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The Impact of Voluntary Agreements on Firms' Incentives for Technology Adoption*

by

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Abstract

The paper analyses the impact of voluntary agreements and other regulatory instruments on firms' incentives to adopt cleaner and more efficient technologies. It takes a viewpoint of political economy and argues that bargaining incentives result when industry can fight planned regulation in the political arena. It presents a model in which a regulator and an industry representative negotiate over which regulatory

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instrument to apply with which stringency. Depending on the parties' respective position in the political contest, voluntary agreements or other (negotiated or mandatory) policy instruments are implemented.

Policy instruments differ in their impacts on firms' profits and market shares, which yields different incentives for technology adoption. A commitment of the regulator to exclusively use emissions taxation is shown to never increase welfare in equilibrium, although, within the model, it is the only instrument that can ensure the first-best allocation and generates the adequate incentives for technology adoption. When the regulator is ready to implement a voluntary agreement, incentives for technology adoption are lower than possible under given welfare, but are possibly traded against more stringent environmental regulation. Overall, however, bilateral voluntary agreements are always welfare-neutral. In consequence, the analysis gives a rationale for traditional command-and-control regulation via mandatory standards, but expresses skepticism with respect to bilateral voluntary agreements.

Technical Abstract

The paper reconsiders the Porter hypothesis in a offer/counter-offer bargaining model, in which a welfare-maximizing regulator and an industry representative negotiate over which regulatory instrument to apply with which stringency. The possibility to contest planned regulation in the political arena is given as an outside option of the bargaining model. Policy instruments differ in their impacts on firms' profits and market shares, which yields different incentives for technology adoption. Furthermore, means of direct regulation may lead to an implicit cartelization of the industry. This later feature shapes the actors' equilibrium threat position, which, in turn, influences incentives to contest the regulation and the subsequent regulatory outcome. Depending on the parties' respective position in the political contest, the implementation of voluntary agreements or of other (negotiated or mandatory) policy instruments, as well as their impact on the technology adoption incentives, is endogenously derived within this single model.

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1 Introduction

According to the Porter hypothesis, environmental policy may lead to innovations that are not only beneficial for the environment, but have additional positive effects on firms' productivity (Porter/van der Linde 1995a, 1995b; Schmutzler 1998). A precondition is that the regulator applies *flexible* policy instruments, that is, instruments that do not prescribe specific technological measures to meet environmental quality standards.

In the discussion on the Porter hypothesis, firms are usually depicted to passively react to the political will of an omnipotentent regulator. In reality, however, instead of merely adapting production technology to changed political constraints, firms can also unfold political resistance against planned regulation. Costly political contests will then follow during the process of formulating mandatory environmental regulation. Incentives to bargain may result in such a setting: While industry may seek to avoid harsher regulation via legislation, the regulator may wish to avoid the delays and other regulatory costs stemming from the political struggles so prominent before legislation is ultimately passed and implemented (Segerson/Miceli 1998, 110). The negotiated, cooperative arrangements that result as an alternative to mandatory environmental regulation have recently gained interest in the political arena (OECD 1999) as well as in the scientific community. Especially prominent are the so-called voluntary agreements, which typically involve multiple firms of an industry branch.

They either unilaterally promise to voluntarily reduce environmental externalities. Alternatively, a bilateral – possibly informal – contract is drafted between the industry group and the regulator to cut emissions of a specific type (Lyon/Maxwell 1999).[1]

How is the validity of the Porter hypothesis affected by such a more realistic setting? Specifically, what incentives for technology adoption result under policy instruments that are not necessarily set by an omnipotent regulator, but are implemented as a result of a cooperative process? To provide an answer to these questions, the present paper will use a Rubinstein bargaining model, in which the parties – a welfare-maximizing regulator and an industry representative – bargain over which policy instrument to apply and over its stringency. They can resort to a political contest as an outside option of the game. Two classical policy instruments that both grant flexibility in Porter's sense are considered: an emissions tax and environmental quality standards. Both can either be prescribed mandatorily or be implemented as a result of negotations. In the latter case, the regulatory outcome will either be labeled a *negotiated tax break* or, in the case of negotiated standards, a *voluntary agreement*.[2]

[1] Note that voluntary agreements in this sense are different from "voluntary programs" for environmental protection, in which participation is voluntary and the regulator subsidizes participants (see Carraro/Siniscalco 1996, Wu/Babcock 1999). The present analysis rules out the possibility of positive monetary transfers to firms.

[2] The reason to restrict this term to negotiated standards is that under voluntary agreements,

As will be spelled out, these policy instruments have different impacts on the market shares and relative profitability of innovative firms. These different impacts shape the other firms' incentives to adopt similar technological innovations. In the model, there are innovative firms from the outset whose technology combines lower emission coefficients with lower marginal costs of production. Despite this technological superiority, it will be shown that incentives for technology adoption may be reduced in the equilibrium regulatory outcome.

The paper assumes that the regulator can credibly commit *ex ante* to exclusively rely on specific instruments, and that firms are privately informed on their avoidance costs. Under this informational structure of the model, first-best efficiency can be implemented by a uniform tax rate per emission unit, but not by quality standards

it is typically left to the industry, i.e., to its representative, to solve coordination and free-riding problems subsequent to the overall agreement. Hence, an important question is how the aggregate policy goal stipulated in the agreement is allocated between the individual firms. When firms are heterogenous and privately informed on the relevant parameters, the industry representative's power to adequately differentiate burden-sharing is limited, because the implementation of intra-industry transfer schemes is usually beyond her competence. For instance, the use of an incentive-compatible mechanism, or of an industry-wide emissions tax collected by an industry federation and redistributed lump-sum cannot be observed empirically. This implies that aggregate emission cuts will have to be allocated on individual firms via standards or quota. Consequently, voluntary agreements, because of adverse selection problems, can be interpreted as a kind of direct regulation suffering from excess uniformity (Nyborg 1998, 2).

(which are either directly prescribed or implemented by a voluntary agreement). Despite this advantage and the fact that taxation generates the adequate incentives for technological adoption, the analysis will demonstrate that a commitment to exclusively use taxation will never increase, and may decrease welfare in equilibrium. Furthermore, to bargain over standards, that is, to conclude a voluntary agreement, will be welfare-neutral.

The analysis proceeds as follows. Section 2 introduces the model. It first presents the technological structure of the industry and the impacts of different policy instruments on the firms' market shares and relative profitability (2.1). Section 2.2 then presents the objectives of the actors, derives the sets of feasible bargaining solutions under different options to commit and spells out the bargaining protocol. Section 3 derives the outcomes contingent on the different commitment options. Section 4 presents the policy results, and section 5 gives concluding remarks.

2 The Model

2.1 Industry Structure and Policy Instruments

Industry Structure The industry consists of N price-taking firms producing an aggregate output X. The firms differ by their environmentally harmful emissions $e_i(x)$ and their production costs $c_i(x)$, where $\frac{dc_i}{dx} > 0$, $\frac{d^2c_i}{dx^2} > 0$ and $c_i(0) = 0$. A firm is one of two types, $i \in \{l, h\}$, where l and h stand, respectively, for *low* and *high* marginal production costs; hence,

$$\frac{dc_l(x)}{dx} < \frac{dc_h(x)}{dx}. \tag{1}$$

Denote by q the fraction of firms of the high type. With respect to emissions production and avoidance, assume that $e_l(x) < e_h(x)$ for any x, and $e_i(0) = 0$. Firms of the low type represent the industry's technological forefront in the sense that they combine lower marginal production costs with lower emissions per output unit. Firms of the high-type have not adopted the new technology because of organizational deficiencies (e.g., problems of generating the adequate managerial incentives, or limited internal information processing and communication capacities; see Porter/van der Linde 1995b, 122; for a summary: Schmutzler 1998, 8-9). Note that the term *industry structure,* as it is used here, refers to the fraction of firms using one of two specific technologies.

This specification of the industry structure, where innovation with respect to pollution has positive impacts on the production technology, allows us to analyse the implications of the Porter hypothesis in a framework of political contests and resulting bargaining incentives. For the Porter hypothesis to hold, a technology which simultaneously lowers production costs and emissions per output unit must be within reach by innovation from the outset. Under the specification made, this precondition is fulfilled. The innovation process itself stemming from environmental regulation is not addressed here, as it is just assumed that there is a fraction of $(1-q)$ innovative firms from the outset. However, it can be investigated whether and to what extent the relative market position of these innovative firms is improved by the introduction of specific regulatory instruments. An improved market position of low-type firms, as given by a higher market share or higher relative profits will, in turn, generate higher incentives for high-type firms to adopt the more productive technology, even under given organizational deficiencies.

For ease of presentation, assume that production costs have the following quadratic form:

$$c_l(x) = 0.5x^2 - bx, \;\; c_h(x) = 0.5x^2. \tag{2}$$

Furthermore, emissions are linear in output; specifically,

$$e_l(x) = \alpha x, \;\; e_h(x) = x, \tag{3}$$

where $b > 0$ and $\alpha \in (0, 1)$. Linear market demand is downward-sloping and given by $X = X_d(p)$, and inverse demand is $p = p(X)$. Aggregate supply is given by

$$X_s(p) = N(qx_h(p) + (1 - q)x_l(p)),$$

where x_l, x_h solve

$$p = \frac{dc_i(x_i)}{dx_i}$$

for any p and $i \in \{l, h\}$. Equilibrium price and outputs without environmental regulation are indicated with the superscript 0; hence, $X_d(p^0) = X_s(p^0)$, $X_s(p^0) = N(qx_h^0 + (1 - q)x_l^0)$, and x_i^0 solves $p^0 = \frac{dc_i(x_i)}{dx_i}$. Because of (1), $x_l^0 > x_h^0$.

Introduce the following notation. Denote a specific emission tax rate by t and specific uniform emission standard by $\bar{e}$. It will be spelled out below why standards have to be uniform. A firm's profit is denoted by $\pi_i(k)$, where k stands for a specific regulatory instrument and its stringency: $k \in \{t, \bar{e}\}$, and $\pi_i(0) = \pi_i^0$. As is the case in most industries, entry costs are positive, such that positive profit levels are sustained in the status quo equilibrium: $\pi_h^0 \geq 0$. Note that under (2) and because of $x_l^0 > x_h^0$, $\pi_l^0 > \pi_h^0$. Furthermore, denote the low-type's market share by

$$h_l(k) = \frac{x_l(p(k))}{N[qx_h(p(k)) + (1-q)x_l(p(k))]},$$

where $p(k)$ is the market price under instrument k and will be specified below. The high type's relative profitability is given by

$$\varpi_h(k) = \frac{\pi_h(k)}{\pi_l(k)}.$$

The analysis adopts the informational structure used by Spulber 1988 (see also Spulber 1989, 372): Emissions are observable, e.g., by technical monitoring devices on stacks, or an emissions tax could not be used. Firms are privately informed of their respective type. The regulator and the industry representative only know the possible types and q. Neither the regulator nor the representative can infer the firm's type from the firms' output x_i. Furthermore, the firm's type cannot be inferred from emissions when regulation is absent, or type-specifically optimal regulation would be trivial: $e_h(x_h^0) = e_l(x_l^0)$ or, using (3), $x_h^0 = \alpha x_l^0$.

External damages from emissions are given by $D(E)$, $\frac{dD}{dE} > 0$, $\frac{d^2D}{dE^2} > 0$, where $E = N(qe_h + (1-q)e_l)$. Consider now the impact of policy instruments on firms' profitability and on market structure.

Taxation When the optimal tax (whose amount is derived below) would be contested in the political arena, the regulator may be ready to agree on a suboptimal low tax rate. Let $p(t)$ be the market price resulting from a given tax rate; using (2) and (3) and the definitions of X, $p(t)$ is implicitly defined by

$$X_d(p(t)) = N[p(t) + (1-q)b - (q + (1-q)\alpha)t]. \tag{4}$$

Differentiating (4) with respect to t and solving for $\frac{dp}{dt}$ yields

$$\frac{dp}{dt} = \frac{N(q + (1-q)\alpha)}{N - \frac{dX_d}{dp}} > 0. \tag{5}$$

Plausibly, a higher market price results when the tax rate is raised. Consider now the impact of a higher tax rate of the high-type's profits. Using (2) and (3) and introducing the tax yields as the high-type's profit function

$$\pi_h(t) = p(t)(p(t) - t) - 0.5(p(t) - t)^2 - t(p(t) - t), \tag{6}$$

where $p(t) - t = x_h(t)$ is the firm's optimal output under t. Assume (6) to be positive (high-type firms produce under relevant tax rates). Differentiating (6) yields

$$\frac{d\pi_h}{dt} = (p - t)(\frac{dp}{dt} - 1) < 0. \tag{7}$$

To see the sign of (7), note that $p(t) - t > 0$, or the firm would quit the market. Furthermore,

$$\frac{dx_h(t)}{dt} = \frac{dp}{dt} - 1 < 0,$$

as can been seen from (5). The high-type firm's profit is reduced under a higher tax rate.

The impact of of a higher tax rate on the low-type's profits can be given analogously. Using again (2) and (3) and deriving yields

$$\frac{d\pi_l}{dt} = (p + b - \alpha t)(\frac{dp}{dt} - \alpha) \gtreqless 0. \tag{8}$$

Again, $(p + b - \alpha t) > 0$; however, $(\frac{dp}{dt} - \alpha) \gtreqless 0$. In contrast to the high-type, the low-type's profit react ambiguously to tax increases. The reason is that higher tax rates increasingly reallocate relative outputs to the more efficient low-type firms[3]. The low-type's profit may even monotonically increase in higher tax rates as long as both firm types keep on producing (monotonicity results from $\frac{dp}{dt} = const$). Using (5) for a reformulation of (8), this will be the case when

$$(1 - \alpha)Nq > -\frac{dX^d}{dp}.$$

[3] As a consequence, industry concentration, as measured by the Herfindahl-index $H(t) = Nq\left(\frac{x_h(t)}{X(t)}\right) + N(1-q)\left(\frac{x_l(t)}{X(t)}\right)$, is increased under higher tax rates. As the low-type's technology is superior both with respect to production and the environment, this result, however, merely shows the limited value of this measure for normative assessments in the present framework.

Assume that this condition is not fulfilled. Even then, relative profitability of the high-type decreases under a higher tax rate, as will be shown now. The relative profitability of the high-type under taxation is given by

$$\varpi_h(t) = \frac{(p(t) - t)^2}{(p(t) + b - \alpha t)^2},$$

which yields

$$\frac{d\varpi_h(t)}{dt} = \frac{2(p - t)(p + b - \alpha t)[(\frac{dp}{dt} - 1)(p + b - \alpha t) - (\frac{dp}{dt} - \alpha)(p - t)]}{(p(t) + b - \alpha t)^4} < 0 \qquad (9)$$

To see the sign of (9), note that $0 > (\frac{dp}{dt} - 1) < (\frac{dp}{dt} - \alpha)$ and $(p + b - \alpha t) > (p - t)$. The relative profitability of the high-type is reduced under a higher tax rate.

The low-type's market share is given by

$$h_l(t) = \frac{(p(t) + b - \alpha t)}{N[qx_h(p(t) - t) + (1 - q)(p(t) + b - \alpha t)]},$$

whose derivation yields

$$\frac{dh_l(t)}{dt} = \frac{Nq[(\frac{dp}{dt} - \alpha)(p - t) - (\frac{dp}{dt} - 1)(p + b - \alpha t)]}{N^2[qx_h(p(t) - t) + (1 - q)(p(t) + b - \alpha t)]^2} > 0 \qquad (10)$$

The sign of (10) is explained analogously to the sign of (9). To prepare the analysis of environmental standards, consider the tax's impact on the types' output and emission levels. Because of $\frac{dx_h}{dt} < \frac{dx_l}{dt}$,

$$x_h^0 - x_h(t) > x_l^0 - x_l(t) \qquad (11)$$

for any $t > 0$. The high type reduces output more than the low type. Denote $\Delta e_i = e_i^0 - e_i(t)$. Using (3) and (11),

$$\Delta e_h > x_l^0 - x_l(t) > \alpha(x_l^0 - x_l(t)) = \Delta e_l.$$

Under any $t > 0$, high-type firms avoid a higher amount of emissions; hence, $e_h(t) < e_l(t)$.

Standards In the setting considered here, any standard $\bar{e}_i < e_i^0$, whether or not voluntarily agreed on, amounts to the introduction of an upper ceiling on production. If the firms' types were publicly known, the first-best could be implemented by prescribing type-specific emissions $\bar{e}_i^* = e_i^*$, where $\bar{e}_h^* \neq \bar{e}_l^*$. Firms would adapt their output accordingly: $x_h(\bar{e}_h^*) = \bar{e}_h^*$, $x_l(\bar{e}_l^*) = \frac{\bar{e}_l^*}{\alpha}$. Because of the adverse selection problem that results when firm types are not observable[4], the regulator introduces a uniform standard $\bar{e} < e^0$. The market price $p(X(\bar{e}))$ reacts to variations in the environmental standard according to

$$\frac{dp}{d\bar{e}} = \frac{dp}{dX} N(q + (1-q)\frac{1}{\alpha}) < 0.$$

[4]For any $\bar{e}_l > \bar{e}_h$, a firm with high marginal avoidance costs has an incentive to conceal its type and to falsely claim to be of the low type, because $x_h(\bar{e}_l) > x_h(\bar{e}_h)$, whereas $x_l(\bar{e}_h) < x_l(\bar{e}_l)$ for any pair of standards $(\bar{e}_l, \bar{e}_h)$ such that $\bar{e}_l > \bar{e}_h$.

Plausibly, the market price is raised for lower permitted emission levels. Using (3), the profit of the high firm type is given by

$$\pi_h(\bar{e}) = p(\bar{e})\bar{e} - 0.5\bar{e}^2,$$

which yields

$$\begin{aligned} \frac{d\pi_h}{d\bar{e}} &= \frac{dp}{dX}N(q + (1-q)\frac{1}{\alpha})\bar{e} + p(X(\bar{e})) - \bar{e} \\ &= p(X(\bar{e}))(\frac{1}{\eta_{\bar{X}}} + 1) - \bar{e} \lesseqgtr 0, \end{aligned} \tag{12}$$

where $\eta_{\bar{X}}$ is the price elasticity of demand at $\bar{X}$. In contrast to taxation, the impact of standards on the high-type's profit is ambiguous.[5] The intuition is that under both a tax and a standard, the market price is raised when the instrument is applied more stringently, and market output and consumer surplus are reduced. Under a standard, however, this loss of consumer surplus is appropriated not by the state (via the tax revenue), but by industry.[6] Clearly, a similar reasoning applies to the low-type's profit. Proceed directly to study the relative profitability of the high-type

[5] Indeed, it is well known since Buchanan/Tullock (1975) that any environmental regulation shifting aggregate supply upwards may lead to an implicit cartelization, in the sense of higher profits for firms under lower output (see also Malony/McCormick 1982; Baumol/Oates 1998, 179) Hence, this result does not hinge on the specification made that emission reductions can exclusively be realized by lower outputs. A similar result holds under the existence of technical abatement opportunities, unless such measures only raise fixed production costs. See Spulber (1989, chap. 13.1).

[6] Carraro/Soubeyran 1996a use this effect of higher marginal costs on market prices to investigate the impact of tax increases on homogenous, oligopolistic firms' profits and market shares.

under uniform standards:

$$\varpi_h(\bar{e}) = \frac{p(\bar{e}) - 0.5\bar{e}}{\frac{1}{\alpha}\left(p(\bar{e}) - 0.5\frac{1}{\alpha}\bar{e} + b\right)},$$

which gives

$$\frac{d\varpi_h(\bar{e})}{d\bar{e}} = \frac{\frac{1}{\alpha}\left[0.5\left(1-\frac{1}{\alpha}\right)p(\bar{e})\left(\frac{1}{\eta_{\bar{X}}}+1\right)+b\left(\frac{dp}{d\bar{e}}-0.5\right)\right]}{\left[\frac{1}{\alpha}\left(p(\bar{e}) - 0.5\frac{1}{\alpha}\bar{e} + b\right)\right]^2} \gtreqless 0. \tag{13}$$

The sign of (13) crucially depends on the expression $\left(\frac{1}{\eta_{\bar{X}}}+1\right)$. Specifically, a reformulation of (13) yields

$$\eta_{X^0} \leq -\frac{0.5p^0\left(\frac{1}{\alpha}-1\right)}{b\left(0.5-\frac{dp(\bar{e})}{d\bar{e}}\right)+0.5p^0\left(\frac{1}{\alpha}-1\right)} > -1 \tag{14}$$

as the condition for when the sign of (13) will be negative under any environmental regulation with a uniform standard. Then, a more stringent uniform standard, i.e., a lower $\bar{e}$, will always *increase* the high-type's relative profitability.

Using (3) and the definition of $X(\bar{e})$, the low-type's market share is given by

$$h_l(\bar{e}) = \frac{\frac{1}{\alpha}}{N\left[q+(1-q)\frac{1}{\alpha}\right]} = const.$$

In contrast to taxation, which increases the market share of the more efficient firms, it remains unchanged under regulation *via* a uniform standard.

Carraro/Soubeyran 1996b use this same effect to compare environmental taxation and subsidies for technology adoption. Both contributions do not involve bargaining.

2.2 Bargaining

The subsequent part will analyze possible bargaining incentives emerging from the fact that the industry representative has the option to fight against intended regulation. An equilibrium of the game will be the implementation of a specific regulatory instrument with a specific stringency. To simplify the analysis, the regulation will not include contingent changes of the regulatory instrument and/or of its strigency. The implemented regulation, whether bargained or not, applies to a given industry structure; the re-negotiations that may happen once industry structure has changed will not be considered.

The formal analysis will address two bargaining constellations. In the first constellation, it is assumed that the regulator is credibly committed to exclusively use taxation. Hence, he cannot use quality standards, neither as a usual mandatory instrument, nor as the result of a voluntary agreement. In the second constellation, it is assumed that he is not committed. A third constellation, in which the regulator commits to never use a bilateral voluntary agreement, that is, to never bargain over standards, will be adressed in part 4.

Consider now the objectives of the two actors, which are both risk-neutral.

The Regulator Two alternative objective functions of the regulator will be considered. In the first variant, the regulator maximizes welfare under a given industry structure, but ignores the possible welfare implications of the incentives for technological adoption stemming from different regulatory instruments, due to changes in firms' relative profits. Note that the diffusion rate of the more efficient technology under ϖ_h^0 will be suboptimal because of the negative external effects stemming from pollution (remember that innovative firms also have lower emissions coefficients). This regulator will be labeled to be of **type 0**. In contrast, a **type 1** regulator also takes the effects on the market structure into account. For easy comparison of these objectives and their impact on the bargaining outcomes, this welfare effect is depicted by a simple function on relative profitability $G(\varpi_h(k))$. Normalize this effect to zero under the status quo: $G(\varpi_h^0) = 0$. Furthermore, $\frac{dG}{d\varpi_h} < 0$, $\frac{d^2G}{d\varpi_h^2} < 0$ for $\varpi_h < \varpi_h^0$ and $\frac{d^2G}{d\varpi_h^2} > 0$ for $\varpi_h > \varpi_h^0$. Hence, the objective of type $r \in \{0, 1\}$ is given by

$$\begin{aligned} W_r(k) &= \int_0^{X(x_h(k), x_l(k))} p(X)dX - N(qc_h(x_h(k)) + \\ & (1-q)c_l(x_l(k)) - D(E(x_h(k), x_l(k) + \\ & rG(\varpi_h((x_h(k), x_l(k)). \end{aligned} \tag{15}$$

A maximum exists and is unique because of the strict convexity of the cost functions and the damage function and strict concavity of $G(.)$. Let W^0 denote the welfare level when regulation is absent.

The Industry Representative The industry representative is assumed to maximize profits of the median firm. To focus on the most interesting case, assume that the innovative firms are the minority: $q > 0.5$, and the representative maximizes profits of high-type firms. Note that, as $\pi_l^0 > \pi_h^0$ and low-type firms have lower marginal costs (produce more efficiently), they will always earn higher profits than high-type firms. Hence, maximizing high-type firms' profit will not violate the participation constraint of low-type firms.

The present analysis assumes that political resistance cannot be mobilized by isolated (coalitions of) firms without support of the industry representative, as it is only the industry association that can provide the necessary staff and finance. Furthermore, the regulator upholds the legislative threat against firms not participating in a possible voluntary agreement. These assumptions carry the consequence that, when a voluntary agreement is stipulated, it is always the grand coalition who will participate in such an agreement. Hence, the assumption allows us to analyze the price effects of industry-wide regulation without having to address the question of how many firms will participate in equilibrium.

Proceed now to characterize the respective sets of feasible bargaining solutions.

The Feasible Set under Taxation Let $W_r(t)$ be the welfare level associated with a specific tax rate; clearly, $\frac{dW_r(t)}{dt} \gtreqqless 0$ for $t \lesseqqgtr t_r^*$. Using (2), (3) and the definition of X and E in (15) gives as first-order condition

$$\left(t - \frac{dD}{dE}\right)\frac{dE}{dt} + r\frac{dG}{d\varpi_h}\frac{d\varpi_h}{dt} = 0. \tag{16}$$

For a type 0 regulator, this condition amounts to the standard textbook solution: the optimal tax rate is given by marginal damage costs. In the case of a type 1 regulator, the optimal tax rate is higher than marginal damage costs because $\frac{d\varpi_h}{dt} < 0$ and, hence, the second term in (16) is positive.

Note that the feasible sets will have the same shape under both regulator types; this is why one can use a general notation. Let

$$F_T = \left\{ (\pi_h, W) \;\middle|\; \begin{array}{c} \pi_h = \beta\pi_h(t) + (1-\beta)\pi_h(t'), \\ W = \beta W_r(t) + (1-\beta)W_r(t'); \\ t, t' \geq 0; \beta \in [0,1] \end{array} \right\} \tag{17}$$

be the set of possible bargaining agreements under the emissions tax. Note that F_T allows for technical inefficiencies: only points $(\pi_h(t), W_r(t))$ are technically efficient; hence, φ_T is the bargaining frontier. For later use, let $W_r(t) = \varphi_T(\pi_h(t))$ denote, for domain $[\pi_h(t_r^*), \pi_h^0]$, the mapping from the firm's profit under a given tax rate into the maximal welfare level attainable under this tax rate. Furthermore, $\pi_h(t) = \varphi_T^I(W_r(t))$ denotes, for domain $[W_r(t^*), W^0]$, the mapping from the welfare level under a given tax rate into the maximal profit level attainable under this tax rate. Both $\varphi_T(.)$ and $\varphi_T^I(.)$ are strictly concave. The feasible set F_T is depicted in figure 1.

The Feasible Set under Standards As an intermediate step, consider the feasible set when the regulator is committed to exclusively use a uniform standards. The regulator would mostly prefer to implement a uniform standard

$$\bar{e}_r^+ = \arg\max_{\bar{e}} \begin{pmatrix} \int_0^{\bar{X}} p(X)dX - N(qc_h(\bar{e}) + (1-q)c_l(\frac{\bar{e}}{\alpha})) \\ -D(\bar{E}) + rG(\varpi_h((x_h(\bar{e}), x_l(\bar{e})) \end{pmatrix}, \tag{18}$$

where $\bar{X} = X(\bar{e}) = N(q\bar{e} + (1-q)\frac{\bar{e}}{\alpha})$ and $\bar{E} = N\bar{e}$. Denote the corresponding second-best welfare level by $W_r^+ = W_r(\bar{e}_r^+)$ and $\frac{dW_r}{d\bar{e}_r} \gtreqless 0$ for $\bar{e} \lesseqgtr \bar{e}_r^+$.

Proceed now to characterize the feasible set. Denote

$$\pi_h^M = \max_{\bar{e}} \pi_h(\bar{e})$$

and the corresponding welfare level by W_r^M, where M stands for *Monopoly* (π_h^M would be the profit level of a high-type firm which can choose the market output by fixing $\bar{e}$ for all firms and, in this sense, has monopoly power). Assume that firms' output X^0 is produced under elastic demand. Then, according to (12), an interior profit maximum exists under a positive uniform standard ($e^0 > \bar{e}^M$) and is unique under linear demand. Note that $\bar{e}^M \gtreqless \bar{e}_r^+$. To focus on a specific case, assume $\bar{e}^M > \bar{e}_r^+$. Let

$$F_S = \left\{ (\pi_h, W) \;\middle|\; \begin{array}{c} \pi_h = \beta\pi_h(\bar{e}) + (1-\beta)\pi_h(\bar{e}'), \\ W = \beta W_r(\bar{e}) + (1-\beta)W_r(\bar{e}'); \\ \bar{e}, \bar{e}' \leq e^0; \beta \in [0,1] \end{array} \right\} \tag{19}$$

be the set of possible bargaining agreements under a uniform standard. For later use, let $W_r(\bar{e}) = \varphi_S(\pi_h(\bar{e}))$ denote, for domain $[\pi_h(\bar{e}_r^+), \pi_h(\bar{e}^M)]$, the strictly concave mapping from the firm's profit under a given standard into the maximal welfare level

Figure 1: Feasible Sets Under Emission Taxation and Uniform Standards

attainable under this standard. Note that $\varphi_S(.)$ is decreasing in π_h. Also, let $\pi_h(\bar{e}) = \varphi_S^I(W_r(\bar{e}))$ denote, for domain $[W_r(\bar{e}^M), W_r(\bar{e}^+)]$, the strictly concave mapping from the welfare level under a given standard into the maximal profit level attainable under this standard. Both F_S and φ_S are depicted in figure 1.

The Feasible Set under No Commitment When the regulator is not committed, the feasible set is given by

$$F_{TS} = F_T \cup F_S,$$

and

$$\varphi_{TS} = (\varphi_T \setminus \{(\pi_h, W_r) \in \varphi_T \,|\pi_h(t) = \pi_h(\bar{e}), W_r(t) < W_r(\bar{e})\}) \cup$$

$$(\varphi_S \setminus \{(\pi_h, W_r) \in \varphi_s \,|\pi_h(t) = \pi_h(\bar{e}), W_r(\bar{e}) < W_r(t)\})$$

To simplify the presentation of the possible outcomes, assume that $(\pi_h^+, W^+) \notin F_T$. Hence,

$$\varphi_{TS}^I = (\varphi_T^I \setminus \{(\pi_h, W_r) \in \varphi_T^I \left|W_r(t) \leq W_r^+\right\}) \cup \varphi_S^I.$$

The Contest Consider first the subgame after the breaking down of negotiations, where at least one party quits the bargaining table. Then, the parties play a Stackelberg game, in which the regulator moves first and the industry representative follows. The regulator has different opportunities. He may decide to "do nothing", thus implementing the status quo. Alternatively, depending on his commitment, he may decide to implement a specific instrument with a specific stringency, which would yield payoffs $(\pi_h(k), W_r(k))$. Which instrument will be chosen with which stringency is spelled out below. After the regulator's regulatory decision, it is to the industry representative to decide whether or not to fight the planned regulation. When she decides to fight, the resulting contest yields payoffs

$$\begin{aligned} \pi_h^c(k) &= \gamma\pi_h^0 + (1-\gamma)\pi_h(k), \\ W_r^c(k) &= \gamma W^0 + (1-\gamma)W_r(k), \end{aligned}$$

where $\gamma \in (0,1)$ is given exogenously. Hence, as $W_r^c(k) > W^0$, the regulator would never choose to "do nothing".

The formulation of the contest allows for two interpretations. The first interpretation is that the industry representative, in the political arena, can push through an immediate and costless rejection of the regulator's plan with probability γ. Alternatively, the industry representative, while not being able to get the planned regulation rejected, can delay realization of the regulation to a specific degree. While first interpretation is straightforward – contest costs could easily be included into the analysis, but do not substantively change the results, the reasoning behind the second interpretation is more involved and is therefore relegated to appendix 1.

The representative will choose to politically fight against the regulator's plans, when

$$\pi_h^c(k) > \pi_h(k). \tag{20}$$

When choosing the instrument to be implemented and its stringency, the regulator will strategically anticipate the representative's opportunity to politically challenge the regulation. Note that under a uniform standard, depending on η and the extent of the externality, $\pi_h(\bar{e}) \lesseqgtr \pi_h^0$. This feature influences the regulator's optimal choice; it is crucial for the following analysis.

Lemma 1 *The representative will fight any tax $t > 0$, but not any uniform standard $\bar{e} < e^0$. Due to the implicit cartelization of the industry under the uniform standard,* *the regulator can implement a standard* $\bar{e}_r^{++} < \bar{e}^0$ *such that the industry representative does not have an incentive to trigger the contest:*

(i) When $\pi_h^+ \geq \pi_h^0$, $\bar{e}_r^{++} = \bar{e}_r^+$. *The regulator can implement the second-best allocation without being contested.*

(ii) When $\pi_h^+ < \pi_h^0$, $\bar{e}_r^{++} > \bar{e}_r^+$. *The regulator can implement a standard which is not even second-best without being contested.*

Proof. Consider taxation. It follows from (7) that

$$\pi_h^c(t) = \gamma\pi_h^0 + (1-\gamma)\pi_h(t) > \pi_h(t).$$

Hence, according to (20), the industry representative would fight against any tax $t > 0$. Consider now the uniform standard. When $\pi_h^+ \geq \pi_h^0$, $\pi_h^c(\bar{e}_r^+) < \pi_h(\bar{e}_r^+)$ and, according to (20), the regulator would not fight against regulation over $\bar{e}_r^+$. When $\pi_h^+ < \pi_h^0$, $\pi_h^c(\bar{e}_r^+) > \pi_h(\bar{e}_r^+)$. But when an interior profit maximum exists ($e^0 > \bar{e}_r^M > e_r^+$), there is a standard $e_r^{++} \in (e_r^+, e^0)$ such that $\pi_h(\bar{e}_r^{++}) = \pi_h^0$; hence,

$$\pi_h^c(\bar{e}_r^{++}) = \pi_h^0 = \pi_h(\bar{e}_r^{++}).$$

Denote $W_r^{++} = \varphi_S(\pi_h(\bar{e}_r^{++}))$. As $\varphi_S(.)$ is decreasing in π_h, $W_r^{++} < W_r^+$. ■

Note that lemma 1 is silent as to whether it is optimal, for the regulator, to avoid the contest by implementing a suboptimal standard. This issue is addressed below. Attention is restricted to the case in which $\pi_h^+ < \pi_h^0$.

Strategic Bargaining and Outside Options While firms are privately informed with respect to their type, the regulator knows the representative's objective and her payoffs resulting from an instrument of given stringency. Hence, bargaining between the regulator and the representative occurs under complete information. The bargaining process between the regulator and the industry representative is modelled as a strategic offer-counter-offer bargaining game (Rubinstein 1986), where parties can take an outside option yielding a specific (expected) payoff. The outside option is taken by a party by quitting the bargaining table, which leads the negotiations to break down. Then, as described above, the regulator will optimally seek to implement a specific instrument with specific stringency, anticipating that the industry representative may decide to politically fight against the planned regulation. Because of lemma 1, the outside option payoffs do not necessarily coincide with the expected payoffs of the contest. Denote the outside option payoffs by $o_j = (\pi_h^{oj}, W_r^{oj})$, $j \in \{T, TS\}$; they are specified below for the respective bargaining constellations. Incentives to bargain exist, when

$$o_j \in F_j \text{ and } o_j \notin \varphi_j.$$

When bargaining incentives exist, it is assumed that no regulation is undertaken, that is, the status quo $s = (\pi_h^0, W^0)$ prevails, as long as the bargaining is ongoing. The industry representative starts the negotiations in period $z = 0$ with an offer implying a specific pair $(\pi_h, W_r) \in F_j$. If the regulator accepts, the game ends. If he rejects, he may either trigger the outside option, as described above, or submit a counter-offer which needs time to prepare: The regulator submits a counter-offer in period $z = 1$. Acceptance by the representative terminates the game. A further rejection opens two opportunities: the representative may take the outside option, or decide to submit a second offer in period $z = 2$. The game is repeated until one party accepts an offer or triggers the outside option.

Note that the industry representative exerts two threats: First, she may threaten to quit the negotiation table, which may or may not be credible. Second, she may threaten to fight forthcoming regulation, which the regulator will strategically anticipate when formulating his policy after negotiations broke down.

Under this protocol, the so-called outside option principle applies, which states that outside options influence the bargaining outcome only when the threat to opt out is credible for a party. In this case, the party has to guarantee its adversary the adversary's (expected) payoff of the outside option in a bargained agreement. When, however, the threat is not credible, the bargaining outcome of the game without outside options remains the solution of the game with outside options (Binmore/Rubinstein/Wolinsky 1986, Binmore/Shaked/Sutton 1989). Hence, the impact of the outside options can be analytically separated, as will be shown in the proof for lemma 2. Also, it is well-known that the solution of the Rubinstein bargaining game without outside options converges, for a common discount factor δ^{Δ} and $\Delta \rightarrow 0$, to the symmetric Nash-solution of the game (see, e.g., Sutton 1986)[7]. Both features allow the bargaining outcome to be concisely stated, as will be done in lemma 2. Denote the corresponding Nash-solution of the bargaining problem (F_j, s), $j \in \{T, TS\}$, by $N_j = (\pi_h^{Nj}, W_r^{Nj})$, whereas the bargaining solution of the game (which may diverge from the Nash-solution when outside options exist) is denoted by $B_j = (\pi_h^{Bj}, W_r^{Bj})$.

Lemma 2 (Outside Option Principle) *Consider the bargaining problem*

$$(F_j, s, o_j),$$

where $j \in \{T, TS\}$. In the equilibrium of the strategic bargaining game, for $\Delta \to 0$, the parties agree immediately.

(i) When $\pi_h^{oj} \leq \pi_h^{Nj}$ and $W_r^{oj} \leq W_r^{Nj}$, a threat to opt out is not credible for any party, and $B_j = N_j$.

(ii) When $\pi_h^{oj} \leq \pi_h^{Nj}$ and $W_r^{oj} > W_r^{Nj}$, the regulator's threat to opt out is credible, and $B_j = (\varphi_j^I(W_r^{oj}), W_r^{oj})$.

(iii) When $\pi_h^{oj} \leq \pi_h^{Nj}$ and $W_r^{oj} \leq W_r^{Nj}$, the industry representative's threat to opt out is credible, and $B_j = (\pi_h^{oj}, \varphi_j(\pi_h^{oj}))$.

Proof. See appendix 2. ■

[7]Furthermore, for $\Delta \to 0$, any first-mover advantage disappears. In contrast to one-sided offer bargaining, it does not play a role which party submits the first offer in the Rubinstein game where $\Delta \to 0$.

3 Regulatory Outcomes

Consider first the case where the regulator is committed to using taxation as the only policy instrument.

Lemma 3 (Taxation) *When the regulator is committed to exclusively using taxation,*

(i) the expected outside option payoffs are $o_T = (\pi_h^c(t_r^*), W_r^c(t_r^*))$. *Bargaining incentives exist.*

(ii) The regulator's threat to opt out is always credible, while the representative's threat to opt out is never credible. The bargained outcome is $B_T = (\varphi_T^{-1}(W_r^c(t_r^*)), W_r^c(t_r^*))$. *The regulator implements an inefficiently low tax rate for* $\gamma \in (0, 1)$.

Proof.

(i) According to lemma 1, the industry representative would fight against any tax $t > 0$. In consequence, the regulator, when bargaining does break down, seeks for implementation of t^*, because

$$t^* = \arg\max_t [\gamma W_r(t) + (1 - \gamma)W^0],$$

against which the representative fights. Hence, $o_T = (\pi_h^c(t^*), W_r^c(t^*))$, where

$$\begin{aligned} \pi_h^c(t_r^*) &= \gamma\pi_h^0 + (1-\gamma)\pi_h^*, \\ W_r^c(t_r^*) &= \gamma W^0 + (1-\gamma)W_r^*. \end{aligned}$$

From (17), as $\{(\pi_h^0, W^0), (\pi_h^*, W_r^*)\} \subset F_T$, $o_T \in F_T$. Because of strict concavity of $\varphi_T(.)$, $o_T \notin \varphi_T$.

(ii) Using part (i) of the proof of lemma 2 yields $N_T = (\pi_h^0, W^0)$. But $\pi_h^c(t_r^*) < \pi_h^0$, and $W_r^c(t_r^*) > W^0$ for any $\gamma \in (0,1)$. Hence, the bargaining result is according to part (ii) of the proof of lemma 2.

■

Such a bargaining outcome is depicted in figure 2. Note that industry reaps all gains from trade. While the regulator realizes his reservation value (his expected payoff of the outside option), any high-type firm receives the gains from trade given by the difference $\pi_h^{BT} - \pi_h^c(t_r^*)$. The intuition behind this division is that the Rubinstein bargaining game explicitly models the time structure of the bargaining process. Remember that the status quo prevails as long as the negotiations are ongoing. Consequently, the representative has an incentive to drag on the negotiations, because any tax $t > 0$ lowers the high-type firm's profits. Under complete information, where agreement is immediate, this incentive turns into bargaining power. For the same reason, the Nash-solution of the bargaining game without outside options degenerates into the status quo: $N_T = (\pi_h^0, W^0)$.

Because of lemma 1, characterizing the outcome in the no-commitment constellation is more involved. For γ being exogenously given, $W_r^c(\bar{e}_r^+) < W_r^c(t_r^*)$ for any γ. Therefore, in the subgame after failed negotiations, the regulator will only have

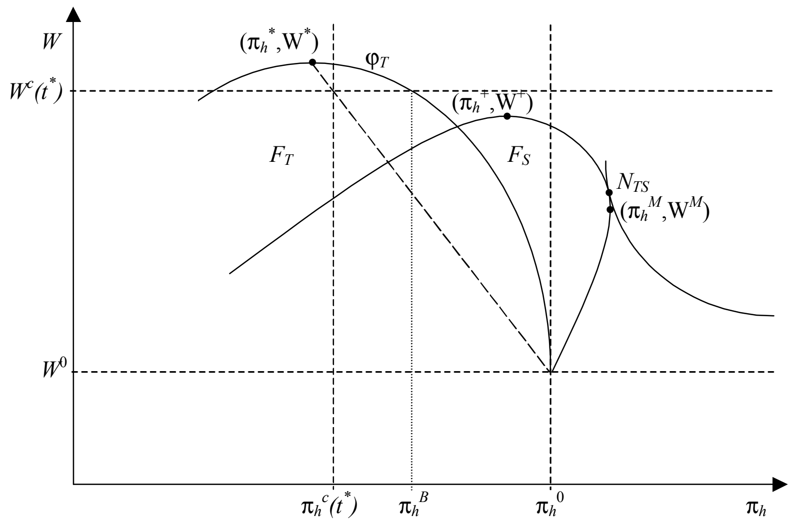

Figure 2: Negotiated Tax Breaks

to compare $W_r^c(t_r^*)$ and $W_r(\bar{e}_r^{++})$. This feature is for presentational convenience. It is possible to derive different "equilibrium" γ in the contests over the tax and over the standard by using an explicit contest model in the spirit of Dixit (1987). As the following proposition states the outcomes emerging from any such equilibrium γ, nothing would be gained by such additional modelling effort. The proposition states the outcomes emerging when γ is gradually and parametrically lowered.

Proposition 4 (No Commitment) *Assume the regulator is not committed to using a specific instrument.*

(i) ***(bargained tax breaks)*** *When $W_r^c(t_r^*) > W_r^+$, bargaining incentives exist. The regulator's threat to opt out is credible, and the bargaining outcome is $B_{TS} = (\varphi_T^{-1}(W_r^c(t_r^*)), W_r^c(t_r^*))$.*

The parties agree on an inefficiently low tax rate.

(ii) ***(voluntary agreement)*** *When $W_r^c(t^*) = W_r^+$, bargaining incentives exist. The regulator's threat to opt out is credible, and the bargaining outcome is $B_{TS} = (\pi_h^+, W_r^+)$. The parties agree to implement the second-best allocation W_r^+ via the optimal uniform standard $\bar{e}_r^+$.*

(iii) ***(voluntary agreement)*** *When $\pi_h^+ < \pi_h^0$ and $W_r^{++} < W_r^c(t_r^*) < W_r^+$, bargaining incentives exist. The regulator's threat to opt out is credible, and the bargaining outcome is $B_{TS} = (\varphi_S^{-1}(W_r^c(t_r^*), W_r^c(t_r^*))$. The parties agree to implement an inefficiently low uniform standard.*

(iv) ***(mandatory standards)*** *When $\pi_h^+ < \pi_h^0$ and $W_r^{++} \geq W_r^c(t_r^*)$, bargaining incentives do not exist. The regulator implements an inefficiently low uniform standard $\bar{e}_r^{++}$. The industry representative does not fight regulation over $\bar{e}_r^{++}$.*

Proof.

(i) Define $\Upsilon \subset F_{ST}$ such that $\Upsilon = \{(\pi_h, W_r) \,|\, (\pi_h, W_r) \in F_{ST} \wedge W_r > W_r^+\}$. Because of $(\pi_h^+, W_r^+) \notin F_T)$ by assumption, $\Upsilon \cap F_S = \emptyset$. As $W_r^c(t_r^*) > W_r^+$, the solution corresponds to lemma 3.

(ii) In contrast to (ii), both the implementation of the second-best via $\bar{e}_r^+$ and of the first-best via t_r^* will be contested in the subgame after failed negotiations.

Strategically lowering the environmental standard to a point where the representative would not fight, according to part (ii) of lemma 1, would yield lower welfare than the contest over t_r^*. Hence, as the outside option, the regulator prescribes t_r^*, against which the representative fights; $o_{TS} = (\pi_h^c(t_r^*), W_r^c(t_r^*))$. From the definition of F_T (17), $o_{TS} \in F_T$. Incentives to bargain exist according to part (i) of lemma 3. For any $W_r \leq W_r^+$, the bargaining frontier of F_{TS} is given by φ_S because of $(\pi_h^+, W_r^+) \notin F_T$. As $\varphi_S(.)$ is decreasing in π_h, $W_r^{++} > W_r^{NS} = W_r^{NTS}$. As $W_r^c(t_r^*) = W_r^+ \geq W_r^{++} > W_r^{NTS}$, the regulator's threat to opt out is credible, and the bargaining result is according to part (ii) of the lemma 2. It further increases gains from trade to implement the optimal uniform standard instead of an inefficiently low tax rate: firm's profit is higher, while realized welfare remains unchanged.

(iii) Again, strategically lowering the environmental standard to $\bar{e}_r^{++}$ such that the representative would not fight, according to part (ii) of lemma 1, would yield lower welfare than the contest over t_r^*. Hence, as the outside option, the regulator prescribes t_r^*, against which the representative fights; $o_{TS} = (\pi_h^c(t_r^*), W_r^c(t_r^*))$. The remaining steps proceed analogously to part (iii).

(iv) Strategically lowering the environmental standard to $\bar{e}_r^{++}$ such that the representative would not fight, according to part (ii) of lemma 1, yields higher welfare

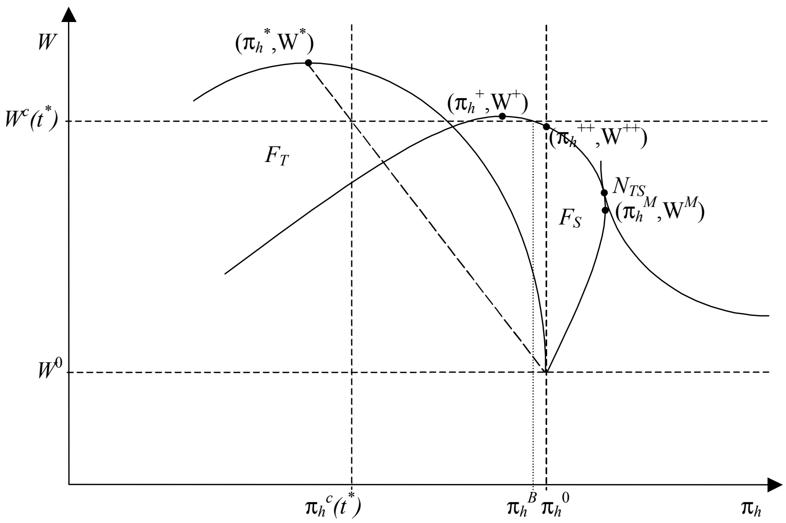

Figure 3: Voluntary Agreement

than the contest over t_r^*,.and $o_{TS} = (\pi_h(\bar{e}_r^{++}), W_r(\bar{e}_r^{++}))$. Clearly, $o_{TS} \in \varphi_{TS}$, so that bargaining incentives do not exist. The regulator rejects any offer $W < W_r(\bar{e}_r^{++})$ and prescribes the uniform standard $\bar{e}_r^{++}$. In equilibrium, the representative offers $W_r(\bar{e}_r^{++})$, which the regulator accepts.

■

Part (i) is depicted in figure 2, and part (iv) in figure 3. Note that again, in any bargained agreement, the industry reaps all the bargaining surplus, for the reasoning given above. The regulator optimally threatens with different instruments, contingent on γ. In cases (i), (iii) and (iv), he threatens with the optimal tax rate, against which the representative will fight. In cases (ii) and (v), he threatens with the implementation of a standard, against which she will not fight. The implementation of standards is the result of a bargained agreement (cases (iii) and (iv)) or not (cases (ii) and (v)). Hence, the analysis gives a rationale why environmental standards are not always implemented as the result of a voluntary agreement between the regulator and the concerned industry. This result may also explain the abundant use of environmental standards in environmental policy without relying on arguments in the spirit of Witzman (1974).[8]

Note that it is only in part (ii) of proposition 4 that profits implemented in equilibrium are higher than those under the status quo. In this case, the policy instrument used in equilibrium is a mandatory standard. Such a situation, where mandatory regulation leads to higher profits, was addressed by Maloney/McCormick (1982). In contrast to these authors, however, the present analysis makes clear that the importance of implicit cartelization goes beyond this case. Specifically, in the case described in part (v) of proposition 4, the standard, even while mandatorily set, will not effect higher profits in equilibrium.

4 Policy Implications

Apparently, taxation has clear advantages in the present setting. First, taxation can implement the first-best, while standards cannot, because differentiated standards

[8]Even a regulator with unlimited power, that is, whose decisions cannot be contested by regulatees, may prefer standards to taxes when relevant cost functions are subject to uncertainty (see, e.g., Adar/Griffin 1976, Glazer/Lave 1996).

lead to adverse selection. Second, taxation generates the right incentives for technological adoption. Any positive tax rate will increase the market share and the relative profitability of the more efficient and less polluting firms. In contrast, any uniform standard will not change market shares and, when (14) holds, will always decrease the relative profitability of more efficient firms. Given these features, one may suspect that a commitment of the regulator to exclusively use taxation as policy instrument may improve welfare. However, when environmental policy may be contested in the political arena, this is not the case.

Proposition 5 *When environmental policy (the use of a specific instrument with specific stringency) may be subjected to a political contest, the regulator, by a credible commitment to exclusively use emissions taxation,*

(i) will never increase welfare in equilibrium,

(ii) may decrease welfare in equilibrium.

This is so, even while taxation can implement the first-best allocation and surely generates the adequate incentives for technological adoption, while other instruments may not.

Proof.

(i) Compare proposition 3 with parts (i), (iii) and (iv) of proposition 4. In equilibrium, the regulator realizes $W_r^c(t_r^*)$ whether he is or is not committed. In the other cases, a commitment will decrease welfare. See part (ii).

(ii) Compare proposition 3 with parts (ii) and (v) of proposition 4. In equilibrium, the regulator realizes $W_r^c(t_r^*)$ when being committed, while realizing W_r^+ in case (ii) and W_r^{++} in case (v). However, by the very definition of cases (ii) and (v), $W_r^c(t_r^*) < W_r^+$, resp., $W_r^c(t_r^*) < W_r^{++}$.

■

The intuition behind this result transpires from lemma 1. When committed to using taxation, the regulator cannot avoid the contest, while he can do so when free to implement a uniform standard $\bar{e}_r^{++}$. When his chances to prevail in the contest are rather low, or when the introduction of the first-best efficient tax would be considerably delayed because of political resistance, the regulator may maximize his payoff by introducing standards that do not even implement the second-best and further reduce incentives for technology adoption. Importantly, this result holds irrespective the regulator is of type 0 or type 1.

Note that in cases (ii) and (v) of proposition 4, where welfare is increased by non-commitment, the policy outcome is usual command-and-control regulation. Hence, the following result can also be stated.

Proposition 6 *Bilateral voluntary agreements do never improve the regulator's payoff according to his objective W_r.*

(i) Under a type 0 regulator, a commitment to not use voluntary agreements will always increase incentives for technological adoption, when (14) holds (sufficient condition).

(ii) Under a type 1 regulator, a commitment to not use voluntary agreements will increase incentives for technological adoption and decrease the stringency of environmental policy, when (14) holds (sufficient condition).

Proof. It results from parts (iii) and (iv) of proposition 4 that in the case of voluntary agreements, the regulator realizes $W_r^c(t_r^*)$. But for these cases, the regulator would also realize $W_r^c(t_r^*)$ if he were committed to the tax.

(i) Immediate from the above and the fact that $\frac{d\varpi_h}{dt} < 0$, while $\frac{d\varpi_h}{d\bar{e}} > 0$ when (14) holds.

(ii) As $\frac{dG}{d\varpi_h}\frac{d\varpi_h}{d\bar{e}} < 0$ for any $\bar{e}$, any voluntary agreement must implement a lower environmental damage to achieve the same level $W_r^c(t_r^*)$ than under a negotiated tax rate.

■

The regulator always realizes the security equivalent of his expected payoff of the political contest, irrespective of whether he is of type 0 or of type 1. The intuition is similar to the one given to explain lemma 3: the representative has an incentive to drag on the negotiations, which turns into bargaining power, and the regulator is pushed down to his reservation value. However, for given equilibrium payoff of the regulator, the firm's equilibrium profit is higher under a voluntary agreement than the equilibrium profit level when the regulator is committed to exclusively using taxation.

The requirement that (14) holds is sufficient to ensure the validity of the claims in proposition 6, but is too strict to be necessary. The condition merely ensures that $\frac{d\varpi_h}{d\bar{e}} > 0$ for any $\bar{e} < e^0$. Hence, these claims will also apply when (14) does not hold, if the level of environmental damages depasses a specific treshold and both firms types keep on producing under regulation.

5 Conclusions

The present contribution takes a skeptical stance with respect to voluntary agreements. As they are to be interpreted as a kind of direct regulation, they will suffer from excess uniformity under heterogenous, privately-informed firms, and will not reliably generate the appropriate incentives for technological adoption. They share these features with direct regulation in general, namely, with standards which are mandatorily set. Despite these disadvantages, a commitment to not use direct regulation altogether was shown to possibly decrease welfare when environmental policy can be contested in the political arena by the industry representative. However, by being ready to *bargain* over standards, that is, to possibly agree on a bilateral voluntary agreement, the regulator will not increase welfare, irrespective of which welfare conception he adheres to. While he will possibly increase the stringency of environmental regulation under the given market structure, he will trade this achievement against lower incentives for the adoption of less polluting technologies. Clearly, he will also accomodate redistribution of economic surplus from consumers to firms. In consequence, the analysis gives an additional rationale for traditional command-and-control-policy from the viewpoint of political economy: it holds even when cost functions are not subject to uncertainty and, hence, arguments in the spirit of Weitzman (1974) would not apply.

Furthermore, the analysis adds the perspective of political economy to the debate on the Porter hypothesis. This discussion often focused on the question whether and to what extent technical innovations are feasible which do not only lead to lower pollution (as required by environmental regulation), but simultaneously to higher productivity and, hence, to higher profits (see Palmer et al. 1995). Intra-firm incentive and coordination problems were then named to explain why firms do not realize innovation offsets by themselves. The present analysis gives an additional argument why firms do not realize these offsets and, at the same time, expresses skepticism with respect to the beneficial incentive effect of environmental regulation, as stated by Porter et al.: Firms are not just passively implementing the environmental prescriptions of an omnipotent state, but can unfold political resistance. Then, instruments may be implemented in the political (bargaining) equilibrium which, despite being "flexible" in the sense that they do not prescribe the use of specific technologies, even reduce incentives to adopt more efficient and less polluting technologies.

6 Appendices

Appendix 1: The threat of delayed regulation For brevity, the subscripts h and r are omitted in the proof. Denote the function that maps expected profits from the contest into expected welfare by $W^c = \psi(\pi_h^c)$. Assume $\pi_h(k) < \pi_h^0$. When the representative can prevent regulation to be passed with probability $\gamma \in (0, 1)$, (π_h^c, W^c) is a convex combination of (π_h^0, W^0) and $(\pi_h(k), W(k))$, and $\psi(.)$ is linear and decreasing on its domain $(\pi_h(k), \pi_h^0)$. It has to be shown that $\psi(.)$ has the same shape under the variant of the contest where the industry representative cannot ultimately prevent mandatory regulation with payoffs $(\pi_h(k), W(k))$, but can only delay its implementation for Z periods, $Z > 0$. Assume the industry is a non-depreciating asset, and π_h and W denote present values. Denote discounting in continuous time to obtain a continuous $\psi(.)$:

$$\pi_h = \int_0^\infty \hat{\pi}_h e^{-rz} dz, W = \int_0^\infty \hat{W} e^{-rz} dz,$$

where $\hat{\pi}_h$ and $\hat{W}$ denote periodical payoffs, and r is the discount rate. Then, payoffs of the contest are defined by

$$\pi_h^c(Z) = \int_0^Z \hat{\pi}_h^0 e^{-rz} dz + \int_Z^\infty \hat{\pi}_h(k) e^{-rz} dz, \quad (21)$$

$$W^c(Z) = \int_0^Z \hat{W}^0 e^{-rz} dz + \int_Z^\infty \hat{W}(k) e^{-rz} dz. \quad (22)$$

Note that $\lim_{Z\to\infty}\pi_h^c(Z) = \pi_h^0$ and $\lim_{Z\to\infty} W^c(Z) = W^0$, and that $\pi_h^c(0) = \pi_h(k)$, $W^c(0) = W(k)$. Deriving (21) and (22) gives

$$\begin{aligned}\frac{d\pi_h^c(Z)}{dZ} &= (\hat{\pi}_h^0 - \hat{\pi}_h(k))e^{-rZ},\\ \frac{dW^c(Z)}{dZ} &= (\hat{W}^0 - \hat{W}(k))e^{-rZ}.\end{aligned}$$

Solving these expressions for e^{-rZ} and substituting gives

$$\frac{d\psi(\pi_h^c)}{d\pi_h^c} = \frac{dW^c(Z)}{d\pi_h^c(Z)} = \frac{(\hat{W}^0 - \hat{W}(k))}{(\hat{\pi}_h^0 - \hat{\pi}_h(k))} < 0.$$

Hence, $\psi(.)$ is decreasing and linear on the interval $(\pi_h(k), \pi_h^0)$.

Appendix 2: Proof of lemma 2 For brevity, denote the industry representative by I and the regulator by R. In the proof, the subscripts h and r are omitted. Remember that $\varphi_i(.)$, $i \in \{T, TS\}$, maps firm's profit into the maximal welfare level attainable under a specific set of instruments. Denote by $\varphi_i^I(.)$ the mapping from welfare into the maximal attainable profit under the same set of instruments; note that for $i = T$, $\varphi_i^I(.) = \varphi_i^{-1}(.)$. Assume that the industry is a non-depreciating asset, and π and W denote present values. Periodical payoffs are given by $\hat{\pi}$ and $\hat{W}$, where

$$\pi = \frac{1}{1-\delta}\hat{\pi}, W = \frac{1}{1-\delta}\hat{W}.$$

By exploiting the stationarity property of the bargaining game, the proof proceeds analogous to Shaked/ Sutton (1984). In the proof, when not indicated otherwise, $\Delta = 1$.

(i) Let $\pi^{\sup}$ be the supremum payoff I may realize in an equilibrium of a subgame in which it is her turn to submit an offer (period $z = Z$ in the table below). In the preceding period, it is up to R to submit an offer. I will accept any offer at least equal to $\max[\delta\pi^{\sup} + \hat{\pi}^0, \pi^{oj}]$, where $\delta\pi^{\sup} + \hat{\pi}^0$ is the present value of its supremum possible payoff in $z = Z - 1$, plus the periodical status quo payoff. When $\delta\pi^{\sup} + \hat{\pi}^0 \geq \pi^{oj}$, $I's$ threat to opt out is not credible, and R may realize at most $\varphi_i(\delta\pi^{\sup} + \hat{\pi}^0)$. To strike a bargain in the preceding period ($z = Z - 2$), I would have to offer at least $\max[\delta\varphi_i(\delta\pi^{\sup} + \hat{\pi}^0) + \hat{W}^0, W^{oj}]$. When $\delta\varphi_i(\delta\pi^{\sup} + \hat{\pi}^0) + \hat{W}^0 \geq W^{oj}$, R's threat is not credible, and I can realize at most $\varphi_i^I(\delta\varphi_i(\delta\pi^{\sup} + \hat{\pi}^0) + \hat{W}^0)$ in period $z = Z - 2$. As the subgame starting in $z = Z - 2$ has the same structure as the one starting in $z = Z$, $\pi^{\sup} = \varphi_i^I(\delta\varphi_i(\delta\pi^{\sup} + \hat{\pi}^0) + \hat{W}^0)$ in equilibrium.

By exchanging the words infimum/supremum, and at least/at most, the argument can be repeated for the infimum payoff which I can realize in equilibrium in a subgame where it submits an offer; thus, $\pi^{\inf} = \varphi_i^I(\delta\varphi_i(\delta\pi^{\sup} + \hat{\pi}^0) + \hat{W}^0)$. $\pi^{\sup}$ and $\pi^{\inf}$ are fixpoints of $\varphi_i^I(\delta\varphi_i(\delta\pi^{\sup} + \hat{\pi}^0) + \hat{W}^0)$. Denote $\tilde{\pi} \in \{\pi^{\sup}, \pi^{\inf}\}$. Note that $\varphi_i^I(\delta\varphi_i(\delta\pi + \hat{\pi}^0) + \hat{W}^0)$ is a continuous mapping from a compact interval into itself (e.g., for φ_T, the interval is $[\pi^*, \pi^0]$). Hence, Brouwer's fixpoint theorem applies, and a fixpoint exists. In a game where I submits the first offer, the equilibrium can be implemented by the following stationary strategies: I

offers $\varphi_i(\tilde{\pi})$ in every period where she has to submit an offer and accepts any offer of at least $\delta\tilde{\pi}+\hat{\pi}^0$. R offers $\delta\tilde{\pi}+\hat{\pi}^0$ in every period where he has to submit an offer and accepts any offer of at least $\varphi_i(\tilde{\pi})$. It results that I will offer $\varphi_i(\tilde{\pi})$ in the first bargaining round, which R immediately accepts.

The reasoning is analogous when R submits the first offer.

Convergence to the symmetrical Nash solution. Note that a fixpoint can also be defined by $\tilde{W} = \delta\varphi_i(\delta\tilde{\pi} + \hat{\pi}^0) + \hat{W}^0$, where, trivially, $\tilde{W} = \varphi_i(\tilde{\pi})$. Using $\hat{W}^0 = (1-\delta)W^0$, $\hat{\pi}^0 = (1-\delta)\pi^0$,

$$\frac{\varphi_i(\tilde{\pi}) - \varphi_i(\delta\tilde{\pi} + (1-\delta)\pi^0)}{\tilde{\pi} - (\delta\tilde{\pi} + (1-\delta)\pi^0)} = \frac{\delta\varphi_i(\delta\tilde{\pi} + (1-\delta)\pi^0) + (1-\delta)W^0 - \varphi_i(\delta\tilde{\pi} + (1-\delta)\pi^0)}{\tilde{\pi} - (\delta\tilde{\pi} + (1-\delta)\pi^0)}$$

or

$$\frac{\varphi_i(\tilde{\pi}) - \varphi_i(\delta\tilde{\pi} + (1-\delta)\pi^0)}{\tilde{\pi} - (\delta\tilde{\pi} + (1-\delta)\pi^0)} = -\frac{\varphi_i(\delta\tilde{\pi} + (1-\delta)\pi^0) - W^0}{\tilde{\pi} - \pi^0}. \tag{23}$$

Note that the left-hand side of (23) is the difference quotient on $\varphi_i(.)$. The limit of (23), for $\Delta \to 0$, is given by

$$\frac{d\varphi_i(\tilde{\pi})}{d\tilde{\pi}} = -\frac{\varphi_i(\tilde{\pi}) - W^0}{\tilde{\pi} - \pi^0},$$

which defines the symmetrical Nash-solution.

(ii) Reconsider the table below. When

$$\delta\varphi_i(\delta\tilde{\pi} + \hat{\pi}^0) + \hat{W}^0 = \delta\varphi_i(\delta\tilde{\pi} + (1-\delta)\pi^0) + (1-\delta)W^0 < W^{oj}, \tag{24}$$

R's threat to opt out is credible, and I has to offer at least W^{oj}, and gets at most $\varphi^I(W^{oj})$. W accepts any offer of at least W^{oj}, opts out when being offered less, and offers at most $\delta\varphi^I(W^{oj})$. In equilibrium, I offers W^{oj}, which R immediately accepts. For $\Delta \to 0$, the condition (24) gives $\varphi_i(V_i^N) < W^{oj}$.

(iii) Analogously to (ii), where I is substituted for R.

per.	offer	I gets at most/at least	R gets at least/at most
Z-2	I	$\varphi_i^I(\delta\varphi_i(\delta\pi^{\sup/\inf} + \hat{\pi}^0) + \hat{W}^0)$ $\varphi_i^I(\delta\varphi_i(\pi^{oj}) + \hat{W}^0)$ $\varphi_i^I(W^{oj})$	$\delta\varphi_i(\delta\pi^{\sup/\inf} + \hat{\pi}^0) + \hat{W}^0$ $\delta\varphi_i(\pi^{oj}) + \hat{W}^0$ W^{oj}
Z-1	R	$\delta\pi^{\sup/\inf} + \hat{\pi}^0$ π^{oj}	$\varphi_i(\delta\pi^{\sup/\inf} + \hat{\pi}^0)$ $\varphi_i(\pi^{oj})$
Z	I	$\pi^{\sup/\inf}$	

References

Adam, Z.; J.M. Griffin (1976): "Uncertainty and the Choice of Pollution Control Instruments". *Journal of Environmental Economics and Management* 3, 178-88.

Baumol, W.J.; W.E. Oates (1988): *The Theory of Environmental Policy.* Cambridge, Mass.: CUP.

Binmore, K.; A. Rubinstein; A. Wolinsky (1986): "The Nash Bargaining Solution in Economic Modeling". *Rand Journal of Economics* 17, 176-88.

Binmore, K.; A. Shaked; J. Sutton (1989): "An Outside Option Experiment". *Quarterly Journal of Economics* 104, 753-770.

Buchanan, J.M.; G. Tullock (1975): "Polluter's Profits and Political Responses: Direct Control Versus Taxes. *American Economic Review* 65, 139-47.

Carraro, C.; A. Soubeyran (1996a): "Environmental Taxation, Market Share, and Profits in Oligopoly". in Carraro, C.; Y. Katsoulacos, A. Xepapadepas, A. (eds.): *Environmental Policy and Market Structure*. Dordrecht: Kluwer, 23-44.

Carraro, C.; A. Soubeyran (1996b): "Enviromental Policy and the Choice of Production Technology". in Carraro, C.; Y. Katsoulacos, A. Xepapadepas, A. (eds.): *Environmental Policy and Market Structure*. Dordrecht: Kluwer, 151-80.

Carraro, D.; D. Siniscalco (1996): "Voluntary Agreements in Environmental Policy": A Theoretical Appraisal". In: Xepapadepas, A. (ed.): Economic Policy for the Environment and Natural Resources. Cheltenham: E. Elgar.

Dixit, A. (1987): "Strategic Behavior in Contests". *American Economic Review 77*, 891-98.

Glazer, A.; C. Lave (1996): "Regulation by Prices and by Command". *Journal of Regulatory Economics* 9, 191-97.

Lyon, T.P.; J.W. Maxwell (1999): "'Voluntary' Approaches to Environmental Regulation: A Survey". in Franzini, M.; A. Nicita (eds.): *Environmental Economics: Past, Present and Future*. Aldershot: Ashgate.

Maloney, M.T.; R.E. McCormick (1982): "A Positive Theory of Environmental Quality Regulation". *Journal of Law and Economics* 25, 99-123.

Nyborg, Karine (1998): *Voluntary Agreements and Non-verifiable Emissions.* mimeo, Statistics Norway, Oslo.

OECD (1999): *Voluntary Approaches for Environmental Policy: An Assessment*. Organisation for Economic Co-operation and Development, Paris.

Palmer, K.; W. Oates; P.R. Portney (1995): "Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm?" *Journal of Economic Perspectives 9, 119-32.*

Porter, M.E.; C. van der Linde (1995a): "Towards a New Conception of the Environment-Competitiveness Relationship". *Journal of Economic Perspectives 9*, 97-118.

Porter, M.E.; C. van der Linde (1995b): "Green and Competitive: Breaking the Stalemate". *Harvard Business Review 9-10/95*, 120-34.

Rubinstein, A. (1982): "Perfect Equilibrium in a Bargaining Model". *Econometrica* 50, 97-109.

Schmutzler, A. (1998): *When do Firms benefit from Environmental Regulation?* discussion paper 263, University of Heidelberg.

Shaked, A., J. Sutton (1984): "Involuntary Unemployment as a Perfect Equilibrium in a Bargaining Game". *Econometrica* 52, 1351-64.

Segerson, K.; T.J. Miceli (1998): "Voluntary Environmental Agreements: Good or Bad News for Environmental Protection?" *Journal of Environmental Economics and Management* 36, 109-30.

Spulber, D.F. (1988): "Optimal Environmental Regulation Under Asymmetric Information". *Journal of Public Economics* 35, 163-81.

Spulber, D.F. (1989): *Regulation and Markets.* Cambridge, Mass.; London: MIT.

Sutton, J. (1986): "Non-Cooperative Bargaining Theory: An Introduction". *Review of Economic Studies* 53, 709-24.

Weitzman, M.L. (1974): "Prices vs. Quantities". *Review of Economic Studies* 41, 477-91.

Wu, J.; B. A. Babcock (1999): "The Relative Efficiency of Voluntary vs. Mandatory Environmental Regulation". *Journal of Environmental Economics and Management* 38, 158-175.