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Taxes versus Cap-and-Trade in Climate Policy when only some Fuel Importers Abate

Jon Strand

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Abstract

I study climate policy choices for a “policy bloc” of fuel-importers, when a “fringe” of other fuel importers have no climate policy, fuel exporters consume no fossil fuels, and importers produce no such fuels. The policy bloc and exporter blocs act strategically in fossil fuel markets. When the policy bloc sets a *carbon tax*, the fuel import price set by the exporter is reduced, and more so when the policy bloc is larger. The carbon tax then serves to extract the exporter’s rent. The fringe also gains from reduced fuel import prices, and gains more when the policy bloc is larger. When the policy bloc sets an *emissions cap*, fuel demand becomes less price elastic. In response, a monopolistic exporter sets the fuel export price higher than under a tax, which hurts both the policy bloc and the fringe. This effect can be stronger when the policy bloc is larger, so that the fringe loses when the policy bloc is larger, opposite to the tax policy case. Overall, a cap is inferior to a tax for fossil fuel importers, both those that implement a climate policy, and those that do not.

JEL-Code: Q31, Q38, Q54, Q58, H23.

Keywords: climate policy, carbon taxes, cap-and-trade schemes, carbon emissions, strategic trade policy.

Jon Strand
Development Research Group
Environment and Energy Team
The World Bank
Washington DC 20433
USA
Jstrand1@wordlbank.org

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1. Introduction

It seems likely that more countries than today will “relatively soon” establish policies which will include formal climate policy targets. Today, only countries under Annex B of the Kyoto Protocol, who have ratified the Protocol, have such policies. A hope is that these will soon be joined by other high-income countries (including the U.S.) and later perhaps by major emerging economies, in establishing formal climate policies. What seems out of the question for the foreseeable future, is a comprehensive climate policy regime, involving all greenhouse gas emitters (focusing in the following on carbon emissions).

The countries with a climate policy (a policy that effectively constrains the policy countries’ overall emissions) comprise not much more than 20 percent of global carbon emissions today. Such policy, established through the Kyoto Protocol, takes the form of a cap on emissions valid for the period 2008-2012, set lower than these countries’ anticipated “business-as-usual” emissions for the period.

Instead of setting an emissions cap, the policy countries could tax carbon emissions. No comprehensive carbon tax policy is so far being used, or seriously contemplated, by major countries.[2] To most observers the differences between a climate policy involving carbon emissions taxes, and a cap on carbon emissions which is equivalent to (expected) emissions under a tax, are small and not decisive for the choice of policy.[3] Two differences between these policy instruments and their effects are however widely recognized. First, under uncertainty, the effects of the two policies differ as only the emissions level will vary under the tax, while only the emissions price level will vary under the cap.[4] A second recognized difference is that the government’s ability to recuperate income may be greater under a tax as many or most emissions permits are, in practice, handed out for free to emitters under a cap. Arguably, both differences work in favor of a tax over a cap.[5]

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[2] It is however true that some nations, including Norway already from 1991, have unilaterally enacted relatively comprehensive carbon taxes. But these countries constitute a very small fraction of global emissions; and their carbon tax rates are too low to matter neither locally nor globally.

[3] We will here and in the following concentrate on “carbon emissions”, and such emissions from fossil fuels. While there are other greenhouse gas emissions, fossil-fuel based carbon emissions are the most important and likely to become more so in the future.

[4] Weitzman’s (1974) static analysis supports the view that when uncertainty takes the form that benefits (in terms of reduced climate change) of mitigation policy are less uncertain than costs in the short run (which, arguably, is the case in practice), a tax solution is preferred on welfare grounds. For dynamic analyses supporting the same basic view, see Hoel and Karp (2001, 2002), Pizer (2002), and Karp and Costello (2004).

[5] A third, politically important, difference between taxes and caps is in terms of transparency of gains and losses to different affected parties. Under c-a-t it is much easier to make these distributional implications obscure. This may be a political reason why many countries seem to opt for c-a-t solutions. We will here ignore such issues by focusing entirely on economic arguments.

This paper demonstrates that, for reasons completely apart from the two reasons just given, taxes and caps are not (and are often far from) equivalent as climate policy instruments when different groups of countries have conflicting interests in fossil fuels markets. This difference works in favor of taxes over cap solutions for the countries implementing (or benefiting from) a climate policy, thus reinforcing the general preference for taxes over caps. This conclusion stems from a fundamental assumption that I consider realistic, namely that fuel markets and climate policy interests are related, and dominated by two groups of countries with clashing interests. One group has interests in establishing such policies, and is at the same time a major fossil fuel importer. The other group exports fossil fuels and has no apparent interest in climate policy. My model below reflects these basic features, in a highly stylized way. In my model, one group of countries consumes all and produces no such fossil fuels, and has a climate policy concern. The other group of countries produces all and consumes no fossil fuels. The first group can then be identified with all countries apart from a small group of fuel (mainly oil) exporters; the second group comprises these fuel exporters, notably the OPEC countries and Russia.[6]

In the model I assume, realistically, that today not all but only some of the policy-oriented group of countries (the "policy bloc") have established a climate policy, and in a fully coordinated way. Other fuel-importing countries (the "fringe") have no policy. They act in an uncoordinated fashion, and each country is small and has no market power. The producer countries as group, and the policy bloc as a group, are however both assumed to behave non-competitively in the fossil fuels markets, so that policies are fully coordinated *within* each of these two groups. Policies are not coordinated *across* these two groups. The model is static by focusing on short-run demand and supply relations. Many further issues are not directly addressed by this paper, in particular, the issue of fossil fuels as exhaustible resources.[7] In particular, Sinn's (2008) "green paradox" argument, that carbon pricing could lead to increased emissions in the short run, is ignored.[8]

I then show that a tax solution is preferred to a cap-and-trade (c-a-t) solution, for both the policy bloc and the fringe. The difference lies in the response of a monopolistic fuel exporter, setting the fossil fuel export price, to a tax versus the response to a cap. Generally, importers' demand for fuel will be less elastic when some of these countries set a cap. This effect is stronger when

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[6] Norway would here be an outlier which, arguably, belongs to both groups.

[7] This requires a dynamic model for a completely realistic analysis. For related dynamic presentations, see e g Bergstrom (1982), Karp (1984), Karp and Newbery (1991); and more recently, Rubio and Escriche (2001), Rubio (2005), Liski and Tahvonen (2004), and Salo and Tahvonen (2001). While not going into details here, the dynamic literature strongly supports the main views exposed here, namely that a carbon tax is an effective instrument for extracting rent from fuel exporters, and that a tax policy is superior to a cap policy for fuel importers as a group, in particular in terms of rent extraction.

[8] A main issue here is the profile of both current and expected future carbon taxes. It can be shown that if the future carbon tax is expected to increase at a particularly rapid rate (in excess of the rate of discount), an increase in the general level of carbon taxation could induce Sinn's paradox by increasing emissions in the short run. Another factor is that if climate policy partly takes the form of support to developing a backstop for replacing fossil fuels, emissions may be worsened in the short run by more stringent climate policy; see e g Strand (2007), Ploeg and Withagen (2010), and Hoel (2010) with a more extensive discussion of the conditions for a green paradox to occur.

the policy bloc is larger. The demand function will then be less elastic, leading to a higher fuel export price. This hurts both the policy bloc and the fringe.

A focus of this paper is on effects on the fringe of alternative climate policy regimes in the policy bloc. The analysis shows that individual countries in the fringe will fare best when the policy bloc sets a carbon tax, and when the fuel demand from the policy bloc constitutes a large fraction of overall demand. Put otherwise, the smaller the fringe, the more each country in the fringe will benefit from being "free riders" on a carbon tax set by the policy bloc. The reason is that a large policy bloc translates into great market power of this bloc in the fossil fuel markets. The optimal carbon tax is then higher for a larger policy bloc; and it puts more downward pressure on the export price for a given tax. This all translates into a lower fuel export price, which benefits the fringe.

A similar benefit for the fringe, due to a large policy bloc, does not materialize under a cap policy. The fuel export price is then in most cases set *higher* by exporters when the policy bloc comprises a larger share of total demand; not *lower* as under a carbon tax.

In the appendix I consider cases where cap set by the policy bloc in the c-a-t case consists of the entire fossil fuel consumption; as is in particular the case when the policy bloc consists of all fuel-importing countries. I show that the equilibrium internal trading price in the bloc's c-a-t scheme then always equals zero. The best possible solution for the policy bloc is then that achieved in a Stackelberg equilibrium with the policy bloc as leader (setting its cap before the exporter sets its fuel tax). This solution is however still inferior to the tax equilibrium, from the point of view of fuel importers.

This paper extends results from previous related papers, Strand (2009, 2011), treating similar cases. None of these papers considers a fringe. Strand (2011) considers two fuels, one imported (oil), and one produced by fuel consumers. The importer's oil demand function is then elastic under a cap, making some rent extraction from the exporter possible in this case. The main conclusion, that a tax policy dominates a cap policy for fuel importers, however remains. A background for these results was derived in an early (static) model by Berger, Fimreite, Golombek and Hoel (1992) (without explicit optimization of climate targets by importers).

Two other papers will be mentioned. Berg, Kverndokk and Rosendahl (1997) studied implications for rent extraction in the oil market of a carbon cap. They argued that OPEC countries, acting as a dominant producer and facing a producing fringe, tends to lose from a cap but largely because this group must take the necessary production cuts in order to maintain a given oil export price (so that the fringe loses less). Johansson et al (2009) consider a long-run model of the oil market, and argue to the contrary that OPEC will lose little by a carbon price implemented by demander countries. Their argument is that oil will remain considerably cheaper than alternative, renewable, energies, making considerable rent extraction possible for oil producers. The strategic difference between a tax and a cap policy, crucial in my model, is not discussed in these two last papers.

2. Model 1: The Policy Bloc Sets a Carbon Tax

Basics

Consider the following aggregate utility function related to fossil-fuel consumption for countries with a climate policy (hereafter the "policy bloc"):

$$W_1 = R_1 - \frac{1}{2}\gamma_1 R_1^2 - pR_1 - c_1 R, \tag{1}$$

where $\gamma_1 > 0$, p = the fossil fuel import price, and c_1 = a climate externality cost associated with fossil-fuel consumption for this group of countries. R_1 is the fossil-fuel consumption for the policy bloc, while R is global fossil-fuel consumption. (1), and other related fuel demand and supply functions presented below, all take "linear-quadratic" forms standard in the literature and adequate representations at least in the neighborhood of equilibrium (and as in related work by Strand (2009, 2011)). We assume that fossil-fuel importing countries produce no fuels, and that producer countries consume no fossil fuels and export all their production.

Under model 1, the policy bloc imposes a carbon tax, in the form of an excise tax, t, per unit of the imported fossil fuel. This leaves the consumer fuel price in these countries at p+t. Fossil fuels are imported by many small agents, each of whom behaves competitively. The public (private sector) demanding fossil fuels in this group of countries maximizes

$$V_1 = R_1 - \frac{1}{2}\gamma_1 R_1^2 - (p+t)R_1 \tag{2}$$

with respect to R_1, yielding the first-order condition

$$R_1 = \frac{1-p-t_1}{\gamma_1}. \tag{3}$$

γ_1 is the inverse demand sensitivity of fossil fuels with respect to price in the policy bloc. There also exists a fringe of fuel-importing countries with no climate policy (with subscripts F), with aggregate utility function

$$W_F = R_F - \frac{1}{2}\gamma_F R_F^2 - pR_F - c_F R, \tag{4}$$

c_F is the climate-related externality of global fossil fuel consumption for the fringe. These countries in aggregate behave competitively and maximize

$$V_F = R_F - \frac{1}{2}\gamma_F R_F^2 - pR_F \tag{5}$$

with respect to R_F, yielding the first-order condition

$$R_F = \frac{1-p}{\gamma_F}, \tag{6}$$

where γ_F (> 0) is the inverse demand sensitivity for the fringe. (2) and (5) imply an assumption that the two blocs have identical demand functions for the fossil fuel apart from the parameters γ_1 and γ_F which may differ. Both functions are assumed to be linear and in both cases with a limit price (at which demand vanishes) of unity, but the functions have different slopes, $1/\gamma_1$ and $1/\gamma_F$. Call the slope of the (global) aggregate demand function $1/\gamma$. Define $\gamma_1 = \gamma/h$, $\gamma_F = \gamma/(1-h)$, where h and 1-h are the relative sizes of the policy bloc and the fringe (corresponding to their relative levels of fuel consumption in the case where the fuel consumer price is the same in both blocs; or if the blocs are in other respects homogeneous, h and 1-h would correspond to the relative sizes of the "policy bloc" and the "fringe"). Aggregate fossil-fuel demand, from both blocs combined, is then

$$R = R_1 + R_F = h\frac{1-p-t}{\gamma} + (1-h)\frac{1-p}{\gamma} = \frac{1-p-ht}{\gamma} \tag{7}$$

Assume a single (unified) producer country or region with aggregate utility function

$$W_2 = \Pi_2 + sR - c_2 R\,, \tag{8}$$

where Π_2 is net profit of petroleum producers, sR is excise tax revenue for governments in fuel exporting countries, while c_2R denotes negative emissions externalities for the exporter. Net profits of producers are

$$\Pi_2 = (p-s)R - p_0 R - \frac{1}{2}\phi R^2\,, \tag{9}$$

where p_0 is a lower bound of marginal fuel extraction cost. Maximizing (8) with respect to R yields the fossil-fuel supply function

$$p = p_0 + s + \phi R\,. \tag{10}$$

ϕ (> 0) here represents the (inverse) supply sensitivity of petroleum output. s is the unit producer excise tax. $p_0+s > 0$; thus the supply elasticity is less than unit.

The externality cost of one unit of carbon emissions for all fuel importers is called c. Assume also that, within the group of importers, their externality cost is proportional to the size parameter h in the fuel demand function. Thus the marginal externality cost for the policy bloc is hc, and for the entire fringe (1-h)c.[9] The global marginal externality cost of fossil fuel consumption equals $c+c_2$, which would correspond to a Pigou tax imposed by a benevolent global regulator, given that markets are otherwise competitive.

Solving (7) and (10) for R and p as functions of the tax parameters t and s yields

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[9] This assumption is made for convenience and for the purpose of facilitate analysis of parametric changes in h, below. Given that we always have a (sizeable) bloc with no policy, we could equally have assumed that the marginal externality cost for this bloc differs from that for the policy bloc. Indeed, we know that the impacts of climate change are likely to vary substantially across countries. A realistic calibration of the model to the world economy would need to take such differences into consideration.

(11) $$R=\frac{1-p_0-s-ht}{\gamma+\phi}$$

(12) $$p=\frac{\gamma}{\gamma+\phi}(p_0+s)+\frac{\phi}{\gamma+\phi}(1-ht).$$

We also derive fuel demand for each of the two blocs as functions of the taxes s and t, as follows:

(13) $$R_1=\frac{h}{\gamma(\gamma+\phi)}\left[\gamma(1-p_0-s)-(\gamma+(1-h)\phi)t\right]$$

(14) $$R_F=\frac{1-h}{\gamma(\gamma+\phi)}\left[\gamma(1-p_0-s)-\phi(1-ht)\right].$$

The importer solution

An authority representing all countries in the policy bloc sets t_1 to maximize W_1 in (1), considering its own fuel demand response (13), the aggregate fuel demand response (11), and the export price response (12), to a change in t.[10] This yields the following first-order condition for the policy bloc:

(15) $$\frac{dW_1}{dt}=(1-\gamma R_1-p)\frac{\partial R_1}{\partial t}-R_1\frac{\partial p}{\partial t}-c_1\frac{\partial R}{\partial t}=0.$$

Inserting for R_1 and p and the various partial derivatives, we derive the following NE importer tax, when expressed as function of the exporter tax, s:

(16) $$t=\frac{h\gamma}{[\gamma+(1-h)\phi][\gamma+(1+h)\phi]}[(\gamma+\phi)c+\phi(1-p_0-s)].$$

When h is small, t is, from (16), always small regardless of other parameters. Small h makes carbon taxes unattractive for the policy bloc, for two separate reasons. First, a low h implies that the climate externality is small for the policy bloc (a small fraction of the global externality), inducing a small "Pigou" tax. Secondly, a low h leads to small market power of the policy bloc in the fossil fuel market, and a small monopsony element in the pricing of carbon.

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[10] In game theory terms, the tax-setting game between importer and exporter can here not be described as a standard Bertrand game whereby each of the two strategic parties (the policy bloc, and the exporter) would take the price set by the other party as exogenous. Rather, the equilibrium concept invoked here can be thought of as involving an iteration process whereby the effects of t_1 on s, and of s on t_1, are brought to bear.

The exporter solution

The producer/exporter bloc maximizes W_2 with respect to s, taking the supply function (10) from individual producers, the price relation (12), and the importer-determined tax rate, t, as given. The first-order condition for this problem is

$$\frac{dW_2}{ds} = (p - p_0 - \phi R - c_2)\left(-\frac{1}{\gamma+\phi}\right) + R\frac{\gamma}{\gamma+\phi} = 0, \tag{17}$$

which yields the following condition for optimal R in terms of the export price, p:

$$R = \frac{p - p_0 - c_2}{\gamma+\phi}. \tag{18}$$

Solving for s, p and R, as functions of the tax t_1 set by the policy bloc, now yields:

$$s = \frac{\gamma}{2\gamma+\phi}(1 - p_0 - ht) + \frac{\gamma+\phi}{2\gamma+\phi}c_2 \tag{19}$$

As expected s is reduced when t is increased, and this effect is stronger when h is larger (when the policy bloc makes up a larger fraction of total demand).

Overall NE solution

We now solve (16) and (19) simultaneously for t and s. The solutions are

$$t = \frac{h\gamma}{D}\left[(2\gamma+\phi)c + \phi(1 - p_0 - c_2)\right]. \tag{20}$$

$$s = \frac{[\gamma+(1-h)\phi][\gamma+(1+h)\phi]c_2 + \gamma[\gamma+(1-h^2)\phi](1-p_0) - h^2\gamma^2 c}{D} \tag{21}$$

where

$$D = (\gamma+\phi)[2\gamma+(1-h^2)\phi]. \tag{22}$$

Each of s and t_1 is found to be a weighted sum of an externality cost (hc for importers setting t, and c_2 for producers setting s), and a strategic (or "optimal tariff") term. We see, as expected, that the strategic tariff increases in the share h of the policy bloc in total fuel demand. s is by contrast seen to fall in h and c, and to increase in c_2, and vice versa for t. In particular, s falls in c since s falls in t (from (22), and higher c raises t.

As for the second (strategic) component, s is affected relatively more by strategic factors when γ is greater (petroleum demand is relatively insensitive to price, from (3)), while t is affected more when ϕ is greater (petroleum supply is insensitive to price, from (6)).

The total tax on carbon facing the policy bloc is $z_1 = s+t_1$, given by

$$(23)\quad z = \frac{1}{D}\left\{h\gamma[(2-h)\gamma+\phi]c + [\gamma^2 + (2-h)\gamma\phi + (1-h^2)\phi^2]c_2 + \gamma[\gamma + (1+h-h^2)\phi](1-p_0)\right\}.$$

To understand (23) better, consider two limiting cases, first h = 1 (the policy bloc consists of all fuel-consuming countries),[11]

$$(20a)\qquad t = \frac{(2\gamma+\phi)c + \phi(1-p_0-c_2)}{2(\gamma+\phi)}.$$

$$(21a)\qquad s = \frac{(\gamma+2\phi)c_2 + \gamma(1-p_0-c_1)}{2(\gamma+\phi)}$$

$$(23a)\qquad z = \frac{1}{2}(c + c_2 + 1 - p_0).$$

In the other limiting case of h = 0 (the policy bloc is very small) we have

$$(20b)\qquad t = 0$$

$$(21b)\qquad s = z = \frac{\gamma}{2\gamma+\phi}(1-p_0) + \frac{\gamma+\phi}{2\gamma+\phi}c_2.$$

In this case, the tax t in the "policy bloc" applies to an infinitesimal amount of fuel consumption. This tax tends to zero, for two reasons: there is no global environmental concern since the policy bloc is infinitesimal; and the bloc has no power in the fuel market. Only the exporter tax s, from (21b), then applies.

From (10), (18) and (21) the overall equilibrium solutions for aggregate fuel consumption and fuel price in terms of fundamental parameters are

$$(24)\qquad R = \frac{1}{D}\left\{[\gamma + (1-h^2)\phi](1-p_0-c_2) - h^2\gamma c\right\}$$

$$(25)\qquad p - p_0 = \frac{\gamma+\phi}{D}\left\{\gamma(c_2 - h^2 c) + [\gamma + (1-h^2)\phi](1-p_0)\right\}$$

Effects on p are particularly important, both for the policy bloc and the fringe. A change in p has a first-order effect on welfare for all three blocs. We find in particular:

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[11] See also Strand (2009), eq (31).

(26) $$\frac{dp}{dh} = -\frac{2h\gamma(\gamma+\phi)^2}{D}\left\{(2\gamma+\phi)c+\phi(1-p_0-c_2)\right\} < 0 .$$

Thus *when the policy bloc constitutes a larger share of total fuel demand, the export price of fuel is reduced in consequence, thus benefiting both the policy bloc and the fringe*. These effects are illustrated in the simulations in section 4 below.

3. Model 2: The Policy Bloc Sets a Cap

Consider now our second case where the policy bloc (region 1) sets a cap on its emissions, while still taking fringe demand as exogenous. We assume free trading of emissions rights within the policy bloc, at a unified quota price.[12] Formally, we can treat the strategy of the policy bloc as setting the quota trading price of emission rights within the bloc, which will be dual to the quantity solution. This implies that we may view the policy of the policy bloc as being determined in the same way as under policy 1, with the bloc setting a tax at the level of the equilibrium quota trading price under the optimal cap. The strategy of the fringe is also the same in this case as under policy 1.

The fuel demand functions for these two blocs are now still given by (3) and (6), where t in (3) is now interpreted as the quota price within the c-a-t scheme in the policy bloc. In fact, little changes formally fuel demanders who are at the same time emitters. (15) still describes the strategy of the policy bloc, interpreted alternatively as the conditions for its optimal energy demand R_1, or its optimal quota price t, in either case taking the fuel import price, p, as determined by (12), where s is taken as exogenous.

What changes is the strategy of fuel exporters. These will now no longer face an importer tax but instead a cap on the amount of fuel demanded from the policy bloc. For the fringe there is no change in strategy. Thus, instead of (7), the exporter will face the following aggregate demand function for fuel:

(27) $$R = R_1 + R_F = R_1 + (1-h)\frac{1-p}{\gamma}$$

where R_1 now is taken as fixed by the exporter. Solving (10) and (27) for p and R yields

(28) $$p = \frac{1}{\gamma+(1-h)\phi}[\gamma(p_0+s)+\gamma\phi R_1+(1-h)\phi]$$

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[12] Whether or not quotas are auctioned plays no formal role here.

(29) $$R=\frac{\gamma}{\gamma+(1-h)\phi}R_1+\frac{1-h}{\gamma+(1-h)\phi}(1-p_0-s)$$

The exporter, taking (28)-(29) and R_1 as given, faces the following responses to changes in s:

(30) $$\frac{\partial p}{\partial s}=\frac{\gamma}{\gamma+(1-h)\phi},\frac{\partial R}{\partial s}=-\frac{1-h}{\gamma+(1-h)\phi}.$$

This yields the following condition for the exporter's optimal strategy in this case:

(31) $$\frac{dW_2}{ds}=(p-p_0-\phi R-c_2)\left(-\frac{1-h}{\gamma+(1-h)\phi}\right)+R\frac{\gamma}{\gamma+(1-h)\phi}=0,$$

with the corresponding optimal condition on R:[13]

(32) $$R=\frac{1-h}{\gamma+(1-h)\phi}(p-p_0-c_2).$$

Note that, even though the exporter considers R_1 as exogenous in its own optimization, as a matter of market equilibrium, (7) and (10) still hold (since, in particular, R_1 and t are still related by (3)).[14] Thus R and p are also still determined by (11)-(12).

We now find s, p and R as functions of t as follows:

(33) $$s=\frac{\gamma}{(2-h)\gamma+(1-h)\phi}(1-p_0-ht)+\frac{(1-h)(\gamma+\phi)}{(2-h)\gamma+(1-h)\phi}c_2$$

(34) $$p-p_0=\frac{\gamma+(1-h)\phi}{(2-h)\gamma+(1-h)\phi}(1-p_0-ht)+\frac{(1-h)\gamma}{(2-h)\gamma+(1-h)\phi}c_2$$

(35) $$R=\frac{(1-h)(1-p_0-ht-c_2)}{(2-h)\gamma+(1-h)\phi}.$$

Comparing to the case where the policy bloc set a carbon tax, p is greater here, for any given t (interpreting t as the carbon tax in model 1, and as the carbon quota price in model 2). It is of interest to consider how the equilibrium export price changes with h when the importer tax, t_1, is taken as given. We can express the effect as follows:

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[13] We remark that this solution is relevant, and reasonable, only when h is "not too large". In fact, no solution with positive production here exists when h tends to unity. This problem is related to the nonexistence problem discussed for model 3, below:

[14] In this case, of course, t is not interpreted as a tax but instead as the equilibrium price at which emissions quotas (proportional to fuel consumption) are traded within the policy bloc, and within that bloc only.

(36) $$\frac{dp}{dh} = \frac{\gamma^2}{[\gamma + (1-h)(\gamma + \phi)]^2}(1 - p_0 - ht - c_2) - \frac{\gamma + (1-h)\phi}{\gamma + (1-h)(\gamma + \phi)} \frac{d(ht)}{dh}$$

This expression is always positive given that ht is held constant when h increases (so that t falls proportionately). But it is also positive when ht increases with h, provided that the first term dominates over the second. This is always the case when h is initially small; t is then also small (from (37) below); and d(ht) must consequently be small. We thus find that *when h is small at the outset, the export price always increases when the policy bloc comprises a larger fraction of total fuel demand* (h increases). This is diametrically opposite to the conclusion under model 1, where the policy bloc was assumed to use a carbon tax. We will also find, in the simulations in section 4 below, that p can increase in h, also for larger h values (when c is low).

The overall equilibrium is in this case found by solving (16) and (33) for t and s. This yields

(37) $$t = \frac{h\gamma}{D_1}\left\{[(2-h)\gamma + (1-h)\phi]c + (1-h)\phi(1 - p_0 - c_2)\right\}$$

(38) $$s = \frac{(1-h)[\gamma + (1-h)\phi][\gamma + (1+h)\phi]c_2 + \gamma[\gamma + (1-h^2)\phi](1-p_0) - h^2\gamma^2 c}{D_1}$$

where the relevant determinant is

(39) $$D_1 = (\gamma + \phi)[2\gamma + (1-h^2)\phi] - h[(\gamma + \phi)^2 - h^2\phi^2]$$

We here first find that t (the quota trading price of carbon) always converges to c as h converges to one. The relationship between t and h is always rising for low h, but may either fall or rise when h is larger; this becomes clear from the simulations below.

The expression for s is identical to (21) except for the determinant, D_1, which is smaller here. Thus s is greater here, and more so when h is higher (for h = 0 the two expressions are identical, as we are back to the case of no climate policy). The exporter then adopts a more aggressive taxation strategy in this case. The reason is the smaller demand elasticity faced by the exporter.

We also find

(40) $$R = \frac{1-h}{D_1}\frac{(\gamma + \phi)[2\gamma + (1-h^2)\phi] - h[(\gamma + \phi)^2 - h^2\phi^2 + h(1-h)\gamma\phi]}{(2-h)\gamma + (1-h)\phi}(1 - p_0 - c_2) - \frac{(1-h)h\gamma}{D_1}hc$$

(41) $$p = p_0 + c_2 + \frac{\gamma + (1-h)\varphi}{1-h}R$$

These expressions will be discussed further in section 4, on simulations.

4. Simluations

This section illustrates the two analytical models above through simulations in some simple cases. I consider a further simplified version of the model where $p_0 = 0$ (the lower bound on marginal fuel extraction cost is zero); $c_2 = 0$ (the fuel exporter has no climate concerns); and $\gamma = \varphi = 1$ (aggregate fuel demand and supply curves are equally sloped). This permits us to express all solutions as simple functions of h (the relative size of the policy bloc) and c (the marginal climate externality for the entire group of fuel-importing countries).

Model 1: Tax setting: Here solution values for t, s, R and p are now given by

$$t = \frac{3c+1}{2(3-h^2)}h \tag{20b}$$

$$s = R = \frac{2-h^2-h^2c}{2(3-h^2)} \tag{21b}$$

$$p = s + R = 2s \tag{25a}$$

Model 2: Cap setting: Our parametric assumptions now imply the following values:

$$t = \frac{h}{D_2}\left[(3c+1)-(2c+1)h\right] \tag{37a}$$

$$s = \frac{2-h^2-h^2c}{D_2} \tag{38a}$$

$$R = \frac{1-h}{D_2}\left[\frac{6-4h-3h^2+2h^3}{3-2h} - h^2c\right] \tag{40a}$$

$$p = s + R \tag{41a}$$

where D_2 is given by:

$$D_2 = 2(3-h^2) - h(4-h^2) \tag{39a}$$

I will first remark that the model is not very suitable for understanding effects of a c-a-t scheme for very high values of h (close to unity). In such cases, the model "breaks down" as the Nash equilibrium solution tends to the case of no fossil fuel production (R=0) in the limit as h tends to one.[15]

With this in mind, the first set of simulations is represented by Figures 1-4, which show the four variables t (importer fuel tax/quota price), s (exporter fuel tax), R (consumed amount of the resource), and p (fuel export price), with formulas given on the previous page, for alternative values of h (the policy bloc as fraction of all fuel-demanding countries). In this first set of simulations, we assume c = 0, which is the special case where fuel-consuming countries have no climate concerns. Fuel taxation is then driven only by strategic concerns. We see that differences between the two models are small for very low h values. The results under the two models however quickly start to diverge as h rises. The export price and tax are, in particular, dramatically higher under c-a-t when h is high.[16] Note also that in this case, both s and p *decrease* uniformly in h under an importer tax policy, but both *increase* uniformly in h under an importer cap policy. The carbon quota price for the policy bloc (under model 2) increases in h up to a point, but is reduced (and becomes much lower than the fuel tax of the policy bloc under model 1) beyond that point. Two factors here work in different directions: a higher h makes the policy bloc behave more collusively, with more aggressive pricing as a result; but a higher h also makes the exporter (much) more aggressive which reduces the scope for rent extraction by the importing policy bloc. Interestingly, the policy bloc's import tax or carbon price is still everywhere positive (except in the limit as h→1 for the trading price under c-a-t), even though this version of the model embeds no explicit climate concern.

Another result is that fossil fuel consumption (and thus the emission level) is reduced when h increases, only slightly in the tax case, and much more dramatically in the cap case. Considering the tax case, this is "good" for importers as a group, as the import price is substantially reduced when h increases. Note also that the drop in R masks an even greater reduction in R_1 (the policy bloc's fuel consumption), and an increase in R_F (the fuel consumption of the fringe).

From figures 1-4 (and also figures 5-12 below), for moderate values of h (corresponding to levels relevant today or in the immediate future) there is little difference in the implemented tax or quota price for the policy bloc. There may however be substantial differences in the exporter's policy. This is seen e g by setting h = 0.5 (as would approximately be the case if the U.S. joined the current Kyoto countries in implementing a climate policy). This implies that the importer bloc is substantially hurt by a c-a-t policy, for such (relevant) h values.

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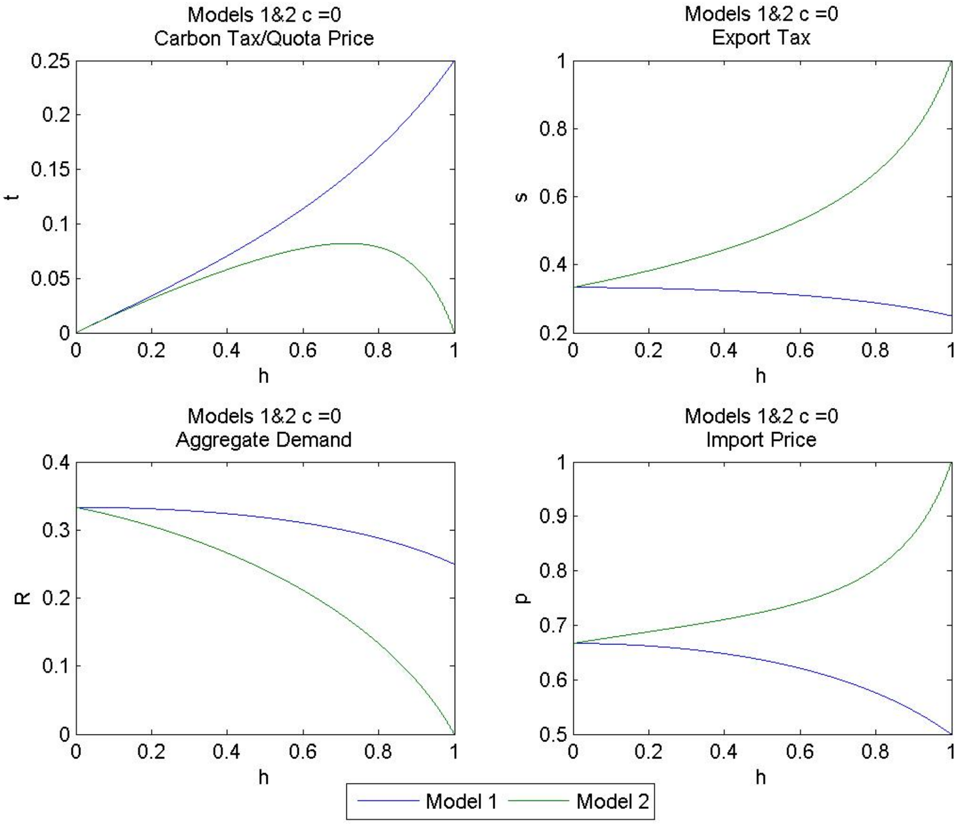
[15] The mechanism behind this is made clear in the appendix, where I study a case with a fixed global carbon cap, which is in some ways equivalent to the case of h = 1 in model 2.

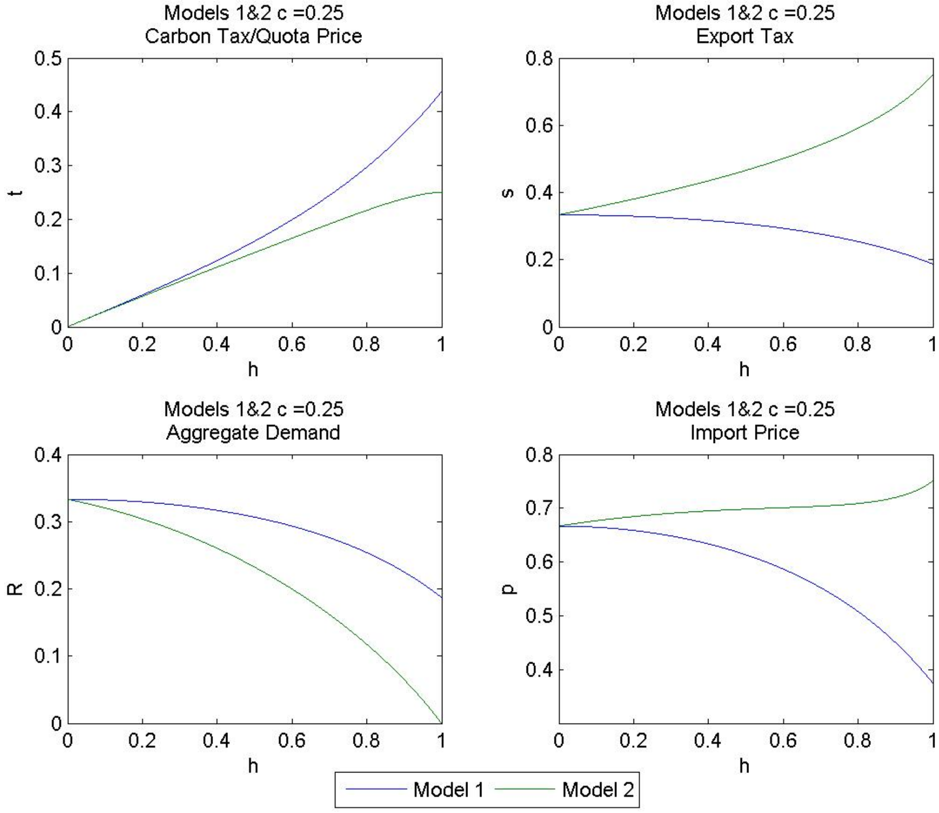
[16] We have though argued above that the model is not likely very suitable for describing what happens under a cap solution for high h values.

Figures 1-4: Comparison of t, s, R and p under models 1 and 2, for alternative values of h, given c = 0 (no climate concern)



Results in figures 5-8 below are not dramatically different from the previous set of figures, but there are certain more detailed differences, which are more pronounced when h is higher. This is because a climate concern by the policy bloc hardly affects the bloc's policy at all when h is very small, and affects it much more when h is high. The level of the carbon tax/quota price is then also much higher, and the quota price under model 2 is now uniformly rising in h. This more aggressive tax strategy of the policy bloc leads to a greater reduction in both the import price, and total fossil fuel consumption, when h increases.

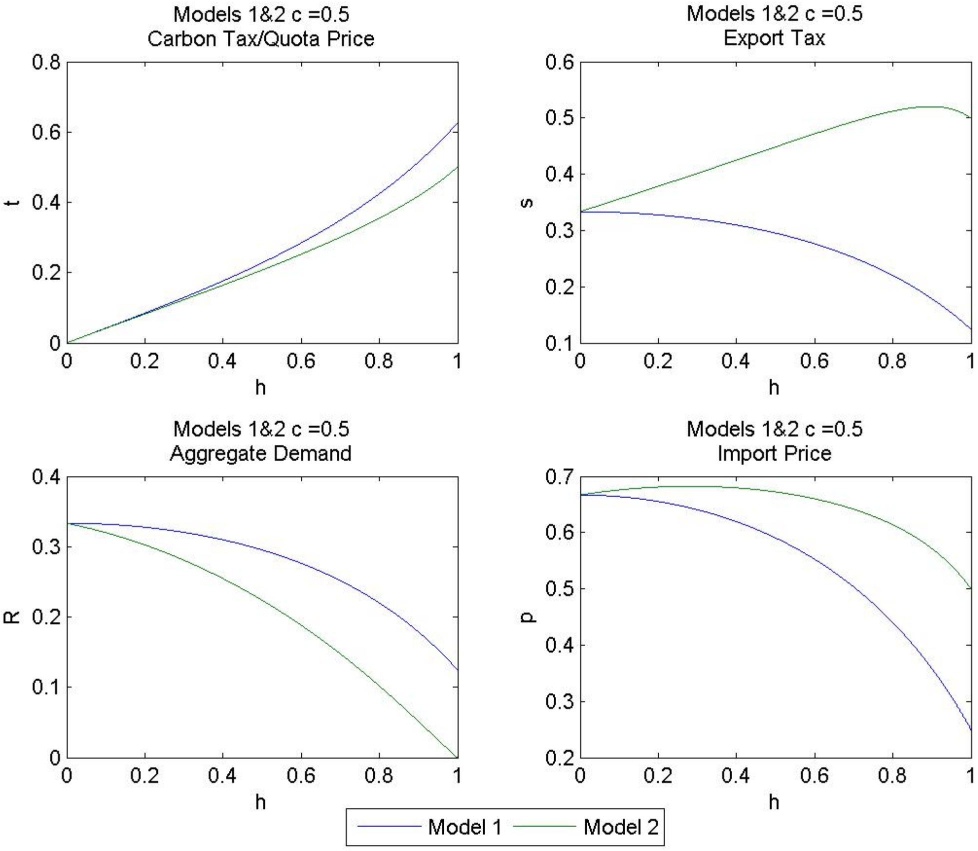
Figures 5-8: Comparison of t, s, R and p under models 1 and 2, for alternative values of h, given c = 0.25 ("moderate" climate concern)



In the final set of simulations below, we consider a case with "high" climate concern on the part of fuel importers. In this case, the carbon quota price (model 2) is not much lower than the carbon tax (model 1). This is because this tax or quota price is now driven mainly by the climate concern. This concern is negligible when h is small, and big when h is big (since the concern is proportional to h which is the fraction of cooperating economies in setting the tax or quota). There is as before a big difference in the export tax between the models. This difference is now however reduced somewhat as h approaches 1, since the quota price in model 2 drops as the policy region expands. Here, fossil fuel demand drops dramatically with h also in the tax case (model 1).

Note that the Pigou tax in this case is 0.5 (while in the previous cases, illustrated by figures 1-4 and 5-8, the Pigou tax was 0 and 0.25 respectively). Total costs per unit of fossil fuels for the policy bloc (p+c) in this case exceeds unity, for small h in model 1, and for all h in model 2. This implies, in effect, that fossil fuel consumption yields no net utility for the population (remember our assumption that the maximum value of fossil fuels is unity).

Figures 9-12: Comparison of t, s, R and p under models 1 and 2, for alternative values of h, given c = 0.5 ("high" climate concern)



A further notable feature, illustrated in the simulations, is that when h is low, climate concerns are unimportant for policy even when true climate concerns can be very great. The absence of climate policy then leads to very unfavorable outcomes for fuel importing countries when their true climate concern is great, given that fuel exporters act collusively (as is assumed here). For h = 0, p = 2/3 under both models. Note our assumption that the fuel limit price = 1 (the maximum consumption value of fossil fuels is 1). Consider then the case of "high" climate concern above, c = 0.5. The net consumption value of fossil fuels is then negative (when considering the negative consumption value of the climate externality), for all units of fossil fuels consumed by importers. This means that, in this model and under these assumptions, consumers in importing countries would have been better off without any fuel imports, or consumption, whatsoever.

5. Conclusions and Final Comments

This paper has studied alternative climate policy strategies used by a fossil fuel-demanding "policy bloc" which implements a climate policy, facing a fuel-demanding group of countries that has no climate policy (a "fringe"), and a fuel-exporting bloc disinterested in climate policy. I consider two policies. The first (model 1, in section 2), is a carbon tax implemented in the policy bloc alone. I show that this tax is influenced by both a climate ("Pigouvian") motive, and a strategic motive whereby the policy bloc recognizes that it is able to influence the exporter's fuel price through its tax. The positive carbon tax leads to a lower fuel import price, which benefits all fuel importers, including the fringe. The tax is set higher, and the reducing effect on the import price is greater, when the policy bloc is larger. The reason is that a larger policy bloc adopts a more aggressive carbon tax strategy, as both the "Pigou" and strategic elements of such a tax is greater for a larger policy bloc. This effect reduces the export price. Fringe countries are then helped, and by more when the policy bloc is larger as a fraction of total fuel demand.

In section 3 I assume that the policy bloc sets a cap on its own carbon emissions (model 2). There is then a major strategic difference from the carbon tax case, as now one part of demand is fixed (the rest of demand, from the fringe, is still variable). Overall fuel demand is then less sensitive to the fuel export price once the cap has been fixed. This leads the exporter to set a higher fuel price. This hurts both the policy bloc and the fringe, when compared to the carbon tax case. A larger policy bloc now does not necessarily lead to a lower exporter fuel price; and does not necessarily benefit the fringe. The reason is that the monopolistic power of the exporter is greater when the policy bloc is larger, since a larger fraction of overall fuel demand is fixed and not responsive to changes in the fuel import price. This may translate into a higher export price, which hurts the fringe, when the policy bloc makes up a larger fraction of total fuel demand.

The overall conclusion from comparing these two models, is that a tax policy is preferred to a cap policy by all fuel consuming countries, both by those that establish a climate policy, and by those that do not. Fundamentally, this is because a monopolistic exporter sets a higher fuel export price when a cap policy implemented by one group of fuel demanders (the "policy bloc"), than when this group instead uses a tax policy; and this higher price hurts all consumer countries.

The c-a-t model in section 3 is, arguably, not very realistic for describing actual policies when the policy bloc is large (h is close to one), or when a more limited policy bloc attempts to enforce a global cap on fuel consumption. In such cases, Nash equilibrium strategies lead so an unreasonable solution where fossil fuel output shrinks to zero in the limit. Appendix A considers the case where the policy bloc sets a cap on global fuel demand (as with c-a-t policies given h = 1) in a Stackelberg fashion (whereby the cap-setting importers act as Stackelberg leaders, and the exporter as follower setting the fuel export tax), instead of as a Nash equilibrium. I show that such a Stackelberg equilibrium with positive fuel consumption exist, but only in cases where the climate externality for the importing bloc is relatively small. In such an equilibrium the trading price of emissions quotas is zero; and the fuel price to consumers is the same in the policy bloc and in the fringe. For any given level of aggregate fuel consumption, the fuel export price is higher, and utility of consumers in all importing countries (both the policy bloc and the fringe) lower.

The conclusions in the paper are derived under highly simplifying assumptions, which ought to be relaxed in extensions. I will here briefly mention the following.

A) There is no fuel production in consuming countries, and no fuel consumption in fuel-producing countries.

B) There is only one, homogeneous, fuel.

C) Dynamic considerations are ignored; in particular, fossil fuels are viewed as a regular commodity with a stable short-run supply function.

D) There is a monolithic, and monopolistic, fuel exporter which can dictate the fuel export price; and there is no fringe of competitive fuel suppliers.

E) There are no policies aimed at affecting emissions in fringe demanders (in particular, no offset markets).

F) All countries are assumed to be equally averse to climate change; and have equal loss (relative to their size) per unit of carbon emissions.

In future research I intend to relax these assumptions. In particular, I intend to study policies aimed at fringe demanders, by the policy bloc, possibly involving mechanisms similar to the current Clean Development Mechanism.[17] I also intend to study dynamic models where intertemporal supply considerations will naturally enter.

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[17] One such policy type would be for the policy bloc to provide additional incentives for the fringe to reduce its emissions, perhaps in similar fashion to the Clean Development Mechanism under the Kyoto Protocol.

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Appendix A: Stackelberg Equilibria when the Importer sets a Global Cap

A1. The Policy Bloc Enforces a Cap on Overall Fuel Demand

This appendix considers additional cases where the exporter sets, and enforces, a cap on global carbon emissions. We may think in terms of a target for global emissions from the policy bloc and the rest of the world economy taken together, which is set and enforced by the countries in the policy bloc. The policy bloc has no *direct* control over emissions from the rest of the world economy. It may however in principle implement the global target using domestic policies so as to exactly eliminate any undesirable (excessive or deficient) emissions level in the fringe.

Assume that such an overall cap is adopted. Assume then first, as done so far, that the importer takes the export price p as given in setting its import tax t. As will first be shown, in this case, *no Nash equilibrium solution with positive fuel demand exists in the model*.

A key to what happens in this case is found on the supply side of the fossil fuels market. The fuel exporter takes the overall fuel demand as exogenously fixed when setting his export tax s. The exporter will then, for any given level of fuel demand, set his export price at the highest possible level compatible with this demand being realized. Consider any particular aggregate fuel demand level R* announced by the policy bloc. From the global fuel demand function (7), the export price achieved given that demand R* is realized is determined by

$$p = 1 - \gamma R^* - ht, \tag{A1}$$

given that the policy bloc (and only this bloc) still implements a tax t on its own consumption of the fuel. The optimal exporter price, p*, for this given R*, is the highest value that p can take, and the demand R* still realized in importing countries. This is found by setting t = 0 in (A1), yielding

$$p^* = 1 - \gamma R^* \tag{A2}$$

corresponding to the following fuel demand as function of the price:

$$R^* = \frac{1 - p^*}{\gamma} \tag{A3}$$

When p is set at p*, the market will exactly clear among all fuel-importing countries. In particular, when a c-a-t regime is implemented within the policy bloc, the trading price of emissions quotas within the bloc will be zero: thus t = 0.[18]

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[18] Some additional formal conditions need to be fulfilled for this to be an equilibrium; see Strand (2009).

We here seek to derive an optimal exporter tax s, which corresponds to an equilibrium for the importing bloc, with a quota price, t, equal to zero. To derive such a solution, we must first find the optimum output for the importer as function of the import price (assumed exogenous), and let the exporter find the optimal export price p given the importer's optimal demand. The importer's optimal demand is found maximizing the following objective function in this case:

$$W_1 = (1-p)(R-R_F) - \frac{1}{2}\frac{\gamma}{h}(R-R_F)^2 - hcR \tag{A4}$$

where R_F is the fuel demand level from the fringe, taken as exogenous by the policy bloc. The policy bloc can here be viewed as maximizing (A4) with respect to R, taking both R_F and the export price p as exogenously given. We find the following first-order condition:

$$\frac{dW_1}{dR} = 1 - p - hc + \frac{\gamma}{h}(R-R_F) = 1 - p - hc + \frac{\gamma}{h}R_1 = 0\,. \tag{A5}$$

The policy bloc in this case incorporates externalities also due to the fringe activity (but still only for itself and not for the fringe), as it is now the entire R that is regulated by the policy bloc. (43) yields the following solution for R (where we take into consideration also the fringe demand):

$$R_{opt} = \frac{1-p-hc}{\gamma} \tag{A6}$$

(A3) and (A6) are incompatible given that $hc > 0$. Since both are conditions for equilibrium, and since they cannot be fulfilled simultaneously, no equilibrium with positive production exists.

This nonexistence problem can be understood intuitively as follows. Consider a dynamic version of the current (static) problem where parties are allowed to adjust their strategies after observing the policy choice of the other party. Consider a given initial price p* set by the exporter, which corresponds to a positive fuel demand for the importer group. Assume that at this price, and with no importer tax, the demand level R* (in aggregate for the policy bloc and the fringe) is given by (A3). When the importer takes the price p* as exogenously given, maximizing (A4) however leads to the lower optimal level, R_{opt} given by (A6). The policy bloc will then attempt to correct for the externality caused by the output R* which is now excessive given the price p*, by setting a positive tax t. But this positive tax is anticipated by the exporter, who responds by increasing the price to a new level p*+t, thus exactly eliminating the importer's import tax at the new demand level R*. Further iterations of this process follow. Nash equilibrium in simultaneous moves for the corresponding static (one-shot) game (with, consequently, no further adjustments of the taxes) is unique, and entails R* = 0.

To remedy this problem we invoke alternative equilibrium concepts. We will, in particular, consider what we here simply call a "reactive equilibrium", where the policy bloc anticipates, and takes into consideration, any reaction of the exporter to an increase in the tax t. This makes the policy bloc refrain from increasing its tax further once this tax has been first eliminated by the exporter. The highest level of R compatible with t = 0, and equilibrium fuel demand, is:[19]

(A7)
$$R_M = \frac{1 - p_0 - c_2}{2\gamma + \phi}.$$

R_M is greater than the related output level in model 1. Comparing to model 2 is even more obvious, as R there is even smaller. Note here however that R_M is the *largest* level of R that can correspond to such an equilibrium; all R levels on the domain $[0, R_M]$ are such equilibrium candidates.

In this case, the exporter tax s is given from (19) setting t = 0, as follows:

(A8)
$$s = \frac{\gamma}{2\gamma + \phi}(1 - p_0) + \frac{\gamma + \phi}{2\gamma + \phi}c_2$$

This value of s could be higher or lower than that found for model 2. But it is the lowest possible s compatible with equilibrium in this case. More generally, all R levels between zero and R_M correspond to a "reactive equilibrium" of this type. The relevant set of s values is found as all solutions to

(A9)
$$s = 1 - p_0 - (\gamma + \phi)R^*,$$

which is derived from (A2) and (10), and where we must have $0 \leq R^* \leq R_M$. (Note also that the unique Nash equilibrium corresponds to $R^* = 0$, and thus to $s = 1 - p_0$.)

In this case there is no rent extraction (via a positive value of tradable emissions quotas; the equilibrium value of these is zero). Also, consumers in the policy bloc and the fringe all face a zero carbon price, and the same fuel price, given by (A2).

A2. Stackelberg Equilibrium Importer Cap Setting With h = 1

I will now consider another variant on the problem posed in A1, where now there is a unified policy bloc (h = 1), which sets a cap on its total fuel consumption. We saw in the text above that, for the case of a Nash Equilibrium, no solution with positive production exists, under a cap with h = 1. I now instead assume that the importer is a Stackelberg leader of the (non-repeated, sequential) importer-exporter game where the importer sets a cap, and the exporter a tax. The importer is then assumed to select its cap prior to the exporter choosing its exporter tax. A constraint on this solution is that the exporter always chooses, ex post, an export price which exactly clears the quota market in the importer bloc, so that the quota price will be zero. This

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[19] See the discussion in A2 below.

implies that p will be given by (A2) for any value of R selected as the cap on fuel imports, which must be taken as a constraint on the importer's problem when setting its optimal value of R.

The optimal R is now found by maximizing welfare as a function of R, which in this case can be expressed as

$$W = R - \frac{1}{2}\gamma R^2 - pR - cR = R - \frac{1}{2}\gamma R^2 - (1-\gamma R)R - cR = \frac{1}{2}\gamma R^2 - cR. \tag{A10}$$

Welfare (if positive) is here an increasing and convex function of R. Solving this problem with respect to R will thus not yield an internal solution but instead a corner solution, where R is set at either its highest or lowest permissible level.[20]

Consider next the solution chosen by the exporter given a particular cap R, set by the importer bloc. We will assume that the importer is not willing to import more than the given cap, call it R*. Two principal types of solutions are then possible: a) the exporter finds it optimal to produce R*; b) the exporter finds it optimal to produce less than R*.

Consider then the exporter's objective function, (9), where we now insert for p from (A2). This yields the modified objective function (as function of a general R level):

$$W_2 = (1 - p_0 - c_2)R - \gamma R^2 - \frac{1}{2}\phi R^2. \tag{A11}$$

Maximizing (A11) with respect to R yields

$$\frac{dW_2}{dR} = 1 - p_0 - c_2 - (2\gamma + \phi)R = 0. \tag{A12}$$

In case a, exporter countries prefer fossil-fuel output to equal at least R*. With no importer tax (t=0), the exporter would, from (A12), ideally produce R(0) given by

$$R(0) = \frac{1 - p_0 - c_2}{2\gamma + \phi}. \tag{A13}$$

Given R* ≤ R(0), R* will be the realized output (since the exporter would not voluntarily choose a lower level). s will be given by (A9), derived from (11) and setting t = 0, which is the level of s that exactly clears the fossil fuel market in importer countries. As a result, the equilibrium price in the quota market in importer countries equals zero.

Consider next R* > R(0). In this case, R* exceeds the optimal (ideal) R level given t = 0, which is simply R(0), from (12). The importer can then not be viewed as constrained by the exporter's

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[20] Optimal welfare given R > 0 can here be negative; this in particular always happens when c is sufficiently large. See the discussion below.

choice of R (= R*), but will instead select a lower R-level, namely R(0). Thus R* = R(0) is the optimal solution.

Consider finally the issue of whether positive fossil fuel demand is optimal or not for the entire importer bloc. This is a meaningful question in the context of the model, since we have seen that there may be two corner solutions to the importer's maximization problem: one with maximal R, and another with minimal R. These two need to be compared, in terms of utility.

In the example for the simulations ($\gamma = \varphi = 1$, $c_2 = p_0 = 0$), maximum utility for the importer can be found from (A10) as

$$W^* = R(0)\left(\frac{1}{6} - c\right). \tag{A14}$$

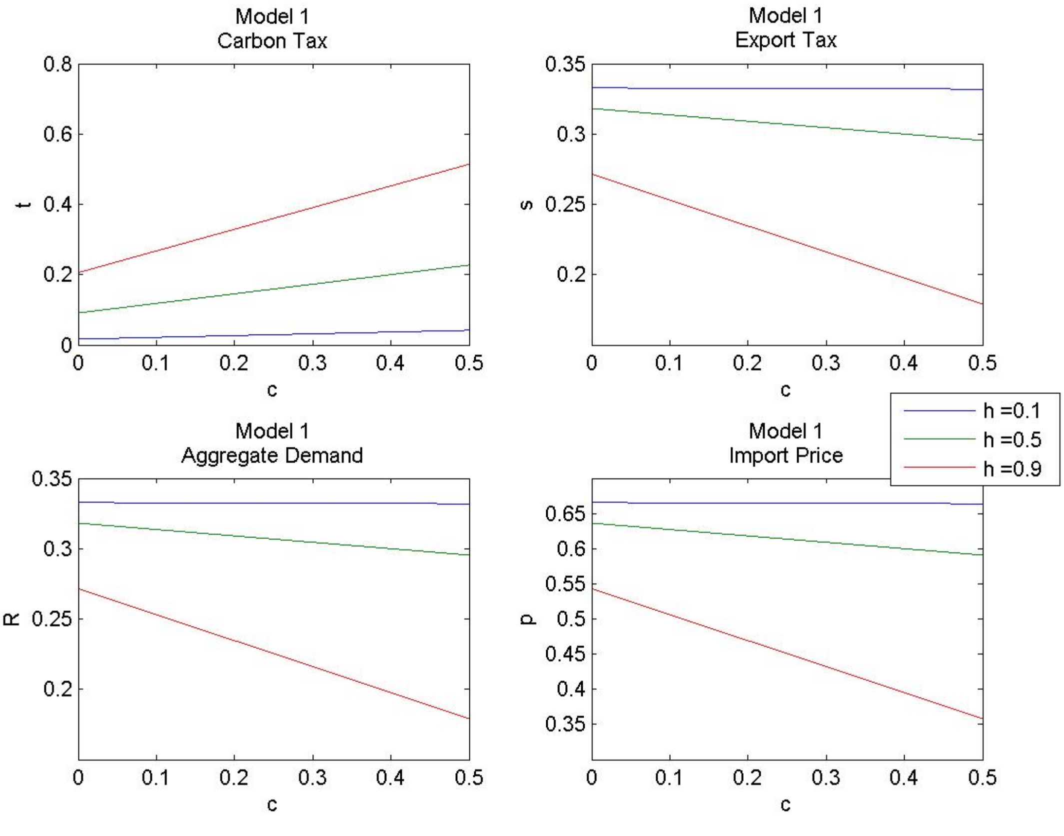
This relation shows that, under the parametric assumptions chosen here, maximized utility from importing and consuming fossil fuels is overall positive only when $c < 1/6$. To a certain degree, this is an artifact of the particular model and parameters applied (where utility of fossil fuels is highly constrained, with in particular a limit price of unity). The feature that two corner solutions must be compared in order to find the overall optimal solution, is however more general.

Overall, we have here shown that the "reactive" equilibrium treated in A1, and the Stackelberg equilibrium with a unified importer bloc setting a consumption cap on fossil fuels, treated in the current section, are identical.

Appendix B: Further Simulation Results for Models 1-2

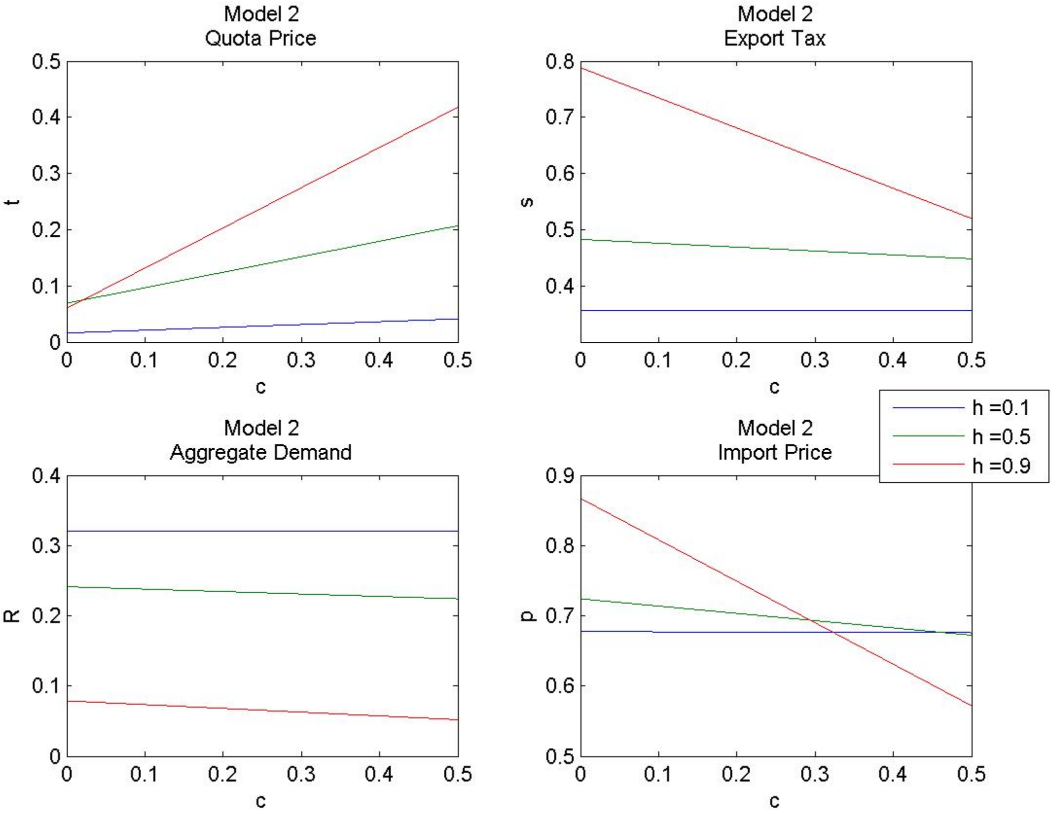
We will here present a few additional simulation results, where we now focus on parametric changes in c (the seriousness of the climate externality for fuel-importing countries), for three given levels of h (the relative size of the policy bloc), namely 0.1, 0.5, and 0.9. B1-B4 provide such results for model 1 (tax setting), B5-B8 for model 2 (cap setting). We still adapt the other parametric assumptions that were used above. The figures B9-B16 consider (3-dimensional) simultaneous changes in h and c.

Figures B1-B4: Effects on solution values of parametric changes in c (magnitude of the climate externality), model 1



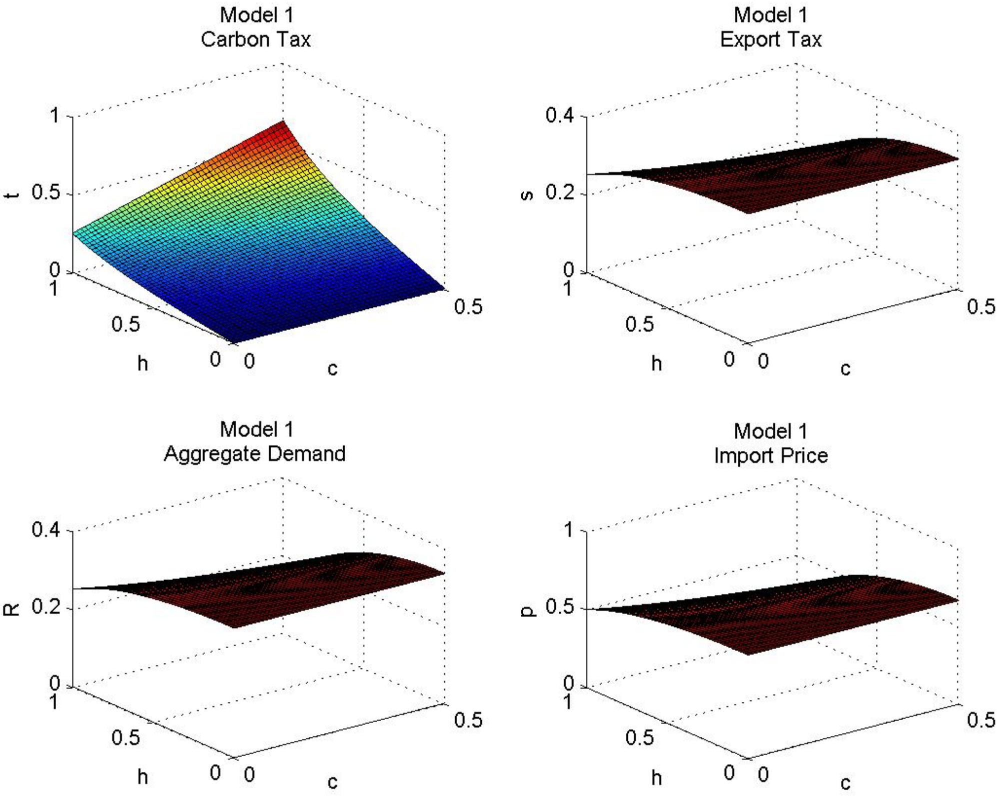
We see that under model 1, the importer tax increases in c, while the exporter tax fall in c. The import price and total fuel consumption both drop. These effects are very weak for h = 0.1 (when the climate concern means little for policy), and quite strong for h = 0.9, with h = 0.5 in an intermediate position. Also, the importer tax is uniformly higher when h is greater, while it is the opposite for the export tax, and the import price.

Figures B5-B8: Effects on solution values of parametric changes in c (magnitude of the climate externality), model 2



Figures B5-B8 show similar relations for the cap model. A noticeable feature when comparing the two models is that both the export tax and import price are much higher for given c under model 2, and this difference is greater for higher h. Thus, when the policy bloc is larger (and thus h larger), the difference between policies of the exporter, under a tax versus a cap, is greater. The relatively more favorable is then a tax, as viewed by both the policy bloc and the fringe (which also gains by the lower import price in the tax case). The quota price under model 2 is also generally lower than the tax under model 1; and the difference is greater for higher h.

Figures B9-B12: Simultaneous changes in h and c under model 1



Figures B13-B16: Simultaneous changes in h and c under model 2