UNIVERSITÄT SIEGEN

Fakultät III
Wirtschaftswissenschaften,
Wirtschaftsinformatik und
Wirtschaftsrecht

Volkswirtschaftliche Diskussionsbeiträge

Discussion Papers in Economics

No. 177-15

December 2015

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Universität Siegen
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Wirtschaftswissenschaften, Wirtschaftsinformatik und Wirtschaftsrecht
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Hölderlinstraße 3
D-57068 Siegen
Germany

http://www.wiwi.uni-siegen.de/vwl/

ISSN 1869-0211

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

Discussion Papers in Economics of the University of Siegen are indexed in RePEc
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Buy coal to mitigate climate damage and benefit from strategic deposit action[1]

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Abstract

In the world economy with interdependent markets for fossil fuel and deposits, some coalition of countries fights climate change by purchasing and preserving fossil fuel deposits, which would be exploited otherwise. If the coalition's policy parameters are the demand and supply of deposits (deposit policy), the outcome is inefficient, but the coalition is better off with than without exerting market power by influencing prices in its own favor. In the special case, in which non-coalition countries do not suffer from climate damage, the outcome is efficient if the coalition is a price taker on both markets, but inefficient otherwise. The latter result demonstrates that Harstad's (2012, Theorem 1) efficiency result is not robust with respect to variations in the concepts of deposit market and strategic behavior. We also analyze a policy where the coalition's first policy parameter is its deposit demand, as before, and the second policy parameter is fuel supply rather than deposit supply. That policy turns out to be equivalent to the deposit policy (as defined above) under some conditions but non-equivalent under others.

JEL classification: Q31, Q38, Q55
Key words: climate coalition, fossil fuel, deposits, extraction, deposit policy

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1 Introduction

Fighting global change requires mitigating greenhouse gas emissions, notably emissions of carbon dioxide from burning fossil fuels. The ongoing international climate negotiations are unlikely to result in effective global cooperation soon. It is therefore important to improve further our understanding of the conditions for successful sub-global cooperation and, in particular, of the performance of alternative unilateral climate policies. While there is a large theoretical literature on demand-side (unilateral) climate policies,[1] supply-side approaches are much less analyzed.[2] Among the under-researched supply-side policies is the policy of purchasing fossil fuel deposits for the purpose to prevent their exploitation. That kind of deposit policy is the focus of the present paper. We aim to analyze how the deposit market works, how it is interconnected with the fuel market and what the differences are in outcome, when a group of countries does or does non exert market power in the form of distorting the prices of deposits and fuel to its own favor.

An important feature of analyzing deposit policies – and the reason for analytical complexity – is the interdependence of the markets for deposits and fuel. To see that, consider a country that buys deposits for preservation. That country needs to be sure that the former owner country would have exploited those deposits in the absence of deposit trading. If no deposits are traded, all those deposits are extracted whose (marginal) extraction costs do not exceed the (anticipated) fuel price. Hence that fuel price is crucial for the policy of purchasing and preserving deposits and thus creates an interdependence of the markets for deposits and fuel.

Bohm (1993), Harstad (2012) and Asheim (2013) are the only studies we know with an analytical approach to deposit policies. Asheim (2013) provides a distributional argument for deposit policies in a Dasgupta-Heal-Solow-Stiglitz growth model. In a stylized parametric model, Bohm (1993) considers a sub-global climate coalition and derives conditions under which a special policy mix consisting of the purchase or lease of deposits and a fuel-demand cap implements the emission cap at lower costs than the stand-alone fuel-demand-cap policy. Harstad (2012) models the deposit market as a set of bilateral trades to the mutual advantage of the trading partners and adds the deposit policy to Hoel's (1994) mix of strategic fuel-demand-cap and fuel-supply-cap policies.[3] He considers a world of heterogeneous countries

[1]Prominent examples are Markusen (1975), Copeland and Taylor (1995), Ulph (1996), Kiyono and Ishikawa (2013), Böhringer et al. (2015), van der Meijden et al. (2015) and van der Ploeg (2015).

[2]For studies combining the unilateral climate policies of capping fuel demand and supply in the absence of a market for deposits see e.g. Hoel (1994), Eichner and Pethig (2015) and Faehn et al. (2014).

[3]Since the coalition turns out to make no use of the cap on fuel demand, actually only the other two instrument are needed.

all of which extract, trade, and consume fossil fuel. Carbon emissions from fuel extraction generate climate damage in some group of countries, and this group forms a coalition to reduce global emissions.

Harstad shows that the coalition's unilateral action implements the first-best[4] if all agents take the price of fossil fuel as given.[5] This outcome is remarkable, because unilateral demand-side policies always are distortionary. Harstad's (2012, Theorem 1) core result is that if the deposit market clears the coalition implements the first-best although it has the option to exert market power via manipulating the fuel price. That 'efficiency-despite-strategic-action result' runs counter the plausible conjecture, and counter the results in numerous studies in other fields of economics,[6] that exerting market power always makes the strategically acting agent better off than price taking.

The observation that the coalition is the monopsonist on the deposit market is a compelling reason, in our view, for assuming that it chooses its deposit demand strategically. Our paper adopts Harstad's analytical framework including his assumption that the fuel market clears after the deposit market, but we will demonstrate that Harstad's Theorem 1 is not robust with respect to the concept of deposit market and the coalition's strategic behavior. On Harstad's (2012, p. 92) deposit market, any pair of countries may trade "some of their deposits at some price" and the market clears "... when there exists no pair of countries that would both strictly benefit from trading ..." In contrast, we will employ the more conventional market concept with a unitary deposit price which clears the market when aggregate demand matches aggregate supply. Second, Harstad allows the coalition to manipulate the fuel price by exerting power on the deposit market in the form of price discrimination. In contrast, we assume that the coalition takes the fuel price as given (in our basic model of Section 2) but let the coalition set its demand and supply of deposits strategically.[7]

[4]Crucial for Harstad's first best result(s) is his assumption that the non-coalition countries do not suffer from climate damage.

[5]Harstad (2012) mentions that important result only in passing in his section IV on generalizations. There he considers the case "... that every $i \in M \cup N$ takes the price as given at stages 2 and 3 (and, perhaps, even at stage 1)" and concludes that then the outcome is first-best. We reproduce that efficiency result in our models in the Sections 2 and 3, if we consider the special case that the non-coalition countries do not suffer from climate damage and drop the assumption that the coalition acts strategically.

[6]See e.g. the results presented in Eaton and Grossman (1986) and Krugman (1986) in the context of strategic trade policy or in Cremer and Gahvari (2006) and Kempf and Rota-Graziosi (2010) in the context of tax competition.

[7]Another minor difference is that we do not follow Harstad in assuming that the non-coalition countries do not suffer from climate damage. Since the climate damage enters the welfare functions in an additive way, it is easy, of course, to get Harstad's special case by "switching the non-coalition countries' climate damage off".

As indicated above, the principal message of the present paper is that Harstad's 'efficiency-despite-strategic-action result' is not robust with regard to our concept of deposit market and our modeling of strategic action. In Section 2 we analyze the case, called deposit policy, in which the coalition sets its demand and supply of deposits strategically while it is a price taker on the fuel market. We show that through its choice of deposit demand and supply the coalition distorts not only the deposit price but indirectly also the fuel price and is better off with than without strategic action. The outcome is always inefficient, even if the climate damage hits the coalition only. Some specific information on how the allocation deviates from the first-best is provided by resorting to simple parametric functional forms. Section 3 analyzes a policy, called deposit-and-cap policy for short in which the coalition's strategic policy parameters are the deposit demand, as before, and the fuel supply (instead of the deposit supply). Since the supply of deposits and fuel are linearly dependent one would expect that the deposit policy (of Section 2) and the deposit-and-cap policy are equivalent. It turns out, however, that equivalence is attained only for a certain subset of the parametric version of the model. There is another subset of parameters, for which the deposit-and-cap policy makes the coalition better off than the deposit policy. The reason for that non-equivalence is the assumption that the deposit market clears prior to the fuel market.

2 Strategic deposit demand and supply

2.1 The basic model

There is a world economy with two groups of countries, M and N. The members of group M participate in an international climate agreement. We refer to group M as coalition M and assume that M acts as one agent. The countries of group $N = \{1, ..., n\}$ are no signatories of the agreement. Each country produces and consumes fossil energy, called fuel, for short. Country $i \in \{M\} \cup N =: \Omega$ derives the benefit $B_i(y_i)$ from consuming y_i units of fuel (with $B_i' > 0$ and $B_i'' < 0$) and produces the quantity x_i of fuel from domestic fossil energy deposits. The cost of extracting fuel is $C_i(x_i)$, where $C_i' > 0$ and $C_i'' > 0$. The marginal extraction function C_i' defines country i's endowment of deposits where deposits are characterized by the amount of fuel stored in them and by the cost of extracting that fuel. Specifically, the function C_i' "... is a mapping from country i's deposits, ordered according to costs, to the marginal extraction cost of these deposits" (Harstad 2012, p. 85). Fuel generates the greenhouse gas carbon dioxide proportional to fuel extraction. These carbon emissions cause climate damage $H_i\left(\sum_\Omega x_j\right)$ in country $i \in \Omega$.

Before we turn to markets and strategic policy, it is useful to have a look at the efficient allocation as a benchmark. Straightforward calculations yield the efficiency rules

$$B_i'(y_i) = B_j'(y_j) \quad \forall\, i, j \in \Omega, \tag{1}$$

$$B_i'(y_i) = C_i'(x_i) + \sum_{\Omega} H_i' \left(\sum_j x_j \right) \quad \forall\, i \in \Omega. \tag{2}$$

Equation (1) represents the rule for fuel consumption efficiency. Equation (2) requires that the marginal benefit of consuming fuel equals its marginal costs, which consist of the marginal extraction costs and the aggregate marginal environmental damage. The analytical framework described so far is Harstad's (2012) with the only exception that we allow for[8] $H_i' > 0$ for all $i \in \Omega$, while Harstad assumes $H_M' > 0$ and $H_i' = 0$ for all $i \in N$.[9]

2.2 The game

As explained in the introduction, we deviate from Harstad's model in two important aspects, the concept of deposit market and the coalition's strategic behavior. Our deposit market is a conventional market with a uniform deposit price that clears the market when aggregate deposit demand and supply matches. As the coalition will be the monopsonist on that deposit market, we assume that it will exert market power by setting its deposit supply and demand strategically while it chooses its fuel demand and supply as a price taker. We follow Harstad (2012) in assuming that the deposit market clears prior to the fuel market. The timing of the game is illustrated in Figure 1. At stage 1, the coalition chooses its deposit policy (z_M^d, z_M^s). At stage 2 the non-coalition countries determine their demand, z_i^d for $i \in N$, and supply, z_i^s for $i \in N$, for deposits and the deposit market clears at the uniform deposit price p_z. Finally, at stage 3 country $i \in \Omega$ supplies fuel in quantity x_i, demands fuel in quantity y_i and the fuel market equilibrates at price p. It is important to observe that deposit trading at stage 2 changes the extraction cost function $C_i(\cdot)$, which represents country i's deposit endowment prior to deposit trading into a cost function $K_i(\cdot)$ after deposit trading. We follow the standard procedure of solving the three-stage game of Figure 1 via backward induction.

[8]Throughout the paper a "prime" indicates the function's partial derivative with respect to its first argument.

[9]It is straightforward, of course, to turn Harstad's case by 'switching off' the non-coalition countries' climate damage.

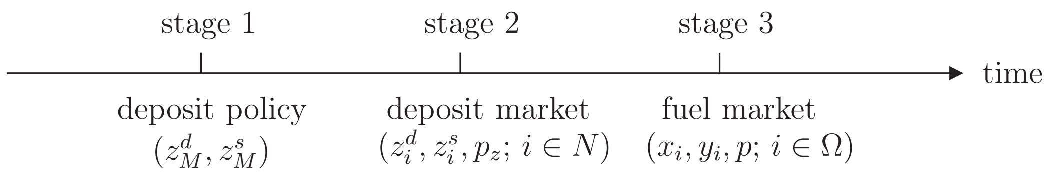

Figure 1: Timing of the game with strategic deposit policy

Stage 3. At stage 3, all countries choose their fuel demand and supply. The representative consumer of country $i \in \Omega$ determines her fuel demand by maximizing with respect to y_i

$$B_i(y_i) - K_i(x_i, p_a, p_z) - p(y_i - x_i) + p_z\left(z_i^s - z_i^d\right). \tag{3}$$

In (3) p_a is the anticipated fuel price at the stages 1 and 2, p is the prevailing fuel price at stage 3, K_i is country i's extraction cost function after the deposit trade at stage 2 which we specify below when needed. The term $p_z\left(z_i^s - z_i^d\right) > [<] 0$ are country i's revenues [expenditures] from selling [buying] deposits. The first-order condition of maximizing (3) readily yields

$$B_i'(y_i) = p \quad \Longleftrightarrow \quad y_i = B_i'^{-1}(p) =: D_i(p) \quad \forall\, i \in \Omega, \tag{4}$$

where $B_i'^{-1}$ is the inverse of the marginal benefit function B_i'.

Next, consider the fuel supply of country $i \in N$. At stage 3, $i \in N$ recalls that it sold at stage 2 all deposits in the interval $[\sigma_i(p_a, p_z), \xi_i(p_a)]$, where

$$\xi_i = \xi_i(p_a) := C_i'^{-1}(p_a), \quad \sigma_i = \sigma_i(p_a, p_z) := C_i'^{-1}(p_a - p_z) \quad \forall\, i \in N \tag{5}$$

and where $C_i'^{-1}$ is the inverse of the marginal cost function C_i'. The deposit sale of country $i \in N$ turns the initial marginal cost function C_i' into the marginal cost function K_i' after deposit trade, where

$$K_i'(x_i, p_a, p_z) := \begin{cases} C_i'(x_i) & \text{for } x_i \leq \sigma_i, \\ C_i'(\xi_i) - C_i'(\sigma_i) + C_i'(x_i) & \text{for } x_i \geq \sigma_i, \end{cases} \quad \forall\, i \in N. \tag{6}$$

Based on (6), the total extraction cost after deposit trading is

$$\begin{aligned} K_i(x_i, p_a, p_z) &= \int_0^{x_i} K_i'(x, p_a, p_z)\mathrm{d}x \\ &= \begin{cases} C_i(x_i) & \text{for } x_i \leq \sigma_i, \\ C_i(x_i + \xi_i - \sigma_i) - C_i(\xi_i) + C_i(\sigma_i) & \text{for } x_i \geq \sigma_i, \end{cases} \quad \forall\, i \in N. \end{aligned} \tag{7}$$

Figure 2a illustrates country i's marginal cost functions C_i' and K_i', and Figure 2b exhibits country i's total cost functions C_i and K_i. The straight line $0D$ in Figure 2a represents the initial marginal cost function C_i'. After having sold the deposits $[\sigma_i, \xi_i]$ at

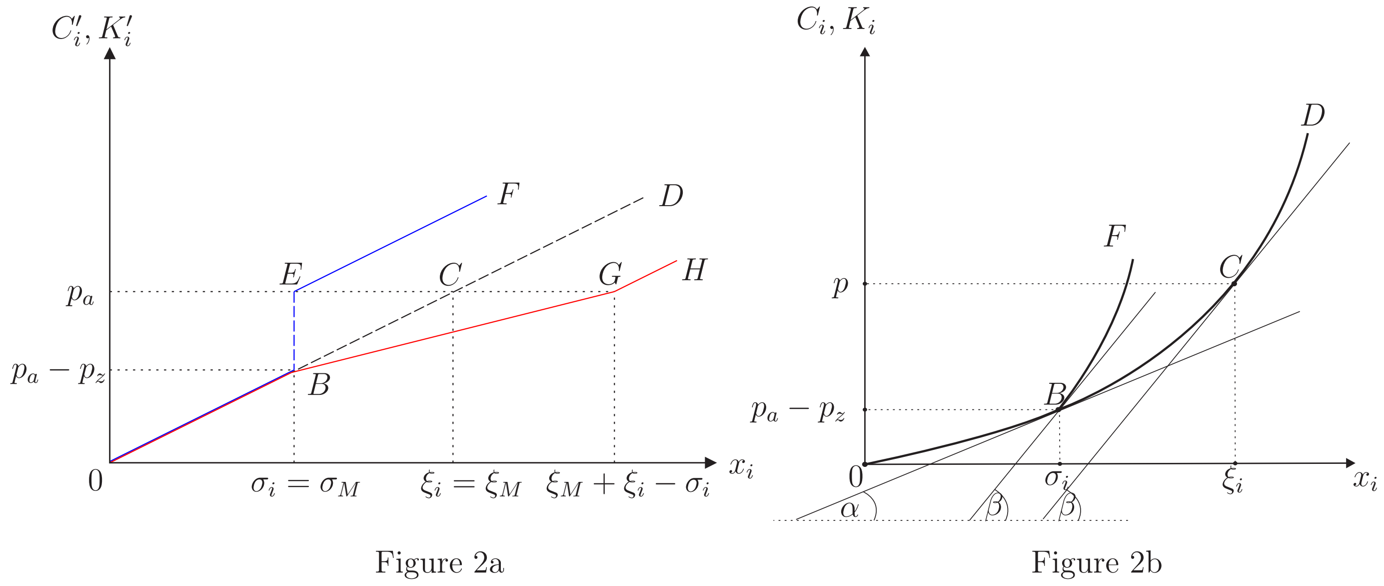

Figure 2: Marginal and total extraction cost curves before and after deposit trading $[\sigma_i, \xi_i]$

stage 2, country $i \in N$'s marginal cost function K_i' is represented by the line $0BEF$. We derive that line from $0D$ by shifting the line segment CD to the left by the amount $\xi_i - \sigma_i$ such that CD moves to EF. Thus, country i's endowment of deposits changed from $0BCD$ to $0BEF$. The function K_i' is discontinuous at $x_i = \sigma_i$, as reflected in the gap BE of the graph $0BEF$. In Figure 2b, $0BCD$ is the graph of the cost function C_i. After the deposit sale at stage 2, the curve $0BF$ represents country i's new cost function K_i. The curve segment BF of K_i results from moving the curve segment CD of C_i from its base point C to the new base point B. The gap BE of the graph of K_i' in Figure 2a translates into the kink of the cost curve $0BF$ at $x_i = \sigma_i$ (= at point B) in Figure 2b. Both panels of Figure 2 illustrate that if σ_i is approached from above, the marginal extraction cost is $K_i' = \tan\alpha = p_a$, and it is $K_i' = \tan\beta = p_a - p_z < p_a$, if σ_i is approached from below. The deposit sale $[\sigma_i, \xi_i]$ of country $i \in N$ to the coalition at stage 2 means that the coalition's initial marginal extraction cost function C_M' is replaced at stage 3 by the marginal cost curve K_M' that is illustrated in Figure 2a by the curve $0BGH$ for the simple case where $N = \{i\}$ and $C_i' = C_M'$.

Maximizing country $i \in N$'s welfare (3) subject to (7) with respect to x_i yields its fuel supply function[10]

$$S_i(p, p_a, p_z) = \begin{cases} C_i'^{-1}(p) & \text{for } p \leq p_a - p_z, \\ \sigma_i(p_a, p_z) & \text{for } p \in [p_a - p_z, p_a], \\ C_i'^{-1}\left[(p) - C_i'(\xi_i(p_a)) + C_i'(\sigma_i(p_a, p_z))\right] & \text{for } p \geq p_a, \end{cases} \qquad \forall\, i \in N. \quad (8)$$

[10]Throughout the present paper we assume that country $i \in N$ does not pursue any climate policy. We therefore ignore the environmental damage H_i when choosing x_i. The derivation of (8) is delegated to the Appendix A.

At stage 3, M recalls that it determined at stage 1 its deposit supply

$$z_M^s = \xi_M(p_a) - x_M, \tag{9}$$

where $\xi_M(p_a) = C_M'^{-1}(p_a)$, simultaneously with its fuel supply x_M. In view of (9) the fuel demand in (4) and the fuel supply in (8), the fuel-market clearing condition therefore is

$$\xi_M(p_a) - z_M^s + \sum_N S_j(p, p_a, p_z) = \sum_\Omega D_j(p). \tag{10}$$

In formal terms, (10) implies a price function P such that the fuel equilibrium price is

$$p = P(z_M^s, p_a, p_z). \tag{11}$$

Stage 2. At stage 2, the coalition has already chosen its deposit policy z_M^s and z_M^d at stage 1. To determine country $i \in N$'s deposit supply z_i^s and demand z_i^d we need to know first which deposits country i would extract at some anticipated fuel price p_a, if there were no deposit market. In that case, country i would maximize with respect to ξ_i the welfare $U_i = B_i(y_i) - C_i(\xi_i) - p_a(y_i - \xi_i)$ which yields its extraction of deposits and supply of fuel $x_i = \xi_i(p_a) = C_i'^{-1}(p_a)$ (see also (5) above). Without deposit trading, country i's deposits in the interval $[0, \xi_i(p_a)]$ are profitable. With deposit trading, country i keeps extracting its low-cost deposits and sells only the highest-cost profitable deposits, if any. Hence its fuel supply x_i and deposit supply z_i^s are linked through the equation

$$x_i = \xi_i(p_a) - z_i^s, \quad z_i^s \geq 0. \tag{12}$$

It is obvious that no country $i \in N$ would sell deposits for a price lower than the profit it foregoes when selling the deposits instead of selling the fuel extracted from those deposits. Hence it is also clear that no country $i \in N$ would ever buy deposits, because it ignores the resultant climate damage reduction by presupposition and because the profits from exploiting purchased deposits would fail to exceed the price paid for them. Hence we only need to determine country $i \in N$'s deposit supply which follows from maximizing with respect to z_i^s the welfare

$$U_i = B_i(y_i) - C_i(x_i) - p_a(y_i - x_i) + p_z z_i^s$$

under consideration of (12). The first-order conditions yields

$$z_i^s = Z_i^s(p_a, p_z) = \xi_i(p_a) - \sigma_i(p_a, p_z), \tag{13}$$

where $\sigma_i(p_a, p_z) = C_i'^{-1}(p_a - p_z)$. The deposit market is in equilibrium if

$$z_M^s + \sum_N Z_j^s(p_a, p_z) = z_M^d. \tag{14}$$

According to (14) the deposit market equilibrium price depends on the anticipated price p_a and on the coalition's deposit policy z_M^s and z_M^d. For analytical convenience we express the deposit price p_z by the price function

$$p_z = P^z\left(z_M^s, z_M^d, p_a\right). \tag{15}$$

Stage 1. At stage 1, it remains to determine the coalition's policy parameters z_M^s and z_M^d. We explained above that for country $i \in N$ the deposits in the interval $[0, \xi_i(p_a)]$ are profitable at the anticipated fuel price p_a. Analoguously, the deposits in $[0, \xi_M(p_a)]$ with $\xi_M(p_a) = C_M'^{-1}(p_a)$ are profitable and the coalition would therefore exploit them, if it would ignore the climate damage. If it wants to prevent own profitable deposits from being exploited, it will supply for preservation some interval $[\sigma_M, \xi_M(p_a)]$ of high-cost profitable deposits. The determination of the lower bound σ_M of that interval is equivalent to determining the deposit supply $z_M^s = \xi_M(p_a) - \sigma_M$ for preservation. Taking advantage of this linear relationship between its supplies of deposits and fuel, the coalition chooses z_M^s and z_M^d by maximizing

$$\begin{aligned} U_M &= B_M\left[D_M(p)\right] - C_M[\xi_M(p_a) - z_M^s] - p\left[D_M(p) - \xi_M(p_a) + z_M^s\right] \\ &\quad - H_M\left[\sum_{\Omega} \xi_j(p_a) - z_M^d\right] + p_z\left(z_M^s - z_M^d\right) \end{aligned}$$

subject to $p = P(z_M^s, p_a, p_z)$ and $p_z = P^z\left(z_M^s, z_M^d, p_a\right)$. The first-order conditions are[11]

$$\frac{\partial U_M}{\partial z_M^d} = H_M' - p_z + (z_M^s - z_M^d)\frac{\partial P^z}{\partial z_M^d} - (y_M - x_M)\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d} = 0, \tag{16}$$

$$\frac{\partial U_M}{\partial z_M^s} = C_M' - p + p_z + (z_M^s - z_M^d)\frac{\partial P^z}{\partial z_M^s} = 0. \tag{17}$$

Solving (16) and (17) yields values of z_M^s and z_M^d that depend on p_a. Thus, we ultimately turn the price functions (11) and (15) into functions of the anticipated fuel price only, say $p = \tilde{P}(p_a)$ and $p_z = \tilde{P}^z(p_a)$. The final step to solve the game is to set $p = p_a$ for reasons of consistency, which amounts to choosing a fixed point of the price functions $\hat{P}$, technically speaking.

2.3 Allocative (in)efficiency

Non-strategic deposit policy. Before we discuss the impact of strategic action on the deposit market we briefly consider the special case of perfect competition on both the fuel and the deposit market. In the formal model, the absence of strategic action is readily

[11] (16) and (17) are derived in the Appendix A.

established by setting $\frac{\partial P}{\partial p_z} = \frac{\partial P^z}{\partial z_M^d} = \frac{\partial P^z}{\partial z_M^s} \equiv 0$ in (16) and (17). When both markets have cleared, the competitive equilibrium is fully characterized by the equations (4), (16), (17) and $C'(x_i) = p_a - p_z$, which follows from (12) and (13). The associated allocation rules are

$$\underbrace{B_i'(y_i)}_{=p} = \underbrace{B_j'(y_j)}_{=p} \quad \forall\, i,j \in \Omega, \tag{18}$$

$$\underbrace{B_i'(y_i)}_{=p} = \underbrace{C_i'(x_i)}_{=p-p_z} + \underbrace{H_M'\left(\sum_j x_j\right)}_{=p_z} \quad \forall\, i \in \Omega. \tag{19}$$

Equation (18) is the rule for fuel consumption efficiency and equation (19) is the rule for the coalition's purchase of deposits. The comparison of (18) and (19) with the efficient allocation rules (1) and (2) readily reveals that the competitive economy is efficient if and only if $\sum_N H_i' = 0$. In that case the deposit purchase fully internalizes the environmental damage in the coalition caused by carbon emissions of non-coalition countries. If $\sum_N H_i' > 0$, the coalition ignores that its own fuel extraction also causes an environmental damage in non-coalition countries, which distorts the allocation. To compare the outcomes of the competitive economy and first-best, suppose all countries have identical benefit, cost and damage functions ($B_i = B_j \equiv B$, $C_i = C_j \equiv C$ and $H_i = H_j \equiv H$ for all $i, j \in \Omega$) and attach a 'hat' to the solution of the competitive economy and a 'star' to the efficient solution. Identical functions imply $x_i^* = x_j^* = y_i^* = y_j^* \equiv x^*$ and $\hat{x}_i = \hat{x}_j = \hat{y}_i = \hat{y}_j \equiv \hat{x}$ and the fuel extraction is determined by $B'(x) - C'(x) - \psi H'(nx) = 0$ with $\psi = n$ for the efficient fuel extraction and $\psi = 1$ for the competitive fuel extraction. Differentiation yields $\frac{\mathrm{d}x}{\mathrm{d}\psi} = -\frac{H'(nx)}{B''(x) - C''(x) - \psi n H''(nx)}$. From $B'' < 0$, $C'' > 0$ and $H'' > 0$ follows $\frac{\mathrm{d}x}{\mathrm{d}\psi} < 0$ and hence $x^* < \hat{x}$. We summarize our findings in

Proposition 1 . *Suppose all agents are price takers on the markets for deposits and fuel.*

(i) The equilibrium allocation is [in]efficient if $\sum_N H_i' = [>]0$.

(ii) Suppose the benefit, cost and damage functions are the same across countries. Compared to the efficient allocation in the competitive economy the countries extract more fuel and hence put up with higher climate damage.

The case of $\sum_N H_i' = 0$ in Proposition 1(i) is remarkable, because efficiency is reached without any regulatory action other than the coalition's price-taking purchase of deposits. The coalition's dilemma is that by assumption, the non-coalition countries contribute to its climate damage through their carbon emissions, but the coalition has no *direct* lever at its disposal for inducing non-coalition countries to curb their emissions. The coalition's purchase of deposits is an *indirect* instrument to reduce the non-coalition countries' fuel supply. It is an effective measure, because it accomplishes the full internalization of the non-coalition countries' transfrontier pollution.

Strategic deposit policy. The price-taking coalition we considered in the previous subsection is a benchmark rather than an empirically relevant case, because the coalition is a monopsonist on the deposit market. The more appropriate way of dealing with a monopsony is to replace price taking by strategic action. That is, we now assume that the coalition takes the impact of its deposit policy on the equilibrium prices of fuel and deposits into account ($\frac{\partial P}{\partial p_z}$, $\frac{\partial P^z}{\partial z_M^d}$, $\frac{\partial P^z}{\partial z_M^s} \neq 0$). Then we infer from (4), (16), (17) and $C_i'(x_i) = p - p_z$ for all $i \in N$

$$\begin{aligned} B_i' &= B_j' \quad \forall\, i, j \in \Omega, && (20)\\ B_i' &= C_i' + H_M' + (z_M^s - z_M^d)\frac{\partial P^z}{\partial z_M^d} - (y_M - x_M)\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d} \quad \forall\, i \in N, && (21)\\ B_M' &= C_M' + H_M' - (y_M - x_M)\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d}. && (22) \end{aligned}$$

The comparison of (20) and (22) with the efficiency rules (1) and (2) shows that strategic action distorts the allocation and hence strategic deposit policy is inefficient. Through its deposit policy z_M^d the coalition directly manipulates the deposit price via[12] $\frac{\partial P^z}{\partial z_M^d}$ and indirectly the fuel price via $\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d}$. The coalition manipulates the deposit (fuel) price either to reduce its expenditures from buying deposits (fuel) or to increase its revenues from selling deposits (fuel).

Even if we consider Harstad's special case $H_i' = 0$ for all $i \in N$, the conditions (21) and (22) deviate fundamentally from the first-order conditions (6) and (7) in Harstad (2012) that yield his efficiency result. In our model, $z_M^d > z_M^s$ and $y_M \neq x_M$, in general, while in Harstad's model the difference $z_M^d - z_M^s$ is irrelevant for strategic action and $y_M = x_M$ is a necessary condition for the deposit market equilibrium as defined in his model.

To gain further insights into the inefficiency of the strategic deposit policy, suppose there is only one non-coalition country ($\#N = 1$) and consider the parametric functional forms

$$\begin{aligned} &B_i(y_i) = \alpha y_i - \frac{b}{2}y_i^2, \quad C_i(x_i) = \frac{c}{2}x_i^2, \quad i = M, N \\ &H_M\left(x_M + x_N\right) = h_M\left(x_M + x_N\right), \quad H_N\left(x_M + x_N\right) = h_N\left(x_M + x_N\right), \qquad (23) \end{aligned}$$

where α, b, c and h_M and are positive parameters, and h_N is a non-negative parameter. In the Appendix B, we calculate for the functions (23) the efficient allocation, the equilibrium

[12]The strategic effect $\frac{\partial P^z}{\partial z_M^s}$ from (17) cancels out in (22) due to $\frac{\partial P^z}{\partial z_M^s} + \frac{\partial P^z}{\partial z_M^d} = 0$. The latter equality follows from differentiating (14).

allocation of the three-stage game with strategic deposit policy as well as the allocation of the perfectly competitive market. As expected, strategic deposit policy renders fuel consumption inefficiently high, and the coalition ends up with excessive climate damage.

The comparison of strategic policy and perfect competition is also interesting. We find that the coalition uses the deposit policy $(\breve{z}_M^d, \breve{z}_M^s)$ to reduce strategically the price of deposits $(\breve{p}_z < \hat{p}_z)$ compared to its perfectly competitive level.[13] The coalition's strategic action results in buying and preserving fewer deposits from the non-coalition country $(\breve{z}_M^d - \breve{z}_M^s < \hat{z}_M^d - \hat{z}_M^s)$ in order to reduce its expenditures for deposits. In case of strategic deposit policy, the coalition imports fuel $(\breve{y}_M > \breve{x}_M)$, and the coalition uses its market power to reduce the fuel price compared to the perfectly competitive one $(\breve{p} < \hat{p})$. Through the manipulation of both prices the coalition is able to consume more fuel and to increase it consumption welfare. Since the reduced fuel price also induces the non-coalition country to boost its fuel supply, the climate damage aggregates $(\breve{H}_M > \hat{H}_M)$. This result gives rise to the question, whether the strategic action pays for the coalition. The answer is straightforward. Since the coalition could have purchased the perfectly competitive amount of deposits, $\hat{z}_M^d - \hat{z}_M^s$, its choice to distort the allocation proves that it is better off with than without strategic action. To put it differently, the welfare gain from higher consumption overcompensates the welfare loss from higher climate damage. The results are summarized in

Proposition 2 .

(i) In the game with strategic deposit policy (z_M^d, z_M^s) the allocation is inefficient.

(ii) In the game with strategic deposit policy (z_M^d, z_M^s) and the parametrical functional forms (23)*,*

  (iia) all countries extract more fuel and hence put up with higher climate damage than in the efficient allocation;

  (iib) the prices of fuel and deposits are lower, the coalition buys fewer deposits, consumes more fuel and hence puts up with higher climate damage than in the case of non-strategic deposit policy. The coalition' welfare loss from higher climate damage is overcompensated by the welfare gain from higher consumption.

Essentially, the coalition takes advantage of its monopsonistic market power to distort the perfectly competitive allocation in its own favor. Since the markets for deposits and fuel are interdependent, the deposit price change caused by the coalition's strategic deposit policy triggers a change of the fuel price, which, in turn, spills back to the deposit market.

[13]Variables relating to the strategic deposit policy are marked by a 'breve' and those relating to non-strategic deposit policy are marked by a 'hat'.

3 Strategic deposit demand and fuel supply

We have shown above in equation (9) that the coalition's supplies of deposits and fuel are linear interdependent for any given anticipated fuel price, $z_M^s = \xi_M(p_a) - x_M$. That observation gives rise to the interesting question, how the coalition's *deposit policy*, i.e. the policy with the strategy parameters (z_M^d, z_M^s) we have analyzed in the previous section, relates to the policy with strategy parameters (z_M^d, x_M). We refer to the policy (z_M^d, x_M) as *deposit-and-cap policy* to avoid clumsy wording and assume for simplicity that the coalition regulates x_M directly by capping its fuel production.[14] One is declined to argue that both policies must be equivalent, because of the linear relationship $z_M^s = \xi_M(p_a) - x_M$. That would be true in a game where the markets for deposits and fuel clear simultaneously but not necessarily in case of sequential market clearing.

To analyze the deposit-and-cap policy, we set up the four-stage game illustrated in Figure 3. At stage 1, the coalition determines its purchase of deposits z_M^d, at stage 2 the deposit market clears, at stage 3 the coalition chooses its fuel supply cap x_M and at stage 4 the fuel market clears.

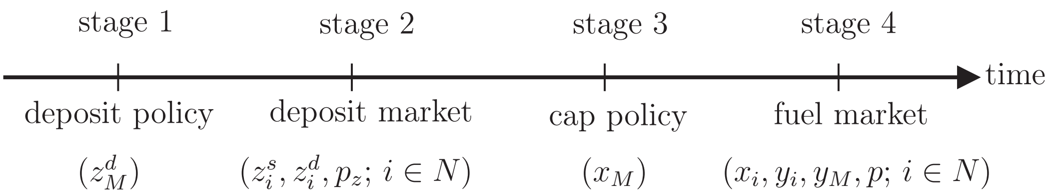

Figure 3: Timing of the game with strategic deposit-and-cap policy

Stage 4. As at stage 3 of the three-stage game of the previous section, the fuel demand and supply is given by $y_i = D_i\left(p\right)$ for $i \in \Omega$ and by

$$S_i(p, p_a, p_z) = \begin{cases} C_i'^{-1}(p) & \text{for } p \le p_a - p_z, \\ \sigma_i(p_a, p_z) & \text{for } p \in [p_a - p_z, p_a], \\ C_i'^{-1}\left[(p) - C_i'(\xi_i(p_a)) + C_i'(\sigma_i(p_a, p_z))\right] & \text{for } p \ge p_a. \end{cases}$$

for $i \in N$ at stage 4 of the game in the present section. The fuel market equilibrium $x_M + \sum_N S_j(p, p_a, p_z) = \sum_\Omega D_j\left(p\right)$ determines the fuel price function[15]

$$p = P(x_M, p_a, p_z) \tag{24}$$

[14] See Hoel (1994) and Harstad (2012) for a discussion of various means such as taxes or emission trading to implement this cap.

[15] Note that the only difference between the price functions (11) and (24) is the use of equation (9) in (11).

Stage 3. At stage 3 the coalition sets x_M strategically. The coalition's deposit purchases at stage 2 turned its initial marginal cost function C'_M into the marginal cost function K'_M defined by

$$K'_M(x_M, p_a, p_z) = \begin{cases} C'_M(x_M) & \text{for } x_M \leq \sigma_M, \\ \tilde{K}'_M(x_M) & \text{for } x_M \in [\sigma_M, \tilde{\sigma}_M], \\ \tilde{K}'_M(\tilde{\sigma}_M) - C'_M(\tilde{\sigma}_M) + C'_M(x_M) & \text{for } x_M \geq \tilde{\sigma}_M, \end{cases}$$

where

$$\begin{aligned} \tilde{\sigma}_M &= \sigma_M + \sum_{\Omega}(\xi_j - \sigma_j), \quad \tilde{K}'_M(x_M) := C'_M(\sigma_M) - \tilde{C}'(\sigma_M) + \tilde{C}'(x_M) \quad \text{and} \\ \zeta &= \tilde{C}'(x) \quad \Longleftrightarrow \quad x = \sum_{\Omega} C_j'^{-1}(\zeta) \end{aligned}$$

Figure 2a illustrates the marginal cost functions C'_M and K'_M.[16] The straight line $0D$ is the graph of C'_M. After having purchased the deposits $\bigcup_N[\sigma_j, \xi_j]$ at stage 2, M's marginal cost function K'_M is represented by the graph $0BGH$. The line segment BG on that graph, which is flatter than the segments $0B$ and GH, contains both M's deposits $[\sigma_M, \xi_M]$ and all acquired deposits $\bigcup_N[\sigma_j, \xi_j]$ reordered according to extraction costs. The line segment GH of the graph $0BGH$ results from shifting the line segment CD to the right by the amount $\sum_N(\xi_j - \sigma_j)$. Thus, M's purchase of deposits changes its deposit endowment from $0D$ to $0BGH$.

M chooses its fuel supply by maximizing with respect to x_M the welfare

$$\begin{aligned} U_M &= B_M\left[D_M(p)\right] - K_M(x_M, p_a, p_z) - p\left[D_M(p) - x_M\right] \\ &\quad - H_M\left[x_M + \sum_N S_j(p, p_a, p_z)\right] - p_z z_M^d \end{aligned} \tag{25}$$

subject to $p = P(x_M, p_a, p_z)$. The first order condition

$$\frac{\partial U_M}{\partial x_M} = -K'_M + p - H'_M - \left(y_M - x_M + H' \sum_N S'_j\right) \frac{\partial P}{\partial x_M} = 0 \tag{26}$$

determines the fuel demand

$$x_M = X_M(p_a, p_z). \tag{27}$$

[16] Figure 2 (approximately) illustrates a world economy with the coalition and one country ($N = \{i\}$); the initial deposit endowments the coalition and the country own are the same ($C'_M = C'_i$).

Stage 2. At stage 2, country $i \in N$ determines its deposit demand and supply. As at stage 2 of the previous section we obtain (13), and the deposit market equilibrium condition[17] is $\sum_N Z_j^s(p_a, p_z) = z_M^d$. That equation implicitly determines the deposit price function

$$p_z = P^z(z_M^d, p_a). \tag{28}$$

Stage 1. Finally, the coalition chooses z_M^d by maximizing its welfare[18]

$$U_M = B_M\left[D_M(p)\right] - C_M(x_M) - p\left[D_M(p) - x_M\right] - H_M\left[\sum_N \xi_j(p_a) + x_M - z_M^d\right] - p_z z_M^d \tag{29}$$

subject to (24), (27) and (28). The first-order condition

$$\begin{aligned}\frac{\partial U_M}{\partial z_M^d} &= H_M' - p_z - z_M^d \frac{\partial P^z}{\partial z_M^d} - (y_M - x_M)\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d} \\ &\quad + \left[-C_M' + p - H_M' - (y_M - x_M)\frac{\partial P}{\partial x_M}\right]\left(\frac{\partial X_M}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d}\right) = 0, \end{aligned} \tag{30}$$

yields

$$z_M^d = Z_M^d(p_a). \tag{31}$$

In view of (27) and (31) we can turn the price functions (24) and (28) into functions of the anticipated fuel price only, say $p = \tilde{P}(p_a)$ and $p_z = \tilde{P}^z(p_a)$. As in the last section, we then solve the game by setting $p_a = p$ for reasons of consistency.

In the remainder of this section we characterize the outcome of the four-stage game, as we did with respect to the three-stage game in Proposition 2, and then turn to answer the question raised in the introduction to the present section as to whether the strategic deposit policy and the strategic deposit-and-cap policy are equivalent.

Consider first the (in)efficiency issue. Making use of (4), $C'(x_i) = p - p_z$, (26) and (30) the allocation of strategic deposit-and-cap policy is characterized by

$$\begin{aligned} B_i' &= B_j' \quad \forall i, j \in \Omega, && (32)\\ B_i' &= C_i' + H_M' - z_M^d \frac{\partial P^z}{\partial z_M^d} - (y_M - x_M)\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d} + \phi \quad \forall i \in N, && (33)\\ B_M' &= K_M' + H_M' + \left(y_M - x_M + H_M' \sum_N S_j'\right)\frac{\partial P}{\partial x_M}. && (34) \end{aligned}$$

[17]The variable z_M^d we use in the present section corresponds to $z_M^d - z_M^s$ in the previous section. Since the coalition demands the deposits it supplies the deposit price is unaffected by the amount of deposits the coalition supplies.

[18]Note that at stage 1 the coalition faces the marginal cost function C_M', while in (25) at stage 3 the marginal cost function is K_M'.

where

$$\phi := \left(K_M' - C_M' + H_M' \sum_N S_j' \frac{\partial P}{\partial x_M} \right) \cdot \frac{\partial X_M}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d} \tag{35}$$

According to (33) and (34), the coalition manipulates the fuel price at stage 3 by choosing the fuel cap x_M, formally $\frac{\partial P}{\partial x_M}$, it sets the deposit demand z_M^d at stage 1 to influence the deposit price in its favor, formally $\frac{\partial P^z}{\partial z_M^d}$. When choosing its deposit demand the coalition also takes into consideration that z_M^d affects the fuel price at stage 3 via $\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d}$ and its own fuel cap via $\frac{\partial X_M}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d}$.

Comparing (32) - (34) with the efficiency conditions (1) and (2) shows that the former equations contain distortionary terms such that the strategic deposit policy in inefficient. It is also straightforward that we end up in perfect competition, if we switch off all strategic effects. From $\frac{\partial P}{\partial p_z} = \frac{\partial P}{\partial x_M} = \frac{\partial X_M}{\partial p_z} = \frac{\partial P^z}{\partial z_M^d} \equiv 0$ follows $K_M' = C_M'$ and (32)-(34) coincide with the allocation rules of perfect competition (18) and (19).

We summarize and prove in the Appendix, respectively,

Proposition 3. *In qualitative terms, the outcome of the strategic deposit-and-cap policy equals that of the strategic deposit policy described in Proposition 2 except that the analogue of Proposition 2(ii) only holds under the additional constraint* $b^3 - 3b^2c - 10bc^2 - 4c^3 < 0$.

Finally, we wish to answer the question whether the strategic deposit-and-cap policy of the present section is equivalent to the strategic deposit policy analyzed in the last section. Closer inspection of (21), (22) and (33), (34) reveals that[19] the allocation rules of the strategic deposit policy are [not] the same as those of the strategic deposit-and-cap policy, if $K_M' = C_M'$, $[K_M' \neq C_M']$ and $S_i' = 0$ $[S_j' \neq 0]$ for all $i \in N$ which implies $\phi = [\neq]0$. Observe that ϕ from (35) is the term by which the equation (21) and (33) differ. When setting x_M directly the coalition faces at stage 1 the marginal cost function K_M' and it takes into account that x_M changes the non-coalition countries fuel supply, formally S_i'. When the coalition implements the strategic deposit policy, at stage 4 it faces the marginal cost function C_M' and its choice of z_M^s determines its fuel supply via $x_M = \xi_M(p_a) - z_M^s$ from (13). At stage 1 there are no effects in the first-order conditions stemming from influencing the non-coalition countries fuel supply S^i, since that fuel supply is now given by $\xi_i(p_a) - z_i^s$. The differences in the first-order conditions (21), (22) and (33), (34) led us to conclude that the strategic deposit policy and the strategic deposit-and-cap policy are not equivalent, in general. To get

[19] In the Appendix A it is shown that $\frac{\partial P}{\partial z_M^s} = -\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^s}$. In addition, observe that $\frac{\partial P}{\partial x_M} = -\frac{\partial P}{\partial z_M^s}$ and $\frac{\partial P^z}{\partial z_M^s} = -\frac{\partial P^z}{\partial z_M^s}$.

further information about the (non-)equivalence of both policies we resort to the parametric functions (23) and show in the Appendix B

Proposition 4 . *Suppose the parametric functional forms (23) apply.*

(i) If $2c(b+5) > b^2 - bc - 4c^2 > 0$, the strategic deposit policy and the strategic deposit-and-cap policy are equivalent.

(ii) If $b^2 - bc - 4c^2 < 0$, the strategic deposit-and-cap policy makes the coalition better off than the strategic deposit policy.

Proposition 4 provides a sufficient condition for which both policies are [not] equivalent. In case of non-equivalence the better policy option from the coalition's viewpoint is the strategic deposit-and cap policy. For the parametric functions the allocation of the strategic deposit policy is always attainable when applying the strategic deposit-and cap-policy, but it is not always the coalition's best option to do so under strategic deposit-and-cap policy. The reverse is not true. If $b^2 - bc - 4c^2 < 0$, under strategic deposit-and-cap policy there is the choice to implement the allocation of the strategic deposit policy or an alternative allocation. Since the allocation of the strategic deposit policy is inferior in terms of the coalition's welfare, the coalition implements the alternative under strategic deposit-and-cap policy, and hence strategic deposit policy and strategic deposit-and-cap policy are not equivalent. The more-in-bebth reason for the non-equivalence lies in the timing of the games. More precisely, in the assumption that the deposit market clears prior to the fuel market.

4 Concluding remarks

The aim of the paper is to improve our understanding of how the deposit market works, how it is interconnected with the fuel market and what the differences are in outcome when the coalition implements strategically, or non-strategically the deposit policy and the deposit-and-cap policy. The efficiency result we attained in the case that all agents are price-takers and non-coalition countries do not suffer from climate damage is an interesting benchmark. Through the purchase of deposits the coalition reduces the non-coalition countries' – and its own - fuel supply by an appropriate amount and thus fully internalizes the 'home-made' negative externality as well as the negative externalities generated by non-coalition countries. The coalition's purchase of deposits from non-coalition countries is a Coasean solution of the externality problem satisfying the pollutee-pays-principle. As expected, the strategic action always distorts the terms of trade to the coalition's favor and thus reduces its burden of unilateral climate policy. That result is at variance with Harstad's (2012) finding of full internalization in spite of strategic action. The reason for that intriguing difference of outcomes in his model and ours is the difference in design of the deposit market and the difference in the analytical treatment of market power.

For the benefit of informative results we followed Harstad (2012) in seeking analytical relief by employing additive, quasi-linear consumer preferences and, more importantly, by assuming that the non-coalition countries refrain from fighting climate damage. From an analytical viewpoint, the policy abstinence of non-coalition countries sharpens the focus on the coalition's climate policy. However, allowing for climate policy not only in the coalition but also in non-coalition countries is a desirable extension of the model and an important item on the agenda of further research. Such an extension would reintroduce the free-rider problem. To see that suppose non-coalition countries that suffer from climate damage consider buying deposits. It is then in their interest to pay for deposits and hence have an incentive to take action, but they would be even more interested in benefiting from the purchase of deposits by the coalition or other non-coalition countries. With climate damage in non-coalition countries and deposit policy, free-rider incentives also jeopardize the formation of self-enforcing climate coalitions, similar as the free-rider incentives in the context of fuel-demand-cap policies studied e.g. by Eichner and Pethig (2013).

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Appendix A

Derivation of (8):

Maximizing (3) subject to (7) with respect to x_i yields

$$K_i'(x_i, p_a, p_z) = p.$$

For $x_i \leq \sigma_i(p_a, p_z)$ we obtain

$$C_i'(x_i) = p \quad \Longleftrightarrow \quad x_i = C_i'^{-1}(p),$$

and for $x_i \geq \sigma_i(p_a, p_z)$ we get

$$C_i'(\xi_i) - C_i'(\sigma_i) + C_i'(x_i) = p \quad \Longleftrightarrow \quad x_i = C_i'^{-1}[p - C_i'(\xi_i) + C_i'(\sigma_i)].$$

Derivation of (16) and (17):

The first-order conditions are

$$\frac{\partial U_M}{\partial z_M^d} = H_M' - p_z + (z_M^s - z_M^d)\frac{\partial P^z}{\partial z_M^d} - (y_M - x_M)\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^d} = 0, \tag{A1}$$

$$\frac{\partial U_M}{\partial z_M^s} = C_M' - p + p_z + (z_M^s - z_M^d)\frac{\partial P^z}{\partial z_M^s} - (y_M - x_M)\left(\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^s} + \frac{\partial P}{\partial z_M^s}\right) = 0. \tag{A2}$$

Next, we prove that $\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^s} + \frac{\partial P}{\partial z_M^s} = 0$. Total differentiation of (10) yields

$$-\mathrm{d}z_M^s + \left(\sum_N \frac{\partial S_j}{\partial p} - \sum_\Omega D_j'\right)\mathrm{d}p + \sum_N \frac{\partial S_j}{\partial p_z}\mathrm{d}p_z = 0. \tag{A3}$$

From (A3) we obtain the properties of the fuel price function

$$\frac{\partial P}{\partial z_M^s} = \frac{1}{\sum_N \frac{\partial S_j}{\partial p} - \sum_\Omega D_j'}, \quad \frac{\partial P}{\partial p_z} = -\frac{\sum_N \frac{\partial S_j}{\partial p_z}}{\sum_N \frac{\partial S_j}{\partial p} - \sum_\Omega D_j'}. \tag{A4}$$

Consider the fuel supply function S_i from (8). Due to $p_z > 0$ we can rule out the case $p \leq p_a - p_z$. Then differentiating S_i with respect to p_z and making use of $\sigma_i(p_a, p_z) = C_i'^{-1}(p_a - p_z)$ yields

$$\frac{\partial S_i}{\partial p_z} = \frac{\partial \sigma_i}{\partial p_z} = -\frac{1}{C_i''}. \tag{A5}$$

Substituting (A5) in (A4) we get

$$\frac{\partial P}{\partial z_M^s} = \frac{1}{\sum_N \frac{\partial S_j}{\partial p} - \sum_\Omega D_j'}, \quad \frac{\partial P}{\partial p_z} = \frac{\sum_N \frac{1}{C_j''}}{\sum_N \frac{\partial S_j}{\partial p} - \sum_\Omega D_j'}. \tag{A6}$$

Turning to the properties of the deposit price function, we insert (13) into (14) and take advantage of $\sigma_i(p_a, p_z) = C_i'^{-1}(p_a - p_z)$ to obtain

$$\sum_N \xi_i(p_a) - \sum_N C_j'^{-1}(p_a - p_z) + z_M^s = z_M^d. \tag{A7}$$

Total differentiation of (A7) leads to

$$\sum_N \frac{1}{C_j''}\mathrm{d}p_z + \mathrm{d}z_M^s = \mathrm{d}z_M^d, \tag{A8}$$

which in turn yields the property of the deposit price function

$$\frac{\partial P^z}{\partial z_M^s} = -\frac{1}{\sum_N \frac{1}{C_j''}}. \tag{A9}$$

(A6) and (A9) establish $\frac{\partial P}{\partial p_z} \cdot \frac{\partial P^z}{\partial z_M^s} + \frac{\partial P}{\partial z_M^s} = 0$.

Appendix B: A parametric model

In the sequel, we consider the two countries M and $i \equiv N$ and the parametric functions (23).

Efficiency. Inserting the parametric functions (23) into (1) and (2) we get

$$\alpha - by_M = \alpha - by_N, \tag{B1}$$

$$\alpha - by_M = cx_M + h_M + h_N, \tag{B2}$$

$$\alpha - by_N = cx_N + h_M + h_N. \tag{B3}$$

Solving (B1)-(B3) and $y_M + y_N = x_M + x_N$ with respect to y_M, y_N, x_M and x_N, we obtain

$$y_M^* = y_N^* = x_M^* = x_N^* = \frac{\alpha - h_M - h_N}{b + c}. \tag{B4}$$

Deposit policy. For the parametric functions (4) - (15) turn into

$$D_i(p) = \frac{\alpha - p}{b}, \tag{B5}$$

$$\xi_N(p_a) = \frac{p_a}{c}, \quad \sigma(p_a, p_z) = \frac{p_a - p_z}{c}, \tag{B6}$$

$$K_N(\cdot) = \begin{cases} cx_N & \text{for } x_N \le \frac{p_a - p_z}{c}, \\ cx_N - p_z & \text{for } x_N \ge \frac{p_a - p_z}{c}, \end{cases} \tag{B7}$$

$$S_N(\cdot) = \begin{cases} \frac{p}{c} & \text{for } p \le p_a - p_z, \\ \frac{p_a - p_z}{c} & \text{for } p \in [p_a - p_z, p_a], \\ \frac{p - p_z}{c} & \text{for } p \ge p_a, \end{cases} \tag{B8}$$

$$P(\cdot) = \begin{cases} \frac{bc}{b+2c}\left(\frac{2\alpha}{b} - x_M\right) & \text{for } p \leq p_a - p_z, \\ \frac{b}{2}\left(\frac{2\alpha}{b} - x_M - \frac{p_a - p_z}{c}\right) & \text{for } p \in [p_a - p_z, p_a], \\ \frac{bc}{b+2c}\left(\frac{2\alpha}{b} - x_M + \frac{p_z}{c}\right) & \text{for } p \geq p_a, \end{cases} \tag{B9}$$

$$Z_N^s(p_a, p_z) = \frac{p_z}{c}, \tag{B10}$$

$$P^z(z_M^s, z_M^d) = c(z_M^d - z_M^s), \tag{B11}$$

$$x_M = \frac{p_a}{c} - z_M^s. \tag{B12}$$

Perfect competition. We determine first the allocation of the perfectly competitive markets. For that purpose we disregard the strategic effects, i.e. we set $\frac{\partial P^z}{\partial z_M^d} = \frac{\partial P^z}{\partial z_M^s} = \frac{\partial P}{\partial p_z} \equiv 0$ in (16) and (17), to the effect that these equations simplify to

$$\frac{\partial U_M}{\partial z_M^d} = h_M - p_z = 0, \tag{B13}$$

$$\frac{\partial U_M}{\partial z_M^s} = c\left(\frac{p_a}{c} - z_M^s\right) - p + p_z = 0. \tag{B14}$$

Solving (B13) and (B14) under consideration of $p = \frac{bc}{b+2c}\left(\frac{2\alpha}{b} - x_M + \frac{p_z}{c}\right)$ and $p_z = c(z_M^d - z_M^s)$ yields

$$z_M^s = \frac{bp_a - \alpha c + (h_M + p_a)c}{(b+c)c}, \quad z_M^d = \frac{b(h_M + p_a) - \alpha c + (2h_M + p_a)c}{(b+c)c}. \tag{B15}$$

Inserting (B15), in turn, into the price function $p = \frac{bc}{b+2c}\left(\frac{2\alpha}{b} - x_M + z_M^d - z_M^s\right)$ and setting $p_a = p$, we obtain the equilibrium price and the deposit demand and supply

$$p = \frac{\alpha c + bh_M}{b+c}, \quad z_M^s = \frac{h_M}{c}, \quad z_M^d = \frac{2h_M}{c}.$$

Straightforward calculations yield the allocation, the prices and the welfare listed in Table 1.

Strategic deposit policy. Since we rule out negative prices, we can exclude the case $p \leq p_a - p_z$. In (B9) remain two cases that have to be analyzed. Suppose that $p \geq p_a$. Then we have $P(\cdot) = \frac{bc}{b+2c}\left(\frac{2\alpha}{b} - x_M + \frac{p_z}{c}\right)$ and the first-order conditions (16) and (17) turn into

$$\frac{\partial U_M}{\partial z_M^d} = h_M - (z_M^d - z_M^s)c + (z_M^d - z_M^s)c$$
$$- \left[\frac{\alpha - P(\cdot)}{b} - \left(\frac{p_a}{c} - z_M^s\right)\right] \cdot \frac{bc}{b+2c} = 0, \tag{B16}$$

$$\frac{\partial U_M}{\partial z_M^s} = c\left(\frac{p_a}{c} - z_M^s\right) - P(\cdot) + (z_M^d - z_M^s)c - (z_M^d - z_M^s)c$$
$$- \left[\frac{\alpha - P(\cdot)}{b} - \left(\frac{p_1}{c} - z_M^s\right)\right]\left(-\frac{bc}{b+2c} + \frac{bc}{b+2c}\right) = 0. \tag{B17}$$

Solving (B16) and (B17) yields

$$z_M^s = \frac{-\alpha c(5b+8c) + 8c^2(h_M+p_a) + b^2(h_M+5p_a) + bc(6h_M+13p_a)}{(5b^2+13bc+8c^2)c}, \quad \text{(B18)}$$

$$z_M^d = \frac{-\alpha c(5b+8c) + 4c^2(3h_M+2p_a) + b^2(3h_M+5p_a) + bc(12h_M+13p_a)}{c(5b^2+13bc+8c^2)}. \quad \text{(B19)}$$

Making use of $p_a = p$, (B11), (B12), (B18) and (B19) in the price function $P(\cdot) = \frac{bc}{b+2c}\left(\frac{2\alpha}{b} - x_M + \frac{p_z}{c}\right)$ we obtain

$$p = \frac{\alpha c(5b+8c) + 3bh_M(b+2c)}{5b^2+13bc+8c^2}.$$

The allocation, the prices and the welfare levels are computed and listed in Table 1.

Next, consider the case $p \in [p_1 - p_z, p_a]$ and hence $P(\cdot) = \frac{b}{2}\left(\frac{2\alpha}{b} - x_M - \frac{p_a - p_z}{c}\right)$. The first-order conditions simplify to

$$\frac{\partial U_M}{\partial z_M^d} = h_M - (z_M^d - z_M^s)c + (z_M^d - z_M^s)c - \left[\frac{\alpha - P(\cdot)}{b} - \left(\frac{p_a}{c} - z_M^s\right)\right]\frac{b}{2} = 0, \quad \text{(B20)}$$

$$\begin{aligned}\frac{\partial U_M}{\partial z_M^s} &= c\left(\frac{p_a}{c} - z_M^s\right) - P(\cdot) + (z_M^d - z_M^s)c - (z_M^d - z_M^s)c \\ &\quad - \left[\frac{\alpha - P(\cdot)}{b} - \left(\frac{p_a}{c} - z_M^s\right)\right]\left(-\frac{b}{2} + \frac{b}{2}\right) = 0. \quad \text{(B21)}\end{aligned}$$

Solving (B20) and (B21) we get

$$z_M^s = \frac{\alpha c(8c-b) + bc(2h_M - 7p_a) + b^2 p_a - 8c^2(h_M + p_a)}{(b^2 - 5bc - 8c^2)c}, \quad \text{(B22)}$$

$$z_M^d = \frac{2[\alpha c(4c-b) + b^2 p_a - 3bcp_a - c^2(6h_M + 4p_a)]}{(b^2 - 5bc - 8c^2)c}. \quad \text{(B23)}$$

Inserting (B22) and (B23) into $P(\cdot)$, setting $p \equiv p_a$ and solving for p we obtain

$$p = \frac{c[a(b+8c) + 6bh_M]}{b^2 + 9bc + 8c^2}.$$

The allocation, the prices and the welfare levels are listed in Table 1.

Finally, we compare the welfare levels $u_M^{II} = \frac{\alpha^2 c(5b+8c) - 4\alpha c h_M(5b+8c)h_M - 3h_M^2(b^2-4c^2)}{(5b^2+13bc+8c^2)2c}$ and $u_M^{III} = \frac{\alpha^2(b+8c)^2 - 4\alpha(b+8c)^2 h_M + 12ch_M^2(8c-3b)}{2(b+c)(b+8c)^2}$ and obtain

$$u_M^{II} - u_M^{III} = -\frac{3b^3(b+16c)h_M^2}{2c(b+c)(b+8c)^2(5b+8c)} < 0. \quad \text{(B24)}$$

(B24) proves that it is optimal for the coalition to use the price function $P(\cdot) = \frac{b}{2}\left(\frac{2\alpha}{b} - x_M - \frac{p_a - p_z}{c}\right)$ (which implies $S_N' = 0$).

	perfect competition	deposit strategy ($p \geq p_a, S'_N > 0$)	deposit strategy ($p \in [p_a - p_z, p_a], S'_N = 0$)
column	I	II	III
z_M^d	$\frac{2h_M}{c}$	$\frac{(b+2c)6h_M}{(5b+8c)c}$	$\frac{12h_M}{b+8c}$
z_M^s	$\frac{h_M}{c}$	$\frac{(b+2c)4h_M}{(5b+8c)c}$	$\frac{8h_M}{b+8c}$
p_z	h_M	$\frac{(b+2c)2h_M}{5b+8c}$	$\frac{4h_M c}{b+8c}$
p	$\frac{\alpha c+bh_M}{b+c}$	$\frac{\alpha c(5b+8c)+3bh_M(b+2c)}{5b^2+13bc+8c^2}$	$\frac{c[\alpha(b+8c)+6bh_M]}{b^2+9bc+8c^2}$
y_M	$\frac{\alpha-h_M}{b+c}$	$\frac{5\alpha b+8\alpha c-3bh_M-6ch_M}{5b^2+13bc+8c^2}$	$\frac{\alpha b+8\alpha c-6ch_M}{b^2+9bc+8c^2}$
x_M	$\frac{\alpha-h_M}{b+c}$	$\frac{\alpha c(5b+8c)-(b^2+6bc+8c^2)h_M}{(5b^2+13bc+8c^2)c}$	$\frac{\alpha(b+8c)-2h_M(b+4c)}{(b+c)(b+8c)}$
$x_M - y_M$	0	$-\frac{(b+2c)h_M}{(5b+8c)c}$	$-\frac{2h_M}{b+8c}$
v_M	$\alpha^2 c - (2b+3c)h_M^2$	$\frac{\alpha^2 c(5b+8c)-3(b+2c)^2h_M^2}{2c(5b^2+13bc+8c^2)}$	$\frac{\alpha^2(b+8c)^2-12c(5b+8c)h_M^2}{2(b+c)(b+8c)^2}$
H_M	$\frac{2h_M(h_M-a)}{b+c}$	$\frac{2h_M(5\alpha b+8c)-3h_M(b+2c)}{5b^2+13bc+8c^2}$	$\frac{2h_M[a(b+8c)-6ch_M]}{b^2+9bc+8c^2}$
u_M	$\frac{\alpha^2 c-4\alpha ch_M+(c-2b)h_M^2}{2c(b+c)}$	$\frac{\alpha^2 c(5b+8c)-4\alpha ch_M(5b+8c)h_M-3h_M^2(b^2-4c^2)}{(5b^2+13bc+8c^2)2c}$	$\frac{\alpha^2(b+8c)^2-4\alpha(b+8c)^2h_M+12ch_M^2(8c-3b)}{2(b+c)(b+8c)^2}$

Table 1: Perfect competition and strategic deposit policy: allocation, prices and welfare

	strategic deposit policy $(p \in [p_a - p_z, p_a], S'_N = 0)$	strategic deposit-and-cap policy case A
$z_N^s - \hat{z}_N^s$	$-\frac{2b^2 h_M}{c(b+8c)(5b+8c)} < 0$	$-\frac{4(b+c)h_M}{c(5b+8c)} < 0$
$p_z - \hat{p}_z$	$-\frac{2b^2 h_M}{(b+8c)(5b+8c)} < 0$	$\frac{(3b^2-26b^2c-88bc^2-64c^3)h_M}{(5b+8c)(b^2-5bc-8c^2)}$
$x_M - \hat{x}_M$	$-\frac{bh_M}{(b+c)(b+8c)} < 0$	$\frac{(2b^2+11bc+12c^2)h_M}{c(15b^3+59b^2c+76bc^2+32c^3)} > 0$
$y_M - \hat{y}_M$	$\frac{(b+2c)h_M}{(b+c)(b+8c)} > 0$	$\frac{(11b^2+22bc+8c^2)h_M}{(b+c)(15b^2+44bc+32c^2)} > 0$
$p - \hat{p}$	$-\frac{(b+2c)bh_M}{(b+c)(b+8c)} < 0$	$-\frac{(11b^2+22bc+8c^2)h_M}{(b+c)(15b^2+44bc+32c^2)} < 0$
$u_M - \hat{u}_M$	$\frac{(2b^3+31b^2c+76bc^2+32c^3)h_M^2}{2c(b+c)(b+8c)^2} > 0$	$\frac{(26b^3+69b^2c+56bc^2+16c^3)h_M^2}{2c(15b^3+59b^2c+76bc^2+32c^3)} > 0$
$v_M - \hat{v}_M$	$\frac{(2b^3+35b^2c+116bc^2+96c^3)h_M^2}{2c(b+c)(b+8c)^2} > 0$	$\frac{(26b^3+113b^2c+144bc^2+48c^3)h_M^2}{2c(15b^3+59b^2c+76bc^2+32c^3)} > 0$
$H_M - \hat{H}_M$	$\frac{2(b+2c)h_M^2}{(b+c)(b+8c)} > 0$	$\frac{2(11b^2+22bc+8c^2)h_M^2}{15b^3+59b^2c+76bc^2+32c^3} > 0$

Table 2: Strategic deposit policy and strategic deposit-and-cap policy: deviations from perfect competition

Deposit-and-cap policy. For the parametric functions, we obtain

$$D_i(p) = \frac{\alpha - p}{b}, \tag{C1}$$

$$\xi_N(p_a) = \frac{p_a}{c}, \quad \sigma_N(p_a, p_z) = \frac{p_a - p_z}{c}, \tag{C2}$$

$$K_N(\cdot) = \begin{cases} cx_N & \text{for } x_N \leq \frac{p_a - p_z}{c}, \\ cx_N - p_z & \text{for } x_N \geq \frac{p_a - p_z}{c}, \end{cases} \tag{C3}$$

$$S_N(\cdot) = \begin{cases} \frac{p}{c} & \text{for } p \leq p_a - p_z, \\ \frac{p_a - p_z}{c} & \text{for } p \in [p_a - p_z, p_a], \\ \frac{p - p_z}{c} & \text{for } p \geq p_a, \end{cases} \tag{C4}$$

$$P(\cdot) = \begin{cases} \frac{bc}{b+2c}\left(\frac{2\alpha}{b} - x_M\right) & \text{for } p \leq p_a - p_z, \\ \frac{b}{2}\left(\frac{2\alpha}{b} - x_M - \frac{p_a - p_z}{c}\right) & \text{for } p \in [p_a - p_z, p_a], \\ \frac{bc}{b+2c}\left(\frac{2\alpha}{b} - x_M + \frac{p_z}{c}\right) & \text{for } p \geq p_a, \end{cases} \tag{C5}$$

$$K'_M(\cdot) = \begin{cases} cx_M & \text{for } x_M \leq \frac{p_a - p_z}{c}, \\ \frac{c}{2}\left(x_M + \frac{p_a - p_z}{c}\right) & \text{for } x_M \in \left[\frac{p_a - p_z}{c}, \frac{p_a - p_z}{c}\right], \\ cx_M - p_z & \text{for } x_M \geq \frac{p_a - p_z}{c}, \end{cases} \tag{C6}$$

$$Z_N^s(p_a, p_z) = \frac{p_z}{c}, \tag{C7}$$

$$P^z(z_M^d) = cz_M^d. \tag{C8}$$

Strategic deposit-and-cap policy. Since the deposit price is positive, we again rule out $p < p_a - p_z$ in (C5). In addition, we can exclude the domain $x_M \geq \frac{p_a + p_z}{c}$ of the coalition's marginal cost function since for $x_M \geq \frac{p_a + p_z}{c}$ the coalition would buy non-profitable deposits, which would be costly without reducing the climate damage. There remain the four cases listed in Table 3 that have to be analyzed. In the sequel we describe the procedure for determining x_M and z_M^d in detail for case A. In cases $B - D$ we only report the results.

	$K'_M =$	
	cx_M for $x_M \leq \frac{p_a - p_z}{c}$	$\frac{c}{2}\left(x_M + \frac{p_a - p_z}{c}\right)$ for $x_M \in \left[\frac{p_a - p_z}{c}, \frac{p_a + p_z}{c}\right]$
$P = \frac{bc}{b+2c}\left(\frac{2\alpha}{b} - x_M + \frac{p_z}{c}\right)$, $S'_N > 0$	case A	case C
$P = \frac{b}{2}\left(\frac{2\alpha}{b} - x_M - \frac{p_a - p_z}{c}\right)$, $S'_N = 0$	case B	case D

Table 3: Distinction of four cases

Case A. For $p \geq p_a$ and $x_M \leq \frac{p_a - p_z}{c}$ the first-order condition (26) turns into

$$\frac{\partial U_M}{\partial x_M} = -cx_M + p - h_M - \left(\frac{\alpha - p}{b} - x_M + \frac{h_M}{c}\right) \cdot \left(-\frac{bc}{b+2c}\right) = 0 \tag{C9}$$

and yields the fuel demand

$$X_M(p_a, p_z) = \frac{\alpha c(3b + 4c) - 4c^2 h_M + b^2 p_z + bc(p_z - 2h_M)}{(3b^2 + 7bc + 4c^2)c}. \tag{C10}$$

Next, we make use of the parametric functions in (28) to obtain

$$\begin{aligned} \frac{\partial U_M}{\partial z_M^d} &= h_M - cz_M^d - cz_M^d - \left(\frac{\alpha - p}{b} - X^M\right) \cdot \frac{bc}{b+2c} \\ &\quad + \left[-cX^M + p - h_M - \left(\frac{\alpha - p}{b} - X^M\right) \cdot \left(-\frac{bc}{b+2c}\right)\right] \frac{b^2 + bc}{(3b^2 + 7bc + 4c^2)c} = 0 \end{aligned} \tag{C11}$$

and

$$z^d = \frac{(b + 2c)2h_M}{(5b + 8c)c}.$$

The associated prices, allocations and welfare levels can be computed as

$$\begin{aligned} p_z &= \frac{(b+2c)2h_M}{5b+8c}, \quad p = \frac{\alpha c(15b^2 + 44bc + 32c^2) + (2b^2 + 11bc + 12c^2)2h_M b}{15b^3 + 59b^2 c + 76bc^2 + 32c^3}, \\ y_M &= \frac{(15b^2 + 44bc + 32c^2)\alpha - (2b^2 + 11bc + 12c^2)2h_M}{15b^3 + 59b^2 c + 76bc^2 + 32c^3}, \quad x_M = \frac{(15b^2 + 44bc + 32c^2)\alpha c + 2(b^3 - 2b^2 c - 16bc - 16c^3)h_M}{c(5b + 8c)(3b^2 + 7bc + 4c^2)}, \\ u_M &= \frac{\alpha^2 c(15b^2 + 44bc + 32c^2) - 4\alpha c h_M(15b^2 + 44bc + 32c^2) - 4h_M^2(b^3 + b^2 c - 9bc^2 - 12c^3)}{(15b^3 + 59b^2 c + 76bc^2 + 32c^3)2c}. \end{aligned}$$

In addition, we get

$$x_M - \frac{p_a - p_z}{c} = \frac{4(b^2 - bc - 4c^2)h_M}{(15b^2 + 44bc + 32c^2)c}. \tag{C12}$$

Case B.

$$
\begin{aligned}
z_M^d &= \frac{4h_M}{b+8c}, \quad p_z = \frac{4ch_M}{b+8c}, \quad p = \frac{c[\alpha(b+8c)+6bh_M]}{b^2+9bc+8c^2}, \\
y_M &= \frac{\alpha(b+8c)-6ch_M}{b^2+9bc+8c^2}, \quad x_M = \frac{\alpha(b+8c)-2(b+4c)h_M}{(b+c)(b+8c)}, \\
u_M &= \frac{\alpha^2(b+8c)^2-4a(b+8c)^2h_M+12ch_M^2(8c-3b)}{2(b+c)(b+8c)^2}.
\end{aligned}
$$

We get

$$
x_M - \frac{p_a - p_z}{c} = -\frac{4h_M}{b+8c}. \tag{C13}
$$

Case C.

$$
\begin{aligned}
z_M^d &= \frac{2(b+2c)^2h_M}{8b^2+22bc+12c^2}, \quad p_z = \frac{2(b+2c)^2h_M}{(9b^2+22bc+12c^2)c}, \quad p = \frac{\alpha c(9b^3+31b^2c+34bc^2+12c^3)+b(b^3+13b^2c+26bc^2+12c^3)h_M}{(b+c)^2(9b^2+22bc+12c^2)}, \\
y_M &= \frac{\alpha(9b^3+31b^2c+34bc^2+12c^3)-(b^3+13b^2c+26bc^2+12c^3)h_M}{(b+c)^2(9b^2+22bc+12c^2)}, \\
x_M &= \frac{\alpha c(9b^3+31b^2c+34bc^2+12c^3)+(b^4-36^3c-26b^2c^2-40bc^3-16c^4)h_M}{c(b+c)^2(9b^2+22bc+12c^2)}, \\
u_M &= \frac{\alpha^2c(9b^3+31b^2c+34bc^2+12c^3)^2-4\alpha ch_M(9b^3+31b^2c+34bc^2+12c^3)^2+h_M^2(-5b^7-36b^6c+115b^5c^2+1026b^4c^3)}{2c(b+c)^3(9b^2+22bc+12c^2)^2} \\
&\quad + \frac{h_M^2(2316b^3c^4+2376b^2c^5+1168bc^6+224c^7)}{2c(b+c)^3(9b^2+22bc+12c^2)^2}
\end{aligned}
$$

We get

$$
x_M - \frac{p_a - p_z}{c} = \frac{2(b^3-3b^2c-10bc^2-4c^3)h_M}{c(9b^3+31b^2c+34bc^2+12c^3)}, \tag{C14}
$$

$$
x_M - \frac{p_a + p_z}{c} = -\frac{2(b^3+13b^2c+26bc^2+12c^3)h_M}{c(9b^3+31b^2c+34bc^2+12c^3)} < 0. \tag{C15}
$$

Case D. In that case, it can be shown that the strategic cap satisfies $x_M < \frac{p_a - p_z}{c}$ which contradicts the observation that the domain in case D requires $x_M \in \left[\frac{p_a-p_z}{c}, \frac{p_a+p_z}{c}\right]$ for the marginal cost function K_M'. I.e. there do not exist feasible parameters for case D.

Proof of Proposition 3. Observe that case B is feasible for all parameter constellations, whereas case D is infeasible for all parameter constellations.
Accounting for $b^3 - 3b^2c - 10bc^2 - 4c^3 < 0$ in (C14) proves that case C is not feasible, too. There remain the cases A and B. For case B the equivalence between strategic deposit policy and strategic deposit-and-cap policy is proven in Proposition 4 (see below). For case A we obtain: Comparing the efficient fuel consumption with the fuel consumption in case A yields

$$y_M^* - y_M^A = -\frac{b^2(11h_M + 15h_N) + 22bc(h_M + 2h_N) + 8c^2(h_M + 4h_N)}{15b^3 + 59b^2c + 76bc^2 + 32c^3} < 0,$$

which establishes the qualitative results of Proposition 2(iia). Proposition 2(iib) follows from Table 2.

Proof of Proposition 4. (i) If $b^2 - bc - 4c^2 > 0$, then $x_M > \frac{p_a-p_z}{c}$ in (C12) such that case A is not feasible. In addition, $2bc(b+5) > b(b^2 - bc - 4c^2)$ implies $b^3 - 3b^2c - 10bc^2 - 4c^3 < 0$ and hence $x_M < \frac{p_a-p_z}{c}$ in (C14) such that case C is infeasible, too. The only feasible case is B. The comparison of the allocation and the welfare levels associated to the strategic deposit policy in column III of Table 1 with the strategic deposit-and-cap policy in case B establishes the equivalence.
(ii) If $b^2 - bc - 4c^2 < 0$, then case A is feasible. Since $b^2 - bc - 4c^2 < 0$ implies $b^3 - 3b^2c - 10b^2c - 4c^3 = b(b^2 - bc - 4c^2) - 2b^2c - 10bc < 0$ in (C14), case C is not feasible. Comparing the welfare levels in the cases A and B yields

$$u_M^A - u_M^B = \frac{2b^2(-b^3 - 17b^2c + 64bc^2 + 128c^3)h_M^2}{c(b+8c)^2(15b^3 + 59b^2c + 76bc^2 + 32c^3)}. \tag{C16}$$

Observe that

$$-b^3 - 17b^2c + 64bc^2 + 128c^3 = -(b^2 - bc - 4bc)(b + 18c) + 14c^2(3b + 4c) > 0,$$

which proves that the coalition is better off in case A than in case B. As an implication, the strategic deposit policy and the strategic deposit-and-cap policy are not equivalent and the strategic deposit-and cap policy makes the coalition better off.