Parts Per Million: A Collective Action Game

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This game allows class members to conduct a group experiment on conditions that favor collective action. We will play a game that simulates the problem of sovereign states deciding whether or not to cooperate to avoid harmful climate change. We will play the game three times under different conditions that theory says should or should not make collective action easier.

Players are asked to observe not just whether there are differences in outcomes, but also whether you observe differences in your own strategic thinking or in what you infer about the thinking of others. Ideally you will devote about ¼ of your attention to actually playing the game with the other ¾ devoted to observing yourself and others and—during the 2^{nd} and 3^{rd} games—to comparing the behavior you observe to what you remember from previous games played under different conditions.

The climate components of this simulation include a great many simplifications; the aim is verisimilitude, not realism. Climate change outcomes in the simulation could be larger, smaller, or different than the models' predictions—let alone compared to what may actually occur.

Common Elements for All Three Simulations

The game is played in up to nine rounds (as time allows), each representing a decade of actual time starting in 2010 and ending in 2100.

Your goal is to maximize your country's per capita income at the end of the simulation. The main choices that you will have to make will concern whether or not to invest in technology to reduce your country's CO_2 emissions and whether or not to aid other countries by transferring technology.

The players will take the roles of 12 countries. You will keep the same country for all three simulations so that you can compare thought processes, behavior, and outcomes. Each country is rated for its 2010 income level, rate of income growth, 2010 technology level, flexibility, and vulnerability to economic harm due to climate change:

Country	Player	2010 Income[1]	Growth Rate[2]	2010 Tech Level	Flexibility	Vulnerability
Germany	Ani	36	5	1	7	Medium
Russia	Bowman	16	5	0	2	Low
Turkey	Dobry	13	7	0	4	High
Iran	Guernier	11	6	0	3	Very High
India	Hannon	4*	8	0	3	Very High
Indonesia	Lenker	5*	8	0	4	Medium
China	Lowrie	7*	10	0	5	High
Japan	O'Neill	34	4	1	6	Low
Australia	Ross	37	7	0	5	Very High
Brazil	Surmachev.	12*	9	0	4	Medium
United States	Uber	47	6	1	5	Low
Canada	Walczak	39	7	1	6	Very Low

In the game, the "technology" level of each country represents some combination of energy production, distribution, and conservation technologies, regulation, social values, and individual behavior that determine the energy efficiency of each country's economy, which in turn determines that country's CO_2 emissions.[3]

Each country is also rated for "flexibility," which is some combination of scientific knowledge base and political, economic, and social flexibility that determines the likelihood that efforts to invest in technology will actual achieve efficiency gains and emissions reductions. (For simplicity, we assume that the success of countries' investment efforts are not affected by the efforts of others. We also assume that flexibility does not change over time.)

Finally, each country is rated for its vulnerability to climate change. The ratings are a rough, impressionistic representation of conventional wisdom about these countries' relative vulnerability based on latitude, vulnerability to drought and storms, and general environmental robustness or fragility.

At the start of the game in 2010, the atmospheric CO_2 level will be 389 ppm (parts per million).[4] This will change—most likely increase--over time. Depending on the CO_2 level at the end of each decade and each country's vulnerability, countries may suffer economic harm from climate change that could erase some of—or all of, or more than all of—their income growth for that decade.[5]

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[1]. GDP per capita at purchasing power parity, $000s. Based on 2008 data from International Monetary Fund, *World Economic Outlook Database.* http://www.imf.org. Assumes no growth from 2008 to 2010 except $1,000 per capita for each of India, Indonesia, China, and Brazil.

[2]. $1,000 per capita per decade. We simplify by assuming constant rates of growth.

[3]. For purposes of the simulation it makes no difference whether what "technology" improves is energy efficiency (less energy consumed per $ of product), emissions efficiency (smaller CO_2 emissions per unit of enery consumed), carbon capture, or all of these.

[4]. The measured level in 2009 is 387 ppm; the average annual increase since 2000 has been about 2.1 ppm. U.S. National Oceanic & Atmospheric Administration Earth System Research Laboratory. http://www.esrl.noaa.gov/gmd/ccgg/trends/

[5]. This omits a step, since any economic harm would not be due to the CO_2 level itself but to its effects, such as increased temperature and altered weather patterns. Provided, however, that we believe that these effects will be monotonically related to the CO_2 level (that more and more CO_2 will yield more and more of the consequences that we care about) this simplification makes no difference.

Since the countries have different starting incomes, different growth rates, and different degrees of vulnerability to climate change, final income levels will not be comparable. Your goal is to do as well as you can regardless of how any other country does. You will have to decide whether you consider the outcome a success or a failure for your country; you cannot "win" by "defeating" others. (In effect the game incorporates the Liberal position in the Liberal/Realist debate about whether states should—or do—consider absolute or relative gains more important.)

When comparing the three simulations *to each other*, a higher final income for a given country can be considered a relative success, as can higher final incomes for all countries collectively and a lower final atmospheric CO_2 level.

1. First game (baseline condition)

Each round, representing a decade of actual time, is played in 5 steps.

A. Investment

We allow several minutes (longer for the first round) for the players to negotiate with each other concerning what each of them plan to do this round. Since technology investment by any country is costly to that country but benefits all, what each player is willing to do each round may depend on what others agree to do. (Note that some countries—the ones most vulnerable to climate change—benefit more than others if anyone invests in energy efficiency.)

Each player who wishes to invest places a designated token in front of themselves. This costs 1 unit ($1,000 per capita) of foregone income growth.

B. Technology Transfer

Countries may transfer technology to other countries whose technology is less advanced than their own. Like technology investment, technology transfer is costly to donor countries but benefits all (indeed it benefits all countries equally, recipients, non-recipients, and donors alike). As for investment we allow some time for negotiation.

Each player who wishes to transfer technology to others places one token—of a different type than those used for investment—in front of themselves for each intended recipient (we will have to remember who the intended recipients are).[6]

Technology transfer costs the donor 0.5 units for each recipient country; there is no cost to the recipients.[7] If several countries donate to the same recipient, they share the cost. *Example: Germany, Japan, and the U.S. all donate technology to Turkey, Iran, India, and*

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[6]. Given how the game is structured there is no motive for any recipient to ever reject technology transfer—at least in the first two games; there could be such a motive in the 3rd game; see below.

[7]. Since technology transfer to reduce carbon emissions would require not only supply of scientific and engineering knowledge and, perhaps, capital equipment by donor countries but also economic and social adjustment by recipient countries, it would not actually be costless to recipients. For simplicity we assume that donor countries somehow compensate recipients for these costs so that net cost to recipients is zero. This is a large assumption because some of the absorption costs, such as political and social dislocation or instability, would be impossible to quantify in economic terms. This assumption is, however, necessary to simplify the playing of our game.

China. Four recipient countries cost 2.0 units (4 x 0.5) shared among three donors comes to 0.7 units each (2.0 / 3, rounded to the nearest 0.1).

C. Adjustment of Technology Levels

Each player that invested in technology this round rolls one 10-sided die (d10).[8] If the number rolled is <= that country's Flexibility, the investment is successful and the country's technology level increases by 1.

Each country that was a recipient of technology transfer increases its technology level by 1.

A country can benefit from both methods of increasing its technology in the same round.

D. Determination of Atmospheric CO_2 Level

First, each player rolls a d10 to determine their country's contribution to increased CO_2 levels.[9] The die roll is modified by two factors:

-Increased emissions due to growing world product. Subtract from 0 to 3 from the die roll depending on the date of each round:[10]

Round Start Date	Die Roll Modifier
2010	none
2020-2040	-1
2050-2070	-2
2080-2090	-3

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8. '0' is read as 0, not 10.

9. Since in the game there are no emissions from other sources, in effect we are treating these countries as if they were the entire world economy. Actually they were 60.3% in 2008. U.S. C.I.A., *World Factbook.* https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html. This is a reasonable simplification if what we are interested in is collective action; we would expect different behavior in a situation where some players cannot even be asked to cooperate.
We are also implicitly treating these countries as if their economic sizes were the same. To do otherwise would involve us in a lot of calculation that would slow the game considerably.

10. This means that we are assuming that, as world product rises, there will be—absent the kinds of special effort represented in the game by technology investment—at least some increase in energy consumption and thus in CO_2 emissions. In the early stages of industrialization energy efficiency usually declines (i.e., energy use and emissions rise faster than income) but in recent years the world's richest countries have seen increases in efficiency (energy use and emissions have risen more slowly than income). Few economies, however, have seen efficiency rise as fast or faster than economic growth (which would be required for energy consumption and emissions to remain stable or actually decline), and it is not clear whether anyone has yet achieved this sustainably.
We could base this effect on each country's calculated economic growth decade by decade, but for simplicity this table assumes that the rise in emissions—again, absent effort represented by technology investment—will be constant. Note that if the atmospheric CO_2 level eventually rises high enough some countries may experience decades in which they have no net income growth or even a decline. It is, however, reasonable to assume that energy needs would continue to grow even in that situation--the phenomenon, once a system exceeds its carrying capacity, of 'having to run faster to stay in the same place' that is familiar from the Maya and Easter Island cases.

-Reduced emissions due to advanced technology. Add each country's technology level to its die roll.

Roll on this table:[11]

Modified Die Roll	Net Change To CO_2
<0	+9 ppm
0	+8.ppm
1-2	+7 ppm
3-4	+6 ppm
5-6	+5 ppm
7-8	+4 ppm
9-10	+3 ppm
11-12	+2 ppm
13-15	+1 ppm
16+	0 ppm

Second, each decade natural decay and absorption processes reduce atmospheric CO_2 by 40 ppm.[12] [13] [14]

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[11] This table yields an expected net contribution of the 12 player countries during the first decade (2010-2020) if none invest in technology of 8x5.5 + 4x5 = 64 ppm.

[12]. In recent decades net removals of CO_2 from the atmosphere due to photosynthesis, respiration, decay, and (especially) sea surface gas exchange have amounted to about half of CO_2 added by burning of fossil fuels, deforestation, and other causes (mainly fossil fuels). This cannot be sustained, however, as the ability of the oceans to absorb CO_2 will decline over time as CO_2 already absorbed makes the oceans more acidic. High atmospheric CO_2 levels may result in increased absorption due to plant growth, but not enough to make up the difference. S. Solomon et al, eds. Climate Change 2007: The Physical Science Basis (Intergovernmental Panel on Climate Change, 2007), pp. 512, 517, and chapter 7, *passim*; S. Khatiwala, F. Primeau, and T. Hall, "Reconstruction of the History of Anthropogenic CO2 Concentrations in the Ocean" (letter), *Nature* 462, November 19, 2009. See also Donald J. Wuebbles and Jae Edmonds, *Primer on Greenhouse Gases* (Lewis Publishers, 1991), pp. 84-86. For simplicity, we treat the rate of removal of CO_2 from the atmosphere as constant.

[13]. In other words, the removal rate is assumed to be constant; the simulation does not take account of possible declining ability of the planet to absorb CO_2.
These numbers also mean that the expected change in the atmospheric CO_2 level for the first decade of the game—absent technology investment—will be 64 - 40 = +24 ppm compared with +21 ppm in the previous decade, about a 15% increase. This is probably low, since the increase in world product will likely be substantially more than that. In effect this assumes that there will be advances in energy efficiency even without special effort.
Note also that, contra fn. 12, the 40 ppm removal rate is > half of the 64 ppm emissions rate. We could have designed the table so that expected emissions would total, say, 50 ppm and set the removal at 25 ppm. It makes no difference, however, as long as the projected net change for the first decade is about +25 ppm. The numbers in table were chosen arbitrarily for convenience in play of the game.

[14]. This simulation makes no allowance for self-acceleration of the greenhouse effect due to melting of permafrost and release of sequestered methane.

E. Determination of Incomes

First, each country's income increases by the growth rate shown in the table on page 2 less any costs for technology investment or technology transfer from step B on page 3.

Then, depending on the atmospheric CO_2 level at the end of the decade determined in Step D above, some or all countries may have to roll a d10 to determine any income losses due to climate change. Each player rolls a d10 and adds or subtracts the modifier shown in the table below:

CO_2 Level in ppm	Vulnerability: Very Low	Low	Medium	High	Very High
<375	none	none	none	none	none
375-399	none	none	none	none	-6
400-424	none	none	none	-6	-5
425-449	none	none	-6	-5	-3
450-474	none	-6	-5	-3	-1
475-499	-6	-5	-3	-1	+1
500-524	-5	-3	-1	+1	+3
525-549	-4	-2	+0	+2	+4
550-574	-3	-1	+1	+3	+5
575-599	-1	+1	+3	+5	+6
600-625	+1	+3	+5	+6	+7
625-649	+3	+5	+6	+7	+8
650-674	+5	+6	+7	+8	+9
675+	+6	+7	+8	+9	+10

The modified result is subtracted from the country's per capita income.

This completes one round (one decade) of the simulation. The next round now begins with Step A.

2. Second game (Immediate Danger)

Numerous observers have suggested that one of the reasons for relatively slow policy response to climate change is short-termism. The costs of reducing emissions would begin immediately but the benefits of reduced emissions would not be significant for decades. Possibly collective action might be easier if the benefits of cooperation were more immediate and obvious.

Accordingly, in our second simulation all countries will be treated as having Very High vulnerability to climate change.

3. Third game (C.O.L.L.E.C.T.I.V.E. A.C.T.I.O.N.)

A commonly proposed solution for collective action problems is to make benefits at least partially excludable. One common way to do this to create a dual-purpose entity that both pursues the collective, non-excludable good as well as providing other goods to members only. AARP (formerly the American Association of Retired People) both lobbies Congress on behalf of elderly Americans (a non-excludable good) and provides news to its members, negotiates insurance and other discounts, and provides other (excludable) goods to its members only.

It is difficult to see how amelioration of harm from atmospheric CO_2 and consequent climate change could be made excludable, but perhaps part of the cost of efforts to reduce emissions could be. Accordingly, in our third simulation players will have the option of joining the *Co-operative Opportunity to Legislate Lasting, Effective Climate-Taming Initiatives Vital to Everyone via Agreement on Carbon Technology Investment—Or Not* (C.O.L.L.E.C.T.I.V.E. A.C.T.I.O.N.).

Steps A and B of each round are modified as follows:

A. Investment

First, any countries that were members of C.O.L.L.E.C.T.I.V.E. A.C.T.I.O.N. during the previous round may leave; if they do, they may not join again during the current round.

Next, countries may join the organization. Once a country joins, it cannot leave until Step A of the *next* round. In effect, joining the organization is a ten-year commitment.

Provided that C. O.L.L.E.C.T.I.V.E. A.C.T.I.O.N has at least 2 members, the member countries:

-*Must* invest in technology this round;

-Gain advantages from synergies, specialization, and enhanced legitimacy that reduce the cost of investment from 1.0 to 0.5.

There is no effect on countries that are not members, who make their decisions as usual.

B. Technology Transfer

Provided that C.O.L.L.E.C.T.I.V.E. A.C.T.I.O.N has at least 2 members, the member countries:

- *Must* transfer technology to all other members with less advanced technology than themselves; and

-For the same reasons of synergy, specialization, and enhanced legitimacy, the cost to donor countries is reduced from 0.5 to 0.25 per recipient.

There is no effect on countries that are not members, who make their decisions as usual.

Steps C, D, and E then proceed as usual.