The Political Economy of Carbon Securities and Environmental Policy

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Abstract

The paper studies carbon abatement policy instruments from a political economy perspective. It illustrates some problems with both traditional cap and trade systems and carbon taxation and then proceeds to propose an alternative policy instrument with significant advantages over these systems. The key feature of the proposed carbon securities is that they entitle their owners to a fixed proportion of ex ante unknown total emissions. The total level of carbon emissions is set by the political process *after* the carbon securities have been sold. In contrast to a traditional permit system, in which a government's choice of emissions quota is influenced by one lobby which represents industries that consume significant amounts of carbon-based energy, a system based on carbon securities creates an additional group of stakeholders with a strong incentive to organize and influence the government's choice of an emission level. The advantages over existing systems include stronger commitment to abatement policy, an equilibrium carbon price closer to the social optimum, a more predictable environmental policy in the presence of either climate or political uncertainty, and higher investment in abatement technology.

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1 Introduction

The design of policy is affected by lobbyists. A common feature is that there is a well-financed interest group on one side of the issue but not on the other. Carbon abatement policy is an example: While there are some environmental interest groups, there are better financed, more influential lobbies representing the interests of industries' that feel that they benefit from a low level of carbon abatement. However, the literature on the design of environmental policy tools rarely formally considers the impact of lobbies and the political economy dimension of the problem.

Most policy proposals to reduce greenhouse gas emissions extend over several decades. Frequently, the optimal policy suggested is characterized by a low initial carbon tax which then rises over time (see for example Nordhaus, 2007). The practical implementation of such a proposal is affected by a commitment problem: can a government today make a credible promise about the level of carbon taxes 20 years from now? This inherent uncertainty in the implementation may discourage investment in carbon abatement technology.

The recent US climate bill, also referred to as Waxman-Markey bill, brings new attention to the question of how a carbon permit system should be designed and also illustrates the effect of lobbies on the application of policy. Markussen and Svendsen (2005) document how interest groups influenced the design of the EU greenhouse gas market. This paper recognizes the role of lobbies in the design of environmental policy and suggests a carbon permit system designed to take advantage of the nature of the lobbying process. Under standard systems, there is one well organized lobby representing the interests of industries that heavily use carbon based energy sources. This lobby pushes for a high emission quota or correspondingly a low carbon tax. In most instances there is no well organized, financially powerful counterlobby in favor of low emissions. The main advantage of the policy instrument I propose is that it creates stakeholders with an interest in low carbon emissions. The active participation of this group in the policy-making process counterbalances the lobbying of the energy-consuming industry.

Specifically, suppose a total of n carbon securities is sold at time t=1. A carbon security gives the owner of the security the right to emit at time t=2 up to $\frac{1}{n}X$, where X is the society's total desired carbon emissions for period 2. The amount X is unknown to the potential buyer of the security at the time when she has to decide whether she wants to purchase a security or not. At the beginning of period 2, the political process determines the society's total desired industrial carbon emissions, X. When choosing X the political process takes into account the voters' preferences and any contributions from lobbies representing either the interests of the energy-consuming industry or the owners of carbon securities.[1] While both traditional permits and these carbon securities establish property rights, there are some important differences. Traditional permits give the owner the right to emit a fixed amount of carbon which is set prior to the sale of the permit. Carbon securities entitle the owner to a fixed proportion of total emissions, which have not yet been set at the time when the securities are sold. The order of selling permits and determining the emission quota is different between carbon securities and traditional permits. Additionally, the government can at any time print additional permits after the initial sale, while it cannot print additional securities until the current securities have matured. Alternatively, it is possible to think of a carbon security as a bond that pays a coupon in the form of a carbon allowance of $\frac{1}{n}X$.

The paper considers a two-period model of an economy using carbon securities. The key results of the two-period model extend in a straight forward manner to a multi-period framework in which a security is valid until period T and gives the owner the right to emit a fixed proportion of total desired emissions each period between 2 and T.[2] Therefore the paper focusses on the more tractable two-period model.

The paper adds a political economy perspective to the literature on environmental policy instrument design. As in Grossman and Helpman (1994), the government's decision making is not only influenced by social welfare considerations but also by lobbies who make campaign contributions if they feel that attempting to influence the carbon price is in their best interest. For example, under a carbon tax system the energy-consuming industry has an incentive to lobby for a low tax rate. Under a carbon securities system, the lobby of the energy-consuming industry is in favor of a large emission total, X, while the owners of the securities have an incentive to organize and lobby in favor of an emission quantity that maximizes the value of the securities.

The games considered are common agency games with one agent, the government, and depending on the choice of the policy instrument, one or two principals, the active lobbies. Two policy instruments are considered: a standard carbon tax, in the following referred to

[1] The term 'energy-consuming industry' is used to refer to all industries which would be subject to a carbon tax or a carbon permit system. For example, the Waxman-Markey proposal applies to about 85% of firms.

[2] A related yet significantly different policy tool are long term permits as proposed by McKibbin and Wilcoxen (2002). However, their long-term permit entitles the owner to emit a specified amount of carbon every year for the life of the permit. To the best of my knowledge no permit system with long term permits with ex ante uncertain yearly emission allowance has been suggested.

as *tax game*, and the carbon securities introduced above, referred to as *carbon securities game*.[3] One lobby represents the interests of firms which consume significant amounts of carbon based energy sources (oil, coal, natural gas etc.). If the profits of these firms depend on the carbon price, their lobby has an incentive to take part in the political process. The other lobby represents the interests of the owners of carbon securities. This lobby is either active or inactive depending on the choice of the policy instrument. Under a traditional tax system the lobby of the owners of carbon securities is inactive. With a system based on carbon securities this lobby is active since the return on investment on these securities depends on the government's choice of a carbon price.

I show that carbon securities have a number of advantages over existing systems. First, the lobbying process leads to a carbon price level that is closer to the social optimum than with a traditional tax or permit system. This is a direct consequence of the presence of stakeholders with an interest in low carbon emissions. Second, climate and political uncertainty have a smaller effect on the expected variance in the carbon price. While there is ex ante uncertainty about the amount of carbon emissions allowed per security, the variance of the carbon price is smaller. Third, there is higher investment in energy saving technology under the system I propose. Carbon securities provide stronger incentives to develop and adopt abatement technology since they encourage both a higher carbon price and a more stable carbon price. Fourth, a system based on carbon securities also has implications for commitment to environmental policy. In contrast to most of the literature which takes commitment as exogenous (either by assuming ex ante commitment to a certain policy level or as ex post optimal, time-consistent policy reaction), the introduction of carbon securities alters the policy environment so that the government can, in effect, credibly commit to long term policies even when the government can only commit to property rights but not to tax rates or policy levels.

The most widely used model to study the competitive process among special interest groups is a common agency game (Bernheim and Whinston, 1986). This framework has been adapted to study a wide variety of issues, including trade policy (Grossman and Helpman, 1994), commodity taxation (Dixit, 1996) and labor market policies (Rama and Tabellini, 1998). Aidt (1998) applies the framework to environmental policy to study how a tax scheme intended to combat an externality affects individual sectors. Similar to Le Breton and Za-

[3]In the framework considered demand is deterministic within a period and therefore a carbon tax is equivalent to a traditional cap and trade system.

porozhets (2007) and Le Breton and Salanie (2003), I extend the common agency framework to include political and climate uncertainty. The Grossman-Helpman model is supported by a number of empirical studies (see for example Goldberg and Maggi, 1999; Gawande and Bandyopadhyay, 2000). Since this type of model describes the political economy of trade remarkably well, the hope is that it is also suitable to describe the underlying dynamics of environmental policy.

The paper also contributes to the literature on environmental policy instruments (see for example Baumol and Oates, 1988; Stavins, 2004; Metcalf, 2009) but takes a new approach to policy instrument design by explicitly taking political economy consideration into account.

The following section describes the model. Sections 3 and 4 study the equilibrium under a traditional tax system and a system with carbon securities, respectively. Section 5 shows how the proposed policy instrument could be implemented in practice. It describes how the carbon securities could be used to optimize the SO_2 allowance trading currently in place in the United States. Section 6 concludes.

2 The Model and Discussion

The first part of the section describes the model, the second part discusses the underlying assumptions of the model.

2.1 The Model

Both the tax game and the carbon securities game consist of two periods. In the first period, the government announces the policy instrument of its choice: either a carbon tax or carbon securities. If carbon securities are the chosen policy instrument, the government holds an auction to sell the securities. There are m energy-consuming firms. Each firm i chooses its level of investment in abatement technology I_i. The energy-consuming industry and the owners of carbon securities each organize themselves as a lobby. It is assumed that the owners of carbon securities are not members of the energy-consuming industry.[4] In the second period, information about the policy maker and the expected cost structure of global warming is revealed. The lobby or lobbies then offer their contribution schedule(s) which are conditional on the carbon price selected. The government chooses the level of the carbon price that maximizes its welfare. Then the owners of carbon securities sell the carbon allowance, $\frac{1}{n}X$, they received per security to firms required to hold a carbon allowances equal to their carbon emission in period 2. The following describes the stages of the game in more detail starting with the last stage.

Consider period 2 of the carbon securities game. Let demand for energy, D, be deterministic, then setting an emission level X and setting a carbon price are equivalent. For each level of aggregate investment in energy-saving technology, X determines the carbon price via

$$D(p, I) = X \tag{1}$$

where D is a decreasing function of both the carbon price p and aggregate investment in energy saving technology I. Alternatively, in the tax game the government sets the price of carbon p directly. For ease of comparison between the tax game and the carbon securities game and also to stay within the established convention of the literature based on Grossman and Helpman's (1994) 'Protection for Sale', the government's choice variable is the carbon price in both games.

[4] The second part of this section considers this and most other assumptions in detail.

Social welfare depends on the amount of carbon emissions. On the one hand, high emissions lead to more global warming and hence higher global warming related costs G_W. These cost are a decreasing function of p, $\partial G_W/\partial p < 0$, and also a decreasing function of I, $\partial G_W/\partial I < 0$.

On the other hand, a high carbon price has adverse effects on social welfare since it has negative effects on the energy-consuming industry and leads to higher consumer prices. Social welfare is here to be thought of as discounted GDP. This consumption cost, G_C, increases with p, $\partial G_C/\partial p > 0$, but decreases with I, $\partial G_C/\partial I < 0$. The social cost of the carbon price is defined as

$$G(p, I) = G_W(p, I) + G_C(p, I) \tag{2}$$

$G(\cdot)$ is the difference between the expected cost of global warming which decrease with emissions, X, and the benefits of a low energy price. Figure 1 shows G, G_W and G_C. The functions G_W, G_C and G satisfy the following assumptions:

Assumption 1 *The cost function G has the following characteristics:*

(a) For a given investment level I, the cost function G has a unique minimizer, referred to as p^*:

$$\frac{\partial G_W}{\partial p \partial p} + \frac{\partial G_C}{\partial p \partial p} > 0$$

(b) The minimizer of G, p^*, increases with aggregate investment:

$$\frac{\partial p^*}{\partial I} > 0$$

(c) If a tighter climate goal is preferred, deviations from the optimal level, p^* are worse. So, for all $p < p^*$ the derivative of G becomes steeper as p^* increases.

The government maximizes the weighted sum of campaign contributions and voters' welfare. W_G denotes the welfare of the government:

$$\max_p W_G(p, \theta, I) = C_B(p, \theta, I) + C_E(p, \theta, I) - \theta G(p, I) \tag{3}$$

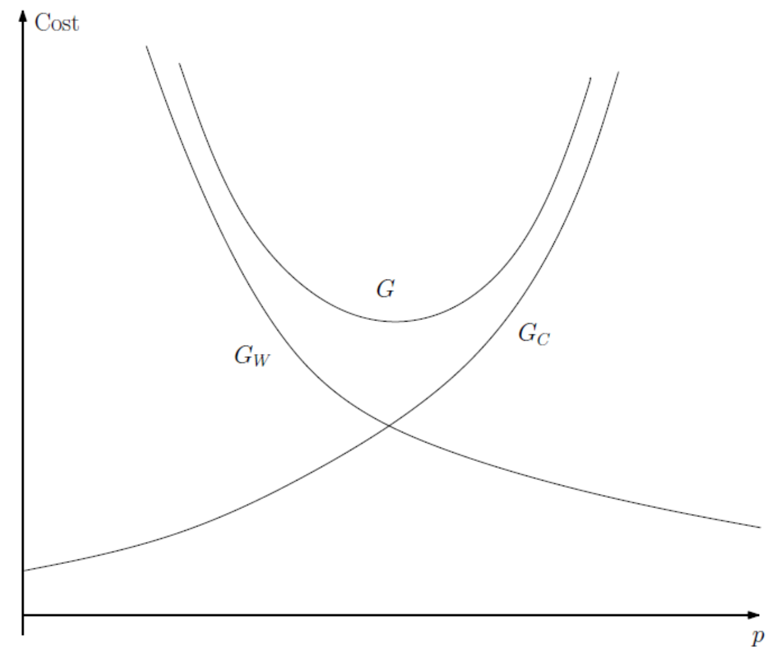

Figure 1: The cost functions.

C_B and C_E are the campaign contributions of the carbon securities holders and the energy-consuming industry, respectively. The variable, θ, can be understood as the government's preference variable. In the Grossman Helpman model it is interpreted as the weight of voter welfare relative to campaign contributions. A politician with a high value of θ values the interests of the electorate more highly than a politician with a low value of θ. In the terminology of Le Breton and Zaporozhets (2007), a politician with a low θ is a bad or corrupt politician since he is more willing to depart from social welfare when deciding upon which price to set. In this paper, θ is interpreted as climate or political uncertainty. So in period 1, when the investment decision is made, θ is unknown. At the beginning of the second period, θ is realized. Section 3.2 elaborates on how θ can be used to describe climate and political uncertainty.

Next, consider the lobbying stage of the game.

Assumption 2 *The energy consuming industry and its lobby satisfy the following assumptions:*

(a) The firms of the energy consuming industry are able to organize themselves into a lobby group in order to influence the political process.

(b) *The lobby of the energy-consuming industry does not face any borrowing constraints when they make campaign contributions.*

The gross of contributions welfare of the energy-consuming industry is

$$W_E = \sum_{i=1}^{m} \pi_i(I_i; p) - I = \Pi(p) - I \tag{4}$$

where p is the carbon price (input price), π_i is the profit of firm i and Π is the total profit of the industry. The lobby of the industry chooses the contribution C_E to maximize net of contributions industry welfare:

$$\max_{C_E} \Pi(p) - I - C_E(p) \tag{5}$$

The gross of contributions welfare of the owners of carbon securities is the value of the securities in the second period minus the amount they had to pay to purchase the securities in the first period:

$$W_B(p, I) = -p\frac{\partial \Pi}{\partial p} - \xi n$$

where ξ is the price that the government sold an security for and n is the total number of securities. The sale of the carbon securities takes the form an auction. So ξ is the equilibrium price at the securities auction.[5] The revenue of the owners of the securities, $-p\frac{\partial \Pi}{\partial p} = -p\Pi'(p)$, is the product of the carbon price and the emission quota. A carbon security holder prefers a carbon price that maximizes $-p\Pi'(p)$.

As for the lobby of the energy-consuming industry, it is assumed that there are no borrowing constraints. So contributions can be as large as gross of contribution welfare of the lobbying group.

Assumption 3 *The owners of the carbon securities satisfy the following assumptions:*

(a) *The owners of carbon securities are able to organize themselves into a lobby group in order to influence the political process.*

[5] This carbon securities auction is not explicitely modelled here. Conducting an auction has the advantage for the government that it maximizes its revenue. However, all results of the paper also follow thorough if the carbon securities would be sold at a fixed price (which could be zero).

(b) *The lobby of the owners of carbon securities does not face any borrowing constraints when they make campaign contributions.*

Finally, consider the investment stage.

Assumption 4 *The individual firms and the industry satisfy the following assumptions:*

(a) *Each firm i believes itself too small to have any meaningful impact on the carbon price p or the aggregate investment level I.*

(b) *No industry-wide coordination is possible on investment.*

(c) *The profit function of the energy consuming industry satisfies (in the relevant range) for all p that $\Pi'(p) < -p\Pi''(p)$ where $-\Pi'(p)$ is the industry demand for coupons.*

(d) *All firms in the industry are monopolistically competitive.*

In period 1, each firm individually chooses an investment level I_i which determines its demand for energy in the following period. For given p, I and θ an individual firm's profit is

$$w_i(I_i; p, I, \theta) = \pi(I_i; p) - I_i - \frac{1}{m} C_E(p, \theta, I) \tag{6}$$

where $\pi(I_i, p)$ is the profit of firm i, C_E is the contribution made by the energy consuming industry, I_i is investment in energy-saving technology. Aggregate investment is $I = \sum_{i=1}^{m} I_i$. The carbon price p is an input price. Thus, $\frac{\partial \pi}{\partial p} < 0$.

and $-\frac{\partial \pi}{\partial p} = -\pi'$ is an individual firm's demand for energy.

If a firm invests, it requires less energy for its production. So for any p,

$$\frac{\partial(-\pi')}{\partial I} < 0.$$

In other words, for a given carbon price, a firm's demand for energy decreases with the investment level.

2.2 Discussion of the Model

An important question is who would buy the carbon securities when the government auctions them in the first period. The effectiveness of carbon securities as a policy tool depends on the allocation of the carbon securites in the second period. There is an incentive to form a lobby in favor of maximizing the value of the securities unless the carbon securities are all held by carbon using firms *and* each firm's proportion of carbon securities is the same as the firm's share of future carbon emissions. The benefits of carbon securities are larger if a high fraction of the securities is held for investment purposes (resale) and not for a firm's own carbon consumption. This paper focuses on the benchmark case in which all securities are held by outsiders to the carbon-using industries since there are several strong arguments why it is unlikely that a large fraction of the securities is bought by carbon using firms in the first period.

Carbon securities are financial assets with a highly uncertain future value. The future value of carbon securities is affected by climate uncertainty, political uncertainty and uncertainty about the demand for fossil fuels.[6] It seems therefore plausible to anticipate that a large share of securities is bought by investment banks and other entities specialized on investment in assets with uncertain returns. Carbon using firms choosing not to buy carbon securities in period 1 but carbon allowances in period 2 is equivalent to firms buying an input for production instead of producing it themselves. Firms frequently choose not to internalize parts of the production process.[7]

A look at the market for forward SO_2 allowances supports this argument. Each year the Environmental Protection Agency (EPA) auctions seven year forward SO_2 allowances, each of which gives the owner the right to emit one ton of SO_2 seven years after the auction takes place. One might expect that these forward allowances are bought by powerplants that anticipate that they will require SO_2 allowances seven years from now. However, this is typically not the case. The majority of bidders in forward SO_2 allowances auctions are not entities that purchase SO_2 allowances for their own consumption. For example, at the 2009 Acid Rain Allowance Auction the three largest bidders were JP Morgan, Barclays Bank and Morgan Stanley. Less than 1% of the allowances were bought by entities that are not investment banks. Forward SO_2 allowances are financial assets characterized by significant uncertainty with respect to their future value. Therefore, entities like investment banks that are specialized on pricing risky assets are at a natural advantage. Also, acquiring information

[6] This last source of uncertainty is not explicitly modelled here but could be added to the model without affecting the main conclusions of the paper.

[7] An alternative way of saying this is to note that firms do not purchase all inputs with long term contracts. Eventually, it seems likely that options markets for carbon coupons would developed to hedge the risk of unexpected coupon price fluctuations.

about the SO_2 market and hiring experts to make forecasts of SO_2 prices is costly. Therefore, there are likely significant economies of scale which favor investment banks.[8] [9]

A notable difference between SO_2 forward allowances and carbon securities is that only for the later there is an incentive to buy them to prevent the formation of a counterlobby.[10] If the lobby of the carbon using firms coordinates and buys all securities it can prevent the formation of a lobby of carbon securities holders. As outlined above there are strong reasons why an average carbon using firm is unlikely to be interested in purchasing carbon securities. So any plan involving a purchase of all carbon securities by the carbon using firms has to overcome a significant free-rider problem. A firms in the carbon using industries prefers that other firms in the industry purchase all securities but would rather not purchase any securities itself. It seems very unlikely that the lobby of carbon using firms would be able to monitor if their members choose to purchase an appropriate amount of carbon securities. This is much more difficult to monitor than if firms pay their lobby contributions.

In addition, both cornering a security market and colluding are illegal in most countries. Politicians have a strong incentive to enforce these laws since they benefits from the presence of an additional interest group. With an addition interest group representing people who bought carbon securities for investment purposes, politicians receive higher campaign contributions and the equilibrium policy level is closer to the social optimum and should hence appeal more to the electorate. Finally, note that in any situation in which there are two or more lobbies there may in principle be advantages for the lobbies if they get together and form one super-lobby since it allows them to capture all surplus from the political relationship with the government. In practice, there is little evidence that lobbies or industries take over competing lobbies or industries to then jointly maximize their lobbying and extract surplus from the government.

Next, consider assumptions about the firm: Assumption 2(a) states that firms are able to coordinate their efforts on lobbying for a favorable carbon price but according to part

[8] It is important to keep in mind that the group of carbon using firms consists of many more firms than just large multi-national energy firms (which might have sufficient economies of scale to hire experts). A carbon system typically affects a very large number of firms - 85% of firm in the case of the Waxman-Markey proposal. Thus, a large number of firm affected by the abatement policy are small and medium size firms.

[9] There is a difference between carbon securities and forward allowances in another respect. Forward SO_2 allowances constitute a very small share of the overall amount of SO_2 allowances. Carbon securities would cover the entire market for carbon emission allowances. However, the argument here addresses the nature of the asset, which is quite similar.

[10] The owner of a forward SO_2 allowance has been promised exactly 1 ton of SO_2 emissions, so there is scope for negotiations and hence no need for lobby formation.

4(b) cannot or choose not to coordinate their investment decisions. There are two main reasons why this is a plausible assumption: First, competition laws in most countries limit opportunities for industry wide coordination when it comes to investment projects. Second, the free-riding problem is harder to overcome when investments are large relative to revenue as is the case when it comes to investment. Also, while it is fairly easy for the other firms to observe if a firms contributes to the lobby, it is much harder to observe how much a firm invests in abatement technology. So free-riding is a more pressing concern when it comes to investment than for lobby contributions. This is a very similar argument as the argument above why firms do not coordinate to purchase carbon securities. Assumption 4(a) is realistic if a large number of firms are subject to the requirement to purchase carbon allowances. This is true for most carbon tax or cap and trade systems.[11] Assumptions 2(b) and 3(b) state that each lobby is sufficiently funded to make optimal campaign contributions. Essentially, this says that the lobby members are able to overcome the free-rider problem when it comes to organizing their lobby. Assumption 4(c) is satisfied in the range of p in which the industry's expenditures on energy increase with the permit price. The condition can also be interpreted as a condition about the curvature of the profit function. At all p, the Arrow Pratt measure, $\frac{-\Pi''(p)}{\Pi'(p)}$, has to be larger than $\frac{1}{p}$. Since empirical observations strongly suggest that at current fossil fuel prices an increase in the price leads to higher expenditures on fossil fuels, this assumption is realistic for virtually every climate policy goal currently under serious consideration.

In the model demand for energy each period is deterministic: there is no uncertainty in the demand for carbon. In other words, this assumption states that the periods for which carbon securities pay carbon allowances are sufficiently short. Including uncertainty would not affect the fundamental results - in particular with respect to the comparison between the traditional permit or tax system and a system with carbon securities.

In principle, environmental policy is also influenced by environmental interest groups like Greenpeace, the Sierra Club, Earthwatch and others. In practice, the influence of these groups on policy setting is likely to be small compared to industry lobbies. A main reason for this is limited funding. In the case that environmental interest groups have the ability to influence policy, it seems likely that their attention would shift from global warming to other environmental issues once a system with carbon securities led to a carbon close to the

[11] In particular, this must hold for any plan similar to the recent Waxman-Markey proposal which covers 85% of carbon emissions.

social optimum. Therefore environmental interest groups are not explicitly considered in the model.

3 The Tax Game

This section considers the tax game. Recall that the key difference between the tax game and the carbon securities game is that in the former one of the two lobbies has no incentive to be active.

3.1 The Equilibrium

The two period game considered here can be solved by backward induction. First, the menu auction stage in which p is determined has to be considered. In a second step, the individual firm's investment decision can be analyzed. The investment decision depends on the expected carbon price and potentially on the variance of the carbon price.

Definition 1 *An equilibrium of the lobbying stage of the tax game is a contribution function* $C_E(p, \theta, I)$ *and a carbon price* p *such that*

a. the contribution function maximizes the joint welfare of the lobby's members given the carbon price p

b. carbon price p *maximizes the government's objective taking the contribution function as given*

The lobby offers a contribution function, which specifies a financial contribution depending on the government's choice of the carbon price. Thus, the game is a menu auction (Bernheim and Whinston, 1986).

Definition 2 *An equilibrium of the tax game is a contribution function* $C_E(p, \theta, I)$*, a set of individual firm investment levels* $(I_1, ...I_m)$ *and a carbon price* p *such that*

a. for each firm i*,* $I_i \in \Im$ *maximizes the expected net of contributions welfare of the firm given the expected equilibrium contribution schedules and carbon price*

b. $C_E(p, \theta, I)$ *and* p *are an equilibrium of the menu auction stage of the carbon securities game*

The following proposition states the necessary and sufficient conditions for an equilibrium of the menu auction stage of the tax game.

Proposition 1 *[Lobbying Stage Equilibrium with Tax] Given the aggregate investment level* I*,* (C_E^0, p_T) *is an equilibrium of the lobbying stage if and only if*

a. C_E^0 *is feasible*

b. p_T *maximizes* $C_E(p; \theta, I) - \theta G(p; I)$

c. p_T *maximizes* $W_E(p; \theta, I) - \theta G(p; I)$

d. there exists a p^E *that maximizes* $W_G(p; \theta, I)$ *such that* $C_E^0(p^E) = 0$

Proof. The proposition follows immediately from Lemma 2 of Bernheim and Whinston (1986). The first condition is a standard feasibility condition. The second condition requires that the carbon price is optimal for the government since $C_E(p; \theta, I) - aG(p; I)$ is the government revenue after contributions have been received. The third and fourth conditions together state that the lobby's contribution schedule has be optimal. ■

In general, there are a large number of equilibria in menu auctions. However, only equilibria supported by so-called truthful contribution schedules are stable to non-binding communication among players. Also, the best response set to any strategy played by an opponent includes a truthful strategy (Bernheim and Whinston, 1986). Therefore, I focus in the following on equilibria supported by truthful contribution schedules.

Definition 3 *A truthful contribution schedule takes the form* $C_i(p; \theta, I, B_i) = \max[0, W_i - B_i]$ *where* B_i *is a constant.*

Corollary 1 *Suppose the contribution schedule is truthful. There is a unique equilibrium. The equilibrium carbon price* p_T *satisfies* $\theta G'(p) = \Pi'(p)$*.*

Proof. First, consider uniqueness. When the contribution schedule is truthful, condition (b) of Proposition 1 simplifies to

$$C_E(p) - \theta G(p) = W_E(p) - B_E - \theta G(p)$$

where B_E is a constant. Therefore, conditions (b) and (c) of Proposition 1 lead to the same first order condition. Second, to see that the equilibrium carbon price p_T satisfies

$\theta G'(p) = \Pi'(p)$ start with either condition (b) and (c) of Proposition 1 and replace W_E with the expression in Equation 4:

$$W_E(p) - B_E - \theta G(p) = \Pi(p) - I - \theta G(p)$$

Note that while I depends on p since the individual firm's investment decision, I_i, in the investment stage in period 1 depends on p, once the lobbying stage is reached I has been determined and the government's choice of p does not affect I. Therefore, the FOC characterizing the equilibrium of the tax game is $\theta G'(p) = \Pi'(p)$. ■

Proposition 2 *[Equilibrium Price Comparison] The carbon price under a tax system is lower than the socially optimal price: $p_T < p^*$.*

Proof. Since p is an input price Π is a decreasing function of p:

$$\Pi' < 0$$

This implies that the tax game equilibrium price, p_T, has to be in the range of p in which it holds that $\theta G'(p) < 0$. Figure 2 shows Π', $\theta G'$, and the social welfare maximizing carbon price p^*. From Assumption 1 it follows that $\theta G'(p) < 0$ for all $p < p^*$ Therefore, $p_T < p^*$: The price under the tax system has to be below the price which maximizes social welfare. ■

Figure 2 illustrates this proposition. The equilibrium price is below the socially optimal price due to the lobbying of the energy-consuming industry.

3.2 Effect of Uncertainty

In period 1, there may be significant uncertainty about the state of the world in period 2. This can take the form of either climate uncertainty (how costly global warming is) or political uncertainty (what party will be in charge). This section shows how both types of uncertainty can be considered within the framework of the model. The goal is to study uncertainty while keeping the model as simple as possible. The following shows that the variance of θ can be interpreted as either political uncertainty or climate uncertainty.

First consider political uncertainty: a situation in which in period 1 it is unknown which party will be in charge of choosing the carbon price once time 2 is reached. Suppose there are

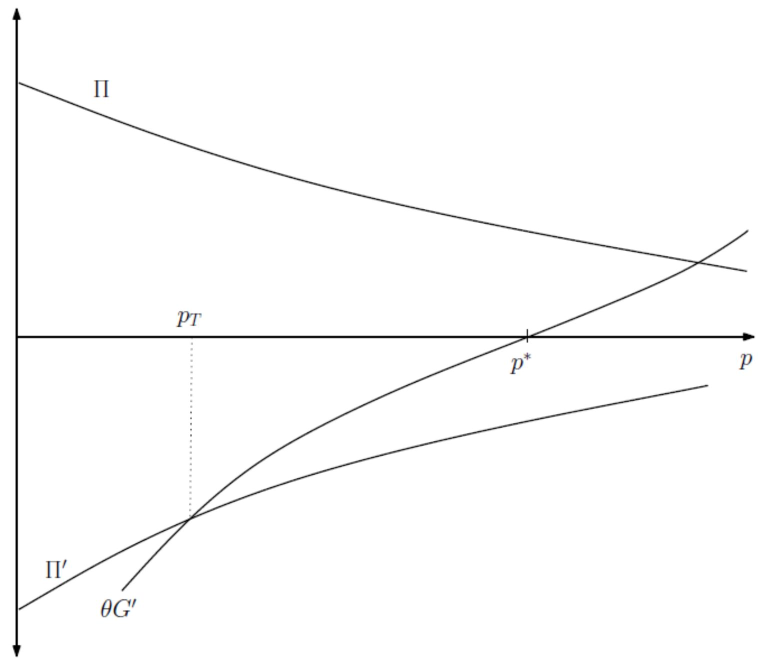

Figure 2: The tax equilibrium.

at least two parties and these parties differ in how important it is for them that the carbon price is close to p^*. In other words, they have different θ's. The ex ante (period 1) variance of period 2's carbon price depends on the distribution of θ. One explanation for differences in θ is that the political parties can differ with respect to how corrupt their politician are. In other words, they may place different weight on campaign contributions relative to voter welfare.

Next, assume that there is no political uncertainty (all politicians have an θ equal to θ_H) but there is considerable uncertainty about the climate. The social cost of carbon function can either be G or F and this uncertainty is not resolved until period 2 is reached. The state of the world characterized by social cost of carbon function G can be thought of as a state with high climate sensitivity and global warming imposing significant cost to society. The state of the world characterized by social cost of carbon function F can be interpreted as a state with either low climate sensitivity, efficient geoengineering options or low cost of global warming. If the social cost of carbon function is G then the socially optimal carbon price is p_G^* and any downward deviations are expensive. Hence G' is steep (see Figure 3). If the social cost of carbon function is F then the socially optimal carbon price is p_F^* and any

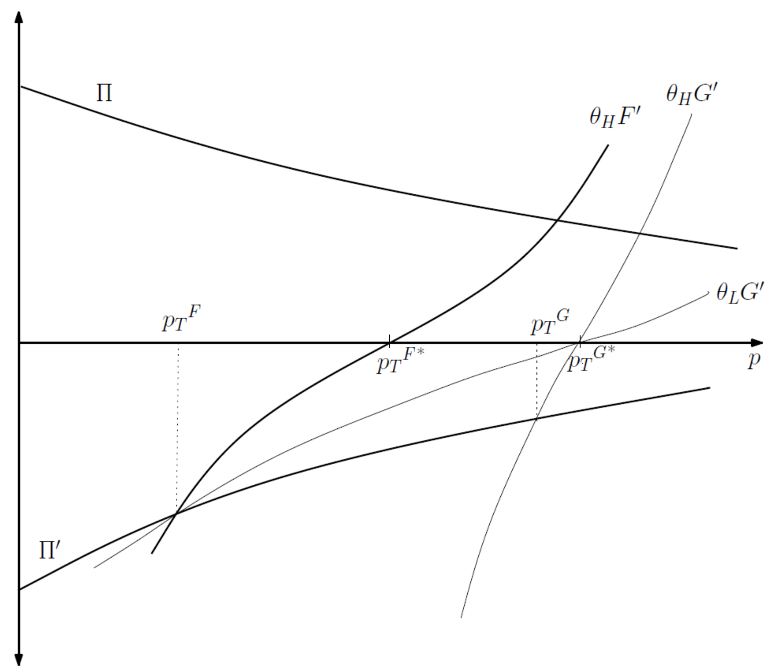

Figure 3: Uncertainty in θ can be interpreted as uncertainty in G.

downward deviations are less expensive than under G.

As Figure 3 shows, the same equilibrium as under F can be found by using G and choosing the appropriate θ - here θ_L. Therefore, to keep things as simple as possible both climate uncertainty and political uncertainty is in the following studied by varying θ.

3.3 A Comparison to a Traditional Permit System

Most of the literature considers carbon tax systems and cap and trade systems as policy instruments with significant differences and correspondingly different advantages and disadvantages. Within the model considered here both instruments have more similarities than differences. Hence it is useful to consider them together. The two policy instruments are essentially equivalent here since (i) there is no demand uncertainty within a period, (ii) both under the tax and the cap and trade system, the policy is set at the beginning of period 2 and (iii) there is no banking of permits since there is only one period. So it does not make a difference whether the carbon price is chosen by the government or whether an emission quantity is chosen. Both lead to the same equilibrium.

The assumption that there is no demand uncertainty within a period, is more realistic for short periods than for long periods. The model could be extended to the case of demand uncertainty. However, demand uncertainty affects both a traditional cap and trade system and the here proposed system equally, so for the purpose of comparing an existing mechanism to a new mechanism, very little is gained by including demand uncertainty.

4 The Carbon Securities Game

The previous section illustrated the effect of the presence of a lobby representing the interests of energy-consuming industry on the equilibrium carbon price, the variance of the carbon price and equilibrium investment in alternative energy. It showed that the equilibrium carbon price under a traditional tax or permit system is below the social optimum. This section proposes an alternative to a traditional tax or permit system which is superior with respect to the level of the carbon price and has interesting properties with respect to climate and political uncertainty.

Compared to other carbon abatement policy instruments, the key feature of system with carbon securities is that the amount of carbon emissions allowed per security is determined after the security has been sold. Each of the n carbon securities gives its owner the right to emit up to $\frac{1}{n}$ of the society's total desired carbon emissions for year 2, X. This amount X is unknown to potential buyers at time 1 when they have to decide whether they want to purchase a security or not. Once all securities have been sold, firms choose their level of investment in energy-saving technology technology. In period 2 the political process determines X, taking into account the voters' preferences, the aggregate investment level and any contributions from lobbies representing either the interests of the energy-consuming industry or the the owners of carbon securities.

The securities game is a common agency game with two principals, the lobbies of the energy-consuming industry and the holders of carbon securities, and one agent, the government, who has the discretionary power of selecting the carbon price (Bernheim and Whinston, 1986). Lobbyists compete by simultaneously offering contribution schedules conditional on the policy ultimately selected. The government chooses the carbon price which maximizes its welfare, which depends on the weighted sum of campaign contributions and social welfare.

As in the previous section on the tax game, there are essentially two periods. In the first period the following actions and events take place: The government sells n securities. The owners of the securities form a lobby and the energy-consuming industry forms a lobby. Each firm in the energy-consuming industry chooses its investment level. In the second period, the lobbies find out how much the government is influenced by campaign contributions. The lobbies then offer their contribution schedules. The government chooses an amount of desired maximum carbon emissions X and thereby determines the price of carbon p. Each security owner sells $\frac{X}{n}$ carbon allowances to firms in the energy-consuming industry at a price of p per unit of carbon.

The government has similar preferences as in the previous section. The only addition is that the government now receives campaign contributions not just from the lobby of the energy-consuming industry but from the lobby representing the interests of the permit holders.

4.1 The Equilibrium of the Carbon Securities Game

The fundamental difference between the carbon securities game and the tax game is that in the former there is political competition while in the later there is not. In the carbon securities game there are two active lobbies, while in the tax game only the lobby of the energy consuming industry is active. Political competition has a strong effect on the equilibrium carbon price and campaign contributions.

Definition 4 *An equilibrium of the menu auction stage of the carbon securities game is a set of contribution functions* $\{C_E(p,\theta,I), C_B(p,\theta,I)\}$ *and a carbon price* p *such that*

a. each contribution function maximizes the joint welfare of the group's members given the carbon price and the other groups contribution function

b. carbon price p *maximizes the government's objective taking the contribution function as given*

Definition 5 *An equilibrium of the carbon securities game is a set of contribution functions* $\{C_E(p,\theta,I), C_B(p,\theta,I)\}$*, an investment level* I *and a carbon price* p *such that*

a. I *maximizes the expected net of contributions welfare of the energy consuming industry given the expected equilibrium contribution schedules and carbon price*

b. $\{C_E(p,\theta,I), C_B(p,\theta,I)\}$ *and* p *are an equilibrium of the menu auction stage of the carbon securities game*

Proposition 3 *[Menu Auction Equilibrium with Securities] Given the investment level* I*,* (C_B^*, C_E^*, p_S) *is an equilibrium if and only if*

a. C_E^**,* C_B^* *are feasible*

b. p_S *maximizes* $C_B(p,\theta,I) + C_E(p,\theta,I) - \theta G(p,I)$

c. p_S *maximizes* $W_B(p,\theta,I) - \theta G(p,I) + C_E(p,\theta,I)$

d. there exists a p^B *that maximizes* $W_G(p,\theta,I)$ *such that* $C_B^*(p^B) = 0$

e. p_S *maximizes* $W_E(p,\theta,I) - \theta G(p,I) + C_B(p,\theta,I)$

f. there exists a p^E *that maximizes* $W_G(p,\theta,I)$ *such that* $C_E^*(p^E) = 0$

Proof. Similarly to Proposition 1, the result follows from Lemma 2 of Bernheim and Whinston (1986). The first condition states that the contribution has to be nonnegative and must not be greater than the aggregate income of lobby's members. Condition (b) states that the government chooses a carbon price to maximize its own welfare. Conditions (c) and (d) ((e) and (f)) ensure that the contribution schedule of the lobby of the banks (the lobby of the energy intensive industry) is optimal. ■

Corollary 2 *Suppose contribution schedules are truthful. There is a unique equilibrium. The equilibrium carbon price* p_S *satisfies* $\theta G'(p,I) = -p\Pi''(p,I)$.

Proof. Uniqueness under truthful strategies follows directly from Propositions 3 and the definition of truthful strategy:

$$C_B(p,\theta,I) = W_B(p) - B_B$$

and

$$C_E(p,\theta,I) = W_E(p) - B_E$$

Therefore, conditions (b), (c) and (e) lead to the same first order condition when strategies are truthful. To derive this FOC, take for instance condition (c):

$$W_B(p,\theta,I) - \theta G(p) + C_E(p,\theta,I) = -p\Pi'(p) - \xi n - \theta G(p) + W_E(p) - B_E =$$

$$= -p\Pi'(p) - \xi n - \theta G(p) + \Pi(p) - I - B_E$$

where I, B_E, ξ and n do not depend (in this stage) on the choice of p. Therefore, the first order condition that characterizes the equilibrium of the carbon securities is $\theta G'(p,I) = -p\Pi''(p,I)$. ■

4.2 Comparison with a traditional tax or permit system

This section addresses the question how the carbon securities system I propose compares to systems currently in use or proposed in the literature. First, I consider the question how the equilibrium carbon prices compare to each other. Second, I look at implications of climate or political uncertainty on the variance of the carbon price. Third, the effect on investment in energy-saving technology is analyzed. Fourth, advantages and disadvantages of either system for the government are considered.

With a traditional permit system or a carbon tax, only the energy consuming industry has a strong financial incentive to lobby for a carbon price in its favor. Introducing property rights for emissions creates a counterbalancing force: now there is a group that has a strong financial interest in lobbying for a high carbon price. Hence, the equilibrium carbon price is higher. However, under both system the carbon price below the social optimum. The following proposition states this.

Proposition 4 *While the carbon price under either system is below the social optimum,* $p_T < p^*(I^{Tax})$ *and* $p_S \leq p^*(I^{Permit})$*, in the carbon securities game the carbon price is higher than in the tax game:* $p_T < p_S$*.*

Proof. First, consider the tax game. The tax equilibrium price, p_T is below the socially optimal carbon price, $p^*(I^{Tax})$. This follows directly from the FOCs of the tax game. Since $\Pi'(p) < 0 \ \forall \ p$, p_T has to be in the range where $G(I^{Tax})$ is downward sloping. Hence $p_T < p^*(I^{Tax})$. Similarly, as $-p\Pi''(p) < 0 \ \forall \ p > 0$, p_S is in the range where $G(I^{Permit})$ is downward sloping. Second, Assumption 4(c) states that

$$\Pi'(p) < -p\Pi''.$$

Assumption 4(c) together with G being convex and investment increasing with the equilibrium carbon price implies that $p_T < p_S$. Note that if the profit function of the industry is linear in p (in other words if it is not possible to substitute away from fossil fuels), p_S is equal to $p^*(I^{Permit})$. Example 1 illustrates the relationship between the equilibrium price in the tax game and in the carbon securities game.

■

Consider Figure 4. Under a tax system, the equilibrium carbon price is p_T. Now suppose that the government switches to the carbon securities system. If firms' investment in the

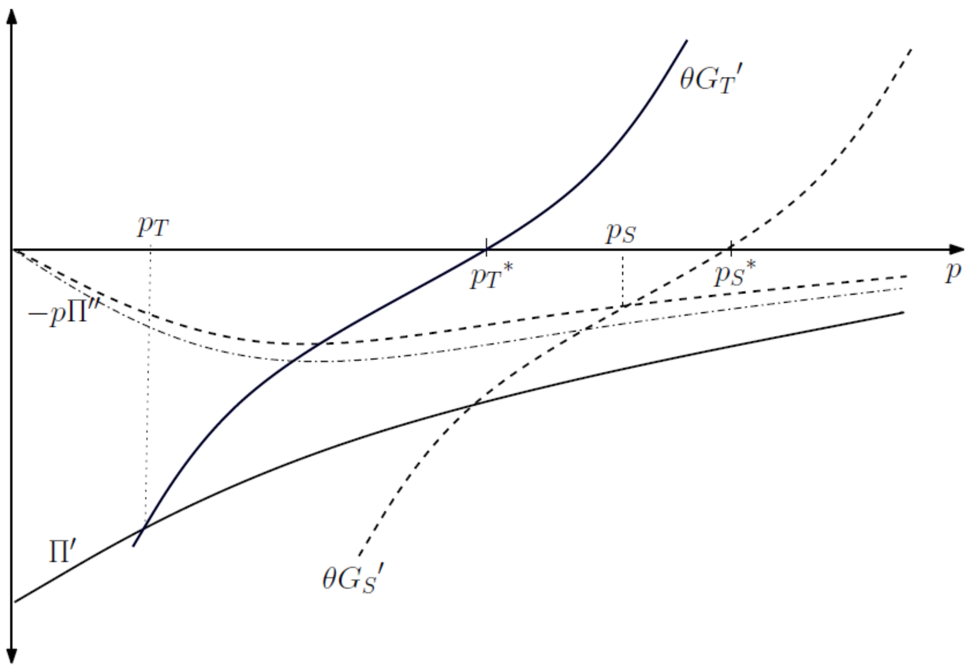

Figure 4: The equilibrium of the carbon securities game.

first period is unaffected by this switch of policy instruments, then the new equilibrium with carbon securities is at the intersection of the dash dotted line and the $\theta G_T'$ line. So there is an increase of the equilibrium carbon price as a result of lobbying by the carbon security holders. As forward looking actors, firms anticipate in period 1 that there switch from a carbon tax to carbon securities implies that carbon emissions in the second period will be more expensive. Therefore, they will invest more in carbon abatement technology in the first period. This increase in first period investment affects both the $\theta G'$ line and the $-p\Pi''$ line. The $\theta G'$ shifts to the right and the $-p\Pi''$ line shifts upwards in response to an increase in aggregate investment I. So the equilibrium carbon price with carbon securities is p_S.

If there is no effect on investment, the carbon price increases to 'p_S under constant investment.' However, since there is now a higher equilibrium carbon price and investment is more attractive under a higher carbon price, there is higher equilibrium investment. Under Assumption 1, an increase of the investment level, leads to an increase of the socially optimal carbon price. The new socially optimal carbon price is $p_S{}^*$. The equilibrium carbon price under the increased investment level is p_S.

Thus, the carbon price is higher in the carbon securities game for two reasons. First, there is the *lobbying effect*. Having political competition over the carbon price mitigates the effect of the lobby of the energy-consuming industry. Second, there is an *investment effect*. A change in the equilibrium price affects investment in energy saving technology. This change in investment level has an effect on the socially optimal carbon price and therefore also on the equilibrium carbon price. The size of the effect depends on how sensitive investment is to carbon price changes, how much the socially optimal carbon price depends on investment and on the industry profit function (how easy it is to substitute away from energy sources that require permits).

Next, consider the effect of the choice of the policy instrument on the variance of the equilibrium carbon price when there is either climate or political uncertainty. As outline in Section 3.2 uncertainty is modeled as change in the parameter θ. Figure 5 illustrates the effect of changing θ from θ_H to θ_L for both the carbon securities and tax game equilibrium.

The change in the tax equilibrium price, $\triangle p_T = p_T^H - p_T^L$, is larger than the change in the carbon security price, $\triangle p_S = p_S^H - p_S^L$ if either one of the following conditions is satisfied (a) Π' is sufficiently smaller than $-p\Pi''$, (b) $2\Pi'' + p\Pi''' > 0$ and (c) Π is close to linear.

Proposition 5 *Suppose one or more of the three conditions above is satisfied. Then the variance of the price of carbon is smaller under carbon securities than under a carbon tax or traditional permit system.*

Proof. Consider Figure 5 and note that by Assumption 1 G'_P is at least as steep as G'_T. The figure includes two horizontal lines, A_P and A_T, for illustration. The horizontal distance between $\theta_H G'_T$ and $\theta_L G'_T$ and between $\theta_H G'_P$ and $\theta_L G_P$ increases as A decreases. The condition (a) states that essentially states that the distance between A_P and A_T has to be sufficiently large. Clearly when that is the case, $\triangle p_T$ is larger than $\triangle p_S$. Condition (b) is a statement about the slope of $-p\Pi''$and Π'. It states that if $-p\Pi''$ is flatter than Π' then since by Assumption 2(e) $\Pi' < -p\Pi''$ it has to be true that $\triangle p_T$ is larger than $\triangle p_S$. This condition does not have to be true for all values of p but only for those in the range of p_S and p_T. The effect of a close to linear Π, condition (c), is illustrated in Example 1. ■

Example 1 *Consider the case of a linear profit function. This is the situation in which investment is essentially equivalent to gaining access to a specific blueprint for production technology and this technology requires a constant amount of carbon based energy per unit of output. If* Π *is linear then* Π'' *and* Π''' *are equal to zero. Therefore,* $p_S = p^*$ *and* $\frac{dp_S}{d\theta} = 0$.

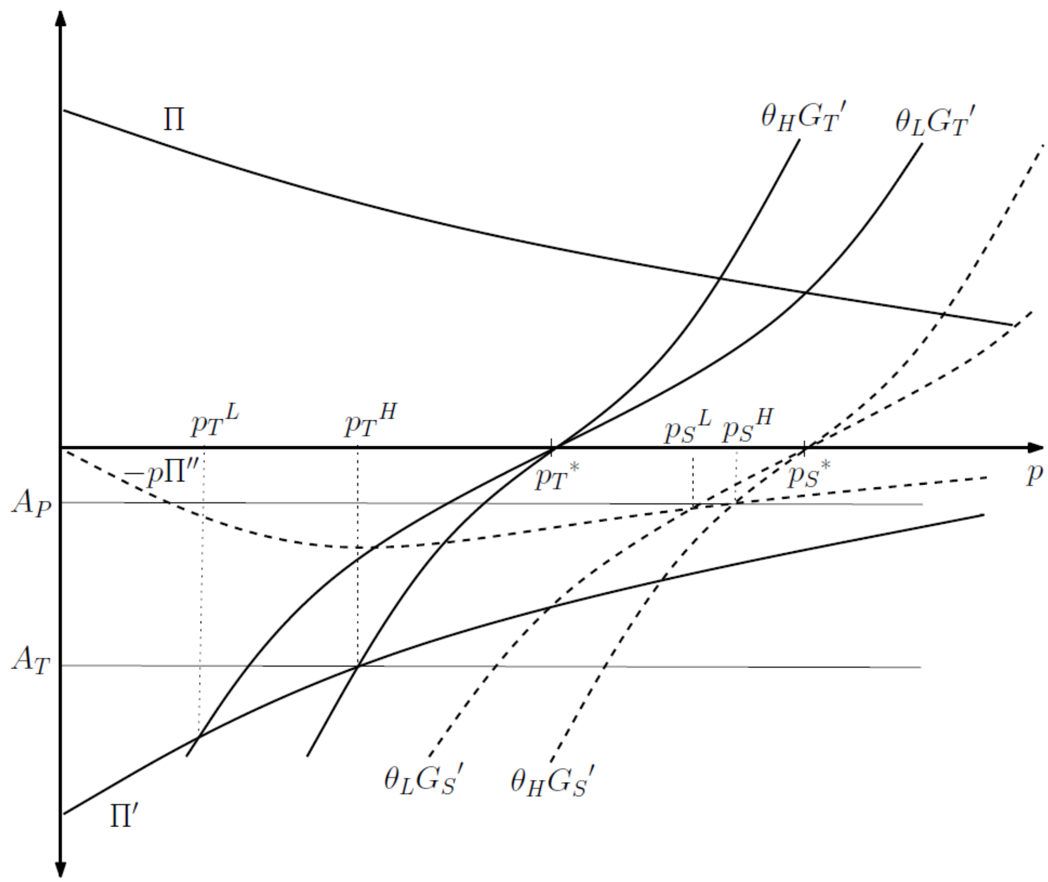

Figure 5: The effect of a change in θ.

However,

$$\frac{dp_T}{d\theta} > 0$$

So as expected, the tax equilibrium price increases with θ: With a high θ, the government puts more weight on social welfare and the tax equilibrium price is higher.

Thus, with a linear profit function variance in θ translates into price uncertainty in the tax game but not in the carbon securities game.

The equilibrium carbon price is a function of θ under either system. However, the carbon price under a tax system is more responsive to changes in θ than with carbon securities.

Suppose θ is large, then both with carbon securities and a traditional scheme, the carbon price is close to p^*, the socially optimal price. However, if θ is small then $p_T \ll p^*$, while p_S

is relatively close to p for all θ.

In general, how close p_S is to p^* depends on the curvature of the profit function. For an almost linear profit function, p_S is very close to p^*. The more convex the profit function the larger the distance between $p_S$and p^*. The profit function is very convex if it is very easy to substitute away from fossil fuels. As long as Assumption 4 (c) holds, the profit function can only have a small amount of curvature. If it had more curvature, then substituting away from fossil fuels would be very easy and the response to an increase in the price of fossils would be a decrease in the total expenditures on fossil fuels.

Next, consider investment in energy-saving technology. So far the model only explicitly considered an investment option in period 1 but of course there also exist opportunities to invest in energy-saving technology at later points in time. Later investment has the advantage that by then some of the uncertainty present in the first period has been resolved. It is important to note that any such investment is not likely to be perfectly recoverable in case it turns out to be an unprofitable investment. The reason is that if investment in energy-saving technology turn out to be unprofitable for one firm this is most likely due to the carbon price being very low. In other words, the investment considered is investment that can only be used for reducing energy consumption, not for other purposes. However, with the carbon price being very low the resale value of energy-saving equipment or machinery is very low. Therefore investment is (mostly) irreversible. The question how early (period 1) investment in energy-saving technology is affected by the choice of the policy instrument is consequently best approached from the perspective of the investment under uncertainty literature (Dixit and Pindyck, 1994).

Assumption 5 *Suppose that θ represents climate uncertainty and that θ follows a random walk (or a Brownian motion if the problem is considered in continuous time).*

Think of θ as a signal that arrives at the beginning of each period and provides information about the expected cost of global warming. Then it is reasonable to assume that the best estimator of θ_{t+1} is θ_t. A random walk is a good characterization for such a process.

Proposition 6 *Assume Assumption 5 holds. Then there is more investment in carbon abatement technology in a system based on carbon securities than under a carbon tax or traditional permit system.*

Proof. There are two forces that encourage early investment under a system based on carbon securities. First, the expected carbon price is higher. The expected return from investment in energy-saving technology increases with the carbon price. Hence, an increase in the expected carbon price increases period 1 investment. Second, since θ follows a random walk, increasing uncertainty delays firm level investment and leads to lower levels of investment. This follows directly from work by Pindyck (1988), Hassett and Metcalf (1994) and others. ■

Switching from a traditional tax system to carbon securities affects both the level of the carbon price and the variance of the carbon price. The increase in the expected carbon price makes investment in alternative energy more attractive. The reduction in the variance of the carbon price also encourages investment if the nature of the uncertainty is a random walk and the investment is (partially) irreversible. Intuitively, investment in abatement technology is attractive if the carbon price is high but not if it is low. By waiting until uncertainty is resolved a firm avoids making the costly mistake of having invested but the state of the world turning out to be a low socially optimal carbon price (global warming not a serious problem). A decrease of the uncertainty over the future returns from investment, reduces the value of waiting and therefore makes investment in period 1 more attractive.[12][13]

Also, in the carbon securities game the expected level of global warming is lower than in the tax game due to two effects: First, the carbon price in the carbon securities game is higher because it is closer to the socially optimal carbon price. Second, the socially optimal carbon price in the carbon securities game is higher because there is more investment in energy saving technology. Both effects leads to less global warming in the case of the securities game.

Next, consider government revenue under both the system with permits as bonds with uncertain coupons and under a traditional tax or permit system. Both a traditional permit system and the carbon securities system can be designed so that there is government revenue from selling or auctioning permits. If permits are auctioned off, the revenue is equal in size to that of a tax that generates the same amount of emissions. Assumption 4 (c) and Proposition 4 imply that government revenue is larger under the here proposed policy instrument than under traditional alternatives.

Finally, consider the effect of the policy instrument choice on total campaign contri-

[12] If uncertainty is better characterized as a mean stationary jump process than as a random walk, Hassett and Metcalf (1994) show that aggregate investment can under some conditions be enhanced by increasing uncertainty. However, in their model profitability of investment is determined by the state of world when the investment is undertaken. Here profitability of investment depends on the entire sequence of states of the world beginning at the moment that the investment is undertaken.

[13] In this paper differs from Acemoglu et al (2009 in so far as that here the trigger for technological change is a change in the policy tool (or institutional setup).

butions. Grossman and Helpman (1994) show that if a lobby faces no opposition from competing interests it is able to extract all surplus from its political relationship with the government. This implies that contributions of the energy-consuming industry in the tax game are equal to the difference of the social cost of carbon function under the tax game equilibrium price and the social cost of carbon function under the socially optimal price. If there are two active lobbies as in the carbon securities game, the government captures all of the surplus from the political relationships.

5 An Application to the US Acid Rain Program SO_2 Allowances

5.1 The SO_2 Allowance System

Acid rain is a broad term referring to both wet and dry deposition from the atmosphere containing higher than normal amounts of nitric and sulfuric acids, which are particularly damaging to lakes, streams, and forests and the plants and animals that live in these ecosystems. The objective of the EPA's Acid Rain Program is to limit the amount of NO_x and SO_2 emitted into the atmosphere since these two chemicals are the main contributors to acid deposition (EPA, 2007).[14]

Title IV of the Clean Air Act set a goal of reducing annual SO_2 emissions by 10 million tons below 1980 levels. To achieve these reductions, the law required a two-phase tightening of the restrictions placed on power plants fired by fossil fuels. Phase I began in 1995 and affected 445 units at mostly coal-burning electric utility plants. Emissions data show that 1995 sulfur emissions at these units were reduced by almost 40 percent below their required level. Phase II began in the year 2000. It tightened the annual emissions limits for the units covered under Phase 1 and also set restrictions on smaller, cleaner plants fired by coal, oil, and gas. The total of units covered increased to over 2,000 units.

Under the SO_2 allowance system, one SO_2 allowance is required for each ton of SO_2 a coal-fired power plant emits during a year. The SO_2 allowances have been allocated for free to the power plants through 2037 based on their operations in the baseline years of 1985-1987. Additional SO_2 allowances can be bought to meet emissions requirements. To create a marketplace in addition to private trades between affected units, the EPA holds an annual auction for 125,000 spot and 125,000 7-year forward allowances.

For each ton of SO_2 emitted in a given year, one allowance is retired, that is, it can no longer be used. Allowances may be bought, sold, or banked. Anyone may acquire allowances and participate in the trading system. Sources are required to hold a quantity of allowances equal or greater than the amount of SO_2 emitted during that year. Any excess allowances can be banked for use in future years. If emissions exceed allowances, units have to pay a

[14] When sulfur dioxide and nitrogen oxides are released from power plants and other sources, prevailing winds blow these compounds across state and national borders, sometimes over hundreds of miles. Thus, a local solution to this externality problem is not feasible.

penalty and have to surrender allowances for the following year to the EPA to offset their excess emissions.

5.2 An evaluation of the SO2 Allowance System

The current system promotes cost-effectiveness by permitting allowance holders to transfer their permits among one another. The intention is that those who can reduce their sulfur emissions at the lowest cost have an incentive to do so and sell their leftover allowances to those for whom it would be more costly to cut emissions.

The system currently is best characterized as a traditional permit system with predominately free allocation of permits and banking of permits. According to the model developed in the previous sections, the emission target of the program, 10 million tons of SO_2 below 1980 level, corresponds to the Tax Game equilibrium of Section 3. This would imply that the amount of SO_2 to be emitted under the Acid Rain Program is above the social optimum. The reason is that there is a strong lobby representing the interests of the power generating industry but no counterbalancing, financially strong lobby representing agents with an interested in a high allowance price.

The hypothesis that the current cap of sulfur emissions is higher than the optimal emission level is supported in the recent literature on the SO_2 Allowance System. Israel (2007) provides evidence for SO_2 emissions being above social welfare maximizing levels by studying the behavior of environmental interest groups. Smith and Yates (2003) provide a theoretical foundation for this result.

5.3 An SO2 Allowance System with Carbon Securities

The current SO_2 allowance system uses a combination of annual allocation and annual allowance auction. With a system based on carbon securities there would be one initial auction of securities and then each year each of the securities pays an allowance which is equal to some ex ante unknown amount of tons of SO_2. Units can purchase the amount of allowances they require at a coupon market place run by the EPA. The allowance that each security pays is determined each year by the EPA or the government.

As under the current system, monitoring can be conducted under the Continuous Emission Monitoring Rule and the Allowance Management System (AMS) can be used to keep track of securities and allowances.

Similar to the current system, units must purchase a quantity of allowances equal to their emissions on the coupon market place. Allowances are only valid for one year and if they are not used during that year they loose their value. Units have to pay a penalty if their emissions in any one year are higher than their total of allowances for that year.

Both the current system and carbon securities encourage cost-effectiveness. In a system based on carbon securities, all SO_2 emitters are required to purchase an amount of allowances equal to their sulfur emissions at the end of each year. Each source has an incentive to reduce emissions up to the point where reducing emissions by one more ton is more costly than the (expected) price of one allowance on the allowance marketplace.

The main advantage of introducing a system based on carbon securities is that it facilitates the setting of an SO_2 price closer to the social optimum than can be expected under the current system as I've shown in Proposition 4. This would mitigate the inefficient level of sulfur emissions found by Israel (2007). As I showed in Proposition 5, another significant advantage of carbon securities is that there is less uncertainty about the future price of allowances. This encourages early investment in technology that allows reductions in SO_2 emissions.

6 Conclusion and Further Research

From a political economy perspective, there are important differences between carbon securities and carbon taxes and cap and trade systems. Previous models comparing these policy instruments ignore this political economy dimension.

The paper showed that carbon securities have significant advantages over existing systems. First, the creation of stakeholders with an interest in a high carbon price counterbalances the efforts of the lobby of the energy-consuming industry. This leads to a carbon price level that is closer to the social optimum than with a traditional tax or permit system. Second, climate uncertainty and political uncertainty have a smaller effect on the expected variance of the carbon price which leads to more predictability for the market participants. Third, there is higher investment in abatement technology with carbon securities. Fourth, commitment to environmental policy is endogenous under the proposed system since it makes commitment to abatement policy the government's optimal choice.

The current model considers two periods. A first period in which securities are sold and investment takes place and a second period in which lobbying takes place. An important extension is the n period model. In this multi-period model each security pays $n-1$ allowances - one allowance in each but the first period. The multi-period model will address the question how the choice of the policy tool affects how investment expenditures are distributed over the n periods. My conjecture is that carbon securities encourage investment in early periods compared to traditional policy tools.

Another area for future research is the application of the mechanism proposed in this paper to other problems which involve a public good, for example public provision of TV broadcast stations.

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