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Ambitious Emissions Goal as a Strategic Preemption *†

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Abstract

We model a political game in which a policymaker pledges a domestic emissions goal to choose an instrument between carbon pricing and a quota approach. We show that, although the policymaker is presented with an emissions goal proposed from an international environmental agreement, she/he may pledge a more stringent goal than the proposed level. We define this stringent goal as an "ambitious emissions goal." We show that such a goal preempts the industry's lobby in the choice of an instrument. Finally, our model extensions show that the policymaker conditionally pledges the ambitious emissions goal, depending on how the emissions trading scheme is designed and how an instrument is chosen.

Keywords: Ambitious emissions goal; Lobby; Carbon pricing; Quota; Revenue refund; Rent-seeking

JEL classification: D72; Q58

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1 Introduction

"... Ambition must guide all Member States as they prepare their nationally determined contributions (NDCs)for 2020 to reverse the present trend in which climate change is still running faster than us. It is our duty to reach for more and I count on all of you to raise ambitions so that we can beat back climate change." UN Secretary-General António Guterres, December 15, 2018, from remarks at the conclusion of the COP24 at Katowice, Poland.[1]

The Paris Agreement suggests two targets: (1) keeping the global temperature rise in this century well below 2 °C, and (2) pursuing efforts to limit the temperature increase even further to 1.5 °C.[2] The Paris Agreement allows the contracting parties to set their own emissions goals (NDCs). Then, the double-standard goals may incentivize the contracting parties to aim for an easier goal (1). Against this conjecture, ambitious groups of countries and cities have emerged, such as the High Ambition Coalition, C40 Cities, and Carbon Neutral Cities Alliance. These groups pledge to reduce net carbon emissions by 80–100% by 2050 to limit the temperature increase to 1.5 °C.

Why are they so ambitious? Emissions abatement is costly but constitutes public good. Policymakers may have an incentive to free ride on others' contributions. One possible answer may be attributed to the altruism or benevolence of the policymakers. Additionally, our study presents another strategic reason for such an ambition by focusing on domestic political processes regarding the design of environmental policy. Pechar et al. (2018) present a relationship between policy design and ambition from the perspective of politics. From an economic perspective, our paper supports their assertion that ambitious countries in emissions reductions tend to have carbon pricing policies rather than quantity regulation policies.

We consider the political processes of the choice of an instrument, either carbon pricing (CP, hereafter) or Quota. This basic issue of environmental policy design has been examined in many previous papers. Grossman and Helpman ' s (1994, 1996) common agency model or electoral model is often used to examine lobbying (e.g., Fredriksson, 1997; Aidt, 1998, 2010; Fredriksson and Sterner, 2005; Sterner and Isaksson, 2006; Miyamoto, 2014). These models imply that lobbyists act as principals by spending contributions to policymakers, and policymakers are agents setting rents for lobbyists (cf. Epstein and Nitzan, 2007). Keeping this principal-agent relationship, we simplify the industry's lobbying as a discrete choice: paying a given amount or not.[3]

We also allow for a citizen campaign in a redistribution conflict regarding CP revenue. "Citizens Climate Lobby (CCL)" is a citizen group in the United States that takes action for the CP. More importantly, CCL advocates a simultaneous full transfer of CP revenue to households. Furthermore, on January 17, 2019, 3,419 U.S. economists published a statement on carbon dividends in the Wall Street Journal. Their statement proposes introducing both CP and a basic income for U.S. citizens. In July 2019, more than 1,500 economists also revealed the same statement via the European Association for Environmental and Resource Economists. These actors advocate for such a policy package because a revenue-refunding scheme of environmental taxes that has been introduced varies by country.[4] For example, in Italy, environmental tax revenue is refunded by reducing employment charges, and in the UK, by reducing national insurance contributions. In the UK and Japan, subsidies also exist for clean production technology development financed

[1]All remarks can be found at https://www.un.org/press/en/2018/sgsm19409.doc.htm

[2]IPCC (2018) provides an estimation of global greenhouse effect gases emissions reduction compared to 2010. Target (1) corresponds to a 25% decrease by 2030 and a 100% decrease by 2070, and Target (2) to a 45% decrease and a 100% decrease by 2050.

[3]A traditional framework of Weitzman (1974) has also been employed to examine the choice of an instrument under asymmetric information. For example, Ambec and Coria (2013) extended the model to consider socially preferable instruments in the presence of multiple pollutants. Shinkuma and Sugeta (2016) extended this to the long term. Our model is simplified by employing the basic framework of Weitzman's model. However, we suppose symmetric information among actors along with the political actions of the economic actors to examine their strategic behavior and its economic consequences.

[4]For details, see Withana et al. (2013) and the OECD database (http://www2.oecd.org/ecoinst/queries/).

by emissions tax revenue. These refunding schemes benefit the industry. In contrast, in Sweden and Australia, revenue is mainly distributed to households. Sweden reduces personal income taxes, and Australia not only reduces income taxes but also increases pensions, allowances, and family payments. In British Columbia, Canada, Denmark, Finland, Germany, the Netherlands, and Norway, both firms and households benefit from revenue.[5]

Based on these facts, we set a five-stage political game of environmental policy design with one citizen, one industry, and one policymaker. In the first stage, the policymaker pledges the domestic emissions goal to minimize the social cost. Simultaneously, she/he is required to achieve the amount of emissions proposed in an international environmental agreement (IEA). Subsequently, one instrument—either CP or Quotas—chosen through a costless citizen vote in the second stage. In contrast, in the third stage, the industry can alter its choice through costly lobbying. The choice of an instrument affects the industry's profit and the citizens' welfare. CP imposes emissions abatement costs and payments for emitting carbon on the industry. Quota increases polluters' costs only through abatement costs. The citizen receives a transfer based on the revenue raised by CP, but not when Quota is introduced. Consequently, the citizen votes for CP, whereas the industry has an incentive to lobby for Quota.[6] However, because lobbying is costly, we show the conditions under which the industry lobbies. If CP is consequently introduced, a rent-seeking contest is held in the fourth stage through which the share of revenue refunds between the industry and the citizen is decided. Both the industry and the citizen spend money in the contest to obtain a larger revenue refund. Finally, the industry decides its emissions level in the fifth stage.

With this model, we show that an ambitious emissions goal can be induced through the industry's lobby on the choice of an instrument. We define the ambitious emissions goal as an emissions level that is strictly lower than the emissions goal proposed in the IEA. We find that when the industry's lobbying cost on the choice of an instrument is sufficiently low, the policymaker pledges the ambitious emissions goal for a certain range of the proposed goals. The ambitious emissions goal then preempts the lobby on the choice of an instrument and decreases the social cost in comparison to a case where the domestic emissions goal is as much as the one proposed in the IEA.

Some studies investigate the redistribution related to environmental policy using the rent-seeking contest proposed by Tullock (1980). Dijikstra (1998) examines the timing of the choice of an instrument and the endogenous revenue division in a two-stage, rent-seeking contest between two agents. MacKenzie and Ohndorf (2012) find that in most cases, a non-revenue-raising policy is socially preferred to a revenue-raising policy because of the wasteful lobbying investments needed to obtain the revenue return. MacKenzie (2017) shows that the distributional rent-seeking behavior of polluting firms affects the choice of an instrument under uncertainty regarding the emission abatement cost. Our study follows these studies but considers how the rent-seeking behavior of firms and households affects the political decisions of a policymaker. Our model thus supports the outcome of MacKenzie and Ohndorf (2012) that non-revenue-raising Quota is socially preferred to revenue-raising CP when the lobbying cost is sufficiently low, and the emissions goals are at a medium level. Moreover, the emissions target is given and fixed in Dijikstra (1998) and MacKenzie and Ohndorf (2012). MacKenzie (2017) derives the policy level that maximizes expected net benefits but does not compare the emissions level with the level of IEA. In contrast to these studies, our model distinguishes the proposed goal in an IEA and the domestic national emissions goal. This distinction between international and national emissions

[5]The revenue refund must have indirect effects. A transfer to the industry benefits firms directly and households indirectly by stimulating employment. In contrast, our study assumes that political actors seek only their own direct benefits.

[6]We suppose the industry lobby as lump-sum spending of a given constant cost. By spending this exogenous amount, the industry can change the policymaker's instrument initially chosen for the other. This lobbying can be interpreted as that conducted by a commercial lobbying industry. Groll and Ellis (2014) consider a lobbying market that determines the unit price of lobbying at equilibrium. Our study is a partial equilibrium analysis that focuses only on the emission abatement sector while assuming a given lobbying service price.

goals allows the policymaker to preempt the lobby on the choice of instruments when ambitious emissions targets are set. Thus, our study shows that emissions goal setting plays the role of a policy instrument in the political context.

For further discussion, we extend the model in three ways. First, the domestic political game of one country is extended to that of two symmetric countries. In this model, the sum of the countries' goals must satisfy a given global goal. Even if each country can free-ride on another country's contribution, we find a Nash equilibrium in which both countries pledge the ambitious emissions goals. Second, an emissions trading scheme is considered in international and domestic contexts. We then show that the policymaker conditionally pledges the ambitious domestic emissions goal under the international emissions trading and domestic emissions trading scheme with a grandfathered allowance. However, we find that under the domestic emissions trading scheme with auctioned allowance, the policymaker never pledges the ambitious goal because the social cost curve decreases with respect to the emissions goal. Finally, a probabilistic Tullock contest on the choice of an instrument is considered instead of a deterministic choice of an instrument. Next, the policymaker does not pledge the ambitious goal because the uncertainty leads to an expected social cost that is monotonically decreasing with respect to the emissions goal. According to the discussions, although the policymaker may strategically pledge the ambitious emissions goal, the political process to choose an instrument and a design of the emissions trading scheme affect its occurrence condition.

2 Model

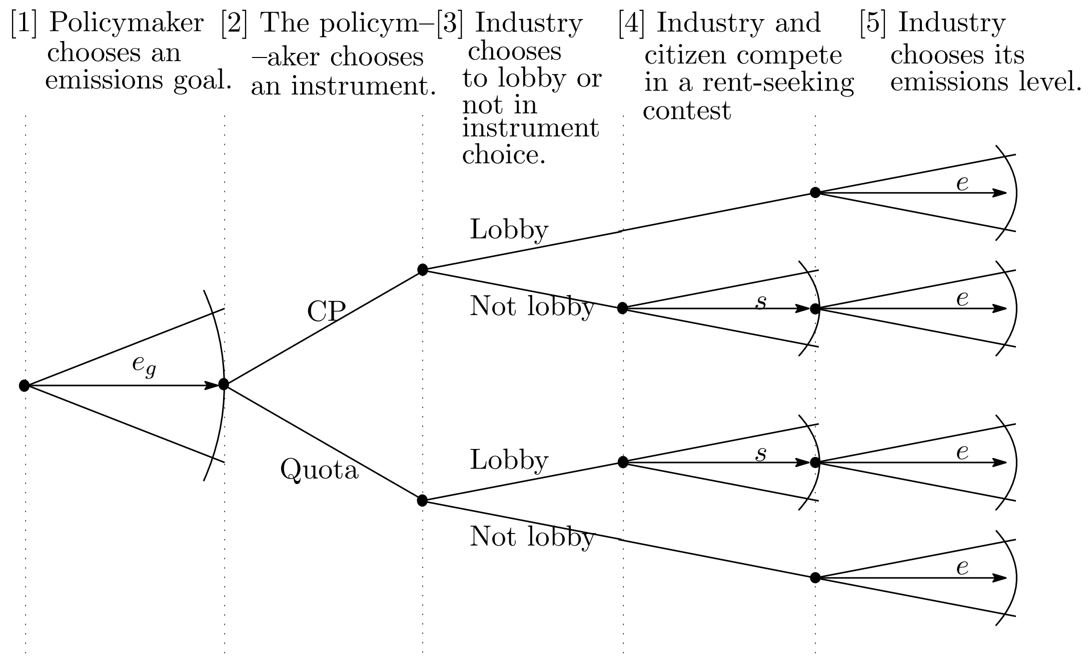

Figure 1: Timings of Decision-making

We model a five-stage choice of an instrument game in a closed country with one citizen, one industry, and one policymaker.[7] Figure 1 describes the timeline of the five-stage game. The

[7]See Section 3 for discussions regarding a two-country game.

policymaker faces an emissions target, e_{int}, set by an IEA.[8] In the first stage, the policymaker pledges the domestic emissions goal of its country, e_g, which does not violate the proposed emissions goal in the IEA, $e_g \leq e_{int}$. If e_g is strictly smaller than e_{int}, we consider e_g as an ambitious goal. In the second stage, based on the citizen's preference, the policymaker initially chooses one instrument, either CP or Quota, to achieve the domestic goal. In the third stage, if the industry does not prefer the instrument chosen in the second stage, the industry lobbies against the instrument. By spending the required amount on lobbying, the industry can change the decision made in the second stage. The fourth stage is void if Quota is introduced in the third stage. However, if CP is introduced in the third stage, public revenue from CP is redistributed to citizens and the industry in the fourth stage. The redistribution share is determined through a standard Tullock contest. Finally, in the fifth stage, the industry chooses its emissions level, e, given the chosen instrument, either Quota or CP. We study this game through backward induction.

2.1 Fifth Stage: Emissions

Industry's Cost

Quota: First, we consider the emissions decision of the industry under Quota. In this study, Quota represents the free allocation of the emission units, e_Q, to the industry.[9] The industry then bears only the costs of reducing emissions. The industry minimizes the emission cost, $c_Q(e) = \frac{c}{2}(\bar{e} - e)^2$, subject to $e \leq e_Q$.[10] Here, $c > 0$ is a marginal abatement cost parameter. $\bar{e} > 0$ is the maximum emissions when the industry does not make any effort to reduce emissions. We assume that $e_Q < \bar{e}$. Then, the industry chooses $e^* = e_Q$. The domestic emissions goal is achieved by setting $e_Q = e_g$. The minimized cost under Quota is given by:

$$c_Q(e_g) = \frac{c}{2}(\bar{e} - e_g)^2. \tag{1}$$

CP: The CP imposes a unit tax rate, $t > 0$, on emissions. The industry chooses its emissions to minimize the cost $c_P(e) = \frac{c}{2}(\bar{e} - e)^2 + te - G$, where G is a lump-sum transfer from the government to the industry. The minimization of $c_P(e)$ yields $e = \bar{e} - t/c \equiv e_P^*$. The policymaker can achieve the emissions goal, e_g, by setting $t = c(\bar{e} - e_g) \equiv t_g$. G is financed by revenues from the emissions tax, with $G = s \cdot t_g e_g$, where $s \in [0, 1]$ is the tax revenue refund rate to the industry. The rest are transferred to the citizen. The minimized cost can be written as

$$c_P(e_g, s) = \frac{c}{2}(\bar{e} - e_g)^2 + (1 - s)c(\bar{e} - e_g)e_g. \tag{2}$$

The first term in (2) is the cost of emissions reductions, which is the same as that in (1). The second term is a net tax payment, $te - G$.

Citizen's Benefit

The citizen suffers from pollution emissions and receives a transfer from the government, if any. Since the two instruments produce identical environmental damage, we omit the damage from

[8] e_{int} can be interpreted as the emissions level proposed to maintain the global average temperature increase much lower than 2 °C above pre-industrial levels. According to IPCC (2018), this goal corresponds to a decline in the 2010 levels of CO_2 emissions by approximately 25% by 2030 and net zero emissions by around 2070 (2065–2080). Moreover, the Paris Agreement ideally aims to limit global warming to 1.5 °C in 2100. This goal corresponds to an approximately 45% reduction in the 2010 global CO2 emissions by 2030, or net zero emissions around 2050 (2045–2055).

[9] Quota in this section is nontradable, whereas domestic and international emissions trading schemes are considered in Section 3.

[10] We can consider a cost function that exhibits non-zero marginal emissions cost at $e = \bar{e}$ such as $c_Q(e) = \frac{c}{2}(\bar{e} - e)^2 + c_0(\bar{e} - e)$ with $c_0 > 0$. However, because our main results do not change in this model, we simply suppose $c_0 = 0$.

the citizen's payoff. Then, the citizen's benefit from each policy can be written as

$$[\text{Quota}] \qquad b_Q = 0; \tag{3}$$
$$[\text{CP}] \qquad b_P(e_g, s) = (1-s)c(\bar{e} - e_g)e_g. \tag{4}$$

Setting aside the environmental damage, the citizen earns nothing under Quota, whereas he or she receives a positive transfer under CP.[11]

2.2 Fourth Stage: Rent-seeking Contest

In the fourth stage, nothing happens if Quota is introduced in the earlier stages. However, if CP is introduced in the third stage, the tax revenue refund rate s is determined through a Tullock contest in the fourth stage.[12] Denote the political contributions of the industry and the citizen by d_I and d_C, respectively. Then, the return rate of the revenue from CP to the industry is $s(d_I, d_C) = \frac{d_I}{d_I + d_C}$.[13]

The industry faces the following updated cost: $C_P(e_g, d_I, d_C) = c_P(e_g, s(d_I, d_C)) + d_I = \frac{c}{2}(\bar{e} - e_g)^2 + \frac{d_C}{d_I + d_C} c(\bar{e} - e_g)e_g + d_I$. The citizen receives the updated benefit, $B_P(e_g, d_I, d_C) = b_P(e_g, s(d_I, d_C)) - d_C = \frac{d_C}{d_I + d_C} c(\bar{e} - e_g)e_g - d_C$.

The non-trivial Nash equilibrium level of spending by each agent in the contest is $d_I^* = d_C^* = \frac{c(\bar{e} - e_g)e_g}{4}$. The numerator is tax revenue. Tax revenue makes the contest competitive by inducing each player to spend. The refund rate, the costs for the industry, and the benefit for the citizen are, respectively, given by

$$s^* = 1/2, \qquad C_P(e_g) = \frac{c}{2}(\bar{e} - e_g)^2 + \frac{3}{4}c(\bar{e} - e_g)e_g, \qquad B_P(e_g) = \frac{1}{4}c(\bar{e} - e_g)e_g. \tag{5}$$

Then, the sum of contributions, $d_I^* + d_C^* = \frac{c(\bar{e} - e_g)e_g}{2}$, represents the social cost of the contest.

From (1) and (5), we have $\Delta C(e_g) = C_P(e_g) - c_Q(e_g) = \frac{3}{4}c(\bar{e} - e_g)e_g > 0$, which means that the industry strictly prefers Quota to CP. This is because the industry incurs a positive net tax payment under CP. From (3) and (4), we have $\Delta B(e_g) = B_P(e_g) - b_Q(e_g) = B_P(e_g) > 0$. In this case, the citizen strictly prefers CP to Quota because the citizen receives a positive transfer under CP. We then obtain the next lemma.

Lemma 1 *The industry prefers Quota, whereas the citizen prefers CP.*

2.3 Second and Third Stages

We consider the second and third stages in order.

Second stage

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[11] We can consider a case in which the industry does not consider G as given. In this case, we obtain $e_P^* = \bar{e} - t(1-s)/c$, which is greater than that in the case in which G is given for the industry. This setting implies that achieving e_g requires higher tax rates: $t_g = c(\bar{e} - e_g)/(1-s)$. The cost and benefit functions of the industry and the citizen are then given as $c_P(e_g) = (c/2)(\bar{e} - e_g)^2 + c(\bar{e} - e_g)e_g$ and $b_P(e_g) = c(\bar{e} - e_g)$, instead of (2) and (4). Because the cost and benefit functions are independent of the share of the revenue refund, s, the industry and the citizen do not pay contributions in a rent-seeking contest, as shown in the fourth stage. This lack of payment results in $s = 1/2$, which does not qualitatively influence the result of the model.

[12] Rent-seeking models in Dijkstra (1998), MacKenzie and Ohndorf (2012), and MacKenzie (2017) suppose that the contest determines players' expected payoffs. Our model inherits their structure but considers deterministic payoffs for simplicity.

[13] We can consider uneven political influences on the tax refund rate, s, between the industry and the citizen, such as $s = \alpha d_I/(\alpha d_I + d_C)$ with $\alpha > 0$ and $\alpha \neq 1$, which may correspond to weights in social welfare for the policymaker, as in the electoral competition model of Grossman and Helpman (1996). This extension does not affect Proposition 1.

In the second stage, the policymaker initially chooses one instrument, either CP or Quota, based on the citizen's preference. Since the citizen prefers CP to Quota from Lemma 1, the policymaker initially chooses CP in the second stage.

Third stage
As mentioned, CP is chosen in the second stage. However, the industry prefers Quota to CP, as shown in Lemma 1. Thus, in the third stage, the industry has an incentive to lobby and change the policymaker's decision.

By spending an exogenous amount $R > 0$ on lobbying activities, the industry can change the policymaker's decision.[14] Industry lobbies if and only if $\Delta C(e_g) > R$.[15] $\Delta C(e_g)$ exhibits an inverted-U curve, with $\Delta C(0) = \Delta C(\bar{e}) = 0$. The trajectory corresponds to the net tax payment, as in a Laffer curve. $\Delta C(e_g)$ is maximized at $e_g = \bar{e}/2$. Let $\bar{R}$ be the maximized value of $\Delta C(e_g)$. Then, we have

$$\bar{R} = \Delta C\left(\frac{\bar{e}}{2}\right) = \frac{3c\bar{e}^2}{16}. \tag{6}$$

When $R \geq \bar{R}$, the industry does not lobby for any e_g. In contrast, when $R < \bar{R}$, two emissions goals exist: $e_g = e_1,\ e_2$, satisfying $\Delta C(e_g) = R$, given by

$$e_1 = \frac{\bar{e}}{2} - \sqrt{\frac{\bar{e}^2}{4} - \frac{4R}{3c}}, \qquad e_2 = \frac{\bar{e}}{2} + \sqrt{\frac{\bar{e}^2}{4} - \frac{4R}{3c}}. \tag{7}$$

The discussion on this point yields Lemma 2.[16]

Lemma 2 *If and only if $R < \bar{R}$, there exist e_1 and e_2 such that for $e_g \in (e_1, e_2)$, the industry lobbies in the third stage.*

If Quota is introduced in the third stage, it is consequential to the industry's lobby. Thus, the industry's cost under Quota is rewritten as:

$$C_Q(e_g, R) = c_Q(e_g) + R = \frac{c}{2}(\bar{e} - e_g)^2 + R. \tag{8}$$

2.4 First Stage: Domestic Emissions Goal

We assume that an emissions goal proposed in an IEA, and e_{int}, is assigned to this country as an emission ceiling.[17] The policymaker chooses the domestic emissions goal, e_g, to minimize the realized social cost subject to $e_g \leq e_{int}$.[18]

[14] We assume that the lobbying cost, R, is given from an external lobbying market, as in Groll and Ellis (2014), which determines a unit price of lobbying services in its equilibrium. The industry is assumed to choose or not to choose lobby as a discrete choice. We will endogenize R by integrating Stages 2 and 3 as a probabilistic Tullock contest between the industry and the citizen in Section 3.

[15] Without loss of generality, we assume that the industry does not lobby when $\Delta C(e_g) = R$.

[16] If the rent-seeking contest is not held, s is exogenously given. For the industry, the cost gap between Quota and CP is then given by the difference between (1) and (2): $\Delta c(e_g, s) = c_P(e_g, s) - c_Q(e_g) = (1-s)c(\bar{e} - e_g) - e_g$. We can easily show that $\Delta c(e_g, s_{pr}) \leq R \Leftrightarrow s \geq 1 - \frac{Re_g}{c}(\bar{e} - e_g)(\equiv s_{pr})$, where s_{pr} is less than 1 for any $R \geq 0$ and $e_g \in [0, \bar{e}]$. By setting $s \geq s_{pr}$, the policymaker can preempt the industry's lobby.

[17] e_{int} is not necessarily the emissions goal optimally distributed to each country in an IEA. For example, the Paris Agreement suggests two levels of emissions goals, as shown in Footnote 8, such as global warming of 1.5 °C and 2 °C in 2100 compared with pre-industrial levels. Whereas the optimal emissions level is still uncertain, the contracting countries share these double standard goals. Our model considers a situation wherein each country is commonly assigned a lax goal but can voluntarily choose a stricter goal.

[18] In reality, the choice of an instrument requires legislative processes and cannot ignore the citizens' opinions. However, the emissions goal tends to be determined only through discussions with the cabinet committee or limited experts and can be declared to the public without sufficient national consensus. Therefore, we assume that, in the first stage, the policymaker sets the emissions goal to minimize the social costs, but in the second and third stages, chooses and introduces the instrument by considering the citizen's voting and the industry's lobbying.

We derive the social cost. If Quota is introduced, the social cost is given by $SC_Q(e_g, R) \equiv C_Q(e_g, R) - b_Q(e_g) = \frac{c}{2}(\bar{e} - e_g)^2 + R$ from (3) and (8). If CP is introduced, the social cost is given by $SC_P(e_g) \equiv C_P(e_g) - B_P(e_g) = \frac{c\bar{e}}{2}(\bar{e} - e_g)$ from (5). Because Quota is introduced if $R < \bar{R}$ and $e_g \in (e_1, e_2)$ from Lemma 2, the social cost is given by

$$SC(e_g, R) = \begin{cases} \frac{c}{2}(\bar{e} - e_g)^2 + R \equiv SC_Q(e_g, R), & \text{if } R < \bar{R} \text{ and } e_g \in (e_1, e_2) \\ \frac{c\bar{e}}{2}(\bar{e} - e_g) \equiv SC_P(e_g), & \text{otherwise.} \end{cases} \tag{9}$$

We examine the emissions goal, e_g, that minimizes the social cost (9) subject to $e_g \leq e_{int}$, taking R and e_{int} as given. If the policymaker chooses e_g that is strictly smaller than e_{int}, we call it an "ambitious emissions goal."

Figure 2 shows the graph of $SC(e_g, R)$ given R. Depending on R, three cases must be considered. First, when $R \geq \bar{R}$, CP is introduced for all e_g. Thus, we have $SC(e_g, R) = \frac{c\bar{e}}{2}(\bar{e} - e_g)(\equiv SC_P(e_g))$ (see Figure 2 (a)). Because $SC(e_g, R)$ is a decreasing function of $e_g \in [0, \bar{e}]$, the policymaker sets $e_g = e_{int}$ to minimize the social cost for all $e_{int} \leq \bar{e}$.

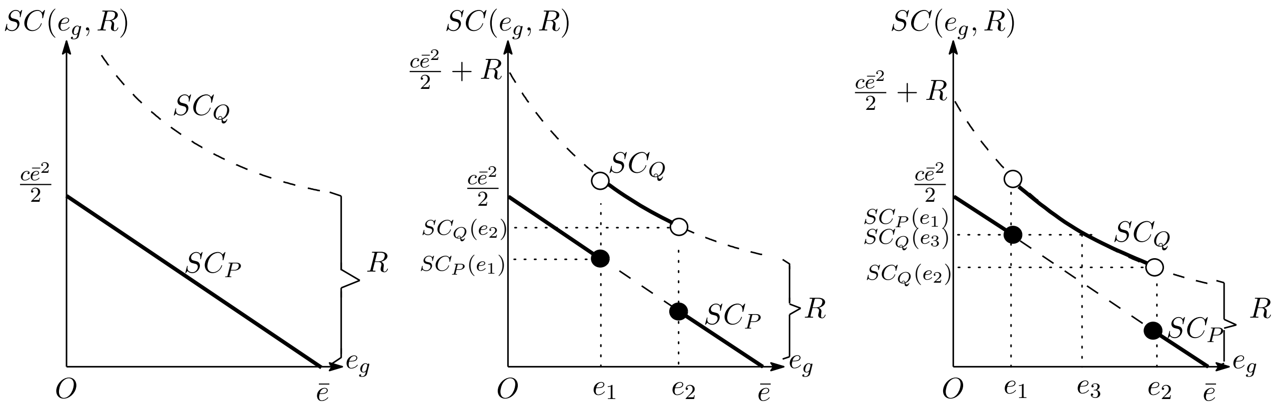


Figure 2: Social Costs

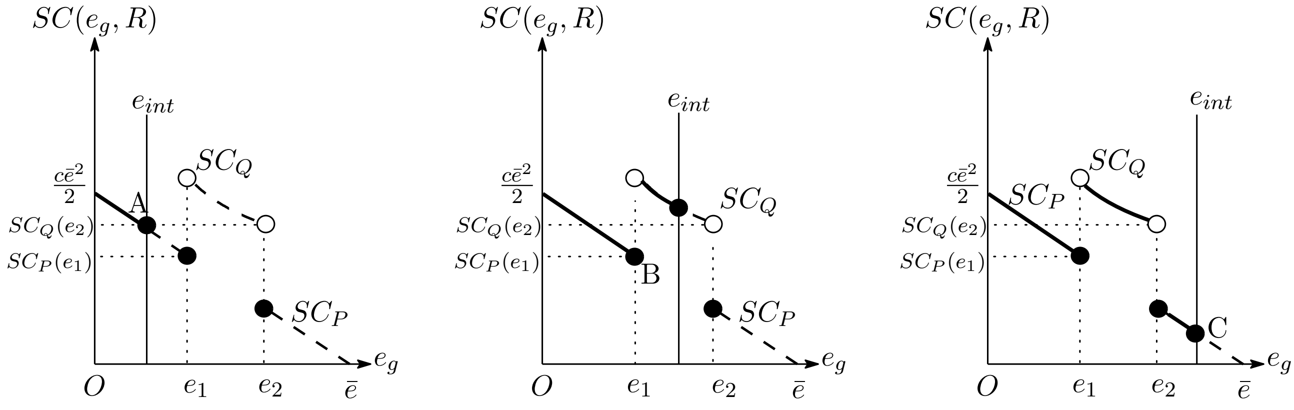
Next, we assume $R < \bar{R}$. From Lemma 2, we know that there exist e_1 and e_2 such that for $e_g \in (e_1, e_2)$, the industry lobbies. To consider the second and third cases, let us define R' by $SC_P(e_1) = SC_Q(e_2, R')$. We can show that $0 < R' < \bar{R}$.[19] Because $SC_Q(e_g, R)$ increases with R, we have $SC_P(e_1) < SC_Q(e_2, R)$ for $R \in [R', \bar{R})$, as shown in Figure 2 (b). In this case, if $e_{int} \leq e_1$, the social cost is minimized by setting $e_g = e_{int}$ (see point A in Figure 3 (a)). Similarly, if $e_{int} \geq e_2$, the social cost is minimized by setting $e_g = e_{int}$ (see point C in Figure 3 (c)). However, if $e_{int} \in (e_1, e_2)$, the policymaker can minimize the social cost subject to $e_g \leq e_{int}$ by setting $e_g = e_1$ (see point B in Figure 3 (b)). This emission goal is strictly smaller than e_{int}, which is an ambitious emissions goal.

Finally, we consider the case of $R < R'$. Because $SC_P(e_1) > SC_Q(e_2, R)$ holds for $R < R'$, there exists a $e_3 \in (e_1, e_2)$ that satisfies $SC_P(e_1) = SC_Q(e_3, R)$. This emission level is shown in Figure 2 (c) and is given by

$$e_3 = \bar{e} - \sqrt{\frac{\bar{e}^2}{2} - 2\frac{R}{c} + \bar{e}\sqrt{\frac{\bar{e}^2}{4} - \frac{4}{3}\frac{R}{c}}}. \tag{10}$$

The discussion used in the second case can be applied to this case. Thus, we have $e_g = e_{int}$ for

[19]Using (7) and (9), we derive R' as $R' = c\bar{e}^2\left(-6 + \sqrt{38 + \frac{1}{4}}\right) \approx 0.185\, c\bar{e}^2 < 0.188 c\bar{e}^2 \approx \bar{R}$.



(a) $e_{int} \leq e_1$ (b) $e_1 < e_{int} < e_2$ (c) $e_{int} \geq e_2$

Figure 3: Social Cost Minimization under $R' \leq R < \bar{R}$

$e_{int} \in [0, e_1]$ or $e_{int} > e_3$. However, we have $e_g = e_1 < e_{int}$ for $e_{int} \in (e_1, e_3]$. The policymaker sets an ambitious emission goal for a medium value of e_{int}.

The discussion thus far yields a plan for domestic emissions goals based on the proposed goals in the IEA and Proposition 1.[20]

$$e_g = f(e_{int}) = \begin{cases} e_{int} \quad \text{for } e_{int} \in [0, \bar{e}] \quad \text{if } R \geq \bar{R}, \\ \left.\begin{array}{ll} e_{int} & \text{for } e_{int} \in [0, e_1] \\ e_1 < e_{int} & \text{for } e_{int} \in (e_1, e_2) \\ e_{int} & \text{for } e_{int} \in [e_2, \bar{e}] \end{array}\right\} \text{if } R' \leq R < \bar{R}, \\ \left.\begin{array}{ll} e_{int} & \text{for } e_{int} \in [0, e_1] \\ e_1 < e_{int} & \text{for } e_{int} \in (e_1, e_3] \\ e_{int} & \text{for } e_{int} \in (e_3, \bar{e}] \end{array}\right\} \text{if } R < R'. \end{cases} \tag{11}$$

Proposition 1 *The policymaker pledges an ambitious emissions goal, $e_g = e_1 < e_{int}$, if and only if $R' \leq R < \bar{R}$ and $e_{int} \in (e_1, e_2]$, or $R < R'$ and $e_{int} \in (e_1, e_3]$.*

From the discussions so far, Proposition 2 is obtained.

Proposition 2
1. The ambitious emissions goal is pledged only if Quota is introduced under $e_g = e_{int}$.
2. The ambitious emissions goal of Proposition 1 realizes the introduction of CP in equilibrium.

From Propositions 1 and 2, the ambitious emissions goal can be interpreted as a strategy of the policymaker that preempts the industry's lobby in the subsequent stages. However, note that Proposition 2.1 is only a necessary condition because a range of e_{int} remains where the ambitious emissions goal cannot reduce the social cost. If $R < R'$ and $e_{int} \in (e_3, e_2)$, we have $SC_P(e_1) > SC_Q(e_int)$. Then, the policymaker cannot disincentivize the industry to lobby in this range with the ambitious emissions goal.

[20] As mentioned in Footnote 13, we could consider an uneven weight on the revenue refund contest with $s = \alpha d_I/(\alpha d_I + d_C)$ with $\alpha > 0$ and $\alpha \neq 1$. Even in this setting, $\bar{R}$, R', e_1, e_2, and e_3 can be derived. Then, we have $R' < \bar{R}$ and $e_1 \leq e_3 \leq e_2$ when $R < R'$ as long as α is strictly positive and finite.

Consequently, we have the social cost in the equilibrium as

$$SC(e_g, R) = \begin{cases} SC_P(e_{int}) \quad \text{for } e_{int} \in [0, \bar{e}] \quad \text{if } R \geq \bar{R}, \\ \left.\begin{array}{ll} SC_P(e_{int}) & \text{for } e_{int} \in [0, e_1] \\ SC_P(e_1) & \text{for } e_{int} \in (e_1, e_2) \\ SC_P(e_{int}) & \text{for } e_{int} \in [e_2, \bar{e}] \end{array}\right\} \text{if } R' \leq R < \bar{R}, \\ \left.\begin{array}{ll} SC_P(e_{int}) & \text{for } e_{int} \in [0, e_1] \\ SC_P(e_1) & \text{for } e_{int} \in (e_1, e_3] \\ SC_Q(e_{int}, R) & \text{for } e_{int} \in (e_3, e_2) \\ SC_P(e_{int}) & \text{for } e_{int} \in [e_2, \bar{e}] \end{array}\right\} \text{if } R < R'. \end{cases} \tag{12}$$

2.5 Socially Preferred Instrument and Emissions Goal

We reexamine the social cost minimization problem as $\min_{e_g} \ S = \min\{SC_P(e_g), SC_Q(e_g, R)\}$ subject to $e_g \leq e_{int}$. This problem implies the emissions goal that the policymaker pledges if the instrument that minimizes the social cost is introduced regardless of the political actions in the subsequent stages. We call this solution a socially preferred policy.

We derive the conditions where $SC_P(e_g) > SC_Q(e_g, R)$ holds. From (9), this inequality can be rewritten as $R < \frac{c}{2}(\bar{e} - e_g)e_g$. The right-hand side of the inequality comes from the total amount spent on contributions in a rent-seeking contest in the fourth stage, $d_I^* + d_C^* = \frac{c}{2}(\bar{e} - e_g)e_g$. That is, Quota is socially preferred to CP if and only if the contributions in the contest are greater than the lobbying cost.

In addition, the right-hand side of $R < \frac{c}{2}(\bar{e} - e_g)e_g$ describes an inverted-U curve with respect to e_g with a maximal value at $\frac{c\bar{e}^2}{8}$. There is a certain range of e_g, where $SC_P(e_g) > SC_Q(e_g, R)$ for $e_g \in (e_4, e_5)$ if $R < \frac{c\bar{e}^2}{8}$. By solving $R = \frac{c}{2}(\bar{e} - e_g)e_g$ with respect to e_g, we obtain

$$e_4 = \frac{\bar{e}}{2} - \sqrt{\frac{\bar{e}^2}{4} - \frac{2R}{c}}, \qquad e_5 = \frac{\bar{e}}{2} + \sqrt{\frac{\bar{e}^2}{4} - \frac{2R}{c}}. \tag{13}$$

Figure 4 illustrates a trajectory of the social cost S when $R < \frac{c\bar{e}^2}{8}$. Note that $R' \approx 0.185c\bar{e}^2 > \frac{c\bar{e}^2}{8}$. Together with footnote 19, we have $\frac{c\bar{e}^2}{8} < R' < \bar{R}$. In addition, we can derive $e_1 < e_3 < e_4 < e_5 < e_2$ when $R < \frac{c\bar{e}^2}{8}$. Both social cost curves, $SC_P(e_g)$ and $SC_Q(e_g, R)$, are decreasing for $e_g \in [0, \bar{e}]$. Therefore, $e_g = e_{int}$ minimizes S for all $R > 0$ and $e_{int} \in [0, \bar{e}]$. The minimized social cost, S, is given by

$$S = \begin{cases} SC_P(e_{int}) \quad \text{for } e_{int} \in [0, \bar{e}] \quad \text{if } R > \frac{c\bar{e},^2}{8}, \\ \left.\begin{array}{ll} SC_P(e_{int}) & \text{for } e_{int} \in [0, e_4] \\ SC_Q(e_{int}, R) & \text{for } e_{int} \in (e_4, e_5) \\ SC_P(e_{int}) & \text{for } e_{int} \in [e_5, \bar{e}]. \end{array}\right\} \text{if } R \leq \frac{c\bar{e}^2}{8} \end{cases} \tag{14}$$

Discussions so far yields the following.

Proposition 3 *Quota is socially preferred to CP if and only if $R \leq \frac{c\bar{e}^2}{8}$ and $e_{int} \in (e_4, e_5)$. Otherwise, CP is socially preferred.*

From (12) and (14), we find differences between results in the equilibrium and in the socially preferred policy outcomes. First, we look at the cases where the policymaker pledges the ambitious emissions goal to minimize the social cost in the equilibrium in (12). The ambitious goal preempts the industry's lobby emerging in the third stage, which provides $SC_P(e_1) < SC_Q(e_{int})$. However, the ambitious goal does not correspond to the socially preferred outcome, and we have

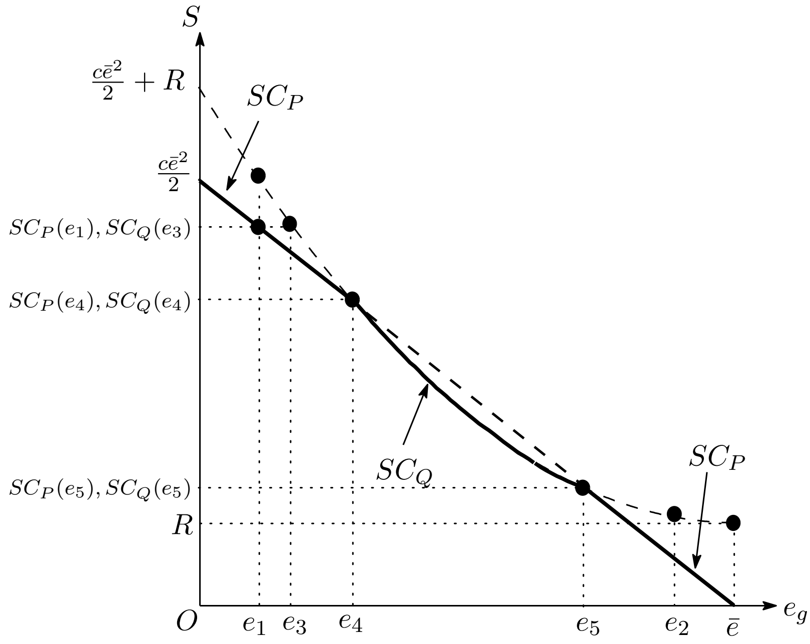


Figure 4: Social cost, S, when $R < \frac{c\bar{e}^2}{8}$

$SC_P(e_1) > S = SC_P(e_{int})$. Therefore, although the ambitious goal may lower the social cost in equilibrium, this is not socially preferred.

Second, if $\frac{c\bar{e}^2}{8} < R < R'$ and $e_{int} \in (e_3, e_2)$, because the ambitious emissions goal cannot reduce the social cost, the policymaker pledges $e_g = e_{int}$ in the equilibrium. Although this goal corresponds to the socially preferred goal, the policymaker cannot introduce the socially preferred instrument because of political actions. Thus, the social cost in the equilibrium is greater than that in the socially preferred outcome, that is, $SC_Q(e_{int}, R) > S = SC_P(e_{int})$.

Finally, suppose that $R < \frac{c\bar{e}^2}{8}$ and $e_{int} \in (e_3, e_2)$. In this case, for the range of $e_{int} \in (e_4, e_5)$, both the instrument and the emissions goal in the equilibrium correspond to those in the socially preferred case (Quota with $e_g = e_{int}$). Although the policymaker chooses CP in the second stage, the industry's lobby corrects this choice to the socially preferred one. In contrast, for $e_{int} \in (e_3, e_4], [e_5, e_2)$, the CP of the socially preferred CP cannot be introduced in the equilibrium, which leads to $SC_Q(e_{int}, R) > S = SC_P(e_{int})$.

3 Discussions

3.1 A Two-country Game

We extend the domestic game in the previous section to a Nash game with two symmetric countries that pledge their emissions goals. We refer to these two identical countries as countries A and B and define e_{gA} and e_{gB} as domestic emission goals in each country. The total amount of emissions from the two countries is then given as $E = e_A + e_B$. Let E_g be the world's total emission goal, such as the international emissions goal under the Paris Agreement. Then, the world goal satisfies $E_g \geq e_{gA} + e_{gB}$. To distinguish the countries, we add subscripts A and B to all domestic variables shown in Section 2. Thus, we have $\bar{e}_A$ and $\bar{e}_B$ as the emission levels when both countries do not make any effort to reduce emissions. If $e_A = \bar{e}_A$ and $e_B = \bar{e}_B$, we obtain the maximum total amount of emission as $E = \bar{E}$, where $\bar{E} \equiv \bar{e}_A + \bar{e}_B = 2\bar{e_A} = 2\bar{e}_B$.

For this section, we focus only on a case subsequently shown.

Assumption 1 *The two symmetric countries aim to achieve half the amount of $\bar{E}$ under an*

IEA, that is, $E_g = \bar{E}/2$.

This assumption implies that $E_g = \bar{e}_A = \bar{e}_B$. Thus, we consider a game where the policymaker in each country pledges its emissions goal, taking the world emissions goal, E_g, and the emissions goal of the other country as given.

Let us consider the emissions goal of country A. The policymaker in country A minimizes its country's social cost in (9) by taking E_g and e_{gB} as given. The two symmetric countries face the same lobbying cost $R \equiv R_A = R_B$. By substituting $E_g - e_{gB}$ into e_{int} of (11), the reaction functions for country A are given as follows:

$$e_{gA} = f_A(e_{gB}) = \begin{cases} E - e_{gB} & \text{for } e_{gB} \in [0, E] \qquad \text{if } R \geq \bar{R}, \\ \\ \left.\begin{array}{ll} E - e_{gB} & \text{for } e_{gB} \in [0, e_1) \\ e_{1A} < E - e_{gB} & \text{for } e_{gB} \in [e_1, e_2) \\ E - e_{gB} & \text{for } e_{gB} \in [e_2, E] \end{array}\right\} & \text{if } R' \leq R < \bar{R}, \\ \\ \left.\begin{array}{ll} E - e_{gB} & \text{for } e_{gB} \in [0, E - e_3) \\ e_{1A} < E - e_{gB} & \text{for } e_{gB} \in [E - e_3, e_2) \\ E - e_{gB} & \text{for } e_{gB} \in [e_2, E] \end{array}\right\} & \text{if } R < R'. \end{cases} \tag{15}$$

The symmetric reaction function is held for country B.

We derive the Nash equilibrium in each case. First, when $R \geq \bar{R}$, no lobby occurs on the choice of instrument.[21] The emissions goal in the two countries then satisfies $e_{gi} = E - e_{gj}$ for all $e_{gj} \in [0, E]$ and for $i, j = A, B$ and $i \neq j$. Figure 5 (a) depicts the reaction functions when $R > \bar{R}$. The Nash equilibrium set thus satisfies $E_g = e_{gA} + e_{gB}$, as shown in Figure 5 (a').

Second, when $R < \bar{R}$, the industry in country A lobbies for $e_{gB} \in [e_1, e_2]$. However, the policymaker can preempt the lobby and introduce CP by pledging the ambitious emissions goal at $e_{gA} = e_1$ for $e_{gB} \in [e_1, e_2]$. Otherwise, country A pledges non-ambitious goals at $e_{gA} = E_g - e_{gB}$ for $e_{gB} \in [0, e_1)$ and $(e_2, E_g]$. The symmetric reactions are derived for country B. These are depicted in Figure 5 (b), (c), and (d). In each case, there are ranges where the policymaker in each country pledges the ambitious emission goal. Consequently, we obtain multiple Nash equilibria, as shown in Figure 5 (b)', (c), and (d)', respectively. From these figures, a set of ambitious emissions goals in the two countries, $(e_{gA}, e_{gB}) = (e_1, e_1)$ is a Nash equilibrium strategy set if $R' \leq R < \bar{R}$.[22] This is illustrated as point N in Figure 5 (b)'. This Nash equilibrium set of emissions goals can be regarded as an ambitious set because $e_{gA} + e_{gB} = 2e_1 < E_g$. In contrast, this ambitious Nash equilibrium strategy set is not unique. The discussion for this case yields the following:

Proposition 4 *A set of ambitious emissions goals pledged in both countries,* $(e_{gA}, e_{gB}) = (e_1, e_1)$ *is a Nash equilibrium if* $R' \leq R < \bar{R}$ *(Point N in Figure 5 (b')).*

3.2 Emissions Trading Schemes

We have considered Quota as a simple emission ceiling in Section 2. Here, we discuss the emissions trading scheme in international and domestic schemes. In the international scheme, we add the international framework to the domestic political game shown in Section 2. In the domestic scheme, we consider two ways of allocating the emissions allowance: emissions allowance is either grandfathered or partly auctioned. We also divide the case of a partial auction of the emissions allowance into two as the revenue from auction is returned to economic agents, or not.

[21] $\bar{R}$ in (15) is given in (6) with $\bar{e}_A$.

[22] R' is a lobbying cost that satisfies $SC^i_P(e_1) = SC^i_Q(e_2, R)$ for $i = \{A, B\}$.

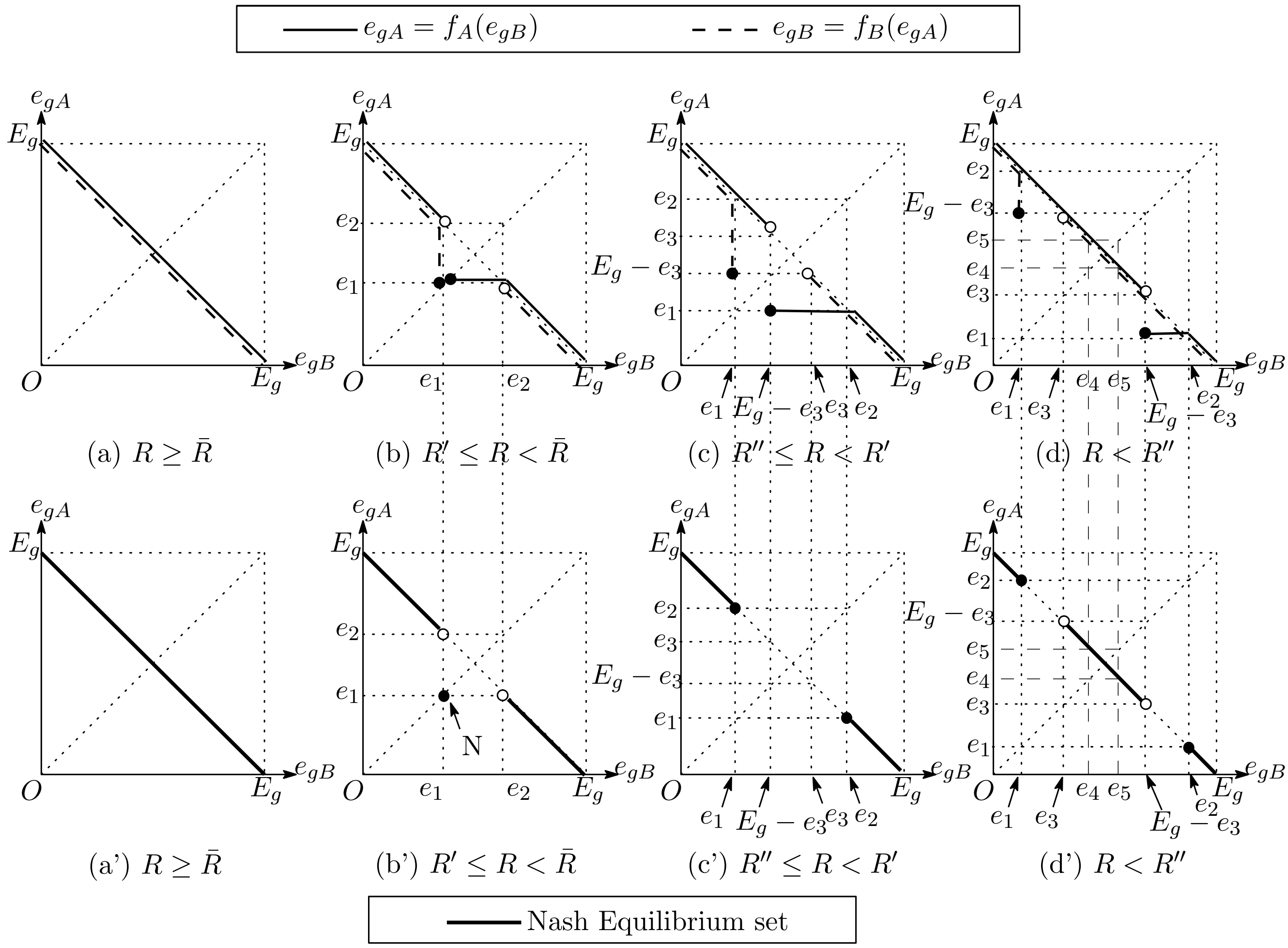


Figure 5: Nash emissions goal strategy set

3.2.1 International Emissions Trading Scheme

We examine an international emissions trading scheme. We suppose a small open economy of a country to the emissions trading market with one citizen, one industry, and one policymaker. The international price of emissions allowances (p) and the amount of allowance to the industry (e_{ET}) are exogenous. The policymaker in this model introduces either Quota or CP as in Section 2, in addition to the international emissions trading scheme.

In the fifth stage, the industry faces the emissions cost of $c_Q(e) = \frac{c}{2}(\bar{e} - e)^2 + p(e - e_{ET})$ if Quota ($e \leq e_Q$) is introduced. Then, taking e_{ET}, p, and e_Q as given, the industry minimizes its cost by $e^* = \min\{\bar{e} - p/c, e_Q\}$. As in Section 2, the policymaker sets its quota at an emissions goal, $e_g = e_Q$. The current model corresponds to the model in Section 2 if $p = 0$. If $e_g > \bar{e} - p/c$, the emissions goal is achieved without a domestic environmental policy, that is, $e^* < e_g$. We focus on the case of $e_g \leq \bar{e} - p/c$ to examine how domestic environmental policy is designed.

Assumption 2 *Given p, an emission goal satisfies* $0 \leq e_g \leq \bar{e} - p/c$.

As the policymaker chooses the emissions goal that satisfies $e_g \leq e_{int}$. We can assume that $e_{int} \leq \bar{e} - p/c$ instead of Assumption 2. Consequently, the industry's minimized cost is

$$c_Q(e_g) = \frac{c}{2}(\bar{e} - e_g)^2 + p(e_g - e_{ET}). \tag{16}$$

Then, the citizen does not receive any benefit from Quota: $b_Q(e_g) = 0$.

Next, if CP is introduced, in the fifth stage, the industry minimizes the emissions cost given by $c_P(e) = \frac{c}{2}(\bar{e}-e)^2+t\cdot e-G+p(e-e_{ET})$. G is a lump-sum transfer from the government, and t is the unit tax rate on emissions. Given e_{ET}, p, G, and t, the emissions level becomes $e^* = \bar{e}-(t+p)/c$. Similar to the case of Quota, this model corresponds to the model of Section 2 if $p = 0$. To achieve the emissions target, e_g, the policymaker chooses the tax rate at $t_g = c(\bar{e}-e_g)-p$.[23] Supposing that $G = st_g e_g$ with s as the refund rate of the tax revenues to the industry, we obtain the minimized cost as $c_P(e_g) = \frac{c}{2}(\bar{e}-e_g)^2 + (1-s)\{c(\bar{e}-e_g)-p\}e_g + p(e_g - e_{ET})$. The citizen then receives a share $(1-s)$ of the tax revenues: $b_p(e_g) = (1-s)\{c(\bar{e}-e_g)-p\}e_g$.

In the third stage, the industry lobbies if and only if $R < \Delta C(e_g)$, where $\Delta C(e_g) = C_P(e_g) - c_Q(e_g) = \frac{3}{4}c\{(\bar{e}-e_g)-p\}e_g$. In contrast to the models in Section 3.2.2, the cost gap between CP and Quota draws an inverted-U curve with respect to e_g in $e_g \in [0, \bar{e}]$. This curve is distorted to the left by p, in contrast to that in Section 2. Thus, we obtain the set of conditions where the industry lobbies as $R < \bar{R}$ and $e_g \in (e_1, e_2)$, where $\bar{R} = \frac{3}{16c}(c\bar{e}-p)^2$, $e_1 = \frac{(c\bar{e}-p)-\sqrt{(c\bar{e}-p)^2-\frac{16cR}{3}}}{2c}$, and $e_2 = \frac{(c\bar{e}-p)+\sqrt{(c\bar{e}-p)^2-\frac{16cR}{3}}}{2c}$. By using these expressions, the social cost is given by:

$$SC(e_g, R) = \begin{cases} \frac{c}{2}(\bar{e}-e_g)^2 + p(e_g - e_{ET}) + R \equiv SC_Q(e_g, R), & \text{if } R < \bar{R} \text{ and } e_g \in (e_1, e_2) \\ \frac{c}{2}(\bar{e}-e_g)^2 + \frac{1}{2}\{c(\bar{e}-e_g)-p\}e_g + p(e_g - e_{ET}) \equiv SC_P(e_g), & \text{otherwise.} \end{cases} \quad (17)$$

From (17) and Assumption 2, the social cost functions, $SC_P(e_g)$ and $SC_Q(e_g, R)$, are decreasing in e_g. We have a discontinuous change at e_1 and e_2 if and only if $R < \bar{R}$. Moreover, we have R' that satisfies $SC_P(e_1) = SC_Q(e_2, R')$ at $R' = \frac{(c\bar{e}-p)^2}{c}(-6+\sqrt{38+(1/4)})$. This implies the existence of e_3 in (e_1, e_2) when $R < R'$. Therefore, in the presence of the international emissions trading scheme, the ambitious emissions goal can appear as well as in Section 2.

3.2.2 Domestic Emissions Trading Scheme: Grandfathered Allowance

We assume two polluters, firm a and b, in the industry to examine a domestic emissions trading scheme. These firms have their marginal emissions cost parameter (c^i) and maximal emissions levels when they do not make any abatement effort ($\bar{e}^i$) for $i = a, b$.

In the fifth stage of this model, if Quota is introduced, the initial emissions allowance (e^i_{ET}) is grandfathered to each firm. Then, the total amount of emissions equals the emissions ceiling (e_Q), that is, $e_Q = e^a + e^b$. We also assume that $e_Q = e^a_{ET} + e^b_{ET}$.

Thus, the emissions cost of each firm is $c^i_Q = \frac{c^i}{2}(\bar{e}^i - e^i) + p(e^i - e^i_{ET})$ for $i = a, b$, where p is the price of emissions allowance. Then, the emissions level realized is $e^i = \bar{e}^i - \frac{p}{c^i}$. The market equilibrium condition, $e_Q = e^a + e^b$, gives the equilibrium price as $p^* = \{(\bar{e}^a + \bar{e}^b) - e_Q\}\frac{c^a \cdot c^b}{c^a + c^b}$. Simultaneously, the equilibrium emission level is $e^{i*} = \frac{(c^i - c^j)\bar{e}^i + c^j e_Q}{c^a + c^b}$ for $i, j = \{a, b\}$ and $i \neq j$.

The minimized emissions cost is[24]

$$c^i_Q(e_Q) = \frac{c^a \cdot c^b\{(\bar{e}^a + \bar{e}^b) - e_Q\}}{(c^a + c^b)^2}\left\{\frac{c^j}{2}\{(\bar{e}^a + \bar{e}^b) - e_Q\} + (c^i - c^j)\bar{e} + c^j e_Q - (c^a + c^b)e^i_{ET}\right\}. \quad (18)$$

Then, the total cost of the industry is given by

$$\sum_{i=a,b} \frac{c^a \cdot c^b}{2(c^a + c^b)}\{(\bar{e}^a + \bar{e}^b) - e_Q\}^2. \quad (19)$$

By defining $c = \frac{c^a \cdot c^b}{c^a + c^b}$ and $\bar{e} = \bar{e}^a + \bar{e}^b$, we can derive $c_Q(e_Q)$ as shown in (1). Thus, we can also present analogous results from this model as those in Section 2.

[23]We have $t_g \geq 0$ from Assumption 2.

[24]We put aside a coalition formation in the industry and simply add the emissions costs of the two firms.

3.2.3 Domestic Emissions Trading Scheme: Auctioned Allowance

We suppose a partially auctioned allowance by simplifying Phase III of the European Union Emissions Trading Scheme (EU-ETS). According to *EU ETS Handbook* by European Union (2015), the allowance is freely allocated based on a benchmark level. In addition, the emitters can obtain further allowances via an auction. Thus, the auction is partial to an emissions goal. The price is uniformly determined from the submitted bids to clear the total amount for auction. The revenues from auctioning allowances are used not to directly compensate firms and households but to combat climate change as public funds.

Based on this framework, we consider an economy with one citizen, one industry, and one policymaker. If Quota is introduced, the policymaker freely allocates a part of the quota to the industry as allowance, $e_{ET} \leq e_Q$. The residual of quota, $e_S = e_Q - e_{ET}$, is auctioned by the polluting industry. The auctioned price (p) is determined at a uniform level to clear the supplied amount of auctioned allowances.[25] In contrast to the grandfathered tradable emissions allowances, the current framework implies that the government earns revenues from issuing the auctioned allowance. We assume that the government maintains revenues and is counted as a benefit at the first stage.[26]

The emissions cost of the industry is given by $c_Q(e) = \frac{c}{2}(\bar{e}-e)^2+p(e-e_{ET})$. The revenues from auctioning allowances are not returned. We suppose that the auctioned price, which clears the residual amount of allowance, is competitively determined at $p^* = \frac{d}{de}[\frac{c}{2}(\bar{e}-e)^2]|_{e=e_Q} = c(\bar{e}-e_Q)$. Consequently, the emissions level was $e = e_Q$.

We assume that the policymaker chooses the total amount of Quota to realize the emissions goal ($e_Q = e_g$). The government earns revenues from this auctioned allowance to the government, $b_G(e_g) = p(e_g - e_{ET}) = c(\bar{e} - e_g)(e_g - e_{ET})$. The minimized cost of the industry is given by $c_Q(e_g) = \frac{c}{2}(\bar{e} - e_g)^2 + c(\bar{e} - e_g)(e_g - e_{ET})$. In contrast, the citizen receives nothing: $b_Q = 0$.

In the third stage, the industry lobbies if and only if $R < \Delta C$, where $\Delta C(e_g) = C_P(e_g) - c_Q(e_g) = c(\bar{e} - e_g)(e_{ET} - \frac{e_g}{4})$. Then, if $e_{ET} < \frac{\bar{e}}{4}$, the industry prefers CP for $e_g \in (4e_{ET}, \bar{e})$. Otherwise, the industry prefers Quota. Then, $\Delta C(e_g)$ is decreasing in e_g for $[0, \bar{e}]$, and we have $\Delta C(0) = c\bar{e}e_{ET}$. Thus, the industry lobbies if $R < c\bar{e}e_{ET}$ and $e_g < e'$, where e' is derived from $\Delta C(e_g) = R$ as $e' \equiv \frac{\bar{e}}{2} + 2e_{ET} - \frac{1}{2} \cdot \sqrt{(\bar{e} - 4e_{ET})^2 + 16\frac{R}{c}}$.[27] Although the cost gap between CP and Quota, $\Delta C(e_g)$, is an inverted-U curve in Section 2, that in the current model is decreasing in e_g for $e_g \in [0, \bar{e}]$.[28] The decreasing cost gap makes the condition where the industry lobbies unilateral in a lower range as $e_g < e'$. Simultaneously, a set of emissions goals that leads to introducing CP among $e_g \in [0, e')$ is made empty.

In the first stage, the emissions goal to minimize the social cost is examined by taking R and

[25]We assume that bidders act competitively and therefore submit bids that correspond to their marginal emissions costs. We assume that n polluting firms bid competitively for the amount of auctioned quota, e_S. Let the emissions cost of firm $i = \{1, \cdots, n\}$ is $C_i(e_{Di})$ with $MC_i(e_{Di}) = dC_i/de_{Di} < 0$ and $MC'(e_{Di}) = dMC_i/de_{Di} \geq 0$, where e_{Di} is the demanded amount of emissions allowance by firm i. The equilibrium is characterized by $\sum_{i=1}^{n} e_{Di} \equiv e_D = e_S$ and $-MC_1(e_{D1}) = \cdots = -MC_n(e_{Dn}) = p$. Then, taking an inversion of $p = -MC_i(e_{Di})$ as $e_{Di} = MC_i^{-1}(-p)$ and summing up e_{Di} of all firms yield the market demand of this auction as $e_D = \sum_{i=1}^{n} MC_i^{-1}(-p)$. By letting $F(p)$ be the sum of the inversed demand of the auction, $F(p) = \sum_{i=1}^{n} MC_i^{-1}(-p)$, we have $p = -F^{-1}(e_D)$. This can be regarded as consequential to competitive bidding by one industry. Therefore, we suppose that one industry is the only one competitive bidder in this section.

[26]We can also examine a case where the revenues are returned to the citizen and the industry through a rent-seeking contest as well as in Section 2. Then, the rent-seeking contest of the revenue refund from auctioning allowances appears in the fourth stage, such as the CP. The qualitative results are the same as those in the case of non-returned revenues.

[27]In the second stage, the policymaker initially chooses CP for any R, e_g, and e_{ET} because $B_P(e_g) > b_Q(e_g) = 0$. We consider only this case.

[28]Technically, this difference occurs because the industry makes a decision whether to lobby under the endogenously determined allowance price. In the current model, the allowance price is endogenously determined in a domestic auction market. We will consider an international emissions trading scheme in which the allowance price is exogenously given. As shown later, the policymaker may pledge the ambitious emissions goal because the cost gap between CP and Quota is an inverted-U curve.

e_{ET} as given. If Quota is introduced, the social cost is given as $SC_Q(e_g, R) = \{C_Q(e_g) + R\} - b_Q - b_G(e_g)$. If CP is introduced, the social cost is expressed in (9). Thus, we have

$$SC(e_g, R) = \begin{cases} \frac{c}{2}(\bar{e} - e_g)^2 + R \equiv SC_Q(e_g, R), & \text{if } R < c\bar{e}e_{ET} \text{ and } e_g < e' \\ \frac{c\bar{e}}{2}(\bar{e} - e_g) \equiv SC_P(e_g), & \text{otherwise.} \end{cases} \tag{20}$$

In this model, if $e_{int} < e'$, the policymaker cannot preempt the industry's lobby by arranging the emissions goal. Thus, the policymaker pledges $e_g = e_{int}$ for any R and e_{int}.

Discussions in Section 3.2 are summarized in the following.

Proposition 5 *The ambitious emissions goal is conditionally pledged if the emissions allowance, which is grandfathered in international or domestic emissions trading schemes, is introduced. In contrast, the ambitious emissions goal is never pledged if the emissions allowance in a domestic emissions trading scheme is auctioned.*

3.3 Probabilistic Choice of the Instruments in a Tullock Contest

Here, we reconsider the choice of instruments at the second and third stages in the model of Section 2. Particularly, we integrate the second and third stages of Section 2 into the one-stage Tullock contest. This extension implicitly endogenizes the lobbying cost R, which is exogenously given so far. Thus, the game here is given as a decision-making of the domestic emissions goal at the first stage, a contest on the choice of instruments at the second, another contest of the rent-seeking of the revenue refund at the third if CP is chosen at the second stage, and a decision on the emissions level by the industry at the fourth stage.

We restart the game backward in the second stage. We suppose that Quota is introduced with a probability of π, whereas CP is introduced with $1-\pi$. π is determined by political contributions from the industry and the citizen, f_I and f_C, as $\pi = \frac{\beta f_I}{\beta f_I + f_C}$. $\beta > 0$ measures the political power of the industry relative to citizens on the choice of instruments. Then, the industry minimizes the expected emissions cost, given by $E[C(e_g)] = \pi c_Q(e_g) + (1-\pi)C_P(e_g) + f_I$. The emissions cost under Quota is given by (1) and that under CP is (5). Contrarily, the citizen minimizes the expected benefit, given by $E[B(e_g)] = \pi b_Q(e_g) + (1-\pi)B_p(e_g)$. The benefit of the citizen if Quota is chosen is $b_Q(e_g) = 0$, and the one if CP is chosen is given from (5). Consequently, the political contributions at the Nash equilibrium are characterized as $f_I^* = \frac{9\beta}{4(1+3\beta)^2}c(\bar{e} - e_g)e_g$ and $f_C^* = \frac{3\beta}{4(1+3\beta)^2}c(\bar{e} - e_g)e_g = f_I^*/3$. Thus, the Nash equilibrium is described as $\pi^* = \frac{3\beta}{1+3\beta}$. The emissions cost of the industry and the benefits of the citizens are given by

$$E[C(e_g)] = \frac{c}{2}(\bar{e} - e_g)^2 + \frac{1+9\beta}{2(1+3\beta)^2}c(\bar{e} - e_g)e_g, \tag{21}$$

$$E[B(e_g)] = \frac{c(\bar{e} - e_g)e_g}{4(1+3\beta)^2}. \tag{22}$$

In the first stage, the policymaker pledges an emissions goal to minimize the social cost. In contrast to Section 2, by substituting (21) and (22), the social cost is measured in expectation, $E[SC(e_g)] = E[C(e_g)] - E[B(e_g)]$; therefore, it does not express a regime change with respect to e_g. The social cost in the current model becomes continuous:

$$E[SC(e_g)] = \frac{c}{2}(\bar{e} - e_g)^2 + \frac{1+9\beta}{2(1+3\beta)^2}c(\bar{e} - e_g)e_g. \tag{23}$$

From this expression, we have $\frac{dE[SC(e_g)]}{de_g} < 0$. Because the expected social cost is continuously decreasing in e_g, the policymaker can minimize the social cost by setting $e_g = e_{int}$ subject to $e_g \leq e_{int}$.

Therefore, we obtain the following.

Proposition 6 *If the choice of the instruments is determined in a probabilistic Tullock contest, the policymaker does not pledge the ambitious emissions goal.*

Proposition 6 indicates that the ambitious emissions goal is sensitive to whether the choice of the instruments is deterministic or probabilistic. As shown in Section 2, if the choice of the instruments is deterministic, the ambitious emissions goal is pledged, depending on the international accord and the lobbying cost on the choice of instruments. In contrast, if the choice is probabilistic as shown in this section, changing a country's emissions goal cannot affect the choice of the instruments. The outcome is seen from the fact that the probability with which Quota is introduced, $\pi^* = \frac{3\beta}{1+3\beta}$, is independent of the emissions goal.

When is the choice of policy instruments probabilistically determined before pledging the emissions goal? In the Paris agreement, the governments first pledge and register their own countries' emissions goal and then introduce or strengthen environmental policies to achieve their goals. Note that there often exists a time lag between pledging an emissions goal and introducing policies. In the interval of the two decision-making steps, politicians who support the pledged emissions goal would be replaced by others who have different beliefs on climate change. Therefore, the government facing a decision-making step of pledging the emissions goal might have probabilistic insights on the subsequent choice of instruments. However, this section presents that the policymaker supposing a probabilistic choice of instruments never pledges the ambitious emissions goal.

4 Conclusion

The Paris Agreement on climate change allows contracting countries to set their nationally determined goals and to share two goals: a global temperature rise of 1.5 °C and well below 2 °C. Rational policymakers who face this fact may choose the easier goal to save costs. However, an increasing number of cities and countries have pledged to strive for ambitious goals.

We define an ambitious emissions goal as one that is more stringent than the proposed emissions goal in an international environmental agreement. An ambitious emissions goal may then decrease social costs by preempting the industry's lobby regarding the choice of an instrument. Indeed, ambitious emissions targets could be set because of policymakers' altruism or benevolence. The present study suggests, in addition to altruism or benevolence, setting the ambitious emissions goal as a strategy for policymakers.

Moreover, we also investigate a costly rent-seeking contest between citizens and the industry for revenue refunds from CP. Although, in most cases, CP is socially preferred to Quota, Quota becomes the socially preferred instrument when the revenue refund contest in the fourth stage is costlier than the industry's lobbying in the third stage. We show that the policymaker initially chooses CP through the citizen's voting result, even if Quota is socially preferred. However, simultaneously, the industry's lobby in the choice of an instrument corrects this socially incorrect choice.

Finally, we discuss other situations where the policymaker may pledge the ambitious emissions goal by extending the model to three directions. First, we assume the game with two countries that share a common international emissions goal. Even so, there exists a Nash equilibrium in which the policymakers in both countries pledge the ambitious emissions goals. Second, we consider emissions trading schemes in international and domestic frameworks. In an international emissions trading scheme and a domestic emissions trading scheme with grandfathered allowances, we also see that the policymaker may pledge the ambitious goal. However, if the emissions allowance is auctioned in the domestic framework, the policymaker does not pledge the ambitious emissions goal. Finally, the policymaker does not pledge the ambitious emissions goal if the instrument is probabilistically chosen in a political contest. Therefore, we conclude that the ambitious emissions goal depends on how the instrument is chosen and how the emissions trading scheme is designed.

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