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Environmental Concerns and Heterogeneity in the Global Commons

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Abstract

We examine a possibility of resolving the climate change problem, i.e., the tragedy of the global commons, through international negotiation from the viewpoint of citizens' environmental concerns. We categorize environmental concerns into two types: environmental concerns for the pleasure from the consequence of the worldwide CO2 emission reduction achievement and the contribution to this achievement. For global citizens to resolve the problem through international consensus building, the balance between the two environmental concerns must be similar across countries. Equalizing the burden of CO2 emission reduction and homogenizing the absolute degree of environmental concerns across countries are unnecessary for solving this issue. An increase of environmental concerns will make international cooperation more difficult and rather exacerbate the climate change problem unless it mitigates the heterogeneity of this balance across countries.

Keywords: Climate Change, Self-Governance, International Negotiation, Common Carbon Pricing, Relative Measure in Environmental Concern.

JEL Classification: C72, DD91, H41, Q54

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1. Introduction

We examine whether and how we can resolve the tragedy of the commons that occurs in climate change. The tragedy of the commons is a free-rider problem in which parties using the commons fail to limit their use, resulting in the deterioration of the commons (Hardin, 1968). Ostrom (1990; 2010) has shown through surveys of various local communities that self-governance by the involved parties can help resolve the tragedy of the commons apart from the use of market through privatization and enforceable governmental control. We consider self-governance as a method of preventing free riding, encouraging the parties to agree on a common commitment rule and abide by this rule through tacit collusion. We elucidate whether and how such self-governance methods effectively resolve the climate change problem.

The climate change problem implies that excessive CO2 (or greenhouse gases) emissions will irreversibly and catastrophically damage citizens' living environments, species diversity, and ecosystems throughout the world. Hence, the worldwide citizens must unite and continue to dramatically reduce CO2 emissions while respecting diverse opinions (Victor, 2001; Uzawa, 2003; Uzawa, 2005; Stern, 2007; Nordhaus, 2013; Wagner and Weitzman, 2015; Cramton et al., 2017; Tirole, 2017). It is referred to separately as the global commons to distinguish climate change from other commons that can be limited to local communities (the local commons). In the global commons, we face a serious lack of a sufficiently enforceable world government. For example, the UN is globally authoritative but not sufficiently coercive. The role of the UN is limited to providing a forum for international negotiation, i.e., the COP, and implementing common rules agreed on in this forum.

To preserve the sovereign state system (the Westphalian sovereignty) as much as possible, we must limit the use of ostracism that collectively sanctions a country for being uncooperative. This limitation inevitably results in uncooperative countries' views being greatly respected and significantly influencing international agreements. Due to the lack of sufficient enforcement power and the preservation of state sovereignty, the tragedy of the global commons should be considered much more difficult to resolve than the tragedy of the local commons.

MacKay et al. (2015) proposed solving the free-rider problem in the global commons by introducing a common commitment rule for setting a carbon price (Pigovian tax, carbon tax) through international negotiation and committing all countries to its implementation. To efficiently distribute the burden of emission reductions across countries and prevent the adverse effects of shifting production sites, i.e., carbon leakage, MacKay et al. (2015) proposed that countries should agree on a common carbon price. See also Cooper (2008), Cramton and Stoft (2012), Cramton, Ockenfels, and Stoft (2015), Gollier and Tirole (2015), and Cramton et al (2017). Specifically, MacKay et al. (2015) demonstrate a common commitment rule that would require each country to declare its respective maximum carbon price that is acceptable as its domestic carbon price. This rule then makes all countries commit to commonly set the lowest price within their acceptable maximal carbon prices as their domestic carbon prices.

MacKay et al. (2015) assumed that countries are homogeneous in that they share a common view on the optimal common carbon price that maximizes the worldwide welfare according to their expectations. MacKay et al. (2015) then showed that under this assumption, the optimal common carbon price, commonly supported by all countries, can be agreed upon under the common commitment rule, that is, the tragedy of the global commons can be resolved from the viewpoint of incentives through international negotiation.

However, if countries have different views on the optimal common carbon price, only the lowest optimal common carbon price can be agreed upon, resulting in inadequate CO2 emission reductions for most countries, that is, failing to resolve the tragedy of the global commons. Therefore, it is essential for countries to have similar views on the optimal common carbon price.

In this study, we unravel how countries form their views on the optimal common carbon price, and determine what factors lead them to differ in their views. We see a heterogeneity in citizens' environmental concerns across countries as the main reason for the divergence of their views.

We classify environmental concerns into two types: the environmental concerns for the pleasure from the consequence of the worldwide CO2 emission reduction achievement and the contribution to this achievement. Each citizen's environmental concern for the pleasure implies the degree to which they can find a higher achievement of worldwide CO_2 emission reduction more pleasant (denoted by α_i in this study). It is defined, for example, by the consideration of the welfare of current and future generations in their own country, the altruistic concern for other countries' welfare, and the compassion for species diversity, as well as how much knowledge and information about environmental and ecological damages has been acquired. The environmental concern for the contribution implies the degree to which they tolerate their effort for contributing to emission reductions (denoted by β_i in this study). It is defined, for example, by the psychological cost associated with their own CO_2 emission reduction and the nature of their prosocial lifestyles, such as recycling habits, consumption boycotts (Buchanan, 1954), labor boycotts, approval of task forces on environment-related information disclosures such as TCFD and TNFD, and prosocial interest in ESG investing (Aghion et al., 2020; Friede et al., 2015; Hartzmark, S. and A. Sussman, 2019; Patel et al., 2021), as well as the level of available CO_2 reduction technology such as energy and circular engineering.

This categorization provides a rich picture of the differences in citizens' (i.e., countries') environmental concerns. It allows us to consider the differences in the relative balance between the environmental concerns for the pleasure and the contribution, i.e., according to this study's terminology, the relative measure in environmental concern, which is defined as the intensity of environmental concern for the pleasure divided by that for the contribution.

We show that all countries have a common view on the optimal common carbon price if and only if they have the same relative measure in environmental concern. The country with the lowest relative measure has the lowest view on the optimal common carbon price. Hence, it is considered the most uncooperative country, a drag on international cooperation. However, due to the limitation of enforcement power and the preservation of state sovereignty, this country's view must be given special respect, and therefore, only the lowest optimal common carbon price can be agreed on in international negotiation. Thus, to resolve the tragedy of the global commons, it will be important for all countries to have similar relative measures. This is in contradiction to the prevailing view that the equitable distribution of the burden of emission reductions across countries is indispensable for the formation of international agreement. Although the COP has been proceeding with negotiations in accordance with this policy, the reality is that the negotiations are proving to be extremely difficult. The contribution of this paper is to break the impasse in international negotiation by presenting an alternative policy.

We examine whether a change of each country's environmental concern can promote the worldwide CO2 emission reduction. We show that barring an overly optimistic outlook, the worldwide CO2 emission reductions will be promoted if and only if this change mitigates the heterogeneity in relative measure across countries. This finding implies a dilemma in the global commons in the sense that growing environmental concern of a country does not necessarily contribute to the worldwide CO2 emission reduction achievement. For example, the citizens in the country with the lowest relative measure adheres more intensely to lower common carbon pricing if they make their environmental concern for the contribution greater.

The Sustainable Development Goals (SDGs) formulated by the UN in 2015 supports campaign activities that stimulate global citizens' environmental concerns (UN, 2015a, 2015b). The finding of this study indicates that such global campaign activities as the SDGs can only be effective if they mitigate this heterogeneity.

This study relates to an economics-and-psychology literature, such as Monin and Kunda (1987), Monin and Miller (2001), Bénabou and Tirole (2003; 2006; 2016), Mazar et al. (2008), Ariely et al. (2009), Mazar and Zhong (2010), Akerlof and Kranton (2010), and Falk and Szech (2013), because it deals with the intrinsic motivation of individuals to make prosocial contributions. However, unlike this literature, we exclude the possibility of citizens making social contributions free of charge, or engaging in prosocial behavior to improve their own social images as with the Veblen effect (Veblen, 1899). Thus, citizens do not oppose a higher carbon price on the grounds that it would worsen their social images, which could be enhanced by contributing to society without compensation. We also rule out the possibility that participation in international negotiations will engender loyalty, and loyalty will lead to greater environmental concern (Hirschman, 1970; Hart and Zingales, 2019). Given this possibility, an uncooperative country could become even more uncooperative by exiting international negotiations. Thus, loyalty can be considered to strengthen the argument of this study such that the country with the lowest relative measure has a strong voice. Moreover, we do not address information about the environment that is not incorporated into the utilities of citizens.

We do not consider the institutional design that allows citizens to honestly express information that is useful but not relevant to their own welfare, thereby promoting higher-level environmental policies (Matsushima, 2008, 2022a; Abeler et al., 2019).

This study relates to historical considerations on how tacit collusion was used in global affairs. We exclude the possibility that international cooperation can be maintained through collective ostracism even without legal mechanisms. Instead, we focus on the possibility that legal mechanisms, which correspond to common commitment rules in the context of climate change, can be maintained by tacit collusion even in the absence of sufficient enforcement power. Edwards and Ogilvie (2012) argued that the institutional mechanisms that contributed to the development of long-distance trade in the medieval European era were primarily reputation-based legal mechanisms, not collective ostracism with informal sanctions. We do not consider any possibility that some limited and influential countries could establish a climate club (Nordhaus, 2015) in a closed way and take the lead in solving the climate change problem, which is a deviation from the Westphalian system. Moreover, we assume the use of joint responsibility to maintain the functioning of an international negotiation forum through tacit collusion. If a country fails to honor its commitment, the forum will lose its authority and international negotiations will stall, to the detriment of all countries of the world. Thus, although the preservation of state sovereignty includes the freedom of choice regarding the content of commitments, any violation of commitments is prohibited. This assumption was consistently made in previous studies concerning common commitments (Matsushima, 2022b).

The novelties of this study can be summarized as the following assertions:

i) The main factor preventing successful international agreements on CO2 emission reductions is neither the difference in absolute level of environmental concerns across countries nor the inequity of the burden of emission reductions across countries.

ii) The main factor is that the balance between environmental concerns for the pleasure and the contribution (i.e., the relative measure in environmental concern) differs across countries.

iii) International campaign activities to change the environmental concerns of the worldwide citizens can only be effective if they work to mitigate the heterogeneity in relative measure.

The remainder of this paper is organized as follows. Section 2 shows the model of the global commons. Section 3 introduces relative measure in environmental concern and explains its importance. Section 4 considers the case where countries are heterogenous in relative measure and shows the dilemma in the global commons. Section 5 considers the case where countries are homogeneous in relative measure and suggests a policy for resolving the tragedy of the global commons. Section 6 generalizes the model. Finally, section 7 concludes the study.

2. The Model

Let $N = \{1, 2, ..., n\}$ denote the set of all countries. The citizens of each country $i \in N$ considers the CO2 emission reduction, which is expressed as $x_i \in [0, \infty)$. Each citizen of country i has an environmental concern for the pleasure from the consequence of the worldwide emission reduction achievement, which is expressed as a monetary value $\alpha_i \sum_{j \in N} x_j$, where $\alpha_i > 0$ implies the degree to which they can find a higher achievement more pleasant. Moreover, in reducing country $i's$ emission by $x_i \in [0, \infty)$, its citizens spend an environmental cost $\frac{x_i^2}{\beta_i}$, where $\beta_i > 0$ implies the environmental concern for the contribution to the world-wide emission reduction achievement, that is, the degree to which they financially or psychologically tolerate their effort for emission reductions. Thus, they have a utility expressed as

$$\alpha_i \sum_{j \in N} x_j - \frac{x_i^2}{\beta_i}.$$

Each citizen $i's$ utility increases with respect to increases in both α_i and β_i, regardless of $(x_j)_{j \in N}$.

Throughout this study, we will consider the impacts of various changes in (α_i, β_i). However, to preclude a too optimistic outlook on the permissive range of these changes, we will only consider changes that increase only one of α_i or β_i. It may be hoped that a better understanding of environment and ecology will increase the degree of the pleasure from the consequence of reduction achievement (α_i) and at the same time increase the willingness to contribute to this achievement (β_i). However, in this study, we consider the impact of changing environmental concerns in a more pessimistic context, where there is no longer room for such optimistic synergies. Instead, our subject of consideration, for example, is an international society in which citizens remain uninspired to contribute to the reduction achievement even as they become more pleased with the consequence of this achievement. Alternatively, some citizens take recycling of PET bottles seriously (like Japanese people), but this is because it is part of their own lifstyle habits, and is not necessarily the result of calculating the effect of recycling on reducing CO2 emissions.

We assume that each country is composed of so many citizens that the set of all citizens in a country is approximated by a continuum. With this assumption, each individual citizen has only a negligible impact on the achievement, and therefore, does not consider their impact on the achievement in their decision-making.[3] Because of this, each country i will set a carbon price $p_i \in [0,\infty)$ to incentivize its citizens to voluntarily reduce emissions, that is, to resolve the tragedy of the local commons within this country. Since each citizen minimizes the sum of their carbon price payment and their cost, country i can achieve the emission reduction $x_i = x_i(p_i)$ that minimizes $-p_i x_i + \frac{x_i^2}{\beta_i}$, that is,

(1) $$x_i(p_i) \equiv \frac{\beta_i p_i}{2}.$$

The higher β_i is, the more country $i's$ citizens are willing to reduce their emission. Note that $x_i(p_i)$ does not depend on α_i. From (1), the resultant welfare of each country i, which is set equal to its citizens' utility, is given by

$$\alpha_i \sum_{j\in N} x_j(p_j) - \frac{x_i(p_i)^2}{\beta_i} = \frac{\alpha_i}{2}\sum_{j\in N}\beta_j p_j - \frac{\beta_i p_i^2}{4}.$$

[3] For simplicity of arguments, we assume that all citizens in each country have the same environmental concerns. However, we can eliminate this assumption with no substantial change. See Section 6.

If country i consider the resolution of the tradgy of the local commons with no regard to global externalities, it sets $p_i = \alpha_i$ to maximize $\alpha_i x_i(p_i) - \frac{x_i(p_i)^2}{\beta_i}$. However, countries should not set their carbon prices on their own individually, because they face the free-rider problem across international borders, i.e., the tragedy of the global commons. Therefore, considering the efficiency across countries and the backlash against international agreement such as carbon leakage, all countries will agree on a common carbon price $\hat{p} \geq 0$ through international negotiation. By setting $p_i = \hat{p}$ to its citizens, each country i achieves their emission reduction $x_i(\hat{p}) = \frac{\beta_i \hat{p}}{2}$. Each country $i's$ resultant welfare is therefore given by

$$\alpha_i \sum_{j \in N} x_j(\hat{p}) - \frac{x_i(\hat{p})^2}{\beta_i} = \frac{\alpha_i \hat{p}}{2} \sum_{j \in N} \beta_j - \frac{\beta_i \hat{p}^2}{4}.$$

Because of the limitation of enforcement power in international negotiation, the common carbon price $\hat{p}$ must satisfy the following constraint that we term the marginal unanimity. If every country's welfare is improved by increasing the common carbon price, all countries will prefer to agree on a higher common carbon price. However, if there exists a country whose welfare is decreased by increasing the common carbon price, the price increase is rejected in international negotiation due to lack of unanimity. (Note that the views of countries that are reluctant to set higher carbon prices must be given special respect, because the enforcement power is limited.) Hence, as the marginal unanimity constraint, we require that for every $i \in N$,

$$\frac{\partial}{\partial p}\{\alpha_i \sum_{j \in N} x_j(p) - \frac{x_i(p)^2}{\beta_i}\}\Big|_{p=\hat{p}} = \frac{\alpha_i}{2} \sum_{j \in N} \beta_j - \frac{\beta_i \hat{p}}{2} \geq 0,$$

where the equality holds, i.e., $\frac{\alpha_i}{2} \sum_{j \in N} \beta_j - \frac{\beta_i \hat{p}}{2} = 0$, for some country $i \in N$. (Note that this country opposes any price higher than $\hat{p}$.) The marginal unanimity constraint uniquely determines the common carbon price, which is given by

$$\text{(2)} \qquad \hat{p} = \{\sum_{i \in N} \beta_i\} \min_{i \in N} \frac{\alpha_i}{\beta_i}.$$

For each country $i \in N$, we define the optimal common carbon price p_i^* by the maximization of the welfare of domestic citizens $\frac{\partial}{\partial p}\{\alpha_i \sum_{j \in N} x_j(p) - \frac{x_i(p)^2}{\beta_i}\}$ in terms of common carbon price p, i.e.,

$$p_i^* \equiv \{\sum_{j \in N} \beta_j\} \frac{\alpha_i}{\beta_i}.$$

Clearly, we have

$$p_i^* > \alpha_i \quad \text{and} \quad p_i^* \geq \hat{p} = \min_{j \in N} p_j^* \quad \text{for each} \quad i \in N.$$

If country i considers common carbon pricing, it will prefer to set $p_i = p_i^*$ rather than $p_i = \alpha_i$, counting on the other countries to contribute to emission reductions more. However, due to marginal unanimity, the international negotiation forum decides to set the common carbon price at $\hat{p} = \min_{i \in N} p_i^*$. For convenience of arguments, we assume that $\hat{p} > \alpha_i$ for each $i \in N$. Therefore, each country $i \in N$ will prefer to set $\hat{p}$ than α_i as their domestic carbon price. (We discuss about the case without this assumption in the Remark in Section 6.)

3. Relative Measure in Environmental Concern

We define the relative measure of each country $i \in N$ in environmental concern as

$$M_i \equiv \frac{\alpha_i}{\beta_i}.$$

The higher the relative measure M_i is, the more concerned country $i's$ citizens are with the pleasure from the consequence of the world-wide emission reduction achievement than the contribution to this achievement. We can rewrite (2) as

$$\hat{p} = \{\sum_{i \in N} \beta_i\} \min_{i \in N} M_i.$$

We can rewrite the optimal common carbon price for each country i as $\{\sum_{j \in N} \beta_j\} M_i$. The higher the relative measure M_i is, the greater the corresponding optimal common carbon price is.

From (1), the incentive for citizens of each country i to reduce emissions depends on the carbon price and β_i, but not on α_i, because citizens ignore their impact on the achievement in decision-making. From (2), α_i can influence the determination of common carbon price $\hat{p}$, but this influence is limited. Only if country $i's$ relative measure is the lowest (i.e., $M_i = \min_{j \in N} M_j$), α_i can affect $\hat{p}$ through changes in the lowest relative measure. However, the following theorem shows that if all countries can maintain the same relative measure (i.e., the homogeneity in relative measure), every country $i's$ α_i will play a decisive role in the determination of the common carbon price $\hat{p}$.

Theorem 1: The common carbon price $\hat{p}$ is less than or equal to $\sum_{i \in N} \alpha_i$. It is equivalent to $\sum_{i \in N} \alpha_i$ if and only if we have the homogeneity in relative measure, that is,

$$M_i = M_1 \text{ for all } i \in N.$$

Proof: From (2), we have

$$\hat{p} = \{\sum_{i \in N} \beta_i\} \min_{i \in N} \frac{\alpha_i}{\beta_i} \leq \sum_{i \in N} \beta_i \cdot \frac{\alpha_i}{\beta_i} = \sum_{i \in N} \alpha_i ,$$

from which $\hat{p} = \sum_{i \in N} \alpha_i$ holds if and only if $\min_{j \in N} \frac{\alpha_j}{\beta_j} = \frac{\alpha_i}{\beta_i}$ for all $i \in N$, that is, $M_i = M_1$ for all $i \in N$.

Q.E.D.

For each $i \in N$, we denote the level of country $i's$ emission reduction associated with $\hat{p}$ by $X_i \equiv x_i(\hat{p})$. Let $X \equiv \sum_{i \in N} X_i$ denote the associated worldwide emission reduction achievement. From (1) and (2), we have

$$X_i = \frac{\beta_i}{2} \{\sum_{j \in N} \beta_j\} \min_{j \in N} M_j \text{ for each } i \in N, \tag{3}$$

and

(4) $$X = \frac{1}{2}\{\sum_{i\in N}\beta_i\}^2 \min_{i\in N} M_i .$$

The following two examples suggest that an increased environmental concern do not promote emission reductions and rather encourage emissions, that is, the dilemma in the global commons occurs. Consider $(\alpha_i, \beta_i)_{i\in N}$ and $(\tilde{\alpha}_i, \tilde{\beta}_i)_{i\in N}$. We write $\tilde{M}_i$, $\tilde{p}$, and $\tilde{X}$ instead of M_i, $\hat{p}$, and X when we replace $(\alpha_i, \beta_i)_{i\in N}$ with $(\tilde{\alpha}_i, \tilde{\beta}_i)_{i\in N}$. We specify $(\alpha_i, \beta_i)_{i\in N}$ by

$$\alpha_i = \beta_i = i \text{ for each } i \in N .$$

Note that

$$\min_{i\in N} M_i = 1, \ \hat{p} = \frac{(n+1)n}{2}, \text{ and } X = \frac{(n+1)^2 n^2}{8}.$$

Example 1: We specify $(\tilde{\alpha}_i, \tilde{\beta}_i)_{i\in N}$ by

$$\tilde{\alpha}_i = \alpha_i \text{ and } \tilde{\beta}_i = n \text{ for each } i \in N .$$

Note that

$$\min_{i\in N} \tilde{M}_i = \tilde{M}_1 = \frac{1}{n}, \ \tilde{p} = n, \text{ and } \tilde{X} = \frac{n^3}{2}.$$

Hence, we have

$$\min_{i\in N} \tilde{M}_i < \min_{i\in N} M_i, \ \tilde{p} < \hat{p}, \text{ and } \tilde{X} < X .$$

Since $\tilde{\beta}_i \geq \beta_i$ for all $i \in N$, Example 1 implies that if the environmental concerns for the contribution are improved, the worldwide emission only gets facilitated.

Example 2: We specify $(\tilde{\alpha}_i, \tilde{\beta}_i)_{i\in N}$ by

$$\tilde{\alpha}_i = n \text{ and } \tilde{\beta}_i = \beta_i \text{ for each } i \in N .$$

Note that

$$\min_{i\in N} \tilde{M}_i = \tilde{M}_n = 1, \ \tilde{p} = \frac{(n+1)n}{2}, \text{ and } \tilde{X} = \frac{(n+1)^2 n^2}{8}.$$

Hence, we have

$$\min_{i\in N}\tilde{M}_i = \min_{i\in N} M_i,\quad \tilde{p}=\hat{p}, \text{ and } \quad \tilde{X}=X.$$

Since $\tilde{\alpha}_i \geq \alpha_i$ for all $i \in N$, Example 2 implies that even if the environmental concerns for the pleasure are improved, the worldwide emission reduction is unchanged.

The following example shows that the homogeneity in relative measure (i.e., $M_i = M_1$ for all $i \in N$) guarantees a successful international negotiation.

Example 3: We specify $(\tilde{\alpha}_i, \tilde{\beta}_i)_{i\in N}$ by

$$\tilde{\alpha}_i = \alpha_i \text{ and } \tilde{\beta}_i = \beta_{n-i+1} = n-i+1 \text{ for each } i \in N.$$

Note that

$$\min_{i\in N}\tilde{M}_i = \tilde{M}_1 = \frac{1}{n},\quad \tilde{p} = \frac{n+1}{2}, \text{ and } \quad \tilde{X} = \frac{(n+1)^2 n}{8}.$$

Hence, we have

$$\min_{i\in N}\tilde{M}_i < \min_{i\in N} M_i,\quad \tilde{p} < \hat{p}, \text{ and } \quad \tilde{X} < X.$$

By changing from $(\alpha_i, \beta_i)_{i\in N}$ to $(\tilde{\alpha}_i, \tilde{\beta}_i)_{i\in N}$, the worldwide citizens' environmental concerns are the same in aggregate, but the relative measures vary across countries. Example 3 implies that if the relative measures become heterogeneous across countries, the worldwide emission gets facilitated.

4. Heterogeneity in Relative Measure

In this section, we consider the case in which all countries are heterogeneous in relative measure, that is,

$$M_i \neq M_j \text{ for all } i \in N \text{ and } j \neq i.$$

The following theorem characterizes the dilemma in the global commons where growing environmental concern does not contribute to the worldwide emission reduction achievement.

Theorem 2: Assume the heterogeneity in relative measure. Consider an arbitrary $i \in N$.

If $M_i = \min_{j \in N} M_j$, then

(5) $$\frac{\partial \hat{p}}{\partial \alpha_i} > 0,\ \frac{\partial X}{\partial \alpha_i} > 0,\ \frac{\partial \hat{p}}{\partial \beta_i} < 0,$$

(6) $$[\sum_{j \neq i} \beta_j > \beta_i] \Rightarrow [\frac{\partial X}{\partial \beta_i} < 0],$$

and

(7) $$[\sum_{j \neq i} \beta_j < \beta_i] \Rightarrow [\frac{\partial X}{\partial \beta_i} > 0].$$

If $M_i > \min_{j \in N} M_j$, then

(8) $$\frac{\partial \hat{p}}{\partial \alpha_i} = 0,\ \frac{\partial X}{\partial \alpha_i} = 0,\ \frac{\partial \hat{p}}{\partial \beta_i} > 0, \text{ and } \frac{\partial X}{\partial \beta_i} > 0.$$

Proof: Suppose that $M_i = \min_{j \in N} M_j$. From (2), we have

$$\frac{\partial \hat{p}}{\partial \alpha_i} = \frac{\partial}{\partial \alpha_i}\{\frac{\alpha_i}{\beta_i}\sum_{j \in N} \beta_j\} = \frac{\sum_{j \in N} \beta_j}{\beta_i} > 0,$$

and

$$\frac{\partial \hat{p}}{\partial \beta_i} = \frac{\partial}{\partial \beta_i}\{\frac{\alpha_i}{\beta_i}\sum_{j \in N} \beta_j\} = \frac{\alpha_i}{\beta_i}(1 - \frac{\sum_{j \in N} \beta_j}{\beta_i}) < 0.$$

From (4), we have

$$\frac{\partial X}{\partial \alpha_i} = \frac{\partial}{\partial \alpha_i}[\frac{1}{2}\{\sum_{j \in N} \beta_j\}^2 \frac{\alpha_i}{\beta_i}] = \frac{1}{2\beta_i}\{\sum_{j \in N} \beta_j\}^2 > 0,$$

and

$$\frac{\partial X}{\partial \beta_i} = \frac{\partial}{\partial \beta_i}[\frac{1}{2}\{\sum_{j \in N} \beta_j\}^2 \frac{\alpha_i}{\beta_i}] = \{\sum_{j \in N} \beta_j\}\frac{\alpha_i}{\beta_i} - \frac{1}{2}\{\sum_{j \in N} \beta_j\}^2 \frac{\alpha_i}{\beta_i^2}$$

$$= \{\sum_{j \in N} \beta_j\}\frac{\alpha_i}{\beta_i}\{1 - \frac{\sum_{j \in N} \beta_j}{2\beta_i}\}.$$

Hence, we have

$$[\sum_{j\neq i}\beta_j > \beta_i] \Rightarrow [\frac{\partial X}{\partial \beta_i} < 0],$$

and

$$[\sum_{j\neq i}\beta_j < \beta_i] \Rightarrow [\frac{\partial X}{\partial \beta_i} > 0].$$

These observations imply that the properties of (5), (6), and (7) hold.

Suppose that $M_i > \min_{j\in N} M_j$. Since $\min_{j\in N} M_j$ is independent of (α_i, β_i), from (2), we have

$$\frac{\partial \hat{p}}{\partial \alpha_i} = \frac{\partial}{\partial \alpha_i}\{K\sum_{j\in N}\beta_j\} = 0,$$

and

$$\frac{\partial \hat{p}}{\partial \beta_i} = \frac{\partial}{\partial \beta_i}\{K\sum_{j\in N}\beta_j\} = K > 0,$$

where we denote $K = \min_{j\in N} M_j$. From (3), we have

$$\frac{\partial X}{\partial \alpha_i} = \frac{\partial}{\partial \alpha_i}[\frac{1}{2}\{\sum_{j\in N}\beta_j\}^2 K] = 0,$$

and

$$\frac{\partial X}{\partial \beta_i} = \frac{\partial}{\partial \beta_i}[\frac{1}{2}\{\sum_{j\in N}\beta_j\}^2 K] = \{\sum_{j\in N}\beta_j\}K > 0.$$

These obsrvations imply that the properties of (8) hold.

Q.E.D.

From (2), the country i with the lowest relative measure has a substantial impact on $\hat{p}$ and X. A change of this country's environmental concerns in the direction of lower relative measure decreases $\hat{p}$, which in turn discourages all other countries from reducing emissions (the inequalities of (5)). Given that the relative magnitude of β_i is not significantly high, an increase of β_i decreases $M_i = \min_{j\in N} M_j$, and leads to a reduction in $\hat{p}$, which in turn reduces X (the property of (6)). Although the increase of β_i allows country i to achieve more emission reduction on their own, it will stick to a lower common carbon price, resulting in lower worldwide achievement. Only in exceptional cases where the relative magnitude of β_i is outstandingly high, the increase of country $i's$ emission reduction caused by an increase of β_i compensates for the loss of other countries' emission reduction caused by the resulting decrease of common carbon price (the property of (7)).

Next, consider any country i whose relative measure is not the lowest. An increase of α_i gives no influence on $\hat{p}$ and X, because α_i and M_i are irrelevant to the determination of $\hat{p}$ (the first and second equalities of (8)). Contrarily, an increase of β_i (i.e., a decrease of its relative measure) can contribute to the increases of $\hat{p}$ and X. This increase provides the country with the lowest relative measure with the benefit of agreeing to a higher common carbon price (the third and fourth inequalities of (8)).

From these observations, we can summarize Theorem 2 as saying that if (and only if) a country's environmental concerns change in the direction of mitigating the heterogeneity in relative measure, i.e., narrowing the gap between each country's relative measure and the lowest relative measure, they can raise the worldwide emission reduction.

The following theorem clarifies a possibility that a country is uncomfortable with promoting the similarity in relative measure. We denote each country $i's$ welfare by

(9) $$W_i \equiv \alpha_i X - \frac{X_i^2}{\beta_i}.$$

Theorem 3: Assume the heterogeneity in relative measure. Consider an arbitrary countries $i \in N$. If $M_i = \min_{\tau \in N} M_\tau$, then,

(10) $$\frac{\partial W_i}{\partial \alpha_i} > 0,$$

(11) $$[\sum_{j \neq i} \beta_j < \beta_i] \Rightarrow [\frac{\partial W_i}{\partial \beta_i} > 0],$$

and

(12) $$[\sum_{j \neq i} \beta_j > \beta_i] \Rightarrow [\frac{\partial W_i}{\partial \beta_i} < 0].$$

If $M_i > \min_{\tau \in N} M_\tau$, then,

(13) $$\frac{\partial W_i}{\partial \alpha_i} > 0,$$

(14) $$[\,2M_i > \{1 + \frac{\sum_{\tau \in N} \beta_\tau}{2\beta_i}\} \min_{j \in N} M_j\,] \Rightarrow [\,\frac{\partial W_i}{\partial \beta_i} > 0\,],$$

and

(15) $$[\,2M_i < \{1 + \frac{\sum_{\tau \in N} \beta_\tau}{2\beta_i}\} \min_{j \in N} M_j\,] \Rightarrow [\,\frac{\partial W_i}{\partial \beta_i} < 0\,].$$

Proof: From (3), (4), and (9), we have

$$W_i = \frac{1}{2} \min_{j \in N} \frac{\alpha_j}{\beta_j} \{\sum_{j \in N} \beta_j\}^2 \{\alpha_i - \frac{\beta_i}{2} \min_{j \in N} \frac{\alpha_j}{\beta_j}\}.$$

Suppose that $M_i = \min_{j \in N} M_j$, that is, $\frac{\alpha_i}{\beta_i} = \min_{j \in N} M_j < \min_{j \in N} \frac{\alpha_j}{\beta_j}$. Then, we have

$$W_i = \frac{\alpha_i^2}{4\beta_i} \{\sum_{j \in N} \beta_j\}^2,$$

and therefore, we have $\frac{\partial W_i}{\partial \alpha_i} > 0$ (the inequality of (10)). We also have

$$\frac{\partial W_i}{\partial \beta_i} = -\frac{\alpha_i^2}{4\beta_i^2} \{\sum_{j \in N} \beta_j\}^2 + \frac{\alpha_i^2}{2\beta_i} \{\sum_{j \in N} \beta_j\} = \frac{\alpha_i^2}{2\beta_i} \{\sum_{j \in N} \beta_j\} \{1 - \frac{\sum_{j \in N} \beta_j}{2\beta_i}\}.$$

Clearly, if $\sum_{j \neq i} \beta_j < \beta_i$, we have $\frac{\partial W_i}{\partial \beta_i} > 0$ (the property of (11)). If $\sum_{j \neq i} \beta_j > \beta_i$, we have $\frac{\partial W_i}{\partial \beta_i} < 0$ (the property of (12)).

Suppose that $M_i > \min_{j \in N} M_j$, that is, $\frac{\alpha_i}{\beta_i} > \min_{j \in N} \frac{\alpha_j}{\beta_j}$. Since $\min_{j \in N} \frac{\alpha_j}{\beta_j}$ is independent of (α_i, β_i), we have

$$\frac{\partial W_i}{\partial \alpha_i} = \frac{1}{2} \min_{j \in N} \frac{\alpha_j}{\beta_j} \{\sum_{j \in N} \beta_j\}^2 > 0,$$

that is, the inequality of (13). Moreover, we have

$$\frac{\partial W_i}{\partial \beta_i} = \min_{j\in N}\frac{\alpha_j}{\beta_j}\{\sum_{j\in N}\beta_j\}\{\alpha_i - \frac{\beta_i}{2}\min_{j\in N}\frac{\alpha_j}{\beta_j}\} - \frac{1}{4}\{\min_{j\in N}\frac{\alpha_j}{\beta_j}\}^2\{\sum_{j\in N}\beta_j\}^2$$

$$= \alpha_i \min_{j\in N}\frac{\alpha_j}{\beta_j}\{\sum_{j\in N}\beta_j\}[1 - \frac{\beta_i}{2\alpha_i}\min_{j\in N}\frac{\alpha_j}{\beta_j}\{1 + \frac{\sum_{j\in N}\beta_j}{2\beta_i}\}].$$

Clearly, we have the properties of (14) and (15).

Q.E.D.

Consider the country i with the lowest relative measure. An increase of α_i improves its welfare simply because its citizens become more pleased with higher achievement (the inequality of (10)). In contrast, an increase of β_i lowers its welfare as long as the relative magnitude of β_i is not significantly high (the property of (12)). If the relative magnitude of β_i is significantly high, the country with the lowest relative measure is uncomfortable with a decrease of β_i, which promotes the similarly in relative measure, because this decrease lowers its welfare (the property of (11)).

Consider any country i whose relative measure is not the lowest. A decrease of α_i lowers its welfare (the inequality of (13)), implying that it is uncomfortable with the promotion of the similarity in this way. An increase of β_i increases its welfare as long as its relative measure is significantly high, because the resultant increase of the common carbon price induces the other countries' emission reductions more (the property of (14)). However, if its relative measure is not significantly high, this country is uncomfortable with an increase of β_i, which promotes the similarly (the property of (15)).

5. Homogeneity in Relative Measure

In this section, we investigate an extreme case where all countries are homogeneous in relative measure, that is,

$$M_1 = M_i \text{ for all } i \in N.$$

The following theorem demonstrates that we can avoid the dilemma in the global commons within the limit of this homegeneity.

Theorem 4: Consider arbitrary $(\alpha_i, \beta_i)_{i\in N}$ and $(\tilde{\alpha}_i, \tilde{\beta}_i)_{i\in N}$. Suppose that they satisfy the homogeneity in relative measure. Then, we have

(16) $$[\tilde{X} > X] \Leftrightarrow [\sum_{i\in N}\tilde{\alpha}_i \sum_{i\in N}\tilde{\beta}_i > \sum_{i\in N}\alpha_i \sum_{i\in N}\beta_i].$$

Proof: From Theorem 1, we have $\hat{p} = \sum_{i\in N}\alpha_i$. From simple calculations, we have

$$M_1 = \frac{\sum_{i\in N}\alpha_i}{\sum_{i\in N}\beta_i}.$$

From (4), we have

$$X = \frac{M_1}{2}\{\sum_{i\in N}\beta_i\}^2 = \frac{\{\sum_{i\in N}\alpha_i\}^2}{2M_1} = \frac{\sum_{i\in N}\alpha_i \sum_{i\in N}\beta_i}{2}.$$

Theorem 4 is straightforward from the above calculations.

Q.E.D.

If the aggregate value of environmental concerns expressed as $\sum_{i\in N}\alpha_i \sum_{i\in N}\beta_i$ is increased while maintaining the homogeneity in relative measure, the worldwide emission reduction is generally increased (the properties of (16)). Thus, we can see that the maintenance of the similarity in relative measure serves to prevent the dilemma in the global commons. Any increase of environmental concerns within a range that does not stray too far from the homogeneity leads to an increase in worldwide emission reduction. It does not matter if there are differences in magnitude of environmental concerns across countries. It is acceptable for the magnitudes to vary across countries. The important thing needed for successful international agreement is that the similarity in relative measure across countries is maintained.

6. Generalization

We assumed that all country has the same population size and that every citizen in each country has the same environmental concern. We can eliminate these assumptions with no substantial change. We can conclude that the heterogeneity in population size across countries does not matter and that the heterogeneity in environmental concern across citizens within a country does not matter.

We denote by a positive real number $\delta_i > 0$ the population size of each country $i \in N$. The set of all citizens in each country $i \in N$ is given by the closed interval $[0, \delta_i]$ with the uniform distribution. Each citizen $\rho \in [0,1]$ has their respective environmental concern, which is expressed as $(\tilde{\alpha}_i(\rho), \tilde{\beta}_i(\rho))$. They achieve the emission reduction $y = \tilde{x}_i(p_i;\rho)$ to minimize $-p_i y + \dfrac{y^2}{\tilde{\beta}_i(\rho)}$, that is,

$$\tilde{x}_i(p_i;\rho) \equiv \frac{\tilde{\beta}_i(\rho) p_i}{2}.$$

Hence, the total emission reduction in country i is given by

$$x_i(p_i) = \int_{\rho=0}^{\delta_i} \tilde{x}_i(p_i;\rho) d\rho = \frac{p_i \int_{\rho=0}^{\delta_i} \tilde{\beta}_i(\rho) d\rho}{2}.$$

We specify the environmental concern of each country $i \in N$, (α_i, β_i), as the aggregate of its citizens' environmental concerns, that is,

$$\alpha_i = \int_{\rho=0}^{\delta_i} \tilde{\alpha}_i(\rho) d\rho \text{ and } \beta_i = \int_{\rho=0}^{\delta_i} \tilde{\beta}_i(\rho) d\rho.$$

Therefore, the welfare of each country i is expressed as the sum of its citizens' utilities, that is,

$$\int_{\rho=0}^{\delta_i} \{\tilde{\alpha}_i(\rho) \sum_{j \in N} x_j(p_j) - \frac{\tilde{x}_i(p_i;\rho)^2}{\tilde{\beta}_i(\rho)}\} d\rho$$

$$= \frac{\alpha_i}{2} \sum_{j \in N} \beta_j p_j - \frac{\beta_i p_i^2}{4},$$

which implies that we can apply the same arguments in the previous sections to the general case.

Note that the relative measure of country i is given by

$$M_i = \frac{\alpha_i}{\beta_i} = \frac{\int_{\rho=0}^{\delta_i} \tilde{\alpha}_i(\rho)d\rho}{\int_{\rho=0}^{\delta_i} \tilde{\beta}_i(\rho)d\rho}.$$

We further define the relative measure of each citizen $\rho \in [0,\delta_i]$ of each country i in environmental concern as

$$M_i(\rho) \equiv \frac{\tilde{\alpha}_i(\rho)}{\tilde{\beta}_i(\rho)}.$$

It should be noted that only the aggregate of citizens' environmental concerns for the pleasure and the aggregate of its citizens' environmental concerns for the contribution are relevant to the determination of each country's relative measure. Thus, the heterogeneity in relative measure across citizens within a country does not matter. This is in contrast with international negotiation, because each country is fully capable of enforcing a carbon price that maximizes its demestic welfare for its citizens.

Remark: Throughout this study, we implicitly assumed that $\hat{p} \geq \alpha_i$ for all $i \in N$. If $\hat{p} < \alpha_i$, country i may prefer to set its carbon price p_i to α_i instead of $\hat{p}$, because it maximizes its citizens' welfare provided the other countries set their prices to $\hat{p}$. However, country i could be hesitant to raise its carbon price above $\hat{p}$ for the fear of carbon leakage. This fear also discourages countries whose relative measures are not the lowest to exclude the country with the lowest relative measure from their international negotiation forum. While this exclusion increases the common carbon price, the excluded country can benefit by setting its domestic carbon price lower than the common carbon price (carbon leakage). Hence, whether we make this assumption or not, a common carbon price can be agreed upon without excluding any country.

7. Conclusion

The presence of an international negotiation forum such as the COP is essential to resolving the climate change problem and it is important that all countries participate in this forum. However, the COP has failed to produce sufficient results over a long period of time. The reason for this is that it has continued to negotiate on how to fairly distribute the burden of emission reductions across countries. Many economists argue that things could be turned around by shifting the focus of international negotiation from allocation of emission permitts to common carbon pricing. However, that is not enough because each country has a different level of environmental concerns and, therefore, a different view on the appropriate level of common carbon price. In this respect, global environmental awareness campaigns such as the SDGs could be essential for consensus building in international negotiation. However, without a well-designed policy on how to conduct such campaigns, recklessly trying to raise environmental concerns would be counterproductive to this consensus building.

We showed that the first step in solving the climate change problem is to approach a situation where countries are similar in the balance of environmental concerns for the pleasure and the contribution, i.e., in relative measure in environmental concern. This similarity would allow us to reach international agreement on a sufficient common carbon price level even if the intensity of environmental concern varies across countries. Under this similarity, we can more effectively change environmental concern on a global scale without worrying about the difficulties of international agreements.

Throughout this study, we proceeded on the assumption that only a low common carbon price can be agreed upon in the presence of severe heterogeneity in relative measure. However, if we consider the possibility of response measures to address carbon leakage such as the Carbon Border Adjustment Mechanism, it is to a certain extent acceptable that the domestic carbon prices can differ across countries. In this case, it would be possible to reach an agreement where some countries have notably low relative measures and only implement low carbon prices, whereas the remaining countries implement sufficient domestic carbon prices. Thus, proposing new commitment rules that are tolerant of such heterogeneity would be an interesting direction for future research. We did not consider cases in which there are multiple venues for negotiations, cases in which the negotiating parties are non-state actors, or the role of emissions trading. These would be better considered using the analysis in this study as a benchmark.

The results of this study have implications for the way in which surveys are conducted on citizens' attitudes toward environmental issues. Existing awareness surveys are limited to examining citizens' interest in them. Those survey results do not provide insight into international comparisons of relative measures. Therefore, an important future study would be to develop an awareness survey design that would reveal the problem-solving capacity of international society by capturing the nature of citizens' interest in environmental issues from the perspective of relative measure.

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