.,* $\widehat{\theta^{\overline{\epsilon}}_{B2}} > \widehat{\theta^{\underline{\epsilon}}_{B1}}$ *is possible.*

Proof. As the biofuels sector's contribution is determined by (8), its contribution is a function of the chosen tariff level, $\widehat{\theta_{Bt}}$. We denote these by $y^{\underline{\epsilon}}_{B1}$ for 'low' emissions and by $y^{\overline{\epsilon}}_{B2}$ 'high' emissions. We use the tariff equations from (13) and examine when $\widehat{\theta^{\overline{\epsilon}}_{B2}} > \widehat{\theta^{\underline{\epsilon}}_{B1}}$, taking into account that $\widehat{m^{\overline{\epsilon}}_{F2}} = \widehat{m^{\underline{\epsilon}}_{F1}}$ since the share of fossil fuels in road transport is fixed and imports are not affected by the level of emissions from biofuels. Using (14) to simplify the denominator (writing $a = \frac{I_B \widehat{y_{Bt}} + \omega}{\widehat{m_{Bt}} e_{\widehat{m_B},\, p_B}}$) yields

$$\left(\widehat{y^{\overline{\epsilon}}_{B2}} - \widehat{y^{\underline{\epsilon}}_{B1}}\right) > a \left[\left(\widehat{m^{\underline{\epsilon}}_{B1}} - \widehat{m^{\overline{\epsilon}}_{B2}}\right) e_{p^w_B,\, \widehat{p_B}} + \frac{\phi'\left(\widehat{\underline{\epsilon_1}}\right)}{\widehat{p^w_B}} \widehat{\underline{\epsilon_1}} e_{\widehat{\underline{\epsilon}},\, p_B} + \frac{\phi'\left(\widehat{\overline{\epsilon_2}}\right)}{\widehat{p^w_B}} \widehat{\overline{\epsilon_2}} e_{\widehat{\overline{\epsilon}},\, p_B}\right]. \tag{16}$$

$\widehat{\theta^{\overline{\epsilon}}_{B2}} > \widehat{\theta^{\underline{\epsilon}}_{B1}}$ signifies $\widehat{y^{\overline{\epsilon}}_{B2}} > \widehat{y^{\underline{\epsilon}}_{B1}}$ since a higher tariff rate increases domestic production. Furthermore, it indicates that $\widehat{m^{\underline{\epsilon}}_{B1}} > \widehat{m^{\overline{\epsilon}}_{B2}}$ since a higher tariff lowers imports. Thus, both the LHS and the RHS of (16) are positive. $\widehat{\theta^{\overline{\epsilon}}_{B2}} > \widehat{\theta^{\underline{\epsilon}}_{B1}}$ is then possible at a sufficiently low level of a:

$$a < \frac{\widehat{y^{\overline{\epsilon}}_{B2}} - \widehat{y^{\underline{\epsilon}}_{B1}}}{\left(\widehat{m^{\underline{\epsilon}}_{B1}} - \widehat{m^{\overline{\epsilon}}_{B2}}\right) e_{p^w_B,\, \widehat{p_B}} + \frac{\phi'\left(\widehat{\underline{\epsilon_1}}\right)}{\widehat{p^w_B}} \widehat{\underline{\epsilon_1}} e_{\widehat{\underline{\epsilon}},\, p_B} + \frac{\phi'\left(\widehat{\overline{\epsilon_2}}\right)}{\widehat{p^w_B}} \widehat{\overline{\epsilon_2}} e_{\widehat{\overline{\epsilon}},\, p_B}}, \tag{17}$$

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

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, $\widehat{y_{Bt}}$, in respective time period. If the biofuels sector expects its production to grow in the next period, it will invest more in lobbying 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 SIGs contribution decision.

4.3 Policy persistence

In this section we examine the persistence and path dependency of policy. 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 $t = \{1,\ 2\}$, right after the adjustment of the tariff rate, the biofuels producers produce approximately the same amount as during the last moments of period $t-1$, and then adjust their production. In order to take this effect into account we adjust the first derivative of the objective function (3) so that this becomes (including a discount parameter δ):

$$\frac{\partial C_{Bt}}{\partial p_F} = \frac{\partial W_{Bt}}{\partial p_F} = (y_{Bt-1} - F_{Bt-1}) + \delta\left(y_{Bt} - F_{Bt}\right), \tag{18}$$

$$\frac{\partial \widehat{C_{Bt}}}{\partial \widehat{p_{Bt}}} = \frac{\partial \widehat{W_{Bt}}}{\partial \widehat{p_{Bt}}} = \widehat{y_{Bt-1}} + \delta \widehat{y_{Bt}}. \tag{19}$$

where (18) applies in the absence of biofuels mandates and (19) in the presence of the mandates.[12] 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 $\widehat{p_{B1}} \geq p_{F0}$, the marginal lobbying effort of the biofuels sector in the presence of a biofuels mandate exceeds the effort in the*

[12]The second order conditions of the contribution functions are $\frac{\partial^2 C_{Bt}}{\partial p_F^2} = \frac{\partial y_{Bt-1}}{\partial p_F} - \frac{\partial F_{Bt-1}}{\partial p_F} + \delta\left(\frac{\partial y_{Bt}}{\partial p_F} - \frac{\partial F_{Bt}}{\partial p_F}\right) > 0$ in the absence of biofuels mandates, as long as the own price effect on production exceeds the effect on factor (fossil fuel) demand, and $\frac{\partial^2 \widehat{C_{Bt}}}{\partial \widehat{p_{Bt}}^2} = \frac{\partial \widehat{y_{Bt-1}}}{\partial \widehat{p_{Bt}}} + \delta \frac{\partial \widehat{y_{Bt}}}{\partial \widehat{p_{Bt}}} > 0$ in the presence of biofuels mandates. The contribution functions are thus convex, i.e., a higher marginal contribution elicits a higher absolute contribution.

absence of a mandate. If $\widehat{p_{B1}} < p_{F0}$, it is possible but not certain that this is the case.

Proof. Starting with the former case ($\widehat{p_{B1}} \geq p_{F0}$), we prove Proposition 4 by contradiction. From Lemma 1 we know that as long as $\widehat{p_{B1}} \geq p_{F0}$, the domestic production of biofuels at $t = 1$ is no smaller than the production in $t = 0$: $\widehat{y_{B1}} \geq y_{B0}$. Examining when $\frac{\partial \widehat{C_{B1}}}{\partial \widehat{p_{B1}}} \leq \frac{\partial C_{B0}}{\partial p_{F0}}$, using Equations (18) and (19) and rearranging yields

$$\widehat{y_{B1}} \leq \frac{1}{\delta}(y_{B0-1} - y_{B0}) + y_{B0} - \frac{1}{\delta}F_{B0-1} - F_{B0}, \tag{20}$$

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) $t = (0 - 1)$. Differentiating (20) w.r.t. y_{B0} yields $-\frac{1}{\delta} + 1 < 0$ since $\frac{1}{\delta} > 0$ as long as $\delta < 1$, i.e., (20) falls the greater is y_{B0}. The highest value that $\widehat{y_{B1}}$ can take for (20) to be satisfied is thus when y_{B0} is at its lowest, i.e., when $y_{B0} = y_{B0-1}$. Substituting into (20) yields

$$\widehat{y_{B1}} \leq y_{B0-1} - \frac{1}{\delta}F_{B0-1} - F_{B0}. \tag{21}$$

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 $F_{Bt} > 0$ ($t = \{0 - 1,\ 0\}$), the LHS of (21) always exceeds the RHS, and it must be that the marginal lobbying effort in the presence of a biofuels mandate exceeds the marginal effort in the absence of a mandate.

If $\widehat{p_{B1}} < p_{F0}$, however, $\widehat{y_{B1}} < y_{B0} = y_{B0-1}$. In this case, we cannot do the last substitution, and while it is possible that the LHS of (20) still exceeds the RHS for certain values of the parameters, it is easy to see that this no longer is always the case. ■

For two time periods with biofuels mandates we formulate the following Proposition:

Proposition 5 *Given that $\widehat{p_{Bt}} \geq p_{F0}$, the biofuels sector's marginal political contribution is at least as high at 'high' emissions as it is at 'low' emissions, when there are biofuels mandates in place at both time periods.*

Proof. For two time periods with a mandate, $t = \{1,\ 2\}$, we examine when the marginal contribution at a later period is *lower* than the marginal contribution at an earlier period. Substituting in from (19) simplifies to

$$\widehat{y_{B2}} < \frac{1}{\delta}\left(y_{B0} - \widehat{y_{B1}}\right) + \widehat{y_{B1}}. \tag{22}$$

Again, an increase in $\widehat{y_{B1}}$ leads to a fall on the RHS of (22). If $\widehat{p_{Bt}} \geq p_{F0}$, from Lemma 1 $\widehat{y_{Bt}} \geq y_{B0}$. Substituting in $\widehat{y_{B1}} = y_{B0}$ yields $\widehat{y_{B2}} < \widehat{y_{B1}} = y_{B0}$. But because of Lemma 1, even in this case the lobbying effort at $t = 2$ is at least as high as during 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. 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.

We end by examining when policy may be 'path dependent'. With this we mean that if information about 'high' emissions were available already at $t = 1$, then a tariff rate $\widehat{\theta_{B1}^{\bar{\epsilon}}}$ would be chosen then, and the tariff would be adjusted at once both for the introduction of the biofuels mandates and the 'high' emissions. Otherwise, a tariff $\widehat{\theta_{B1}^{\epsilon}}$ is chosen at $t = 1$, the biofuels sector adjusts its production, and first at $t = 2$ is the trade policy adjusted for 'high' emissions. The question is then whether $\widehat{\theta_{B1}^{\bar{\epsilon}}}$ may exceed $\widehat{\theta_{B2}^{\bar{\epsilon}}}$ or vice versa.

Proposition 6 *Biofuels trade policy may be path dependent if the government is susceptible to lobbying and given that* $\widehat{p_{Bt}} \geq p_{F0}$.

Proof. We prove Proposition 6 by examining when is $\widehat{\theta_{B1}^{\bar{\epsilon}}} \leq \widehat{\theta_{B2}^{\bar{\epsilon}}}$. Instead of the marginal welfare change, we insert the marginal contribution, $\frac{\partial \widehat{C_{Bt}}}{\partial \widehat{p_{Bt}}}$ by the biofuels sector in the numerator of Equation (13). Using (14) and simplifying yields the following condition:

$$\frac{\partial \widehat{C_{B1}}}{\partial \widehat{p_{B1}}} - \frac{\partial \widehat{C_{B2}}}{\partial \widehat{p_{B2}}} < a \left[\left(\widehat{m^{\epsilon}_{B2}} - \widehat{m^{\epsilon}_{B1}} \right) e_{p^w_B,\ \widehat{p_B}} + \left(\frac{\phi'(\widehat{\epsilon_1})}{\widehat{p^w_B}} \widehat{\epsilon_1} - \frac{\phi'(\widehat{\epsilon_2})}{\widehat{p^w_B}} \widehat{\epsilon_2} \right) e_{\widehat{\epsilon},\ p_B} \right]. \tag{23}$$

From Proposition 5 we know that $\frac{\partial \widehat{C_{B1}}}{\partial \widehat{p_{B1}}} - \frac{\partial \widehat{C_{B2}}}{\partial \widehat{p_{B2}}} \leq 0$ given that $\widehat{p_{Bt}} \geq p_{F0}$. Furthermore, from Lemma 1, $\widehat{y^{\epsilon}_{B1}} - \widehat{y^{\epsilon}_{B2}} \leq 0$, which implies that $\widehat{m^{\epsilon}_{B2}} - \widehat{m^{\epsilon}_{B1}} \leq 0$ since higher domestic production lowers imports, and $\frac{\phi'(\widehat{\epsilon_1})}{\widehat{p^w_B}} \widehat{\epsilon_1} - \frac{\phi'(\widehat{\epsilon_2})}{\widehat{p^w_B}} \widehat{\epsilon_2} \leq 0$ since emissions are determined by the level of domestic production of biofuels and increase in greater production. Solving (23) for a yields

$$a \leq \frac{\widehat{C'^{\epsilon}_{B1}} - \widehat{C'^{\epsilon}_{B2}}}{\left(\widehat{m^{\epsilon}_{B2}} - \widehat{m^{\epsilon}_{B1}} \right) e_{p^w_B,\ \widehat{p_B}} + \left(\frac{\phi'(\widehat{\epsilon_1})}{\widehat{p^w_B}} \widehat{\epsilon_1} - \frac{\phi'(\widehat{\epsilon_2})}{\widehat{p^w_B}} \widehat{\epsilon_2} \right) e_{\widehat{\epsilon},\ p_B}}. \tag{24}$$

In other words, given that $\widehat{p_{Bt}} \geq p_{F0}$ 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 'path dependent'. ■

As was the case in Propositions 4 (and 5), 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.

The policy persistence model here can usefully be compared to that by Coate and Morris (1999, p. 1327), who show that "policy persistence may give rise to political failure, in the sense that the policy sequence emerging in political equilibrium can be Pareto dominated. Political failure arises because voters forgo support for policies which provide temporary efficiency benefits, anticipating that they will persist once they have been implemented." Here, we do not implicitly model the policy process of choosing whether to implement the biofuels mandates or not, but show that once the mandate is in place, even if new information about emissions comes available, the direction of change in trade taxation may well be to raise the tariff, not to lower it in order to take into account new information. The driving force is lobbying, where the biofuels sector, like the sector gaining support in Coate and Morris' model, has adjusted to the support policy, and continues to lobby for a retained level of trade protection.

5 Conclusions

We have developed a model of trade policy determination for the biofuels sector, where the production of biofuels may either raise or lower the emissions of greenhouse gases. We examine trade policy both in the absence, and in the presence of (local) biofuels mandates. Our main results pertain to the situation with biofuels mandates in place, however. We show that it would be optimal from a societal point of view to lower the tariff rate on biofuels if information about 'high' emissions becomes available. If the government is sufficiently susceptible to lobbying, it may be that the tariff rate is raised instead of lowered when information about 'high' emissions comes out, however.

We further show that as long as the domestic price of biofuels does not fall after the introduction of biofuels mandates, the marginal lobbying effort by that sector will not fall. Even if the domestic price falls, the marginal lobbying effort may increase (or remain constant). At the present level of generality we cannot show this analytically, however. The result holds even for two time periods with biofuels mandates, again given that the domestic price of biofuels does not fall. Since the political contribution function is convex in the own domestic price, a higher marginal contribution translates to a higher contribution.

We are then able to show that the biofuels trade policy may be persistent, i.e., a once imposed high tariff rate will not be lowerd, given that the domestic price of biofuels does not fall due to the introduction of biofuels mandates. We end by showing that the policy may furthermore be path dependent in the sense that if the policy was adjusted to 'high' emissions earlier (at the first time period), the resulting tariff rate would be lower than the tariff rate that will be determined when information about 'high' emissions becomes available first later (at the second time period). The terms persisten and path dependent are closely related, but we want to make the difference between the two clear.

The present model contributes, within the confines of a specific model and examining a specific sector, to our understanding of why once determined high tariffs may be difficult to change, even if new information comes out. In period zero in our model, tariffs were motivated by the fact that no other policy instrument was available for internalising the negative external effect from greenhouse gas emissions. Implementing biofuels mandates and adjusting trade policy to these may, however, under imperfect information, lead to a sub-optimal situation if it is later shown that the production of biofuels is indeed very energy intensive. By then it may be too late to change earlier policies supporting the domestic production of biofuels. The model also gives some insights to why, for instance, the EU does not lower the tariff on biofuels despite the fact that from a climate point of view, Brazilian ethanol, produced from sugar cane, would be much better than the domestically produced biofuels.

The model in this paper makes one particularly gross simplification, namely 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 mandates; 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.

References

Aidt, T. S. (1998). Political internalization of economic externalities and environmental policy. *Journal of Public Economics 69*, 1–16.

Bombardini, M. (2008). Firm heterogeneity and lobby participation. *Journal of International Economics 75*, 329–348.

Cadot, O., L.-H. Röller, and A. Stephan (2006). Contribution to productivity or pork barrel? the two faces of infrastructure investment. *Journal of Public Economics 90*(6-7), 1133–1153.

Coate, S. and S. Morris (1999). Policy persistence. *American Economic Review 89*(5), 1327–1336.

Crutzen, P., A. Mosier, K. Smith, and W. Winiwarter (2008). N2o release from agro-biofuel production negates global warming reduction by replacing fossil fuels. *Atmospheric Chemistry and Physics 8*(2), 389–395.

Damania, R. (2002). Influence in decline: Lobbying in contracting industries. *Economics and Politics 14*(2), 209–223.

de Gorter, H. and D. R. Just (2009). The economics of a blend mandate for biofuels. *American Journal of Agricultural Economics 91*(3), 738–750.

Dixit, A. (1996). Special-interest lobbying and endogenous commodity taxation. *Eastern Economic Journal 22*(4), 375–388.

Energimyndigheten (2009). Kvotpliktsystem för biodrivmedel. energimyndighetens förslag till utformning. Technical report, Energimyndigheten.

Fargione, J., J. Hill, D. Tilman, S. Polasky, and P. Hawthorne (2008). Land clearing and the biofuel carbon debt. *Science 319*, 1235–1238.

Fredriksson, P. G. (1997). The political economy of pollution taxes in a small open economy. *Journal of Environmental Economics and Management 33*(1), 44–58.

Goldberg, P. K. and G. Maggi (1999). Protection for sale: An empirical investigation. *American Economic Review 89*(5), 1135–1155.

Grossman, G. M. and E. Helpman (1994). Protection for sale. *American Economic Review 84*(4), 833–850.

Grossman, G. M. and E. Helpman (1995). Trade wars and trade talks. *Journal of Political Economy 103*(4), 675–708.

Jussila Hammes, J. (2009). Biofuels production versus forestry in the presence of lobbies and technological change. *S-WoPEc Working Paper 2009:7*.

Le Breton, M. and F. Salanie (2003). Lobbying under political uncertainty. *Journal of Public Economics 87*(12), 2589–2610.

Magee, C. (2002). Endogenous trade policy and lobby formation: An application to the free-rider problem. *Journal of International Economics 57*(2), 449–471.

Melillo, J. M., J. M. Reilly, D. W. Kicklighter, A. C. Gurgel, T. W. Cronin, S. Paltsev, B. S. Felzer, X. Wang, A. P. Sokolov, and C. A. Schlosser (2009). Indirect emissions from biofuels: How important? *Science Sciencexpress*, 1–8.

Mitra, D. (1999). Endogenous lobby formation and endogenous protection: A long-run model of trade policy determination. *American Economic Review 89*(5), 1116–1134.

Olson, M. (1965). *The Logic of Collective Action: Public Goods and the Theory of Groups*. Cambridge, Mass.: Harvard University Press.

Ploeg, F. v. d. and C. Withagen (2010). Is there really a green paradox? *CESifo Working paper No. 2963*.

Searchinger, T. D., R. Heimlich, R. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokoz, D. Hayes, and T.-H. Yu (2008). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science 319*, 1238–1240.

Soimakallio, S., T. Mäkinen, T. Ekholm, K. Pahkala, H. Mikkola, and T. Pappanen (2009). Greenhouse gas balances of transportation biofuels, electricity and heat generation in finland - dealing with the uncertainties. *Energy Policy 37*, 80–90.

Wibe, S. (2010). Etanolens koldioxideffekter. en översikt av forskningsläget. *Rapport till Expertgruppen för miljöstudier 2010: 1*.

6 Appendix

We differentiate domestic emissions with respect to the (total) biofuels mandate:

$$\frac{d\widehat{\epsilon_t^d}}{d\widehat{\rho}} = \varepsilon N \left[(1-\widehat{\rho}) \frac{\partial \widehat{d_{Rt}}}{\partial \widehat{p_R}} \left(\widehat{p_{Bt}} - \widehat{p_{Ft}} + \widehat{\rho} \frac{\partial \widehat{p_B}}{\partial \widehat{\rho}} + (1-\widehat{\rho}) \frac{\partial \widehat{p_F}}{\partial \widehat{\rho}} \right) - \widehat{d_{Rt}} \right]$$
$$+ \left[\varepsilon E \frac{\partial \widehat{X_B}}{\partial \widehat{p_B}} + E\mu^d \frac{\partial \widehat{D_B}}{\partial \widehat{p_B}} \right] \frac{\partial \widehat{p_B}}{\partial \widehat{\rho}} + \left[\varepsilon E \frac{\partial \widehat{X_B}}{\partial \widehat{p_F}} + E\mu^d \frac{\partial \widehat{D_B}}{\partial \widehat{p_F}} \right] \frac{\partial \widehat{p_F}}{\partial \widehat{\rho}}. \quad (25)$$

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.

The two terms on the second line of (25) 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 rising above that of fossil fuels. This in turn raises demand for fossil fuels and land as input factors to biofuels production. The term in the first square brackets is thus positive. 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 (25).

We differentiate domestic emissions with the domestic price of biofuels:

$$\frac{d\epsilon_t^d}{dp_{Bt}} = \varepsilon N (1-\widehat{\rho}) \widehat{\rho} \frac{\partial d_{Rt}}{\partial p_{Rt}} + \varepsilon E \frac{\partial X_{Bt}}{\partial p_{Bt}} + E\mu^d \frac{\partial D_{Bt}}{\partial p_{Bt}}, \quad (26)$$

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, which are positive, reflect the increased demand for production factors in the production of biofuels as the higher price of biofuels induces more (domestic) production. The net effect is determined by whether the first, or the second and third terms dominate (26).

Finally, we differentiate domestic emissions with the domestic price of fossil fuels:

$$\frac{d\epsilon_t^d}{dp_F} = \varepsilon \left[N (1-\rho)^2 \frac{\partial d_{Rt}}{dp_F} + E \frac{\partial X_B}{\partial p_F} + E \frac{\partial X_B}{\partial p_B} \frac{\partial p_B}{\partial p_F} \right] + E\mu^d \left[\frac{\partial D_B}{\partial p_F} + \frac{\partial D_B}{\partial p_B} \frac{\partial p_B}{\partial p_F} \right] < 0, \quad (27)$$

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 is positive, reflecting the increase in biofuels output price in the absence of biofuels mandates. The sign of the first term in the latter square brackets is positive if land and fossil fuels are substitutes in the production of biofuels, and negative if they are complements. The second term is positive.