UNIVERSITÄT SIEGEN

Fakultät III
Wirtschaftswissenschaften,
Wirtschaftsinformatik und
Wirtschaftsrecht

Volkswirtschaftliche Diskussionsbeiträge

Discussion Papers in Economics

No. 150-11

November 2011

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Universität Siegen
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Hölderlinstraße 3
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http://www.uni-siegen.de/fb5/vwl/

ISSN 1869-0211

Available for free from the University of Siegen website at
http://www.uni-siegen.de/fb5/vwl/research/diskussionsbeitraege/

Discussion Papers in Economics of the University of Siegen are indexed in RePEc
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Competitive trilateral lobbying for and against subsidizing green energy

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Abstract. A small open economy operates a carbon emission trading scheme and subsidizes green energy. Taking cap-and-trade as given, we seek to explain the subsidy as the outcome of a trilateral tug of war between the 'green' energy industry, the 'black' energy industry and consumers. With parametric functions we fully solve the competitive economic equilibrium and the lobbying Nash equilibrium. We show how the resultant subsidy depends on the political influence of all three lobbying groups and we trace its determinants. Whether consumers have 'green preferences' turns out to be crucial for the results.

JEL classification: Q42, Q43, Q52, Q54, D72, D78, H23

Keywords: green preferences, fossil fuel, green energy, green energy subsidy, cap-and-trade, overlapping regulation, competitive lobbying,

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Competitive trilateral lobbying for and against subsidizing green energy

Rüdiger Pethig, University of Siegen

1 The problem

Many countries have adopted policies to curb carbon emissions and promote renewable energy with a wide variety of policy instruments. Prominent are command-and-control measures, energy or emission taxes, cap-and-trade schemes, implicit or explicit green energy subsidies, and/or renewable portfolio standards with either tradable green certificates or feed-in tariffs. To keep focused, we will consider an economy that fights climate change via an economy-wide cap-and-trade scheme for carbon emissions and, in addition, sets up a per-unit subsidy on green energy. Notwithstanding practical complexities, the stand-alone cap-and-trade scheme tends to implement the (binding) carbon cap in a cost effective way. It follows that if we focus on the climate policy target exclusively, the overlapping green energy subsidy creates an excess cost because it is distortionary and, by policy design, leaves unchanged the level of carbon emissions. The theoretical and applied economic literature (e.g. Fischer and Newell 2008, Böhringer et al. 2009) widely agrees on that conclusion.[1]

To provide a convincing economic rationale for double regulation we therefore need to examine possible market imperfections other than the climate externality the green energy subsidy might be capable to alleviate. The theoretical literature on green energy promotion addresses learning-by-doing and technology spillovers (e.g. Fischer 2008, Bläsi and Requate 2010) and some other distortions such as imperfect property rights or information (e.g. Ben-near and Stavins 2007). However, there appears to be little agreement on whether such market imperfections are empirically relevant enough to make the case for green energy subsidies. Toman (1993) surveys potential externalities relating to insecurity of energy supply and argues that more analysis is needed to demonstrate that there are substantial external cost spill-overs associated with import dependence. Eichner and Pethig (2010) reach a similar conclu-

[1] In a report to the ministry, the Scientific Council to the German Federal Ministry of Economic Affairs (2004) recommended terminating the promotion of green energy on the grounds that the introduction of the European emission trading scheme has turned the promotion of green energy into an ecologically useless and economically expensive instrument.

sion in a model with risk avers consumers. Overall, welfare economic arguments in favor of overlapping subsidies to green energy do not yet seem to be sufficiently substantiated on scientific terms (Böhringer et al. 2010). Our assessment is that the reasons for governments to subsidize green energy are not compelling.

That assessment is in stark contrast with the practice of double regulation in many countries. We therefore suggest searching for an explanation in the realm of political economy. That is, we will focus on the political decision making process that accounts for the preferences of consumer-voters and/or for the political influence and activity of pressure groups in favor of or against green energy subsidies. Along with consumers we envisage the industries producing *green* energy from regenerative resources and *black* energy from fossil fuel as relevant stakeholders in the formation of subsidy policy. Throughout the paper these three groups are assumed to take a predetermined cap-and-trade scheme as given and seek to shift the subsidy rate in their group's favor against the resistance of at least one other group.

Suppose first, a well-informed[2] median consumer-voter adopts the economists' prevailing view on overlapping green energy subsidies outlined above and is asked to vote on the subsidy rate. As she would then rightly expect a utility loss from the green energy subsidy (to be demonstrated below in analytical terms) she would clearly vote against its introduction, unless her preferences have a green component amounting to a positive willingness to pay for green energy. We interpret that *green preference* - which consumers may or may not have - as their desire (and willingness to pay) for a sustainable development, their desire to reduce and eventually phase out the consumption of fossil fuel and/or, perhaps, their desire to reduce the dependence on insecure fossil fuel imports.

The straightforward conclusion is that if one takes the standard median-voter approach in isolation, green preferences are necessary and sufficient for explaining the existence of the subsidy. That is less clear, however, if we add to the scenario the industries producing green and black energy as important stakeholders in the formation of subsidy. As expected, the black industry turns out to be against and the green industry in favor of the subsidy. In the present paper we model both industries as well as the 'group of consumers' as pressure groups, where the consumer group may owe its political influence partly to its political weight

[2] Incomplete or incorrect information on the part of consumers may be an important issue that we do not address. For example, the environmental group BUND has argued in a recent message that the subsidized expansion of green energy is the so far most successful climate policy measure in Germany.

as voters (see above) and partly to their own lobbying activity. The policy makers fix the subsidy rate by responding to the complementary or countervailing pressure of these three interacting stakeholders. The lobby groups play Nash in a general equilibrium model of a small open economy, and our principal interest is to identify the determinants of the sign and magnitude of the subsidy rate resulting from pressure group competition.

In the large literature on the economic theory of policy, analyses of voting, special interest groups, rent seeking and pressure group competition (e.g. Olson 1965, Becker 1983, Mueller 2003) are well established. Yet many theoretical studies on pressure group competition focus on two groups only. We are not aware of analytical studies on pressure group competition aimed at explaining the introduction of green energy subsidies observed in practice.

The paper is organized as follows. Section 2 develops the parametric model of a small open economy. Section 3 solves the competitive equilibrium in that economy for alternative predetermined rates of the green energy subsidy and shows how the stakeholder groups benefit or lose from exogenous variations in the subsidy rate. Section 4 introduces simple hypotheses on how the three stakeholder groups build up political pressure and under which conditions and how their political influence contributes to fixing the subsidy rate. Section 5 concludes.

2 The economy

Figure 1 illustrates the structure of the simple model. The economy produces three goods: a consumption good, energy from fossil fuel (called black energy, for short) and energy from renewable resources (called green energy).

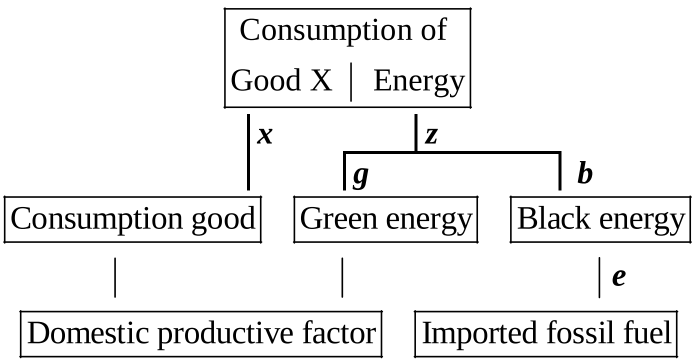

Figure 1: The structure of the model

Both types of energy are perfect substitutes. All fossil fuel, *e,* is imported and is used as an input in the production of black energy. For the benefit of informative results we resort to parametric functions. Carbon emissions are proportional to fossil fuel. The analytical model is completely described as follows.

$x = x_o - \frac{\xi}{2} g^2$	Possibilities of producing consumption good *X* and green energy *G* (= the *green industry*)	(1)
$b = e^{\beta}$	Production of black energy *B* with fossil fuel *e* (= the *black industry*)	(2)
$z_s := b + g$	Total energy supply (Black and green energy are perfect substitutes)	(3)
$u = c_0 z_d - \frac{c}{2} z_d^2 + x_d + \gamma g$	Utility of the representative consumer	(4)
$e = \overline{e}$	Permit market clearing ($\overline{e}$ = carbon emission cap)	(5)
$x - x_s - p_e e = 0$	Trade balance (good *X* = numéraire)	(6)
$x_s = x_d$	Market clearing for consumption good *X*	(7)
$z_s = z_d$	Energy market clearing	(8)
$\pi_b = p_z b - (p_e + t) e$	Profit of the black industry	(9)
$\pi_g = x + (p_z + s) g$	Profit of the green industry[3]	(10)
$y := \pi_b + \pi_g - sg + te = x - p_e e + p_z (b + g)$	National income	(11)

In the model (1) – (11), x_o, $c_0, c, \xi > 0, \gamma \geq 0$ and $\beta \in]0,1[$ are parameters and $p_e > 0$ is the exogenous import price of fossil fuel. ξ is the marginal cost of the first unit of green energy in terms of good X, formally $dx/dg\big|_{g=1} = -\xi$. We refer to γ as 'green preference pa-

[3] π_g includes the profit proper of the green industry as well as the market value of a (domestic) input that is implicit in the production possibility function (1). Ultimately, both components of π_g belong to the consumer's income, (11).

rameter', because the component γg of the utility function (4) reflects the consumers' preference for domestic green energy. Although we allow for $\gamma = 0$, $\gamma > 0$ will turn out to play a a key role for the outcome of the lobbying game.

There are three policy instruments: the emission cap $\bar{e}$ assumed to be binding, the emission permit price *t*, and the green energy subsidy *s* (green subsidy, for short). The government aims to prevent total carbon emissions (= total fossil fuel input) from exceeding the cap $\bar{e}$ and implements that goal by means of an emission trading scheme. The (endogenous) permit price *t* equilibrates the permit market[4], (5). Throughout the paper that cap-and-trade scheme will be assumed to be given. That is, our analysis of political decision making will not include the determination of the emission cap but rather focuses on the green subsidy, *s*, in an economy with the cap-and-trade scheme being preinstalled.

To prepare for the analysis of subsidy policy formation, we first need to explore how the consumers and the black and green industries are affected by alternative *exogenous* subsidy rates.

3 The competitive economy with predetermined green energy subsidy

For any given green subsidy $s \geq 0$, the allocation $(b, e, g, x, x_d, x_s, z_s, z_d)$ and the prices (p_z, t) constitute a competitive equilibrium, if $(b, e, g, x, x_d, x_s, z_s, z_d)$ and (p_z, t) satisfy (1) – (11), if the consumer maximizes (4) subject to (11) taking *g*, *y* and p_z as given, and if the industries maximize (9) and (10), respectively, taking p_z, *s* and *t* as given. In this section we will first calculate the equilibrium allocation and then determine the equilibrium levels of utility and profits.

Since $e = \bar{e}$, the first-order condition $d\pi_b / de = \beta p_z e^{\beta - 1} - p_e - t = 0$ immediately determines the permit price $t = \beta p_z \bar{e}^{\beta - 1} - p_e$ which implements the emission cap $\bar{e}$. From $d\pi_g / dg = = -\xi g + p_z + s = 0$ and (1) follows

[4] Alternatively, *t* can be interpreted as an emission tax whose rate is set as to satisfy (5).

$$g = \frac{p_z + s}{\xi} \quad \text{and} \quad x = x_o - \frac{(p_z + s)^2}{2\xi} . \tag{12}$$

The consumer maximizes with respect to z_d her utility (4) subject to $x_d = y - p_z z_d$. When we combine the resulting demand function $z_d = \frac{c_0 - p_z}{c}$ with (3) and g from (12), the equilibrium condition (8) turns into $\frac{c_0 - p_z}{c} = \frac{p_z + s}{\xi} + \bar{b}$, where $\bar{b} := \bar{e}^{\beta}$. We solve for p_z and obtain

$$p_z = \tau_0 - (1-\tau)s, \qquad \text{where}^5 \;\; \tau_0 := \tau\left(c_0 - \bar{b}c\right) \;\text{ and }\; \tau := \frac{\xi}{c+\xi} \in \left]0,1\right[. \tag{13}$$

Since we envisage an economy in which $p_z > 0$ in case of $s = 0$, it is natural to assume that the composite parameter τ_0 in (13) is positive. From $z = \frac{c_0 - p_z}{c}$ and (13) follows

$$z = \zeta_0 + \zeta s, \quad \text{where } \zeta_0 := \frac{(1-\tau)c_0 + \tau\bar{b}c}{c} = \frac{c_0 - \tau_0}{c} > 0 \;\text{ and }\; \zeta := \frac{1}{c+\xi} > 0, \tag{14}$$

$$p_z + s = \tau_0 + \tau s . \tag{15}$$

Next we determine the equilibrium utility by accounting for (3), (11), (15) and the equilibrium values g and z in (12) and (14) in the utility function $u = c_0 z - (c/2)z^2 + y - p_z z + \gamma g$. We find, after some rearrangement of terms,

$$\hat{u} = v_0 + \frac{\gamma\tau}{\xi}s - \frac{\tau}{2\xi}s^2, \qquad \text{where } v_0 := \frac{\gamma\tau_0}{\xi} + c_0\zeta_0 + x_0 - p_e\bar{e} - \frac{c\zeta_0^2}{2} - \frac{\tau_0^2}{2\xi} . \tag{16}$$

Equation (16) specifies the consumers' stakes in the green energy subsidy. Obviously, without green preferences ($\gamma = 0$) consumers lose from subsidizing green energy, because $\left(d\hat{u}/ds\right)_{\gamma=0} < 0$ and $\left(d^2\hat{u}/ds^2\right)_{\gamma=0} < 0$ for all $s \geq 0$. But the consumers' favorite subsidy rate is positive, if and only if their preferences have a green component ($\gamma > 0$). Their favorite rate is the larger, the greater is the green preference parameter γ.

[5] To avoid clutter, we define (here and below) various letters for frequently used composite terms. A list of all such terms is provided in the Appendix A.1.

Since the form (4) of the utility function is quite restrictive, concerns are justified about the robustness of (16). Yet we know from the general theory of taxation that all distortionary taxes and subsidies create excess burdens and therefore the property $\left(d\hat{u}/ds\right)_{\gamma=0} < 0$ for all $s \geq 0$ is not specific to the functional form (4). Moreover, the excess burden tends to be progressively increasing in distortionary taxes or subsidies[6] which is exactly the property of (16) ($\left(d^2\hat{u}/ds^2\right)_{\gamma=0} < 0$). One might therefore prefer replacing the utility function (4) with a more general function. Yet out tentative calculations with a Cobb-Douglas utility function turned out to get so complex that meaningful analytical results cannot be derived. That is why we will keep using (4) and (16) in the present paper.

Next consider the equilibrium profits of the industries. Making use of $t = \beta p_z \bar{e}^{\beta-1} - p_e$ in (9), of g and x from (12) in (10) and of (13) and (15) we derive

$$\hat{\pi}_b = (1-\beta)\bar{b}p_z = (1-\beta)\bar{b}\left[\tau_0 - (1-\tau)s\right] \quad \text{and} \quad \hat{\pi}_g = x_o + \frac{(p_z+s)^2}{\xi} = x_o + \frac{(\tau_0+\tau s)^2}{\xi}. \tag{18}$$

The black industry's only way to influence its profit through lobbying is to influence the energy price which, in turn, depends on the rate of the subsidy, (13). As (18) implies $d\hat{\pi}_b/ds < 0$, the black industry's interest clearly is to use its political influence for reducing the subsidy rate.[7] The green industry is affected by an increase in s through two channels. The direct effect $ds > 0$ raises the producer price from $p_z + s$ to $p_z + s + ds$. But p_z declines (see (13)) and therefore the net effect is what matters. The net effect turns out to be positive (see (15)) which implies $d\hat{\pi}_g/ds > 0$, as expected. Therefore the green industry will lobby for an increase in the subsidy. Thus we have established

Result 1.

(i) *The profit of the green industry is progressively increasing in the subsidy.*

(ii) *The profit of the black industry is linearly declining in the subsidy.*

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[6] Auerbach (1991, p. 74) shows in a partial equilibrium market model that if a single tax is imposed upon a state without taxes, the excess burden increases approximately with the square of the tax.

[7] We have disregarded in our simple model that in real economies the consumption good industry also uses substantial amounts of energy as an input. Since the price of energy is decreasing in the subsidy the energy input becomes less expensive which, in turn, would tend to increase the green industry's pressure for the subsidy.

(iii) If consumers have no green preferences ($\gamma = 0$), they suffer a loss from the subsidy which is progressively increasing in the subsidy. Otherwise, their favorite subsidy rate, s_c^*, is positive, and is the higher, the stronger are their green preferences ($s_c^* = \gamma$).

For the case $\gamma = 0$, Result 1iii is in line with the pertaining economic literature: If a cap-and-trade scheme is preinstalled and fighting climate change is considered the stand-alone political target, green energy subsidies are not only ecologically useless (by presupposition) but also create excess costs that take the form of a loss in utility here. The subsidy causes an allocative distortion as it boosts green energy production and reduces the production of the consumption good, and it also causes a shift in profits from the black to the green industry (Results 1i and 1ii). The clear message of Result 1 is that the subsidy cannot be justified on normative welfare economic grounds unless the consumers' preferences are sufficiently green. It is worthwhile noting that for all $\gamma \geq 0$ the consumers lose when a green energy *tax* ($s < 0$) is levied, because the tax is also distortionary.[8] As a consequence, if $\gamma = 0$, the consumers' favorite tax/subsidy rate is $s = 0$.

4 The lobbying game

We have identified above three stakeholder groups regarding the policy of subsidizing green energy: the green industry, the black industry, and the (group of) consumers, indexed *g*, *b* and *c*, respectively. We now conceive of each group i, $i = b, c, g$ as a lobby for or against the green subsidy that is capable to invest the effort r_i in order to influence in its own favor the political process of fixing the subsidy rate. The lobbying input r_i is supposed to be a real expenditure of group *i* in units of consumption good X. More specifically, group *i*'s lobbying activity is a process of exerting *pressure*, $\tilde{q}_i \cdot r_i^{1/2}$ with $\tilde{q}_i \geq 0$, exerted on policy makers in order to induce them to shift the subsidy rate in group *i*'s favor. The pressure parameter $\tilde{q}_i$ indicates the 'productivity' of building up pressure. For given lobbying input r_i the level of pressure depends on various group characteristics, notably on the effectiveness of the institutional and organizational structure of lobby activities. The better organized the group's inter-

[8] For analytical convenience - rather than for empirical relevance - we will later allow for a green energy tax ($s < 0$) without placing much attention on scenarios where the outcome is a tax.

ests are in the political arena[9], the larger is $\tilde{q}_i$. Yet how effective group *i*'s pressure is in shifting the subsidy in its favor does not only depend on its lobbying productivity $\tilde{q}_i$ but also on the *political weight*, w_i, which policy makers attach to the group and which will be further specified below. We assume that in response to the lobby groups' activities the government determines the rate of the subsidy according to

$$s = S(r) = w_c q_c r_c^{1/2} + w_g q_g r_g^{1/2} - w_b q_b r_b^{1/2} = a_c r_c^{1/2} + a_g r_g^{1/2} - a_b r_b^{1/2}, \tag{19}$$

where $r := (r_b, r_c, r_g)$, $a_i := w_i q_i$ for $i = b, c, g$, $q_i = \tilde{q}_i$ for $i = b, g$, $q_c = \tilde{q}_c \cdot sign\left[\gamma - S(r_{-c})\right]$ and $S(r_{-c}) := S(r)$ for $r_c = 0$. We assume $w_i \geq 0$ and interpret w_i as the *political weight* the sitting government attaches to group *i*. The more the government cares for the interests of group i – for whatever reasons – the larger is w_i.Given the specific functional form of *S* in (16), it is natural to set $q_b = \tilde{q}_b$ and $q_g = \tilde{q}_g$ because $sign\, ds / dw_i = sign\, d\hat{\pi}_i / ds$ for $i = b, g$. However, since $d\hat{u} / ds$ can take on any sign, we need to take a closer look at what the appropriate sign of q_c is. To that end denote by $S(r_{-c})$ the rate of the subsidy or tax for $r_c = 0$ and recall that $s_c^* = \gamma$ is the consumers' favorite rate. With this notation, suppose that $S(r_{-c})$ > $s_c^* = \gamma \geq 0$ which means that the black lobby's influence on the subsidy is stronger than the green lobby's. In that case the consumers lobby for a reduction in the subsidy rat, hence $q_c = -\tilde{q}_c$. If, however, $S(r_{-c}) < \gamma$, the consumers lobby for an increase in the subsidy rate and hence $q_c = \tilde{q}_c$. Casual empirical evidence suggests the opposite, i.e. that $S(r_{-c})$ > s_c^* appears to be unlikely and the more so the greater is γ.[10] For these reasons we will consider the case $q_c \geq 0$ in the subsequent analysis unless stated otherwise.

The weight w_c may also be interpreted as partly reflecting the consumers' role as voters (see above) and to some extent their role as lobbyists[11] with the implied distance or nearness to the government in office. It indicates, in particular, the amount of attention the consumers'

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[9] The strategies and obstacles of providing the public good 'promoting the goals of a special interest group' are analyzed in a large literature initiated by the seminal work of Olson (1965).

[10] We provide rigorous conditions for $S(r_{-c})$ > 0 in the Nash equilibrium without consumers in Result 3 below.

[11] There are also various 'lobby' groups of citizens (NGOs etc.), mainly pro renewable energy, that are not explicitly modeled here.

preferences receive from the government. A plausible hypothesis appears to be that the smaller is the actual majority for the incumbent government and hence its probability of being reelected, the larger is w_c in absolute terms and the smaller are w_b and w_g.

The definition $a_i := w_i q_i$ serves to simplify the notation in the remainder of the paper. We refer to a_i as group *i*'s *political influence*. Note that exogenous changes in a_i whose impact we will study below can result from a shift in group *i*'s lobbying productivity $\tilde{q}_i$ and/or from a shift in the political weight the government attaches to the group. In particular, $a_i = 0$ may either follow from the group's failure to voice its interests in the political arena ($\tilde{q}_i = 0$) or from the government's reluctance to give in to the group's pressure ($w_i = 0$).

As the lobbying efforts r_i are real resource costs, they cut into the industries' profits as well as into the consumer's utility via a decline in disposable income. Accordingly, we account for (19) and replace the equations (16) and (18) by the payoff functions

$$\Pi^b(r) := (1-\beta)\bar{b}\tau_0 - (1-\tau)(1-\beta)\bar{b}S(r) - r_b, \tag{20a}$$

$$\Pi^c(r) := v_0 + \frac{\gamma\tau}{\xi}S(r) - \frac{\tau}{2\xi}S(r)^2 - r_b - r_c - r_g, \tag{20b}$$

$$\Pi^g(r) := x_o + \frac{\left[\tau_0 + \tau S(r)\right]^2}{\xi} - r_g. \tag{20c}$$

$\Pi^b(r)$ and $\Pi^g(r)$ are profits *net* of the industries' lobbying efforts and $\Pi^c(r)$ is the consumers' utility in the presence of lobbying efforts. To verify the definition of $\Pi^c(r)$ observe that the consumers' disposable income $y = x - p_e e + p_z z$ from (11) needs to be replaced by[12] $y = x - r_b - r_c - r_g - p_e e$. Hence it is ultimately the consumers who bear the total social cost of lobbying. It is also worth recalling that $\Pi^i(r)$ for $i = b, c, g$ re the equilibrium profits and the equilibrium utility, respectively, in an economy with fixed lobbying efforts.

[12] Correspondingly, the trade balance (6) needs to be replaced by $x - r_b - r_c - r_g - x_s - p_e e = 0$.

Summing up, we have turned the competitive economy with fixed subsidy of Section 3 in a lobbying game model with the three players B, C and G whose strategies are r_b, r_c and r_g, respectively, and whose payoffs are $\Pi^i(r)$ for $i = b, c, g$ in (20). Since the players have opposing interests regarding government action and refrain from cooperation, the Nash equilibrium is the natural solution concept. Using the standard notation[13] $(r_i, r_j, r_k) \equiv (r_{-i}, r_i)$ for $i = b, c, g$ the triple (r_b^N, r_c^N, r_g^N) constitutes a Nash equilibrium, if for $i = b, c, g$ the inequality $\Pi^i_{r_i}(r_{-i}^N, r_i^N) \geq \Pi^i_{r_i}(r_{-i}^N, r_i)$ holds for all $r_i \geq 0$. Hence the Nash equilibrium is the solution of the equations[14]

$$\Pi^b_{r_b}(r) = \frac{a_b(1-\beta)(1-\tau)\bar{b}}{2r_b^{1/2}} - 1 \leq 0 \quad \text{and} \quad r_b \Pi^b_{r_b} = 0, \tag{21a}$$

$$\Pi^c_{r_c}(r) := \frac{a_c \tau [\gamma - S(r)]}{2\xi r_c^{1/2}} - 1 \leq 0 \quad \text{and} \quad r_c \Pi^c_{r_c} = 0, \tag{21b}$$

$$\Pi^g_{r_g}(r) = \frac{a_g \tau [\tau_0 + \tau S(r)]}{\xi r_g^{1/2}} - 1 \leq 0 \quad \text{and} \quad r_g \Pi^g_{r_g} = 0. \tag{21c}$$

For both analytical convenience and notational simplification we replace the strategies r_i by $\rho_i := r_i^{1/2}$ for $i = b, c, g$ keeping in mind that since $r_i \geq 0$, we require $r_i = \rho_i^2$, if $\rho_i \geq 0$ and $r_i = 0$ otherwise. Suppose, for the time being, there is an interior Nash equilibrium. We set $\Pi^i_{r_i} = 0$ for all *i* and use (21) to calculate the reaction functions

$$\rho_b = \frac{a_b \bar{b} \bar{\tau}}{2} =: \rho_b^N, \qquad \text{with } \bar{\tau} := (1-\beta)(1-\tau) \in \,]0,1[\tag{22}$$

$$\rho_c = \frac{a_c \gamma \tau}{2\xi + a_c^2 \tau} + \frac{a_b a_c \tau}{2\xi + a_c^2 \tau}\rho_b - \frac{a_c a_g \tau}{2\xi + a_c^2 \tau}\rho_g, \tag{23}$$

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[13] The definition of r_{-i} is $r_{-i} := (r_j, r_k)$ for $i, j, k = b, c, g$; $j, k \neq i$; $j \neq k$.

[14] For further properties of the payoff-functions and, in particular, for the second-order conditions of maximizing $\Pi^i(r)$ with respect to r_i see the Appendix A.1.

$$\rho_g = \frac{a_g \tau_0 \tau}{\xi - a_g^2 \tau^2} - \frac{a_b a_g \tau^2}{\xi - a_g^2 \tau^2} \rho_b + \frac{a_c a_g \tau^2}{\xi - a_g^2 \tau^2} \rho_c \,. \tag{24}$$

Observe first that according to (22) the black industry has a dominant strategy, ρ_b^N, and ρ_b^N is positive, if and only if that sector has political influence ($a_b > 0$). Its strategy is dominant for two reasons. The other stakeholders' strategies affect the black industry's payoff (20a) only through their impact on the subsidy rate $S(\rho)$, and in (19) $S(\rho)$ is assumed to be additive in ρ_b, ρ_c and ρ_g. An immediate implication is that irrespective of whether or not the other players exert political influence, the black industry lobby is active if and only if $a_b > 0$. It generates the pressure $h_c \rho_b^N$ and thus reduces the subsidy rate compared to the level without its lobbying activity. Obviously, if the black industry is the only active lobby group, then green energy would be taxed rather than subsidized ($S(\rho) = -a_b \rho_b^N < 0$).

The shape of the green industry's reaction function (24) depends on the sign of $\left(\xi - a_g^2 \tau^2\right)$. Closer inspection shows that $c > a_g^2 / 4$ is sufficient for $\xi > a_g^2 \tau^2$, all $\xi > 0$. Since casual evidence suggests that the green industry lobby's influence appears to be relatively small (a_g small) and the consumer demand for energy is rather price inelastic[15] (c large), the condition $c > a_g^2 / 4$ is plausible and will therefore be assumed to hold hereafter.

The dominant strategy (22) considerably simplifies the analysis of the game because we can insert the constant ρ_b^N directly into the reaction functions of the players C and G. Given ρ_b^N from (22), it is straightforward to solve (23) and (24) for ρ_c^N and ρ_g^N. Yet we postpone the solution and discussion of the full three-players game in order to characterize and interpret first the 'partial' lobbying games generated by setting equal to zero one or two parameters a_i.

The median voter solution as limiting case of lobbying. Consumer-voters dominate the political decision process, if the political weight of the black and green industries vanishes (

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[15] The price elasticity of energy demand, $\frac{dz}{dp_z} \cdot \frac{p_z}{z} = -\left(\frac{c_0}{cz} - 1\right) < 0$, is the smaller in absolute terms, c. p., the larger is c.

$a_b, a_g \to 0$) and the voters weight becomes large. If $a_b, a_g \to 0$, then (22) and (24) readily yield $\lim_{a_i \to 0} a_i \rho_i^N = 0$ for *i* = *b*, *g*. Moreover, (21b) implies $\lim_{\substack{a_c \to \infty \\ a_b, a_g = 0}} \rho_c = \lim_{\substack{a_c \to \infty \\ a_b, a_g = 0}} \frac{a_c \gamma \tau}{2\xi + a_c^2 \tau} = 0$ and $\lim_{\substack{a_c \to \infty \\ a_b, a_g = 0}} S(\rho) = \lim_{\substack{a_c \to \infty \\ a_b, a_g = 0}} \frac{a_c^2 \gamma \tau}{2\xi + a_c^2 \tau} = \gamma$. Hence we have established

Result 2. *Suppose in a two-candidate political system with majority rule policymakers are immune against political pressure from the black and green lobbies ($a_b, a_g = 0$). To win the election a candidate must place arbitrarily high political weight on the consumer-voters ($a_c \to \infty$) and thus offer them their favorite rate $s_c^* = \gamma$ of the green energy subsidy.*

Consumers contra the black industry. Suppose next the green industry is small relative to the black industry and it lacks political influence ($a_g = 0$). Then the equations (22) and (23) readily yield the Nash equilibrium

$$\rho_b^N = \frac{a_b \bar{b} \bar{\tau}}{2} \quad \text{and} \quad \rho_c^{N1} = \frac{a_c \gamma \tau}{2\xi + a_c^2 \tau} + \frac{a_b a_c \tau}{2\xi + a_c^2 \tau} \rho_b^N . \tag{25}$$

Accounting for (25) and $a_g = 0$ in (19) results in $S(\rho) = \frac{a_c^2 \gamma \tau - a_b^2 \bar{b} \bar{\tau} \xi}{2\xi + a_c^2 \tau}$ and

$$S(\rho) \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \Leftrightarrow a_c^2 \gamma \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} = a_b^2 \bar{b} c (1 - ß).$$

That equivalence immediately yields

Result 3. *Suppose the green industry lacks political influence ($a_g = 0, a_b, a_c > 0$),*

(i) *The consumer lobby is always active against the black industry lobby.*

(ii) *Green preferences ($\gamma > 0$) are a necessary condition for subsidizing green energy. The necessary and sufficient condition is that the product $a_c^2 \gamma$ exceeds some threshold value which is the higher,*

- *the larger is the black industry's political influence (a_b large),*
- *the less stringent is the carbon emission cap $\bar{e}$,*

- *the more price inelastic is the energy demand (c large),*
- *the less increasing is the unit cost of producing black energy (β large).*

We have thus shown that $\gamma > 0$ is necessary but not sufficient for $S(\rho) > 0$. In other words, if the green industry lobby is inactive, the green energy subsidy is not an outcome of the lobbying game with $a_g = 0$ unless consumers exhibit green preferences. Yet it is also interesting to observe that if $\gamma = 0$, the consumer lobby is still active ($\rho_c^{N1} > 0$ in (25)) because in that case the consumers' favorite rate is *s* = 0. The outcome of the two-group lobbying game is still a tax, $S(\rho) < 0$, whose rate $|S(\rho)|$ is smaller, though, than that which would prevail when the black industry were the only active lobby group.

The green and black industries competing for political influence. If the consumers lack political influence ($a_c = 0$), the equations (22) and (24) readily yield the Nash equilibrium

$$\rho_b^N = \frac{a_b \bar{b} \bar{\tau}}{2} \quad \text{and} \quad \rho_g^{N1} \begin{cases} = \dfrac{a_g \tau \left(\tau_0 - a_b \rho_b^N \tau \right)}{\bar{\xi}} > 0, \text{ if } a_b \rho_b^N < c_0 - \bar{b} c \\ = 0 \ \text{ otherwise} \end{cases} . \tag{26}$$

If $a_b \rho_b^N \geq c_0 - \bar{b} c$ (with $c_0 > \bar{b} c$ by assumption) the black industry lobby's pressure and political influence is so strong that it does not pay for the green industry to build up counter-pressure. That outcome is the less likely, the more stringent is the emission cap ($\bar{b} = \bar{e}^{\beta}$ small) and the greater and the less price elastic is the demand for energy (c_0 large and *c* small). Note, however, that $\rho_g^{N1} > 0$ is only necessary but not sufficient for $S(\rho) > 0$. To see that, we combine (26) with (19) and $a_c = 0$ and obtain $S(\rho) = \dfrac{2 a_g^2 \tau \tau_0 - a_b^2 \bar{b} \bar{\tau} \xi}{2\left(\xi - a_g^2 \tau^2 \right)}$ and

$$S(\rho) \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \Leftrightarrow \frac{a_g^2}{a_b^2} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \frac{\bar{b} c (1 - ß)(c + \xi)}{2 \xi \left(c_0 - \bar{b} c \right)} .$$

That equivalence immediately yields[16]

Result 4. *Suppose, the consumers lack political influence (* $a_c = 0, a_b, a_g > 0$ *).*

[16] From $\rho_g^N < 0$ and $r_g = 0$ follows $S(r) = - a_b \rho_b^N$.

(i) *The green industry refrains from lobbying (leaving the political arena to the black industry), if the black industry lobby is very strong ($a_b\rho_b^N \geq c_0 - \bar{b}c$).*

(ii) *Otherwise the green industry lobby succeeds inducing the government to subsidize green energy, if and only if its* ***relative*** *political weight, a_g / a_b, exceeds some threshold value which is the higher,*

- *the smaller is the marginal cost of green energy (in terms of good X) (ξ small),*
- *the less stringent is the carbon emission cap $\bar{e}$,*
- *the more price inelastic is the energy demand (c large, c_0 small),*
- *the less increasing is the marginal costs of producing black energy (β large).*

Consumers and green industry contra black industry. The special cases discussed above provided insights into the conditions for introducing a green subsidy under the constraint that one or two players are inactive. We will now complement that analysis by studying the interaction of all three players. As pointed out above, our attention will be restricted to consumers with green preferences ($\gamma > 0$), because in view of Result 4 and casual empirical evidence it is unrealistic that the green industry lobby would succeed in introducing a green subsidy against the joint counter pressure of black industry *and* consumers.

The observation (22) that the black industry has a dominant strategy allows us to replace ρ_b in the reaction functions (23) and (24) by the positive constant ρ_b^N. Technically speaking, we disregard the black industry as a player and focus on the (non-cooperative) game between consumers and the green industry both of which have an interest, to prevent the green energy tax that would be levied if they would not take part in the lobbying game. The pertaining reaction functions are

$$\rho_c = \frac{a_c\tau\left(\gamma + a_b\rho_b^N\right)}{2\xi + a_c^2\tau} - \frac{a_c a_g \tau}{2\xi + a_c^2\tau}\rho_g \quad \text{and} \quad \rho_g = \frac{a_g\tau\left(\tau_0 - a_b\rho_b^N\tau\right)}{\xi - a_g^2\tau^2} + \frac{a_c a_g \tau^2}{\xi - a_g^2\tau^2}\rho_c . \qquad (27)$$

In (27) the consumers' reaction function is downward sloping implying that the green industry's lobbying efforts are strategic substitutes for the consumers' efforts. Under the assumption $\xi > a_g^2\tau^2$ (see above) the slope of the consumers' reaction function is positive implying that the consumers' support for the subsidy is a strategic complement for the green industry's lobbying efforts. In other words, if the green industry steps up its lobbying efforts, it discourages the consumers' lobbying. In contrast, the green industry responds to an increase in the consumers' lobbying efforts by stepping up its own lobbying. The reason for that asymmetry in best replies is that the profit of the green industry ($\hat{\pi}_g$ in (18)) is increasing and strictly convex in the subsidy, whereas the consumer's utility ($\hat{u}$ in (16)) is strictly concave.

We have derived the solution of the equations (27) for ρ_c^N and ρ_g^N in the Appendix A.3. It reads[17]

$$\rho_c^N = \frac{a_c\tau\left(\gamma\bar{\xi} + a_b\rho_b^N\xi - a_g^2\tau\tau_0\right)}{\left(2\bar{\xi} + a_c^2\tau\right)\xi} \begin{Bmatrix} > \\ = \end{Bmatrix} 0 \Leftrightarrow \gamma \begin{Bmatrix} > \\ \leq \end{Bmatrix} \frac{a_g^2\tau^2\left(c_0 - \bar{b}c\right) - a_b\rho_b^N\xi}{\bar{\xi}}, \tag{28}$$

$$\rho_g^N = \frac{a_g\tau\left[a_c^2\tau\left(\tau_0 + \gamma\tau\right) + 2\xi\left(\tau_0 - a_b\rho_b^N\tau\right)\right]}{\left(2\bar{\xi} + a_c^2\tau\right)\xi} \begin{Bmatrix} > \\ = \end{Bmatrix} 0 \Leftrightarrow a_b\rho_b^N \begin{Bmatrix} < \\ \geq \end{Bmatrix} + \frac{a_c^2\gamma\tau + \left(2\xi + a_c^2\tau\right)\left(c_0 - \bar{b}c\right)}{2\xi} \tag{29}$$

When combined with some further properties of the Nash equilibrium that we have established in the Appendix A.3, the equations (28) and (29) yield

Result 5. *Suppose, all stakeholders have political influence ($a_c, a_b, a_g > 0$).*

(i) *If the green industry's political influence is strong (a_g large) and/or the consumers' green preferences are weak (γ small), the consumers refrain from lobbying.*

(ii) *If the consumer lobby is active along with the lobby of the black industry and the black industry's influence is intermediate,*

i.e. $a_b^2 \in \left]k_0, \frac{\left(2\xi + a_c^2\tau\right)k_0}{2\xi} + \frac{2\gamma}{2\bar{b}\tau\xi}\right[$ *with* $k_0 := \frac{2\left(c_0 - \bar{b}c\right)}{\bar{b}\bar{\tau}} > 0$,

the green industry joins the pressure group competition even though it would have remained inactive in the absence of the consumer lobby's activity.

(iii) *If all lobby groups are active ($\rho_i^N > 0$ for i = b, c, g) and the black industry lobby is not too strong ($a_b\rho_b^N > c_0 - \bar{b}c$),*

[17] Note that (28) and (29) yield $\rho_c^N = \rho_c^{N1}$ for $a_g = 0$ and $\rho_g^N = \rho_g^{N1}$ for $a_c = 0$, which is required for consistency.

(a) *the subsidy rate is higher than in the case where either the consumers ($a_c = 0$) or the green industry lobby ($a_g = 0$) lack political weight;*

(b) *the consumers' lobbying effort is smaller than in the case where the green industry lacks political weight ($a_g = 0$);*

(c) *the green industry's lobbying effort is larger than in the case where the consumers lack political weight ($a_c = 0$).*

The straightforward reason for Result 5i is that the green industry's payoff is increasing and strictly convex in the subsidy, whereas the consumers' utility is strictly concave in the subsidy. Consumers will even switch sides in the lobbying game, if a_g becomes too large and/or γ too small.[18] While the green industry's lobbying discourages the consumers' drive for the subsidy (Result 5i), the consumers' lobbying activity encourages the green industry's lobbying efforts (Result 5ii). Essentially, the Results 5i and 5ii are in line with our finding above that the green industry lobby takes the consumers' efforts to be complementary while the consumers consider the green industry lobby's efforts as substitutes. That asymmetry is also the principal driving force for the observations listed in Result 5iii which compare subsidy decision making in the case where all players are active with scenarios in which either the consumers or the green industry lack political influence.

In order to gain further insights into the determinants of subsidizing green energy, we now perform some comparative statics of a Nash equilibrium with positive lobbying efforts of all players. The analysis (in the Appendix A.4) of the displacement effects of exogenous changes in various model parameters yields

Result 6. *Suppose all lobby groups have political influence and are active ($a_i > 0$ and $\rho_i^N > 0$ for i = b, c, g). Following the (exogenous) variation of the parameter $a_b, a_c, a_g, \overline{e}$ or γ the direction of change is*

(i) *in the lobby groups' efforts:*

$\mu \Rightarrow$	a_b	a_c	a_g	$\overline{e}$	γ

[18] To avoid additional notational complexity, we will not include that scenario in the formal model, however.

$\partial r_b / \partial \mu$	+	0	0	+	0
$\partial r_c / \partial \mu$	+	±?	±?	+	+
$\partial r_g / \partial \mu$	-	±?	+	-	+

(ii) in the subsidy rate: $\frac{\partial s}{\partial a_b} < 0,\ \frac{\partial s}{\partial a_g} > 0,\ \frac{\partial s}{\partial \overline{e}} < 0,\ \frac{\partial s}{\partial \gamma} > 0$ *and*

$$\frac{\partial s}{\partial a_c} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \Leftrightarrow \gamma \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \underbrace{\frac{a_g^2 \tau^2 \left(c_0 - \overline{b} c\right)}{\overline{\xi}}}_{(+)} - a_b \rho_b^N \xi.. \tag{30}$$

Result 6i summarizes the shifts in the groups' lobbying efforts following small variations in model parameters. As expected, the efforts of both the black and green industry are increasing in their respective political influence ($\partial r_i / \partial a_i > 0$ for *i* = *b*, *g*), but the sign of $\partial r_c / \partial a_c$ is unclear. Interestingly, we find that $\frac{\partial\left(a_c \rho_c^N\right)}{\partial a_c} = \rho_c^N + a_c \frac{\partial \rho_c}{\partial a_c} = \frac{4\rho_c^N \overline{\xi}}{2\overline{\xi} + a_c^2 \tau} > 0$ irrespective of the sign of $\partial r_c / \partial a_c$, i.e. the consumers always use their increased political influence $\partial a_c > 0$ for raising the subsidy rate. The characteristics of the players C and G do not impact on the black industry's lobbying effort, of course, because the strategy ρ_b^N is dominant. However, the black industry's political influence has an impact on the other groups. It stimulates the lobbying effort of the consumers and discourages that of the green industry. Another interesting observation is that the response of group C's [group G's] effort to an increase in the political influence of group G [group C] is ambiguous. Both cross effects $\partial r_i / \partial a_j$ *for i, j =c, g,* $i \neq j$ are the more likely positive, the greener the consumer preferences (γ large) and the greater is the black industry's political influence (a_b large). The greening of preferences raises the effort of group C and group G, but tightening the emission cap ($\partial \overline{e} < 0$) diminishes the consumers' lobbying effort while the green industry increases its effort. The latter pushes harder for the subsidy taking advantage of the black industry's weakening through reduced profits. In contrast, the consumers aim to retard the green industry's revitalized drive because their marginal utility is declining in the subsidy.

Result 6ii is as expected with regard to the impact on the subsidy of changes in a_b, a_g and γ. Tightening the emission cap increases the subsidy rate ($\partial s / \partial e > 0$) mainly because it reduces the profit of the black industry that then lowers its pressure to curb the green energy subsidy. The shift in the subsidy induced by an increase in the consumers' political influence, ($\partial s / \partial a_c$), is particularly interesting, because in contrast to $\partial s / \partial a_g$, which is unambiguously positive, $\partial s / \partial a_c$ may attain either sign. $\partial s / \partial a_c > 0$ is the more likely[19],

- the greener are consumer preferences (γ large);
- the smaller is the political influence of the green and black industry (a_b and a_g small):
- the smaller and the more price elastic is the demand for energy (c_0 and c small).

5 Concluding remarks

As we have pointed out in the introduction, we cannot see convincing welfare economic arguments in favor of a subsidy on green energy that complements a country's carbon emission cap-and-trade scheme. In order to understand the wide-spread double regulation in practical policy, we focus on the political economy of the green energy subsidy and seek to explain its rate as the outcome of a trilateral tug of war between the pertinent stakeholder groups. Quite obviously, the green industry uses its political influence to push for the subsidy while the black industry exerts countervailing pressure. Casual empirical evidence suggests that the former is far smaller and likely also less influential than the latter in the process of policy formation. Therefore the explanation of the subsidy crucially depends on the interaction of both industry lobbies with a third stakeholder group, the consumers, whose political influence may reflect their role as voters and/or lobbyists. If the consumers would share the view that the overlapping subsidy merely generates excess costs, then our model of competitive lobbying would predict under plausible conditions a green energy *tax* rather than a *subsidy*. Most likely a precondition for a subsidy being the outcome of the lobbying game is that the consumers have 'green preferences', i.e. that they derive extra utility from green energy. That hypothesis might be interpreted as reflecting the consumers' 'warm glow' environmental awareness or their willingness to support a more sustainable development.

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[19] A necessary condition for $\partial s / \partial a_c < 0$ is that $\partial \rho_g^N / \partial a_c < 0$, because $\partial s / \partial a_c = \partial\left(a_c \rho_c^N\right) / \partial a_c + \left(\partial \rho_g / \partial a_c\right) a_g$ and $\partial\left(a_c \rho_c^N\right) / \partial a_c$ has been shown to be positive above.

The game of competitive lobbying is developed in the framework of a simple small open economy with endogenous determination of both the energy price and the green energy subsidy. The upside of using parametric functions is that we can fully solve the competitive economic equilibrium as well as the lobbying Nash equilibrium which, in turn, allows us to trace the determinants of the equilibrium subsidy rate in great detail. The price to be paid for the specific and informative results is that various real-world complexities are omitted. Among the issues in need of more careful future consideration and modeling are the following. Real-world energy markets are far from perfectly competitive; the consumption good sector and the green energy industry should not be lumped together, as we did for reasons of tractability; our model abstracts from the empirical feature of energy as an important intermediate good in the consumption good sector; the additive separable function of subsidy formation (19) that results in the black industry's strategy being dominant should be replaced by a less restrictive function.

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Appendix A

A.1 List of terms defined to simplify notation

$a_i := q_i w_i$ for $i = b, c, g$, $\quad \bar{b} := \bar{e}^{\beta} > 0$, $\quad \bar{\xi} := \xi - a_g^2 \tau^2$,

$\zeta := \dfrac{1}{c+\xi} > 0$, $\quad \zeta_0 := (1-\tau)c_0 + \bar{b}c\tau > 0$, $\quad \rho_i := r_i^{1/2}$ for $i = b, c, g$,

$\tau := \dfrac{\xi}{c+\xi} \in \left]0,1\right[$, $\quad \tau_0 := \tau\left(c_0 - \bar{b}c\right)$, $\quad \bar{\tau} := (1-\beta)(1-\tau) > 0$,

$v_0 := \dfrac{\gamma\tau_0}{\xi} + c_0\zeta_0 + x_0 - p_e\bar{e} - \dfrac{c\zeta_0^2}{2} - \dfrac{\alpha_0^2}{2\xi}$, $\quad v_1 := c_0\zeta - c\zeta\zeta_0 - \dfrac{\tau\tau_0}{\xi} + \dfrac{\gamma\tau}{\xi} = \dfrac{\gamma\tau}{\xi}$.

Assumptions on the parameter space: We assume $c_0 > \bar{b}c$ and hence $\tau_0 > 0$, because otherwise $p_z = \tau_0 - (1-\tau)s < 0$ for $s = 0$. We also assume $c > a_g^2/4$ because that inequality is plausible (see the discussion following equation (24)). It implies $\bar{\xi} = \xi - a_g^2\tau^2 > 0$ which, in turn, is sufficient for the payoff function Π^c being strictly concave in r_c (see below).

A.2 Properties of the payoff functions Π^i, $i = b, c, g$.

$$\lim_{r_b \to 0} \Pi_{r_b}^b = \infty \quad \text{and} \quad \Pi_{r_b r_b}^b(r) = -\frac{a_b \bar{b}\bar{\tau}}{4 r_b^{3/2}} < 0,$$

$$\lim_{r_c \to 0} \Pi_{r_c}^c = \begin{Bmatrix} +\infty \\ -1 \\ -\infty \end{Bmatrix} \Leftrightarrow \gamma \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \left(a_g\rho_g - a_b\rho_b\right) \quad \text{and} \quad \Pi_{r_c r_c}^c = -\frac{a_c\tau\left[\gamma - \left(a_g\rho_g - a_b\rho_b\right)\right]}{4\rho_b^3\xi}$$

$$\lim_{r_g \to 0} \Pi_{r_g}^g = \begin{Bmatrix} +\infty \\ -1 \\ -\infty \end{Bmatrix} \Leftrightarrow \left(c_0 - \bar{b}c\right) \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \left(a_b\rho_b - a_c\rho_c\right) \quad \text{and}$$

$$\Pi^c_{r_c r_c} = -\frac{a_g \tau^2\left[\left(c_0 - \bar{b}\bar{c}\right) - \left(a_b \rho_b - a_c \rho_c\right)\right]}{2\rho_g^3 \xi}$$

We conclude: (i) $\Pi^b_{r_b r_b} < 0$ holds unconditionally and $\arg\max_{r_b} \Pi^b > 0$.

(ii) $\arg\max_{r_c} \Pi^c$ is unique and $\begin{cases} > 0, \text{ if and only if } \gamma > \left(a_g \rho_g - a_b \rho_b\right) \\ = 0 \text{ otherwise} \end{cases}$

(iii) $\arg\max_{r_g} \Pi^g$ is unique and $\begin{cases} > 0, \text{ if and only if } \left(c_0 - \bar{b}\bar{c}\right) > \left(a_b \rho_b - a_c \rho_c\right) \\ = 0 \text{ otherwise} \end{cases}$

A.3 Nash equilibrium

In our calculations below we disregard temporarily the constraints $\rho_i \geq 0$. We know from (22) that $\rho_b^N = a_b \bar{b}\bar{\tau}/2$. To compute ρ_c^N we insert ρ_g from (24) into (23):

$$\rho_c = \frac{a_c \tau\left(\gamma + a_b \rho_b^N\right)}{2\xi + a_c^2 \tau} - \frac{a_c a_g \tau}{2\xi + a_c^2 \tau} \cdot \frac{a_g \tau\left(\tau_0 - a_b \rho_b^N \tau\right)}{\bar{\xi}} - \frac{a_c^2 a_g^2 \tau^3}{\left(2\xi + a_c^2 \tau\right)\bar{\xi}} \rho_c^N,$$

$$\frac{\overbrace{\left(2\xi + a_c^2 \tau\right)\bar{\xi} + a_c^2 a_g^2 \tau^3}^{A_0}}{\left(2\xi + a_c^2 \tau\right)\bar{\xi}} \rho_c^N = \frac{\overbrace{a_c \tau \bar{\xi}\left(\gamma + a_b \rho_b^N\right) - a_c a_g^2 \tau^2\left(\tau_0 - a_b \rho_b^N \tau\right)}^{A_1}}{\left(2\xi + a_c^2 \tau\right)\bar{\xi}}$$

We simplify the terms A_0 and A_1 as follows:

$$A_0 = \left(2\xi + a_c^2 \tau\right)\left(\xi - a_g^2 \tau^2\right) + a_c^2 a_g^2 \tau^3 = 2\xi^2 + a_c^2 \tau \xi - 2a_g^2 \tau^2 \xi = \left(2\bar{\xi} + a_c^2 \tau\right)\xi,$$

$$\begin{aligned} A_1 &= a_c \tau\left(\gamma + a_b \rho_b^N\right)\left(\xi - a_g^2 \tau^2\right) - a_c a_g^2 \tau^2\left(\tau_0 - a_b \rho_b^N \tau\right) \\ &= a_c \gamma \tau \bar{\xi} + a_b a_c \rho_b^N \tau \xi - a_b a_c a_g^2 \rho_b^N \tau^3 - a_c a_g^2 \tau^2 \tau_0 + a_b a_c a_g^2 \rho_b^N \tau^3 \\ &= a_c \tau\left(\gamma \bar{\xi} + a_b \rho_b^N \xi - a_g^2 \tau \tau_0\right). \end{aligned}$$

Hence

$$\rho_c^N = \frac{a_c \tau\left(\gamma \bar{\xi} + a_b \rho_b^N \xi - a_g^2 \tau \tau_0\right)}{\left(2\bar{\xi} + a_c^2 \tau\right)\xi} = \frac{a_c \tau\left[\left(\gamma + a_b \rho_b^N\right)\xi - \left(\gamma \tau + \tau_0\right) a_g^2 \tau\right]}{\left(2\bar{\xi} + a_c^2 \tau\right)\xi}. \quad \text{(A1)}$$

(28) follows from (A1) after the constraint $\rho_c^N \geq 0$ has appropriately been accounted for.

We rearrange terms and rewrite (A1) as follows:

$$\rho_c^N = \frac{2\xi + a_c^2\tau}{2\bar{\xi} + a_c^2\tau}\rho_c^{N1} - \frac{a_c a_g^2 \tau^2 (\gamma\tau + \tau_0)}{(2\bar{\xi} + a_c^2\tau)\xi} = \rho_c^{N1} + \frac{a_g^2\tau^2\left[2\rho_c^{N1}\xi - a_c(\gamma\tau + \tau_0)\right]}{(2\bar{\xi} + a_c^2\tau)\xi}, \qquad \text{(A2)}$$

where ρ_c^{N1} is defined in (25). Moreover, we find that

$$a_c(\gamma\tau + \tau_0) = a_c\gamma\tau + a_b a_c \rho_b^N \tau + a_c\tau_0 - a_b a_c \rho_b^N \tau = (2\xi + a_c^2\tau)\rho_c^{N1} + \frac{a_c\bar{\xi}}{a_g\tau}\rho_g^{N1}$$ and obtain

$$\rho_c^N = \rho_c^{N1} - \frac{a_c^2 a_g^2 \tau^3}{(2\bar{\xi} + a_c^2\tau)\xi}\rho_c^{N1} - \frac{a_c a_g \tau \bar{\xi}}{(2\bar{\xi} + a_c^2\tau)\xi}\rho_g^{N1}, \qquad \text{(A3)}$$

where ρ_g^{N1} is defined in (26). (A3) implies that if $\rho_i^N > 0$ for all i and $\rho_g^{N1} > 0$, then $\rho_c^N < \rho_c^{N1}$ (Result 4iiib). Next we compute ρ_g^N by inserting ρ_c from (23) into (24):

$$\rho_g^N = \frac{a_g\tau(\tau_0 - a_b\rho_b^N\tau)}{\bar{\xi}} + \frac{a_c a_g \tau^2}{\bar{\xi}} \cdot \frac{a_c\tau(\gamma + a_b\rho_b^N)}{2\xi + a_c^2\tau} - \frac{a_c^2 a_g^2 \tau^3}{2\xi + a_c^2\tau}\rho_g^N;$$

$$\frac{\overbrace{(2\xi + a_c^2\tau)\bar{\xi} + a_c^2 a_g^2 \tau^3}^{A_0}}{(2\xi + a_c^2\tau)\bar{\xi}}\rho_g^N = \frac{a_g\tau(\tau_0 - a_b\rho_b^N\tau)}{\bar{\xi}} + \frac{a_c^2 a_g \tau^3(\gamma + a_b\rho_b^N)}{(2\xi + a_c^2\tau)\bar{\xi}} =$$

$$= \frac{\overbrace{a_g\tau(\tau_0 - a_b\rho_b^N\tau)(2\xi + a_c^2\tau) + a_c^2 a_g \tau^3(\gamma + a_b\rho_b^N)}^{A_2}}{(2\xi + a_c^2\tau)\bar{\xi}}.$$

We simplify the term A_2 as follows:

$$\begin{aligned} A_2 &= a_g\tau(\tau_0 - a_b\rho_b^N\tau)(2\xi + a_c^2\tau) + a_c^2 a_g \tau^3(\gamma + a_b\rho_b^N), \\ &= a_g\tau\left[(2\xi + a_c^2\tau)\tau_0 - 2a_b\rho_b^N\tau\xi - a_b a_c^2 \rho_b^N \tau^2 + a_c^2\gamma\tau^2 + a_b a_c^2 \rho_b^N \tau^2\right], \\ &= a_g\tau\left[a_c^2\tau(\tau_0 + \gamma\tau) + 2\xi(\tau_0 - a_b\rho_b^N\tau)\right]. \end{aligned}$$

Hence

$$\rho_g^N \;=\; \frac{a_g\tau\left[a_c^2\tau\left(\tau_0+\gamma\tau\right)+2\xi\left(\tau_0-a_b\rho_b^N\tau\right)\right]}{\left(2\overline{\xi}+a_c^2\tau\right)\xi}=\frac{2\overline{\xi}}{2\overline{\xi}+a_c^2\tau}\rho_g^{N1}+\frac{a_c^2a_g\tau^2\left(\tau_0+\gamma\tau\right)}{\left(2\overline{\xi}+a_c^2\tau\right)\xi} \tag{A4}$$

$$=\; \rho_g^{N1}-\frac{a_c^2\tau}{2\overline{\xi}+a_c^2\tau}\rho_g^{N1}+\frac{a_c^2a_g\tau^2\left(\tau_0+\gamma\tau\right)}{\left(2\overline{\xi}+a_c^2\tau\right)\xi} \;=\; \rho_g^{N1}+\frac{a_c^2\tau\left[a_g\tau\left(\tau_0+\gamma\tau\right)-\xi\rho_g^{N1}\right]}{\left(2\overline{\xi}+a_c^2\tau\right)\xi}$$

We further convert the term

$$\left[a_g\tau\left(\tau_0+\gamma\tau\right)-\xi\rho_g^{N1}\right] = \frac{a_g\tau^2}{\overline{\xi}}\left[\left(\gamma+a_b\rho_b^N\right)\xi-\left(\gamma\tau+\tau_0\right)a_g^2\tau\right]=\frac{\left(2\overline{\xi}+a_c^2\tau\right)\xi}{a_c\tau}\rho_c^N .$$

and rewrite (A4) as

$$\rho_g^N \;=\; \rho_g^{N1}+a_ca_g\tau\,\rho_c^N . \tag{A5}$$

(A5) implies that if $\rho_i^N>0$ for all *i* and $\rho_g^{N1}>0$, then $\rho_g^N>\rho_g^{N1}$ (Result 4iiic).

A.4 Comparative statics of the Nash equilibrium (interior solution)

Response of the subsidy rate to parameter changes. We combine the equations (19), (22), (25), (26) (A2) and (A4) to obtain $s^N=-a_b\rho_b^N+\frac{\tau\theta}{\omega}$, where $\omega:=2\overline{\xi}+a_c^2\tau>0$, $\theta:=a_c^2\left(\gamma+a_b\rho_b^N\right)+2a_g^2\left(\tau_0-a_b\rho_b^N\tau\right)$, and $\tau_0:=\tau\left(c_0-\overline{b}c\right)$. Differentiation with respect to the parameters $a_b, a_c, a_g, \overline{b}$ and γ yields

$$ds \;=\; -\rho_b^Nda_b-a_bd\rho_b-\frac{\tau}{\omega^2}\left(-4a_g\tau^2da_g+2a_c\tau da_c\right)\theta+\frac{\tau}{\omega}\Big[\left(\gamma+a_b\rho_b^N\right)2a_cda_c+a_c^2d\gamma+$$

$$+a_c^2\rho_b^Nda_b+a_ba_c^2d\rho_b+\left(\tau_0-a_b\rho_b^N\tau\right)4a_gda_g-2a_g^2c\tau db-2a_g^2\rho_b^N\tau da_b-2a_g^2a_b\tau d\rho_b\Big]$$

$$=\frac{1}{\omega^2}\Big\{\left(-\rho_b^N\omega^2+a_c^2\rho_b^N\tau\omega-2a_g^2\rho_b^N\tau^2\omega\right)da_b+2a_c\tau\left[\omega\left(\gamma+a_b\rho_b^N\right)-\tau\theta\right]da_c+a_c^2\tau\omega d\gamma-$$

$$-2a_g^2c\tau^2\omega db+4\left[a_g\tau^3\theta+a_g\tau\omega\left(\tau_0-a_b\rho_b^N\tau\right)\right]da_g+\left(-a_b\omega^2+a_ba_c^2\tau\omega-2a_ba_g^2\tau^2\omega\right)d\rho_b ,$$

$$\omega^2ds \;=\; -4\rho_b^N\xi\omega da_b+4a_c\tau\left[\overline{\xi}\left(\gamma+a_b\rho_b^N\right)-a_g^2\tau\left(\tau_0-a_b\rho_b^N\tau\right)\right]da_c+a_c^2\tau\omega d\gamma+$$

$$+4a_g\tau\left[a_g\tau^2\theta+\omega\left(\tau_0-a_b\rho_b^N\tau\right)\right]da_g-\omega\left(2a_g^2c\tau^2+a_b^2\overline{\tau}\xi\right)db$$

Inspection of ds/da_c reveals $\frac{ds}{da_c}=\frac{4a_c\tau}{\omega^2}\left[\gamma\overline{\xi}+a_b\rho_b^N\overline{\xi}-a_g^2\tau^2\left(c_0-\overline{b}c-a_b\rho_b^N\right)\right]$ and hence

$$\frac{\partial s}{\partial a_c}\begin{Bmatrix}>\\=\\<\end{Bmatrix}0\Leftrightarrow\gamma\begin{Bmatrix}>\\=\\<\end{Bmatrix}\underbrace{\frac{a_g^2\tau^2\left(c_0-\overline{b}c\right)}{\overline{\xi}}}_{(+)}-a_b\rho_b^N\xi.$$

Response of lobbying efforts to parameter changes. To simplify notation (for use in the Appendix only) we invoke (28) and (29) and define $\rho_i^N=\frac{N(i)}{D(i)}$ for *i* = *c*, *g*, where

$N(g):=a_g\tau\left[a_c^2\tau\left(\tau_0+\gamma\tau\right)+2\xi\left(\tau_0-a_b\rho_b^N\tau\right)\right]$,

$N(c):=a_c\tau\left(\gamma\overline{\xi}+a_b\rho_b^N\xi-a_g^2\tau\tau_0\right)$ and $D(c)=D(g):=\left(2\overline{\xi}+a_c^2\tau\right)\xi$.

Observe also that $d\tau_0=-c\tau db$ and $d\overline{\xi}=-2a_g\tau^2da_g$. Total differentiation of (22), (25) and (26) yields $d\rho_b^N=\frac{\overline{b}\overline{\tau}}{2}da_b+\frac{a_b\overline{\tau}}{2}db$ and $D(i)d\rho_i^N=dN(i)-\rho_i^NdD(i)$ for *i* = *c*, *g*.

More specifically,

$$D(c)d\rho_c^N=\frac{N(c)}{a_c}da_c+a_c\tau\left(\overline{\xi}d\gamma-2a_g\gamma\tau^2da_g+a_g^2c\tau^2db+2\rho_b^N\xi da_b+\right.$$
$$\left.+\frac{a_b^2\overline{\tau}\xi}{2}db+2a_g\tau\tau_0da_g\right)+4a_g\rho_c^N\tau^2\xi da_g-2a_c\rho_c^N\tau\xi da_c.$$

$$2a_cD(c)d\rho_c^N=4a_c^2\rho_b^N\tau\xi da_b+\left[2\overline{\xi}+\left(a_c-1\right)a_c\tau\right]\rho_c^N\xi da_c+a_c^2\tau\left(2a_g^2c\tau^2+a_b^2\overline{\tau}\xi\right)db\ -$$
$$+4a_g\tau^2\left[\rho_c^N\xi+a_c^2\tau\left(\gamma-c_0+\overline{b}c\right)\right]da_g+2a_c^2\tau\overline{\xi}d\gamma.$$

$$D(g)d\rho_g^N=\frac{N(g)}{a_g}da_g+a_g\tau\left[2a_c\tau\left(\tau_0+\gamma\tau\right)da_c-a_c^2c\tau^2db+a_c^2\tau^2d\gamma-2c\tau\xi db-\right.$$
$$\left.-4a_g^2\rho_b^N\tau^2\xi da_b-a_b^2a_g^2\tau^2\overline{\tau}\xi db\right]+4a_g\rho_g^N\tau^2\xi da_g+2a_c\rho_g^N\tau\xi da_c,$$

$$a_gD(g)d\rho_g^N=-4a_g^2\rho_b^N\tau\xi da_b+2a_c\tau\left[a_g^2\tau\left(\tau_0+\gamma\tau\right)-\rho_g^N\xi\right]da_c+\left(N(g)+4a_g\rho_g^N\tau^2\xi\right)da_g$$

$$+ \quad + a_c^2 a_g^2 \tau^3 d\gamma - a_g^2 \tau^2 \left(a_c^2 c\tau + 2c\xi + a_b^2 \overline{\tau} \xi \right) db \, .$$