Climate Economics:

International Cooperation

Take-Home Exam FT2024

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Prof. Dr. Ralph Winkler

Author:	Thanh Truc Phan
Field of study:	Master in Economics
Student ID:	20-120-093
Postal address:	Waldmannstrasse 31/A8
	3027 Bern
Email:	thanh.phan@students.unibe.ch
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Part I: Essay

"Son, years ago, when I was your age, I often played on the beach with my friends, racing to see who could reach the sea first. Back then, we had to run for a long time. Today, the beach is barely half the size it was when I was a child."

This simple conversation between my father and me took place years ago in a small village in Vietnam, where he was born and raised. At the time, I was only seven years old and did not think much of his story. Perhaps I even assumed he was exaggerating. After all, how could the beach have been significantly larger in the past? The idea seemed unimaginable to me. However, looking back, I now realize that this conversation may have been my first personal encounter with the effects of climate change. It is likely the reason I still remember it so clearly and vividly.

Fast forward several years, and discussions about climate change have become widespread. Across the globe, individuals, communities, organizations, and governments have taken action, as exemplified by the Paris Agreement of 2015. But has anything truly changed?

In 2023, I found myself walking along the same beach with my father once again. Now in my twenties and more aware of global issues, I reflected on the photos we had taken years earlier and compared them to the beach's current state. The difference was undeniable - the once expansive shoreline had been reduced to a narrow strip of sand, with the sea encroaching further than ever before. The imbalance between land and water was striking.

As I sat beside my father, listening to him speak, he shared a troubling reality: According to friends and family, fishing was no longer a viable livelihood. This was particularly devastating, as the village had long depended on fishing as its primary source of income. Although my father had left the village at an early age, he still considered it the place where he truly belonged. Seeing the sadness in his expression moved me deeply, and I could not help but reflect on the injustice of climate change - a crisis disproportionately affecting

those who have contributed the least to it.

The villagers, whose way of life had been so drastically altered, had little to no influence on the emissions and policies that led to these changes. However, that was not the only change - the summer heat had become almost unbearable. With constant temperatures exceeding 40 degrees Celsius during the day and barely dropping below 30 at night, living without air conditioning had become nearly impossible. A large proportion of Vietnam's population does not have access to air conditioning, making extreme heat waves particularly deadly. The rising number of heat-related deaths, coupled with prolonged heavy rainfall and widespread flooding, underscores the harsh reality that climate change is no longer a distant threat - it is happening now.

Why, despite global awareness, does climate action remain insufficient? Examining past climate policies reveals a paradox. Most world leaders recognize that the carbon budget is depleting rapidly, as seen in agreements such as Kyoto (1997), Copenhagen (2009), and Paris (2015). Yet, despite these commitments, global emissions continue to rise. A natural question arises: Why is this happening?

This paradox is known as the **Climate Puzzle**. The core issue is that climate stability is a global public good. It is non-rival, meaning that emissions reductions benefit everyone, regardless of which country takes action. It is also non-excludable, meaning that no one can be prevented from benefiting from lower global emissions. On the other hand, if someone releases more emissions, then not only the emitting country is affected by the consequences but also every other country on the planet – this is called externality. Every country can choose between maximizing global welfare (**Global Social Optimum, GSO)** or prioritizing domestic welfare **(Global Emissions Game, GEG)**. Theoretically, following the GSO leads to an optimum where there are lower domestic emissions and as well as global emissions. Yet, no country has an incentive to reduce emissions. Why? Because countries face a prisoner's dilemma.

This situation presents a classic game theory dilemma: If all countries commit to reducing emissions, the benefits would be substantial - both economically and environmentally. The problem lies in the nature of the game. As a country decides to reduce its emissions, it bears the economic cost, while the benefits - cleaner air and climate stability - are shared globally. This creates an incentive for countries to undercut their commitments, leading to collective inaction. As a result, no country meaningfully reduces its emissions, and the overall benefits remain lower than in the socially optimal scenario where all parties uphold their commitments.

The framework conditions for combating climate change are not ideal either. Governments often hesitate to impose strict regulations due to economic and political pressures, resulting in weak enforcement of international agreements. The challenge of free-riding makes it difficult for nations to cooperate effectively. This leads to the question: Under what conditions can international coalitions form and succeed in reducing emissions?

The Coalition Formation Game demonstrates that optimal agreements emerge only in coalitions smaller than three. However, the real world consists of nearly 200 countries. The Modest International Cooperation (MIC) model attempts to address this by introducing a factor γ (degree of ambition), which directly affects the *willingness-to-pay* (WTP) of a country. This represents the amount a country is willing to sacrifice to mitigate climate damage. A lower degree of ambition means a lower WIP and the country will abate less. There is a trade-off between a stable coalition size and the degree of ambition. A lower γ can increase coalition size but pays in a reduction of overall abatement. Theoretically, a grand coalition including all nations could exist, yet as γ decreases, countries contribute less to emissions reduction, making the agreement weaker overall. This dynamic in the model explains why large-scale agreements, such as the Paris Agreement, struggle to enforce ambitious targets.

While the MIC model aligns with reality in some ways - nearly all nations have joined the Paris Agreement - progress has been insufficient to meet

the 2-degree Celsius target. The theory explains how coalitions form, but not whether members will actively cooperate. Without a supranational authority to enforce commitments, some countries join agreements without fully complying.

Furthermore, the theory assumes that all nations are homogeneous, yet real-world disparities in economic and geographic conditions make uniform cooperation unrealistic. While a smaller coalition of top emitters (China, the U.S., and India, responsible for over 50% of global emissions) could enhance efficiency, this raises another fundamental challenge: the divide between developed and developing nations over financial responsibility and climate justice.

Another major challenge is the divide between developed and developing nations. One of the central challenges in international climate negotiations is the disagreement between developed and developing countries over financial transfers. Historically, developed countries bear the greatest responsibility for climate change, having industrialized using gas, oil and coal. Today's developing nations argue that they too have the right to economic growth. While this may be true, the circumstances have changed, making it unlikely that developing nations can follow the same industrialization path as their predecessors.

Some of the developed countries acknowledge the need to support developing nations in transitioning to clean energy, yet they dispute financial responsibility: Many shift the burden onto others. Who should pay whom? The northern side of the globe - e.g. US or the EU - which industrialized a few decades before and contributed a lot to the greenhouse gas emissions. or the upcoming developing countries from the South – e.g. China or India - who are currently one of the top emitters. A major example – as seen in the article (Sengupta and Bearak, 2024) - in climate finance is whether China, the largest emitter today, should contribute financially to developing nations. While China classifies itself as a developing country, its economic and industrial dominance complicates this claim. Some argue that China should be held to

the same financial responsibilities as Western nations, while others contend that its per capita emissions and historical emissions remain lower than those of wealthier nations.

One of the important questions is in which form should be help transferred from the developed countries to the less developed countries? The answer to this question is difficult as both sides have a possibility to reduce their emissions and to fight against the climate change. Should developed countries prioritize their own transition to green and renewable energy, given their built infrastructure allows for a smoother shift? Should developed countries directly invest in developing nations to help them build infrastructure and transition more efficiently? But is it fair to leave developing countries to fend for themselves? Should the developed countries directly invest to developing countries so that they can build their infrastructure and catch up with the developed countries? That way the developing countries may skip the industrialization part where a lot of greenhouse gases are emitted and directly aim for a greener infrastructure.

As a matter of fact, developing nations are already suffering the consequences of climate change, diverting large portions of GDP toward disaster recovery rather than economic growth. They need financial help from the developed countries to overcome this crisis and more than the formal Loss and Damage fund is currently providing. Without urgent action, the gap between rich and poor nations will widen, pushing many developing economies into a cycle of survival rather than sustainable development. While developed countries may not feel the full impact yet, they will inevitably face severe consequences in the near future - more intensely than ever before.

The Road Ahead: Having witnessed firsthand the impact of climate change, I believe international cooperation must go beyond symbolic agreements. The crisis has gone beyond all bounds, and it is no longer possible for one country alone to overcome this global crisis for everyone. We need cooperation that is binding so that the goals become reality. Large-

scale cooperation has historically failed due to the free-rider problem, and recent geopolitical tensions make climate unity even more difficult. With trade barriers and conflicts increasing, can a functional coalition still emerge? Or must we reconsider our approach to addressing this crisis?

The current trend of imposing tariffs on Chinese green technology may protect Western industries in the short term, but it ultimately hinders global progress. Climate change is an existential crisis - we cannot afford to prioritize economic fears over environmental survival. Developing nations are already struggling, and if we fail to act, entire communities, like my father's village, will disappear beneath rising seas.

The article highlights the role of the U.S. and China, the two largest polluters. The article's prediction came true: Donald Trump was re-elected as the US-President. If he keeps his promise, then the U.S will withdraw from climate commitments, which could trigger a domino effect, weakening global cooperation. Meanwhile, China leads in renewable energy production, but its high emissions raise concerns. Yet, I argue that the cost of China's emissions is a necessary investment in clean energy development. I would rather incur a high immediate cost if we adopt clean energy now, as this would significantly reduce future costs to near zero. If Western fears materialize and China rises (if it has not already) to a global superpower, history suggests that humanity is more likely to unite against a common enemy. Unfortunately, climate instability does not present such a clear adversary - it is more like a child we are responsible for, requiring care and attention without the expectation of immediate returns.

Debating fairness: What does it mean to be fair in this crisis? Should every country contribute equally to the crisis, or should different countries abate more? If yes, under which criteria? In my opinion, without a supranational organization to hold countries accountable, such agreements within a grand coalition are little more than empty promises. As discussed in the lecture, Canada is prime example for not complying with the Kyoto Protocol. But who should have the authority to enforce compliance? Is such a thing even

fair?

As mentioned earlier, a smaller coalition consisting of past top GHG emitters (U.S., EU) and current top emitters (India, China) may be more effective. Together, these nations account for over 60% of global emissions. Reflecting on my childhood memories and my connection to the home country of my parents, I believe that the major emitters, responsible for a significant portion of global emissions, should bear the responsibility and take the lead in combating climate change. Furthermore, with fewer members, the free-rider problem is less pronounced than in a larger coalition. It would be ideal to establish an organization similar to a supranational body that oversees this small coalition. However, realistically, this seems unlikely. The European Union has a comparable structure that imposes penalties for any violations of the agreement. I doubt the EU would come into existence if it were being created today. Instead, as mentioned in the article, the remaining countries could foster something like the 'rise of climate leadership in the South' to contribute as much as possible to addressing climate change. Dividing the world into two groups based on their share of global emissions seems to me a more reasonable approach than forming a unified grand coalition.

The prospects for successful global cooperation grow dimmer as time passes. If the world does not urgently shift toward meaningful climate action, our future will not be dictated by policies or debates, but by unstoppable climate catastrophes. Whether it's a fisherman in a small village or an entire country, everyone suffers from the impacts of climate change. The time for half-measures is over. The world stands at a crossroads - either we commit to urgent, meaningful action now, or we risk leaving future generations with a planet beyond repair.

Part II: DBM with Transfer Scheme in Bi-quadratic Setup

Consider a world consisting of a set $I = \{1, \ldots, n\}$ of countries, in which country i's domestic benefits and damages are given by:

$$B_i(e_i) = \alpha_i e_i \left(\epsilon_i - \frac{e_i}{2}\right),$$
$$D_i(E) = \frac{\beta_i}{2} E^2, \quad i \in I,$$

where e_i denotes the domestic emission level of country i, ϵ_i denotes business-as-usual (BAU) emissions of country i and E is the level of global emissions:

$$E = \sum_{i=1}^{n} e_i.$$

Exercise (a)

Solve the Global Social Optimum (GSO):

$$\max_{[e_i]_{i=1}^n} \sum_{i=1}^{n} W_i(e_i, E) \quad \text{s.t.} \quad E = \sum_{i=1}^{n} e_i$$

$$\max_{[e_i]_{i=1}^n} \sum_{i=1}^{n} [B_i(e_i) - D_i(E)] \quad \text{s.t.} \quad E = \sum_{i=1}^{n} e_i$$

Remember the First Order Condition:

$$B_i'(e_i) = \sum_{i=1}^{n} D_i'(E), \quad i = 1, \ldots, n$$

And we get:

$$B_i'(e_i) = \alpha_i(\epsilon_i - e_i), \quad D_i'(E) = \beta_i E. \tag{1}$$

Thus, the FOCs read:

$$\alpha_i(\epsilon_i - e_i) = \sum_{i=1}^{n} \beta_i E = \mathscr{B} E$$

solving for e_i:

$$e_i = \epsilon_i - \frac{\mathscr{B}}{\alpha_i} E.$$

First, define $\mathcal{A} = \sum_{i=1}^{n} \frac{1}{\alpha_i}$ and $\mathscr{E} = \sum_{i=1}^{n} \epsilon_i$, and then sum over all countries, $i = 1, \ldots, n$:

$$E = \mathscr{E} - \sum_{i=1}^{n} \frac{B}{\alpha_i} E = \mathscr{E} - \mathcal{A}BE \quad \Rightarrow \quad E^* = \frac{\mathscr{E}}{1 + AB} \tag{2}$$

Inserting back, we obtain:

$$\epsilon_i^* = \epsilon_i - \frac{\mathscr{B}}{\alpha_i} E^* = \epsilon_i - \frac{\mathscr{B}}{\alpha_i} \frac{E}{1 + \mathscr{A}\mathscr{B}} \tag{3}$$

Social welfare of country i is given by:

$$W_i(e_i, E) = B_i(e_i) - D_i(E)$$

In our case:

$$W_i(e_i^*, E^*) = B_i(e_i^*) - D_i(E^*) \tag{4}$$

Then using equation (2) and (3):

$$\begin{aligned} W_i^*(e_i^*, E^*) &= \frac{1}{2}\alpha_i \left(\epsilon_i^2 - \frac{B^2}{\alpha_i^2} (E^*)^2 \right) - \frac{1}{2}\beta_i (E^*)^2 \\ &= \frac{1}{2}\alpha_i \left(\epsilon_i^2 - \frac{B^2}{\alpha_i^2} \left(\frac{\mathscr{E}}{1 + AB} \right)^2 \right) - \frac{1}{2}\beta_i \left(\frac{\mathscr{E}}{1 + AB} \right)^2 \end{aligned}$$

Exercise (b)

Solve Nash Equilibrium of the Global Emissions Game:

$$\max_{e_i} W_i(e_i, E_{-i}) \quad \text{s.t.} \quad E_{-i} = \sum_{j \neq i} e_j$$

$$\max_{e_i} \left[B_i(e_i) - D_i(E) \right] \quad \text{s.t.} \quad E_{-i} = \sum_{j \neq i} e_j$$

Again the first-order conditions:

$$B_i'(e_i) = D_i'(E), \quad i = 1, \ldots, n$$

with the same solutions:

$$B_i'(e_i) = \alpha_i(\epsilon_i - e_i), \quad D_i'(E) = \beta_i E$$

Thus, the first-order conditions become:

$$\alpha_i(\epsilon_i - e_i) = \beta_i E$$

Solving for e_i:

$$e_i = \epsilon_i - \frac{\beta_i}{\alpha_i} E$$

This time defining $\mathscr{C} = \sum_{i=1}^{n} \frac{\beta_i}{\alpha_i}$, then sum up over all countries $i = 1, \ldots, n$:

$$E = \mathscr{E} - \sum_{i=1}^{n} \frac{\beta_i}{\alpha_i} E = \mathscr{E} - \mathscr{C} E \quad \Rightarrow \quad \hat{E} = \frac{\mathscr{E}}{1 + \mathscr{C}} \tag{5}$$

Inserting back, we obtain:

$$\hat{e_i} = \epsilon_i - \frac{\beta_i}{\alpha_i} \hat{E} = \epsilon_i - \frac{\beta_i}{\alpha_i} \frac{\mathscr{E}}{1 + \mathscr{C}} \tag{6}$$

Social welfare of country i is again given by:

$$W_i(e_i, E) = B_i(e_i) - D_i(E)$$

In our case:

$$\hat{W}_i(\hat{e_i}, \hat{E}) = B_i(\hat{e_i}) - D_i(\hat{E})$$

Then using equation (5) and (6):

$$\begin{aligned} \hat{W}_i(\hat{e_i}, \hat{E}) &= \frac{1}{2}\alpha_i \left(\epsilon_i^2 - \frac{\beta_i^2}{\alpha_i^2} \hat{E}^2 \right) - \frac{1}{2}\beta_i \hat{E}^2 \\ &= \frac{1}{2}\alpha_i \left(\epsilon_i^2 - \frac{\beta_i^2}{\alpha_i^2} \left(\frac{\mathscr{E}}{1 + \mathscr{C}} \right)^2 \right) - \frac{1}{2}\beta_i \left(\frac{\mathscr{E}}{1 + \mathscr{C}} \right)^2 \end{aligned}$$

Exercise (c)

Setup: if a country i is compliant, it sets $e_i = e_i^*$ (eq. 3 if the country is non-compliant, it sets $e_i = e_i^*$ (eq. 6) given that a set C of other countries is also compliant (i.e., $e_j = e_j^*$ for all $j \in C$).

Calculating the global emissions for country i:

$$E^C(\mathcal{C}) = e_i^* + \sum_{j \in \mathcal{C}} e_j^* + \sum_{j \notin \mathcal{C}} \hat{e_j}, \quad \text{if country } i \text{ is compliant} \tag{7}$$

$$E^{NC}(\mathcal{C}) = \hat{e_i} + \sum_{j \in \mathcal{C}} e_j^* + \sum_{j \notin \mathcal{C}} \hat{e_j}, \quad \text{if country } i \text{ is non-compliant} \tag{8}$$

Further, calculate the welfare level of i in stage 2, whether he is compliant or non-compliant.

$$W_i(\mathcal{C}, i \in \mathcal{C}) = B_i(e^*) - D_i(E^C) \quad \text{if country } i \text{ is compliant} \tag{9}$$

$$= \frac{1}{2}\alpha_i \left(\epsilon_i^2 - \frac{B^2}{\alpha_i^2}(E^*)^2 \right) - \frac{1}{2}\beta_i (E^C)^2 \tag{10}$$

$$W_i(\mathcal{C}, i \notin \mathcal{C}) = B_i(\hat{e_i}) - D_i(E^{\mathrm{NC}}) - \delta_i \quad \text{if country } i \text{ is non-compliant} \tag{11}$$

$$= \frac{1}{2}\alpha_i \left(\epsilon_i^2 - \frac{\beta_i^2}{\alpha_i^2}(E^{\mathrm{NC}})^2 \right) - \frac{1}{2}\beta_i (E^{\mathrm{NC}})^2 - \delta_i \tag{12}$$

Exercise (d)

Using the stability condition:

$$S_i(C) = W_i(\mathcal{C}, i \in \mathcal{C}) - W_i(\mathcal{C}, i \notin \mathcal{C}) \tag{13}$$

$$= \frac{1}{2}\left(-\frac{\mathcal{B}^2}{\alpha_i}(E^*)^2 + \beta_i \left[(E^{NC})^2 - (E^C)^2 \right] + \frac{\beta_i^2}{\alpha_i}(E^{NC})^2 \right) + \delta_i > 0 \tag{14}$$

put δ_i on one side:

$$\Rightarrow \delta_i > \bar{\delta}_i(\mathcal{C}) := \frac{1}{2}\left(\frac{\mathcal{B}^2}{\alpha_i}(E^*)^2 - \beta_i \left[(E^{NC})^2 - (E^C)^2 \right] - \frac{\beta_i^2}{\alpha_i}(E^{NC})^2 \right) \tag{15}$$

Show that $\bar{\delta}_i(\mathcal{C})$ is highest if all other countries comply. Because E^* doesn't depend on $\mathcal{C}$, we have to minimize:

$$\beta_i[(E^{NC})^2 - (E^C)^2] + \frac{\beta_i^2}{\alpha_i}(E^{NC})^2$$

From exercise c, we know equations 7 and 8 and from the lecture $e^* < \hat{e}_i$.

$$E^C = e_i^* + \sum_{j \in \mathcal{C}} e_j^* + \sum_{j \notin \mathcal{C}} \hat{e_j} \tag{16}$$

which is maximized when all other countries comply. And

$$(E^{\mathrm{NC}})^2 - (E^C)^2 = (E^{\mathrm{NC}} + E^C)(E^{\mathrm{NC}} - E^C) \tag{17}$$

$$= 2(\sum_{j \in \mathcal{C}} e_j^* + \sum_{j \notin \mathcal{C}} \hat{e_j}) + e_i^* + \hat{e_i})(\hat{e_i} - e_i^*) \tag{18}$$

which is also maximized if all countries j comply.

Therefore, indeed $\bar{\delta}_i(\mathcal{C})$ is highest if all other countries comply.

Exercise (e)

Take the assumptions from the exercise: $n = 4$, $\alpha_L = 1$, $\alpha_H = 2$, $\beta_L = 0.1$, $\beta_H = 0.2$, $\epsilon_L = \epsilon_H = 0.7$, where half of all countries is of type L and half of which is of type H.

Then calculate the variables using the formulas we derived in the previous exercises:

$$\begin{aligned} \mathcal{A} &= 2 \times 1 + 2 \times \frac{1}{2} = 3 \\ \mathcal{B} &= 2 \times 0.1 + 2 \times 0.2 = 0.6 \\ \mathcal{C} &= 2 \times \frac{0.1}{1} + 2 \times \frac{0.2}{2} = 0.4 \\ \mathcal{E} &= 4 \times 0.7 = 2.8 \end{aligned} \tag{19}$$

$$E^* = \frac{2.8}{1 + 3 \times 0.6} = 1 \tag{20}$$

$$e_H^* = 0.7 - \frac{0.6}{2} = 0.4 \tag{21}$$

$$e_L^* = 0.7 - \frac{0.6}{1} = 0.1 \tag{22}$$

Set $\bar{\delta}_i(\mathcal{C})$ as derived in exercise (d):

$$E^C = E^C_H = E^C_L = \sum_{j\in\mathcal{C}} e^*_j + e^*_i = 2 \times 0.4 + 2 \times 0.1 = 1 = E^* \tag{23}$$

$$E^{NC}_H = \sum_{j\in\mathcal{C}} e^*_j + \hat{e_H} = 0.4 + 2 \times 0.1 + \hat{e_H} = 0.6 + \hat{e_H}$$

$$E^{NC}_L = \sum_{j\in\mathcal{C}} e^*_j + \hat{e_L} = 2 \times 0.4 + 0.1 + \hat{e_L} = 0.9 + \hat{e_L}$$

$$\hat{e_H} = 0.7 - 0.1(0.6 + \hat{e_H}) \Longrightarrow \hat{e_H} = \frac{0.64}{1.1}$$

$$\hat{e_L} = 0.7 - 0.1(0.9 + \hat{e_L}) \Longrightarrow \hat{e_L} = \frac{0.61}{1.1}$$

$$E^{NC}_H = 0.6 + \hat{e_H} = 0.6 + \frac{0.64}{1.1} = \frac{13}{11} \tag{24}$$

$$E^{NC}_L = 0.9 + \hat{e_L} = 0.9 + \frac{0.61}{1.1} = \frac{16}{11} \tag{25}$$

Deriving the deposits for type L and type H by plugging (19)-(25) into (15):

$$\bar{\delta_H}(\mathcal{C}) = \frac{1}{2}\left\{\frac{0.6^2}{2}(1)^2 - 0.2\left[\left(\frac{13}{11}\right)^2 - (1)^2\right] - \frac{0.2^2}{2}\left(\frac{13}{11}\right)^2\right\} \approx 0.0364 \tag{26}$$

$$\bar{\delta_L}(\mathcal{C}) = \frac{1}{2}\left\{\frac{0.6^2}{1}(1)^2 - 0.1\left[\left(\frac{16}{11}\right)^2 - (1)^2\right] - \frac{0.1^2}{1}\left(\frac{16}{11}\right)^2\right\} \approx 0.1136 \tag{27}$$

Type L has to pay a higher deposit than countries with type H, which is already evident if we compare the alphas and betas. Because of $\alpha_L < \alpha_H$ and $\beta_L < \beta_H$, it directly follows that $\bar{\delta}_L > \bar{\delta}_H$. This leads to the conclusion that type L countries, which are countries in transition and developing countries have to pay a higher deposit than developed countries. It doesn't seem fair to make poorer countries pay more deposit than richer countries.

Exercise (f)

GSO: Plugging (20)-(22) into $W_i(e_i, E)$:

$$W^*_H(e^*_i, E^*) = 2 \times 0.4\left(0.7 - \frac{0.4}{2}\right) - \frac{0.2}{2} \times 1^2 = 0.3 \tag{28}$$

$$W^*_L(e^*_i, E^*) = 1 \times 0.1\left(0.7 - \frac{0.1}{2}\right) - \frac{0.1}{2} \times 1^2 = 0.015 \tag{29}$$

GEG: Continue putting in the parameters:

$$\hat{E} = \frac{2.8}{1+0.4} = 2 \tag{30}$$

$$\hat{e_H} = 0.7 - \frac{0.2}{2} \times 2 = 0.5$$

$$\hat{e_L} = 0.7 - \frac{0.1}{1} \times 2 = 0.5$$

$$\hat{W}_H(\hat{e_H}, \hat{E}) = 2 \times 0.5 \left(0.7 - \frac{0.5}{2}\right) - \frac{0.2}{2} \times 2^2 = 0.05 \tag{31}$$

$$\hat{W}_L(\hat{e_L}, \hat{E}) = 1 \times 0.5 \left(0.7 - \frac{0.5}{2}\right) - \frac{0.1}{2} \times 2^2 = 0.025 \tag{32}$$

Comparing $(W_L^*(e_i^*, E^*) + W_H^*(e_i^*, E^*) = 0.315 > 0.3 = \hat{W}_L(\hat{e_L}, \hat{E}) + \hat{W}_H(\hat{e_H}, \hat{E}))$, it's clear, that the global social welfare is higher in GSO than in GEG. Comparing the domestic welfare:

$$\Delta W_H = W_H^* - \hat{W}_H = 0.3 - 0.05 = 0.25$$

$$\Delta W_L = W_L^* - \hat{W}_L = 0.015 - 0.025 = -0.01$$

We can observe that it's a Pareto improvement for type H countries but it's not a Pareto improvement for type L countries which are clearly better off in GEG. From a GSO perspective, it is inefficient for highly developed countries to have lower welfare. The GSO focuses solely on global welfare rather than domestic welfare. Since highly developed countries (type H) face higher abatement costs, it is logical that they will always identify potential improvements within the GSO framework.

Exercise (g)

Because the type L of countries are worse off in the GSO than in the GEG the GSO, they won't pay the deposit in the first stage of the DBM. It is always best to allocate resources in the least costly way first and then reallocate them for maximum efficiency. Consider the total welfare increase of 0.15, which can be easily redistributed to type L countries. This approach not only increases total welfare but also ensures a Pareto improvement for both poorer and richer countries. The GSO with transfers represents a Pareto improvement over the GEG:

$$\hat{W}_H(\hat{e_H}, \hat{E}) \leq W_H^*(e_i^*, E^*) - T < W_H^*(e_i^*, E^*)$$

$$W_L^*(e_i^*, E^*) < \hat{W}_L(\hat{e_L}, \hat{E}) \leq W_L^*(e_i^*, E^*) + T$$

leading to:

$$T \in [0.025 - 0.015, 0.3 - 0.05] = [0.01, 0.25]$$

Based on these calculations, the set of feasible transfer payments is given by $T \in [0.01, 0.25]$. In the first stage, countries of type H make their required deposits, which serve as an upfront commitment, along with the transfer payment. In the second stage, countries of type L receive their deposits back, along with the allocated transfer payments, contingent on their compliance with the agreement. This sequential timing of deposits and transfers ensures that compliance remains incentive-compatible, motivating countries of type L to adhere to the terms, while also maintaining a Pareto improvement for both types of countries.

References

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