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Abstract

Policy diffusion refers to the process by which a political innovation – like the introduction of a novel emission tax – disseminates over time among countries. In order to analyze this issue from an economic point of view we develop a simple two-country-model of the taxation of emissions in presence of (possible) policy diffusion. Contrary to the usual Nash setting of simultaneous decision making we consider a Stackelberg game: In the first step the domestic government introduces an emission tax t_d thus acting as Stackelberg-leader, in the second step the foreign government decides whether or not to introduce an emission tax t_f and in the third step the firms decide on their output quantities to be sold on a third country's market. For the case of an exogenous given probability of policy diffusion we show that the optimal domestic tax rate is c.p. the higher, the higher the probability of policy diffusion is. Moreover, we explore under which conditions first-mover behaviour by the domestic government leads to a higher tax rate compared to the Nash solution In the next step we introduce an endogenous probability of policy diffusion by combining our model with a strategic lobbying approach. As a result, the probability of policy diffusion is c.p. the smaller, the higher domestic tax rate t_d is. Consequently, in fixing the optimal tax rate the domestic government has to account for the foreign firm's lobbying activities otherwise it will choose a tax rate too high.

Keywords: emission taxes, first-mover behaviour, strategic environmental policy, policy diffusion.

JEL Classification: F18, Q55, Q58

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1. Introduction

An essential topic of strategic environmental policy models is the reaction of one government upon the policy decision of its counterpart. Decades of research within the political sciences contributed to a conceptual abundance in terms of how trans-national governance functions, which ultimately coalesces into three explanations (Elkins & Simmons 2005): (1) policy makers respond similarly to similar conditions in an independent and uncoordinated way; (2) the propagation of policies ensues from an interdependent and coordinated process (Jörgens 2004); (3) policy makers decide uncoordinatedly but in doing so they consider their counterparts' choices. The latter explanation, which has also been dubbed "uncoordinated interdependence" (Elkins & Simmons 2005, p. 35), refers to the diffusion of policies. According to the majority of scholars we view policy diffusion as the process by which a political innovation – like the introduction of a novel emission tax – disseminates over time among countries. Rogers 1995, p. 5). This implies that at least one country has to act as a first-mover in terms of policy making. The choice of the first-mover is then expected to alter the probability of further policy adoptions (Strang 1991). These notions can be readily translated into a non-cooperative Cournot-game in which a government e.g. sets an emission tax under consideration of the other player's decision whereas no coordination among each other occurs. A domestic government that acts as a first-mover thus plays Stackelberg. Therefore, this setting involves a game-sequence that departs from the usual simultaneous decision-making.

Consequently, the incorporation of policy diffusion into a strategic environmental policy game opens up new vistas on the optimal taxation of emissions. We can analyze how the prospect of policy diffusion affects the decisions of a government concerning the optimal emission tax. In doing so, we start with an exogenous probability of policy diffusion and ask how this probability influences the optimal domestic tax rate. In the next step we extend our analysis by asking how the results change if we endogenize the probability of policy diffusion by combining our model with a strategic lobbying approach. We then show that (1) the adverse impact on the foreign firm's profits and (2) the foreign firm's political influence govern the foreign policy maker's decision whether to adopt the domestic taxation or not. This mechanism, in turn, influences the decision of the domestic government.

Contrary to previous models (cf Simpson & Bradford 1996), we therefore investigate a novel mechanism in a strategic environmental policy game. Further insights into the properties of policy diffusion may consequently shed more light on the deadlocked discussion on ecological dumping: strategic environmental policy models predominantly predict lax environmental regulation, since weak policies are assumed to offer a comparative cost advantage, but this result only finds little if any empirical support (Jaffe et al. 1995).

The remainder of the paper is organized as follows. In section 2, we describe the model. Section 3 provides the equilibrium domestic tax rate in the case of an exogenously given probability of policy diffusion. Section 4 then compares the results of our Stackelberg-setting with the conventional Nash-Equilibrium. In section 5 we briefly discuss the determinants of policy diffusion from an empirical point of view. In section 6 we combine our model with a strategic lobbying approach which serves for the endogenization of the probability of policy diffusion. Finally, in section 7 we summarize the main conclusions of our model.

2. The Model

Consider a model with one domestic firm indexed by "d" and one foreign firm indexed by "f". Both firms produce a homogenous good which they sell on a third country's market. Inverse market demand is linear and downward sloping, i.e. $p = a - (y_d + y_f)$ where y_j (j=d,f) denotes the output of firm j which results from Cournot quantity competition. For simplicity, production costs are neglected, but it is assumed that production leads to the emission of a pollutant which is harmful to the environment of the respective country. The relationship between output and emission is described by a fixed emission coefficient $\varepsilon>0$. Environmental damages are given by a quadratic damage function $D_j = \gamma_j(\varepsilon y_j)^2$. In order to guarantee an internal solution with positive tax rates we assume $\gamma_j > 1/(4\varepsilon^2)$ for j=d,f.[1] Moreover, to motivate the domestic government's role as a first-mover in environmental policy we assume that the domestic damage parameter is higher than its foreign counterpart $(\gamma_d > \gamma_f)$. The difference between the damage parameters can either be due to a higher domestic preference for environmental quality or to a more vulnerable domestic environment.

The game under consideration consists of three stages. In the first stage the domestic government introduces an emission tax t_d which initiates the process of possible policy diffusion. In the second stage policy diffusion occurs with a probability of $\bar{\sigma} \in [0,1]$ which prompts the foreign government to introduce an emission tax t_f. Without policy diffusion − i.e. with a probability $1-\bar{\sigma}$ − no foreign emission tax emerges. In the third stage the firms choose their output level given the governments' decisions from the first and the second stage.

To begin with we treat the probability of policy diffusion as exogenous. However, in Section 5 we discuss the determinants of policy diffusion and in Section 6 we introduce an en-

1 In the case of $\gamma_j < 1/(4\varepsilon^2)$ the effect of strategic trade policy dominates and the governments will subsidize their industries.

dogenous probability of policy diffusion by combining the above model with a strategic lobbying approach.

By setting their respective emission taxes both governments aim at maximizing national welfare which is given by the firms' profits plus tax revenues net of environmental damages. In contrast to the Nash-approach employed by e.g. Simpson and Bradford (1996) in their article on strategic environmental policy, the sequence of decisions described above establishes a Stackelberg-relationship between the two governments: Provided that policy diffusion occurs the optimal foreign tax rate t_f depends on the domestic tax rate t_d. Hence, we can derive a reaction function $t_f(t_d)$ which has to be accounted for by the domestic government in stage one of the game.

3. Equilibrium and Comparative Statics

Due to the sequence described above, the model can be solved by backwards induction. In the third stage for the case *with* policy diffusion profit maximization leads to the output levels $y_d^P(t_d,t_f)=[a+\varepsilon(t_f-2t_d)]/3$ and $y_f^P(t_d,t_f)=[a+\varepsilon(t_d-2t_f)]/3$ (see Appendix I).[2] Analogously, we obtain $y_d^N(t_d)=[a-2\varepsilon t_d)]/3$ and $y_f^N(t_d)=[a+\varepsilon t_d]/3$ for the case *without* policy diffusion. The accompanying profit levels of the firms are $\pi_j^i(t_d,t_f)=y_j^i(t_d,t_f)^2$ for j=d,f and i=P,N.

In the second stage, the welfare function to be maximized by the foreign government in the case of policy diffusion is given by $w_f(t_d,t_f)=\pi_f^P(t_d,t_f)+\varepsilon t_f y_f^P(t_d,t_f)-\gamma_f[\varepsilon y_f^P(t_d,t_f)]^2$. This leads to the reaction function:

$$[1] \qquad t_f(t_d)=\frac{(a+\varepsilon t_d)(4\gamma_f\varepsilon^2-1)}{4(\varepsilon+2\gamma_f\varepsilon^2)}.$$

Due to $\gamma_f>1/(4\varepsilon^2)$ we obtain $\partial t_f/\partial t_d>0$, i.e. the two tax rates are strategic complements. Moreover, the increase in t_f induced by a marginal increase in t_d is c.p. the higher, the higher the emission coefficient ε and the damage parameter γ_f are. By inserting the reaction function [1] into the above results for $y_j^P(t_d,t_f)$ we can express the output levels in the case with policy diffusion solely in terms of the domestic tax rate t_d, where the accompanying profit levels are again given by $\pi_j^P(t_d)=y_j^P(t_d)^2$:

2 We use the superscripts "P" and "N" to indicate the case with and the case without policy diffusion. All calculations have been done using Mathematica version 5.2. The program file is available from the authors on request.

[2a] $$y_d^P(t_d) = \frac{a(1+4\gamma_f\varepsilon^2) - \varepsilon t_d(3+4\gamma_f\varepsilon^2)}{4(1+2\gamma_f\varepsilon^2)},$$

[2b] $$y_f^P(t_d) = \frac{a+\varepsilon t_d}{2(1+2\gamma_f\varepsilon^2)}.$$

Now we turn to the first stage where the domestic government introduces the tax rate t_d which may trigger the process of policy diffusion. For simplicity, we assume that the domestic government behaves risk neutral and aims at maximizing expected welfare which is given by $E[w_d(t_d)] = \overline{\sigma}\cdot w_d^P(t_d) + (1-\overline{\sigma})\cdot w_d^N(t_d)$ with $w_d^i(t_d) \equiv \pi_d^i(t_d) + t_d\varepsilon y_d^i(t_d) - \gamma_d[\varepsilon y_d^i(t_d)]^2$ for i=P,N. Accounting for the results derived above concerning output and profit levels, maximization of expected welfare leads to the following tax rate:

[3] $$t_d^* = \frac{8a(4\gamma_d\varepsilon^2-1)(1+2\gamma_f\varepsilon^2)^2 + \overline{\sigma}a(4\gamma_f\varepsilon^2-1)[1+(5\gamma_d+8\gamma_f)\varepsilon^2+4\gamma_d\gamma_f\varepsilon^4]}{32\varepsilon(1+2\gamma_d\varepsilon^2)(1+2\gamma_f\varepsilon^2)^2 - \overline{\sigma}\varepsilon(4\gamma_f\varepsilon^2-1)[(17\gamma_d-4\gamma_f)\varepsilon^2+28\gamma_d\gamma_f\varepsilon^4-5]}.$$

In interpreting t_d^* we start with the extreme case of probability $\overline{\sigma}=0$. Under this condition [3] reduces to $t_d^*|_{\overline{\sigma}=0} = [a(4\gamma_d\varepsilon^2-1)]/[4(\varepsilon+2\gamma_d\varepsilon^3)]$. This expression represents the optimal solution in the case of a pure national emission tax that is unbiased by any prospect of policy diffusion. Due to $\gamma_d > 1/(4\varepsilon^2)$ we obtain $t_d^*|_{\overline{\sigma}=0} > 0$. Hence, the positive welfare effects of reduced emissions always outweigh the negative effects of reduced output such that the introduction of t_d^* pays even if there is no chance for policy diffusion.

For the general case with $0 \le \overline{\sigma} \le 1$ we obtain $\partial t_d^* / \partial\overline{\sigma} > 0$ as shown in Appendix II.[3] Consequently, the optimal domestic tax rate is c.p. the higher, the higher the probability of policy diffusion σ is. The same holds with respect to the damage parameters γ_d and γ_f, whereas the impact of a marginal increase of the emission coefficient ε is ambiguous. Since the domestic and the foreign tax rates are strategic complements, the same conclusions hold for the comparative statics concerning t_f^* which can be obtained from inserting t_d^* into reaction function [1].

Next, we analyze how variations in the probability of policy diffusion will affect domestic welfare in equilibrium. In doing so, we have to distinguish between an ex ante and an ex post perspective. In the ex ante perspective it is not clear whether policy diffusion will occur in the end such that the relevant magnitude is *expected* welfare $E[w_d(t_d^*)]$; in the ex

[3] Note that $t_d^*|_{\overline{\sigma}=0} > 0$ and $\partial t_d^* / \partial\overline{\sigma} > 0$ implies that t_d^* is always strict positive for $\gamma_d > 1/(4\varepsilon^2)$ and $\overline{\sigma} \in [0,1]$.

post perspective policy diffusion has occurred or not, such that the resulting welfare level $w_d^P(t_d^*)$ or $w_d^N(t_d^*)$ has to be considered. Obviously, ex post an increase in $\overline{\sigma}$ leads to an increase in welfare if policy diffusion occurs and to a decrease in welfare if policy diffusion does not occur, i.e. $\partial w_d^P(t_d^*)/\partial\overline{\sigma}>0$ and $\partial w_d^N(t_d^*)/\partial\overline{\sigma}<0$.[4] Ex ante, however, an increase in $\overline{\sigma}$ has two opposite effects on expected welfare: On the one hand, $\sigma w_{2d}^P(t_d^*)$ increases, on the other hand, $(1-\overline{\sigma})w_{2d}^N(t_d^*)$ decreases. Consequently, a high probability of policy diffusion need not be beneficial per se in the ex ante perspective. The reason for this result is that a high probability $\overline{\sigma}$ leads to maladjustment in the sense of a too high domestic tax rate if policy diffusion finally does not occur.

4. First-Mover Behaviour vs. Nash Competition

In order to explore the consequences of first-mover behaviour by the domestic government, it is also interesting to compare the above results with the results of a standard model of strategic environmental policy where both governments fix their emission taxes simultaneously. In this case, we can restrict the analysis to a two stage game. In order to distinguish the outcome of this game from the results derived in the last section, we use upper case letters. In the second stage of the modified game, the tax rates T_d and T_f are already given and the firms simultaneously choose their output levels. This leads to $Y_d(T_d,T_f)=[a+\varepsilon(T_f-2T_d)]/3$ and $Y_f(T_d,T_f)=[a+\varepsilon(T_d-2T_f)]/3$ with the accompanying profit levels $\Pi_j(T_d,T_f)=Y_j(T_d,T_f)^2$ for j=d,f. In the first stage of the game, both governments simultaneously maximize the welfare function $W_j(T_d,T_f)=\Pi_j(T_d,T_f)+\varepsilon T_j Y_j(T_d,T_f)-\gamma_j[\varepsilon Y_j(T_d,T_f)]^2$ for j=d,f. The resulting reaction functions can be solved for the following tax rates:

[4a] $$T_d^* = \frac{a(4\gamma_d\varepsilon^2-1)(4\gamma_f\varepsilon^2+1)}{5\varepsilon+12(\gamma_d+\gamma_f)\varepsilon^3+16\gamma_d\gamma_f\varepsilon^5},$$

[4b] $$T_f^* = \frac{a(4\gamma_f\varepsilon^2-1)(4\gamma_d\varepsilon^2+1)}{5\varepsilon+12(\gamma_d+\gamma_f)\varepsilon^3+16\gamma_d\gamma_f\varepsilon^5}.$$

4 The reason for this is straightforward: On the one hand, if policy diffusion does not occur, the difference between the tax rate chosen in period 1 and the ex post optimal tax rate $t_d^*\big|_{\overline{\sigma}=0}$, is c.p. the higher, the higher $\overline{\sigma}$ is. On the other hand, if policy diffusion does occur, the difference between the tax rate chosen in period 1 and the ex post optimal tax rate $t_d^*\big|_{\overline{\sigma}=1}$ is c.p. the smaller, the higher $\overline{\sigma}$ is.

In order to analyze whether first-mover behaviour implies a more stringent environmental policy in the sense of a higher (domestic or foreign) tax rate, we calculate the difference $\Delta t_d = t_d^* - T_d^*$. As shown in Appendix III, the sign of Δt_d is given by:

$$[5] \qquad \Delta t_d \begin{cases} >0 & if \quad \gamma_d < \hat{\gamma}_d \\ <0 & if \quad \gamma_d > \hat{\gamma}_d \end{cases} \qquad \text{with } \hat{\gamma}_d \equiv \frac{1}{8}\left[\frac{4+5\overline{\sigma}+4\gamma_f \varepsilon^2(2+7\overline{\sigma})}{\varepsilon^4(1+2\gamma_f \varepsilon^2)(1-\overline{\sigma})}\right]^{1/2}.$$

Let us first consider the special case with probability $\overline{\sigma}=0$. Under this condition the threshold level $\hat{\gamma}_d$ degenerates to $\hat{\gamma}_d = 1/(4\varepsilon^2)$. However, an interior solution with positive tax rates requires $\gamma_d > 1/(4\varepsilon^2)$. Consequently, without any chance for policy diffusion (i.e., $\overline{\sigma}=0$) first-mover behaviour always implies a smaller domestic tax rate compared to the Nash solution.

In the more general case with $0<\overline{\sigma}<1$ we obtain $\hat{\gamma}_d > 1/(4\varepsilon^2)$ such that both outcomes are possible. In particular, first-mover behaviour leads to higher tax rates compared to the Nash solution if the domestic damage parameter falls short of the threshold level $\hat{\gamma}_d$. The latter, in turn, depends on the foreign damage parameter γ_f, the probability of policy diffusion σ and the emission coefficient ε. In Appendix III we show that the threshold level $\hat{\gamma}_d$ is c.p. the larger, the higher the probability of policy diffusion is. The same holds with respect to γ_f, whereas an increase in ε leads to a smaller threshold level $\hat{\gamma}_d$. Consequently, the outcome that first-mover behaviour implies a more stringent environmental policy compared to the Nash case is c.p. the more likely, the higher the probability of policy diffusion σ is, the higher the foreign damage parameter γ_f is and the smaller the emission coefficient ε is.

5. Determinants of Policy Diffusion

A prominent example for environmental policy diffusion is the emergence of carbon/energy taxes. The first carbon/energy tax was implemented in Finland in 1990. Since then further countries have introduced a similar regulatory measure. The gradual introduction of carbon/energy taxes is neither the result of harmonization nor of imposition but an outcome of policy diffusion (Busch & Jörgens 2005). The first adoptions occurred in the Scandinavian countries which in turn took the Finnish example as a model. Later adoptions involved institutionalized informational networks (Lazer 2005) whereby other countries learned from the early-movers. This process indicates that the notion of policy diffusion opposes the belief that change in national policy patterns, e.g. towards a regulatory convergence, is largely due to external structural forces like globalization (Levi-Faur 2005). Instead the diffusion perspective treats change in trans-national governance as the result of non-cooperative but still interdependent national policy making. Consequently, whether a first-mover policy will be adopted in another country also depends on internal factors. What these determinants have in common is that they are mostly knowledge-based (Dolowitz & Marsh 2000), which is also captured in the notions "policy-learning" (Sabatier & Jenkins-Smith 1988) and "lesson drawing" (Rose 1991). Mechanisms such as learning imply that the potential adopter holds sufficient capacities in terms of integrating a new policy into his context. Thus, such an adoption of course gives rise to a host of possible impediments and deficiencies: the foreign government may not comprehend the policy; essential information may get lost in transmission; the foreign government receives not enough support to implement the policy; lobbying groups may fear the emergence of adverse impacts on their clientele after the policy has been introduced. Especially the last two points capture the importance of "advocacy coalitions" which are defined as groups of people who "share a particular belief system" and operate on a long-term basis (Sabatier 1988, p. 139). Hence, a lobby that anticipates the diffusion of a policy which it deems detrimental for its clientele has a strong incentive to oppose the adoption of that policy. Therefore, it will lobby for the refusal of the policy or at least for the implementation of a laxer version. The impact of such lobbying activities then depends, amongst others, on the funds which are at the advocacy group's disposal. Consequently, policy diffusion is the less probable the stronger the opposition of the affected interest groups is.

Empirical evidence supports this prediction since the introductions of carbon taxes in the USA (1993), Australia (1995), and New Zealand (1997 and again in 2005) failed due to the respective domestic industries' concerns about a decreasing international competitiveness (Hoerner & Muller 1996, Tews 2002). These observations indicate that any proposal to introduce a taxation policy will be profoundly debated. The thus emerging opposition explains why the spread of such taxes has been rather slow compared to other environmental policy instruments like, e.g., quotas or feed-in tariffs for renewables in power supply (Busch & Jörgens 2005).

6. Policy Diffusion and the Impact of Lobbying

Following the discussion in Section 5 it seems sensible to assume within our model that the probability of policy diffusion depends on two factors: the magnitude of the adverse impact on the foreign firms' profits and the degree of their political influence. In order to account for these considerations, we combine the above model with a strategic lobbying approach in the spirit of Tullock (1967). In particular, we assume that the foreign government can be subdivided into a "regulation group" which promotes the introduction of the optimal emission tax t_f^* and a "non-regulation group" which refuses the taxation of emissions at all. Without lobbying activities by the foreign firm, the (exogenous) probability that the "regulation group" is successful and policy diffusion occurs is given by the probability $\overline{\sigma} \in [0,1]$ as introduced in Section 2.[5] In order to describe the impact of the foreign firm's lobbying we use an approach that is similar to the well known "contest success function" from the rent-seeking literature (see, e.g., Ursprung 1991):

$$[6] \qquad \sigma(z_f) = \frac{\overline{\sigma}}{1+\alpha z_f}.$$

Here z_f denotes the lobbying expenditures of the foreign firm, α is a productivity parameter that measures the impact of lobbying, and $\sigma(z_f)$ is the resulting probability of policy diffusion. In order to fix the optimal level of lobbying expenditures the foreign firm maximizes its expected profit $\sigma(z_f)\pi_f^P + (1-\sigma(z_f))\pi_f^N$ minus political outlays z_f. The resulting first order condition is given by:

$$[7] \qquad -\frac{\partial \sigma(z_f)}{\partial z_f} \cdot \hat{\pi}_f = 1 \quad \text{with} \quad \hat{\pi}_f \equiv \pi_f^N - \pi_f^P .$$

The LHS of [7] represents the change in expected profits caused by a marginal increase in lobbying expenditures. Consequently, condition [8] states that marginal costs and benefits of influencing the political process are balanced: The last dollar spent on lobbying activities yields an increase in expected profits of just one dollar. Differentiating [6] with respect to z_f and accounting for the non-negativity condition $z_f \geq 0$, equation [7] can be solved for the optimal amount of lobbying expenditures:

$$[8] \qquad z_f^* = \begin{cases} \frac{1}{\alpha}\left[\sqrt{\alpha\overline{\sigma}\hat{\pi}_f} - 1\right] & \text{if } \hat{\pi}_f > \hat{\pi}_f^{\min} \\ 0 & \text{if } \hat{\pi}_f \leq \hat{\pi}_f^{\min} \end{cases} \quad \text{with} \quad \hat{\pi}_f^{\min} \equiv \frac{1}{\alpha\overline{\sigma}}.$$

Equation [8] shows that the foreign firm's incentive for lobbying is driven by the difference in profits $\hat{\pi}_f$, i.e. $\partial z_f^* / \partial \hat{\pi}_f > 0$. However, it also turns out that a positive $\hat{\pi}_f$ alone does not necessarily imply $z_f > 0$: The foreign firm will undertake lobbying efforts only if

[5] For simplicity we assume that the possible impact of lobbying activities by environmental pressure groups is already included in $\overline{\sigma}$. Alternatively, it would be possible to model the impact of competing lobbying activities (see, e.g., Michaelis 1994).

the difference in profits is sufficiently large.[6] Moreover, [8] indicates that the optimal amount of lobbying expenditures is c.p. the higher, the higher the initial probability of policy diffusion is, i.e. $\partial z_f^* / \partial \overline{\sigma} > 0$. Finally, by inserting [8] into [6] we can derive the probability of policy diffusion that results from the foreign firms' lobbying activities

$$[9] \qquad \sigma(z_f^*) = \begin{cases} \sqrt{\overline{\sigma}/\alpha\hat{\pi}_f} & \text{if } \hat{\pi}_f > \hat{\pi}_f^{\min} \\ \overline{\sigma} & \text{if } \hat{\pi}_f \leq \hat{\pi}_f^{\min} \end{cases} .$$

Taking into account the previous considerations, our model now represents a four stage game: In the first stage the domestic government introduces the emission tax t_d and thereby initiates a political process which leads to policy diffusion with probability $\overline{\sigma}$; in the second stage the foreign firm engages in lobbying activities that aim at reducing the probability of policy diffusion; in the third stage policy diffusion will occur with probability $\sigma(z_f^*) \leq \overline{\sigma}$ and in the fourth stage the firms choose the amount of output to be sold on the third country's market. Although this game is too complex to allow for an explicit backwards solution, it is possible to derive some insights concerning the interaction between first-mover behaviour, lobbying activities and policy diffusion. From [2a] and [2b] we can calculate the impact of the domestic tax rate t_d on the foreign firm's difference in profits:[7]

$$[10] \qquad \hat{\pi}_f(t_d) = \frac{(a + \varepsilon t_d^2)(4\gamma_f \varepsilon^2 - 1)(5 + 4\gamma_f \varepsilon^2)}{36(1 + 2\gamma_f \varepsilon^2)^2} .$$

Assuming an internal solution with $z_f^* > 0$ and inserting [10] into [9] yields the probability of policy diffusion as a function of the domestic tax rate t_d:

$$[11] \qquad \sigma(t_d) = 6(1 + 2\gamma_f \varepsilon^2)\sqrt{\frac{\overline{\sigma}}{\alpha(a + \varepsilon t_d^2)(4\gamma_f \varepsilon^2 - 1)(5 + 4\gamma_f \varepsilon^2)}} .$$

As indicated by [11], the probability of policy diffusion c.p. the smaller, the higher the domestic tax rate t_d is. This effect is c.p. the larger, the higher the foreign damage parameter γ_f is and the higher the initial probability $\overline{\sigma}$ is. Moreover, as already derived in Section 2, the optimal domestic tax rate t_d^* is the smaller, the smaller the probability of policy dif-

[6] For $\hat{\pi}_f < \hat{\pi}_f^{\min}$ the first Dollar spent on lobbying activities would yield an increase in expected profits of *less* than one Dollar such that lobbying doesn't pay at all for the foreign firm.

[7] Note that $\hat{\pi}_f(t_d) = \pi_f^N(t_d) - \pi_f^P(t_d)$, i.e., for the case with policy diffusion equation [11] assumes that the foreign government adjusts the tax rate t_f according to the reaction function [1].

fusion is. Consequently, in fixing t_d^* the domestic government has to recognize the effect of the foreign firms' lobbying activities, otherwise it will choose a tax rate too high. This result highlights that optimal first mover behaviour in environmental policy has to account not only for the reaction of the foreign government but also for possible lobbying activities which influence this reaction.

7. Summary and Conclusions

Policy diffusion describes the process by which a political innovation – like the introduction of a novel emission tax – disseminates over time among countries. This implies that at least one country has to act as a first-mover in terms of policy making. The choice of the first-mover is then expected to alter the probability of further policy adoptions. In order to analyze this issue from an economic point of view we have developed a simple two-country-model of the taxation of emissions in presence of (possible) policy diffusion. Contrary to the usual approach of simultaneous decisions on tax rates we consider a Stackelberg game: In the first step the domestic government introduces an emission tax t_d thus acting as Stackelberg-leader, in the second step the foreign government decides whether or not to introduce an emission tax t_f and in the third step the firms decide on their output quantities to be sold on a third country's market. For the case of an exogenous given probability of policy diffusion we show that the optimal domestic tax rate is c.p. the higher, the higher the probability of policy diffusion is. Moreover, we show that first-mover behaviour by the domestic government leads to a higher tax rate compared to the Nash solution with simultaneous decisions on tax rates if the domestic damage parameter falls short of a critical threshold. It turns out that this threshold is the higher the higher the probability for policy diffusion is.

In the next step we introduce an endogenous probability of policy diffusion by combining our model with a strategic lobbying approach. In so doing we obtain a feedback effect in the sense that the now endogenous probability of policy diffusion also depends on the magnitude of the domestic tax rate: the higher the latter is the smaller the probability is. Thus, by taking policy diffusion into consideration we find that the usual prediction of ecological dumping is reversed. However, this result is weakened when the foreign firm is able to engage in strategic lobbying.

Appendix I

Profit maximization by the domestic firm implies:

(I.1) Max! $\pi_d = [a - y_d - y_f]y_d - \varepsilon t_d y_d \quad \rightarrow \quad y_d = 0.5[a - y_f - \varepsilon t_d]$.

Analogously, profit maximization by the foreign firm implies:

(I.2) Max ! $\pi_f = [a - y_d - y_f]y_f - c\varepsilon t_f y_f \quad \rightarrow \quad y_f = 0.5[a - y_d - c\varepsilon t_f]$,

where c is a dummy variable associated with the foreign tax rate, i.e., we use c=1 for the case with policy diffusion and c=0 for the case without policy diffusion, respectively. Solving [I.1] and [I.2] for the equilibrium yields:

(I.3) $y_d = (1/3)[a + \varepsilon(ct_f - 2t_d]$, (I.4) $y_f = (1/3)[a + \varepsilon(t_d - 2ct_f)]$.

Appendix II

Differentiating t_d^* with respect to σ, γ_d and γ_f and rearranging terms yields:

(II.1) $$\frac{\partial t_d^*}{\partial \sigma} = \frac{72a}{\varepsilon\omega}[\varphi^2(4\gamma_f\varepsilon^2 - 1)(1 + \varepsilon^2(4\gamma_f + \gamma_d(4\gamma_f\varepsilon^2 - 1 + 4\varepsilon^2\gamma_d(3 + 4\gamma_f\varepsilon^2))))]$$

(II.2) $$\frac{\partial t_d^*}{\partial \gamma_d} = \frac{6a\varepsilon}{\omega}[256\varphi^4 - 20\sigma(2\gamma_f\varepsilon^2 + 8\gamma_f^2\varepsilon^4 - 1)^2 + \sigma^2(1 - 4\gamma_f\varepsilon^2)^2(1 + 2\gamma_f\varepsilon^2)(7 + 20\gamma_f\varepsilon^2)],$$

(II.3) $$\frac{\partial t_d^*}{\partial \gamma_f} = \frac{36a\varepsilon\sigma}{\omega}[8\varphi(1 + \varepsilon^2(8\gamma_f + \gamma_d(4\varepsilon^2(3\gamma_f + \gamma_d(5 + 4\gamma_f\varepsilon^2)) - 3))) + (1 - 4\gamma_f\varepsilon^2)^2\sigma(1 + \gamma_d\varepsilon^2(2\gamma_d\varepsilon^2 - 3))],$$

where ω indicates $\omega \equiv [\sigma(4\gamma_f\varepsilon^2 - 1)(28\gamma_d\gamma_f\varepsilon^4 + (17\gamma_d - 4\gamma_f)\varepsilon^2 - 5) - 32(1 + 2\gamma_d\varepsilon^2)(1 + 2\gamma_f\varepsilon^2)^2]^2 > 0$ and φ indicates $\varphi \equiv (1 + 2\gamma_f\varepsilon^2) > 0$. Due to $\gamma_f > 1/(4\varepsilon^2)$ we obtain $\partial t_d^* / \partial\sigma > 0$ from (II.1). With respect to (II.2), ambiguity concerning the sign could arise from the term $256\varphi^4 - 20\sigma(2\gamma_f\varepsilon^2 + 8\gamma_f^2\varepsilon^4 - 1)^2$. However, the maximum possible value of σ is σ=1. Inserting this and accounting for $\varphi \equiv (1 + 2\gamma_f\varepsilon^2)$, the term under consideration can be recalculated as $4(1 + 2\gamma_f\varepsilon^2)^2[59 + 8\gamma_f\varepsilon^2(37 + 22\gamma_f\varepsilon^2)] > 0$ which proofs $\partial t_d^* / \partial\gamma_d > 0$. Finally, (II.3) contains two terms that might be ambiguous, the first one of which is $4\varepsilon^2(3\gamma_f + \gamma_d(5 + 4\gamma_f\varepsilon^2)) - 3$. However, this can be factorized as $20\gamma_d\varepsilon^2 + 16\gamma_d\gamma_f\varepsilon^2 + 3(4\gamma_f\varepsilon^2 - 1) > 0$. The second ambiguous term is $\sigma(1 + \gamma_d\varepsilon^2(2\gamma_d\varepsilon^2 - 3))$ which cannot be ruled out to be negative. However, due to σ≤1 it suffices to show for σ =1 that the complete expression on the RHS of (II.3) is positive even if $\sigma(1 + \gamma_d\varepsilon^2(2\gamma_d\varepsilon^2 - 3))$ is negative. Inserting σ=1 into (II.3), accounting for ω as well as φ and rearranging terms yields:

(II.4) $$\frac{\partial t_d^*}{\partial \gamma_f}\Big|_{\sigma=1} = \frac{4a\varepsilon[(1 + 4\gamma_f\varepsilon^2)^2 + \gamma_d\varepsilon^2(4\gamma_f\varepsilon^2 - 1)(3 + 4\gamma_f\varepsilon^2) + 2\gamma_d^2\varepsilon^4(3 + 4\gamma_f\varepsilon^2)^2]}{(3 + 4\gamma_f\varepsilon^2)^2[1 + \varepsilon^2(3\gamma_d + 4\gamma_f) + 4\gamma_d\gamma_f\varepsilon^4]^2}.$$

Due to $\gamma_f > 1/(4\varepsilon^2)$ the expression on the RHS of (II.4) is positive which completes the proof for $\partial t_d^* / \partial\gamma_f > 0$.

Appendix III

Calculating the difference $\Delta t_d = t_d^* - T_d^*$ from [3] and [4a] yields:

(III.1) $\Delta t_d = -\dfrac{\omega_1}{\omega_2\omega_3}$

with $\omega_1 \equiv 2a(1+2\gamma_f\varepsilon^2)(4\gamma_f\varepsilon^2-1)(4+64\gamma_d^2\varepsilon^4(\sigma-1)+5\sigma+4\gamma_f\varepsilon^2(2+32\gamma_d^2\varepsilon^4(\sigma-1)+7\sigma))$,

and $\omega_2 \equiv \varepsilon[5+12(\gamma_d+\gamma_f)\varepsilon^2+16\gamma_d\gamma_f\varepsilon^4]$,

and $\omega_3 \equiv \sigma(4\gamma_f\varepsilon^2-1)[(17\gamma_d-4\gamma_f)\varepsilon^2+28\gamma_d\gamma_f\varepsilon^4-5]-32(1+2\gamma_d\varepsilon^2)(1+2\gamma_f\varepsilon^2)^2$.

We first show that the denominator is always negative such that the sign of Δt_d depends only on the sign of the numerator. Due to $\omega_2>0$ the sign of the denominator equals the sign of ω_3. By expanding and rearranging terms this expression can be recalculated as:

(III.2) $\omega_3 = 5\sigma-32-(64+17\sigma)\gamma_d\varepsilon^2-(128+16\sigma)\gamma_f\varepsilon^2-(256-40\sigma)\gamma_d\gamma_f\varepsilon^4-(128+16\sigma)\gamma_f^2\varepsilon^4$
$-(256-112\sigma)\gamma_d\gamma_f^2\varepsilon^6$.

Due to $\sigma\leq 1$ we obtain $\omega_3<0$ such that the denominator of (III.1) is always negative. Now we turn to the numerator whose sign is ambiguous. However, by solving the inequalities $\omega_1>0$ and $\omega_1<0$ for γ_d we obtain:

(III.3) $\omega_1\begin{cases} >0 \text{ if } \gamma_d<\hat{\gamma}_d \\ <0 \text{ if } \gamma_d>\hat{\gamma}_d \end{cases}$ with $\hat{\gamma}_d \equiv \left(\dfrac{\varphi}{64}\right)^{1/2}$ and $\varphi \equiv \dfrac{4+5\overline{\sigma}+4\gamma_f\varepsilon^2(2+7\overline{\sigma})}{\varepsilon^4(1+2\gamma_f\varepsilon^2)(1-\overline{\sigma})}$.

This completes the proof of [5]. Finally, we consider the derivatives of $\hat{\gamma}_d$ with respect to γ_f, σ and ε. The signs of these derivatives are identical with the signs of the respective derivatives of φ:

(III.4) $\dfrac{\partial\varphi}{\partial\gamma_f} = \dfrac{18\sigma}{(1-\sigma)(\varepsilon+2\gamma_f\varepsilon^3)^2} > 0$,

(III.5) $\dfrac{\partial\varphi}{\partial\sigma} = \dfrac{9(1+4\gamma_f\varepsilon^2)}{\varepsilon^4(1+2\gamma_f\varepsilon^2)(\sigma-1)^2} > 0$,

(III.6) $\dfrac{\partial\varphi}{\partial\varepsilon} = \dfrac{4[4+5\sigma+\gamma_f\varepsilon^2(16+29\sigma+8\gamma_f\varepsilon^2(2+7\sigma))]}{\varepsilon^5(1+2\gamma_f\varepsilon^2)^2(\sigma-1)} < 0$.

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