Teaching and Educational Methods

Making Learning about Climate Change Fun and Interactive

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Abstract
Climate change policy is a challenging subject to teach to undergraduates as it requires knowledge of a complex physical system (our planet) combined with an understanding of our global social-political-economic structures, which engender puzzling, yet, predictable behavior by participants. Further complicating this learning environment are the personal and social implications of choosing to combat climate change versus allowing others to address the problem (i.e., free-riding). To simulate the complex decision environment for climate change policy making, a "public good game" classroom experiment is a useful activity that allows students to make decisions regarding the provision of a public good (climate mitigation) while observing how their behavior and the behavior of others results in benefits (or costs) that are shared by all. In this paper, six public good games are played by students in an undergraduate environmental economics course with different parameterizations in each game simulating different aspects of climate change negotiations that can help explain why some policies related to climate change succeed while others fail. Special considerations for face-to-face versus online implementation are explored.

1 Statement of Purpose and Objectives

Climate change is an important topic that is commonly included in environmental economics classes, yet it can remain a challenging topic to teach. It requires a great deal of effort to avoid overwhelming students with the complexity of the earth's atmospheric and land/ocean conditions combined with an equally complex social-political-economic policy making environment. Global climate change policy takes place at the international level by way of the United Nations Intergovernmental Panel on Climate Change (IPCC). The IPCC is charged with compiling and assessing the scientific information on climate change to inform global policies to mitigate greenhouse gas emissions and adapt to the impacts of climate change (IPCC 2020). Mitigation of climate change, such as through emission controls or carbon sequestration, often comes at significant cost to nations implementing those strategies while the benefits, such as a slower rise in global temperature, are shared by everyone. Additional complexity to the decision-making setting is that, instead of contributing to a public good, nations are often working toward avoiding a public bad, often referred to in climate science as a tipping point (Lenton 2011). Finally, the ability to combat climate change is not consistent across the globe as not all countries equally contribute to the problem and therefore cannot necessarily combat climate change on their own (Trollip, Gunfaus, and du Toit 2015).

According to NASA, 97 percent of climate scientists agree that global warming is anthropogenic (human-induced) and therefore is a problem that must be addressed with human action (NASA 2020). Furthermore, scientific evidence supports the idea that human-induced climate change could trigger several "tipping points" from which there may be no return (Lenton 2011). This bleak picture can often make climate change a challenging topic to broach in class, as it is a highly emotional topic for teachers

and students alike (Lombardi and Sinatra 2012). To effectively communicate this challenging topic, innovative games may be used to allow students to understand the gravity of climate change in a tangible and compelling manner. Meya and Eisenack (2018) have found that games are an innovative and fun way to teach about scientific and social aspects of climate change and climate action. Providing students the opportunity to experience a practical simulation of climate change and climate action in a game often opens doors for successful communication and learning (Meya and Eisenack 2018).

The presented approach to address the complexities in climate change negotiations has been to use an economic game that starts out as a simple public good game and works up to addressing the complexities inherent in climate negotiations. In this way, students have a gentle introduction to the subject, stripping away much of the context to then be added back in during discussion, which has the benefit of reducing the potential for emotional conflation that occurs with many discussions about climate change. The purpose of this teaching note is to (1) describe how to implement the game in a relevant course, (2) discuss strategies for implementation, and (3) provide an example assessment that can follow the experiment and test student learning.

2 Intended Audience and Student Learning Objectives

This activity is appropriate for any course that introduces concepts related to public good provision, sustainability, and climate change. It has been successfully implemented in different courses at the University of Florida including lower- and upper-level environmental economics courses and a course on developmental economics. This activity targets the following student learning objectives (SLOs). After completing this activity, students should be able to:

1) Articulate how economic incentives influence individual and group behavior incorporating theories from game theory, behavioral economics, and political economy,
2) Empirically assess an economically efficient outcome versus a socially optimal outcome in a public goods game, and
3) Calculate net benefits of various climate policies, identifying net welfare impacts.

3 Teaching Strategy

In this classroom activity, students have an opportunity to play six games that relate to various aspects of public good provision, tipping points, inequality in climate mitigation, and ideas related to economic subfields such as behavioral economics and political economy. It has been played in a 50-minute period, face-to-face and virtually.

Students are provided with a worksheet that includes important terms (Supplement 1) and a payoff table (Table 1), so that students can keep track of their decisions and payoffs. If implementing this game virtually, it may be easiest to provide a blank payoff table that they can download or fill out on their own (such as this one on Google Drive). In the table, students are informed of their endowment (e) of bonus points, which they can then choose to contribute (c) to the public good. The public good accrues differently based on the game (shown by the equations in Table 1 and described in detail in the following). Finally, students can calculate their payoff as their endowment minus contributions plus the public good provided. One game is selected at random to be the "binding" game to create incentive compatibility for every game.[1] Shortly after the game, students are assigned a homework to assess achievements of the SLOs (Supplement 2). The rest of this section goes into more details about the parameterizations within each game and the relevant terms for each game. There is an accompanying PowerPoint that moves students through the six games (Supplement 3). After describing each game, facilitation and results are discussed.

[1] If there are a lot of points in the class, or if this is the only bonus activity, there is an alternative strategy that allows for bonus point accrual across all games. This may result in students optimizing across all games rather than each independent game, which may impact behavior.

Table 1. Payoff Table for the Climate Change Public Good Game

Your Name:				
Game	**Endowment (e)**	**Contribution (c)**	**Public Good (pg)**	**Total Bonus Points $e - c + pg$**
Game 1	3		$pg = \frac{\sum c}{40} =$	
Game 2	3		$pg = \frac{\sum c}{40} =$	*don't add the public good (pg) to your bonus here
Game 3	3		$pg = 2$ if $\sum c \geq 55$, and $pg = 0$ otherwise	
Game 4	3		$pg = 1$ if $\sum c \geq 55, 0$ and $pg = -1$ otherwise	
Game 5	4		$pg = 0$ if $\sum c \geq 55$, and $pg = 0$ otherwise	
Game 6	1		$pg = 0$ if $\sum c \geq 55$, and $pg = -1$ *otherwise*	

3.1 Game 1: Basic Public Good Game

The basic setup is that each student has an "endowment" of bonus points that they can contribute to a public good. This should be roughly equal to what you would typically award for a bonus activity. A consistent endowment of 3 bonus points for the first four games is used in all supplemental materials as a means of demonstration. The payoff for the public good in the first game is a simple conversion depending on one's class size. For an 80-person class (N), a conversion rate of contributions/(0.5 × N) works well because if each student contributes 1 (resulting in 80 contributions), the class is better off by 2 bonus points. If everyone contributed all bonus points, each student would earn 6 bonus points. This is an appropriate time for the instructor to point out *behavioral economics*, *game theory*, a *win-win situation*, and *free-riding* (see Supplement 1 for the definitions of these terms). This is always the highest earnings game of the six games.

3.2 Game 2: Future Generations Public Good Game

Since the benefits of climate mitigation will primarily help future generations while coming at a cost to current generations, this dilemma is simulated with a future generations public good game. Students repeat the basic game except that the public good (contributions/(0.5 × N)) is given to a future teaching of the course at the beginning of the semester. This is an appropriate time for the instructor to point out *altruistic* behavior (or a lack thereof) and to remind students of the concept of discount rates, if these have already been discussed, or to introduce the concepts briefly. Nuances of altruistic behavior can be discussed or incorporated into the games such as fixing past generation problems (e.g., bonus points go to remedying lost points from a previous class) or giving to future generations along various timelines (e.g., their children or a future class). This is also an opportunity to remind students of nonuse values if they have been discussed or to introduce the topic briefly.

3.3 Game 3: Threshold Public Good Game

Climate negotiations have been modeled as a threshold public good game (Feige, Ehrhart, and Krämer 2018). In this scenario, students must meet a threshold level of contributions to achieve the public good (which is simply a constant value of 2). Any threshold above the previous conversion rate but less than

the class size is appropriate to induce expected free-riding and the idea of a *zero-sum game*.[2] If the threshold is closer to the previous conversion rate, students will likely overshoot the threshold. If the threshold is closer to the class size, students may not think it is reachable and therefore consider it a zero-sum game that they should not participate in. As a general rule, for an 80-person class, a good arbitrary threshold is 55.

3.4 Game 4: Threshold Public Bad Game

Instead of contributing to meeting a threshold and gaining a good, mitigation of climate change is often framed as working toward avoiding a global catastrophe. In the threshold public bad game, students contribute to meet a threshold (the same threshold as in Game 3). If the threshold is met, they get nothing. However, if the threshold is not met, they lose one bonus point. It is important students know that the instructor will deduct points from their score if their bonus points are negative, which would happen if a student contributed all of their bonus points and the threshold was not reached. This is a good time to allow students to make one minute grandstand appeals where the rest of the class can indicate social approval with snapping of fingers. These appeals can be anyone who chooses to speak on a first-come, first-speak basis by raising of hands. The great thing about the grandstands is that students tend to reach an informal agreement, yet the behavior does not always match the consensus, which creates the perfect opportunity to introduce the concept of a *two-level game* and *political economy*. If implementing the game online synchronously, the chat and raise hands feature can be used.

3.5 Game 5: Threshold Public Good Game with Unequal Endowments

For Game 5, Game 3 is repeated with one change: there are a distribution of endowments across students. Students are randomly assigned endowments of 1, 2, 3, or 4[3] and are then asked to contribute to the threshold public good. Students are also instructed to discuss as a class how to best manage this game and create rules that will govern contributions. Based on experience running these games, this is where the dynamics of your class really come out: some students at this point feel hopeless as they were previously altruistic but may now have a very small endowment; others feel like equity can be a consideration in economic negotiations, and "fairness" can be achieved by deciding on collective rules (norms); still others are delighted that they are well-endowed and they are hoping to maximize their bonus points by not contributing to the public good; and/or a small group of students start showing their math skills and direct their peers to an "optimal" outcome. It is highly encouraged that the professor allows for highly emotional pleas while maintaining an inclusive and respectful classroom. You should also not allow this discussion period to last more than 5 minutes to remain on time. With a longer class period this could be extended, but 5 minutes has been found to be sufficient to develop these rules based on previous experience.

3.6 Game 6: Threshold Public Bad with Unequal Endowments

This is a repeat of Game 3 but with unequal endowments, and endowments are the opposite of Game 5. If a student had an endowment of 1 in Game 5, they now have an endowment of 4; if they had an endowment of 2, they now have an endowment of 3; if they had an endowment of 3, they now have an endowment of 2; and if they had an endowment of 4, they now have an endowment of 1. Again, there should be time for student communication as an opportunity to work together to meet the threshold. Since there is a potential for the students with an endowment of 1 to lose points in the class (if they

[2] This could also be dynamically based on previous levels of contribution, but that is harder to plan for, hence why an arbitrary threshold of 55 is used in all supplemental materials. It provides an anchor from which to judge previous behavior and potential future behavior.

[3] If implementing this in person, simply have an even number of papers with each endowment amount. If implementing online, it may be easier to create a fast rule like last name for the endowment distribution (see Google Sheet example).

contribute their one bonus point and the threshold is not met), students often remove the enforcement from student's purview to that of the professor (those endowed with 4 give 2, those with 3 give 1—no individual decision is made but rather contributions are set based on endowment) or they agree to throw the game even though some may experience net-zero bonus points and hope that this will not be the binding game.

4 Facilitation Considerations

This game is easy to facilitate in a face-to-face format or in an online setting. The time requirement depends on how many games the instructor wants to play in one session. For a face-to-face or synchronous class session, 50 minutes is the minimum time requirement to get through all six games. Successful implementation requires a poling mechanism, preferably anonymous to peers but not anonymous to the facilitator. Students should be given the vocabulary list (Supplement 1), the concept map (Supplement 4), and the payoff tables prior to starting the game (Table 1). The next two sections outline the procedures for face-to-face and virtual implementation as there are slight modifications that are required for online implementation.

4.1 Face-to-Face Implementation

The supplemental PowerPoint (Supplement 3) gives instructions for each game and should be presented to students throughout the activity. After slides 3, 4, 5, 6, 7, and 8, students should be presented with a poll using any polling software (TopHat, Canvas, iClickers, etc.). Students choose their contributions privately where a = 0, b = 1, c = 2, d = 3 (and e = 4 for Games 5 and 6). Once the facilitator sees the results of the game, they can enter them into the supplemental spreadsheet to determine the amount of public good provided (Supplement 5). For example, if 20 students answered a (0) and 12 answered b (1), enter the number 20 in cell C3 and 12 in C4, and the points will be automatically calculated in cell E8 for Game 1 (which would be 12 in this simple example). It is important that students know the amount of the public good provided so that they can record it in their public good earnings in the public good column of their own payoff table (Table 1) for each game. Students should calculate their own bonus points as their endowment minus their contribution plus the amount of the public good that accrued to each student. It is helpful for the facilitator to do the math for each contribution on the first game so that students can successfully perform this simple calculation in the remaining games.

After each game, it is interesting to display the results of each game to students to draw attention to economic behavior and ask students why they behaved as they did. Figure 1 shows results from the six games played in Spring 2020. Students contribute a lot in Games 1 and 3 as they are win-win situations, whereas Games 4 through 6 become more complex as the game becomes zero-sum for some or all participants. Game 2 illustrates altruism as participants are giving to a bonus pool that only future classes will accrue. It is nice to ask if anyone who contributed to the game wants to discuss why they did so. Most of the time it is because they do not need bonus points, or they want to prove that it is possible to care for future generations.

Having played this activity in over eight classes, each class is different in terms of their game outcomes because of differences in class size, class composition (environmental students versus economics students), and personalities. For the results shown above, the students decided on a completely free-riding scenario for Game 4. Some students still contributed in spite of agreement as a whole class to avoid meeting the threshold. In Game 5, they chose to meet it as they had a proven record of success in Game 3 (the only difference being unequal endowments). Students better planned their contributions such that roughly ¼ should give 0 (those with an endowment of 1), ¼ should give 1 (those with an endowment of 2), ¼ should give 2 (those with an endowment of 3), and ¼ should give 3 (those with an endowment of 4). Students largely played along with this scenario, overshooting the threshold, but there were still free riders. Angered by the cheating behavior in Game 5, the class decided that it

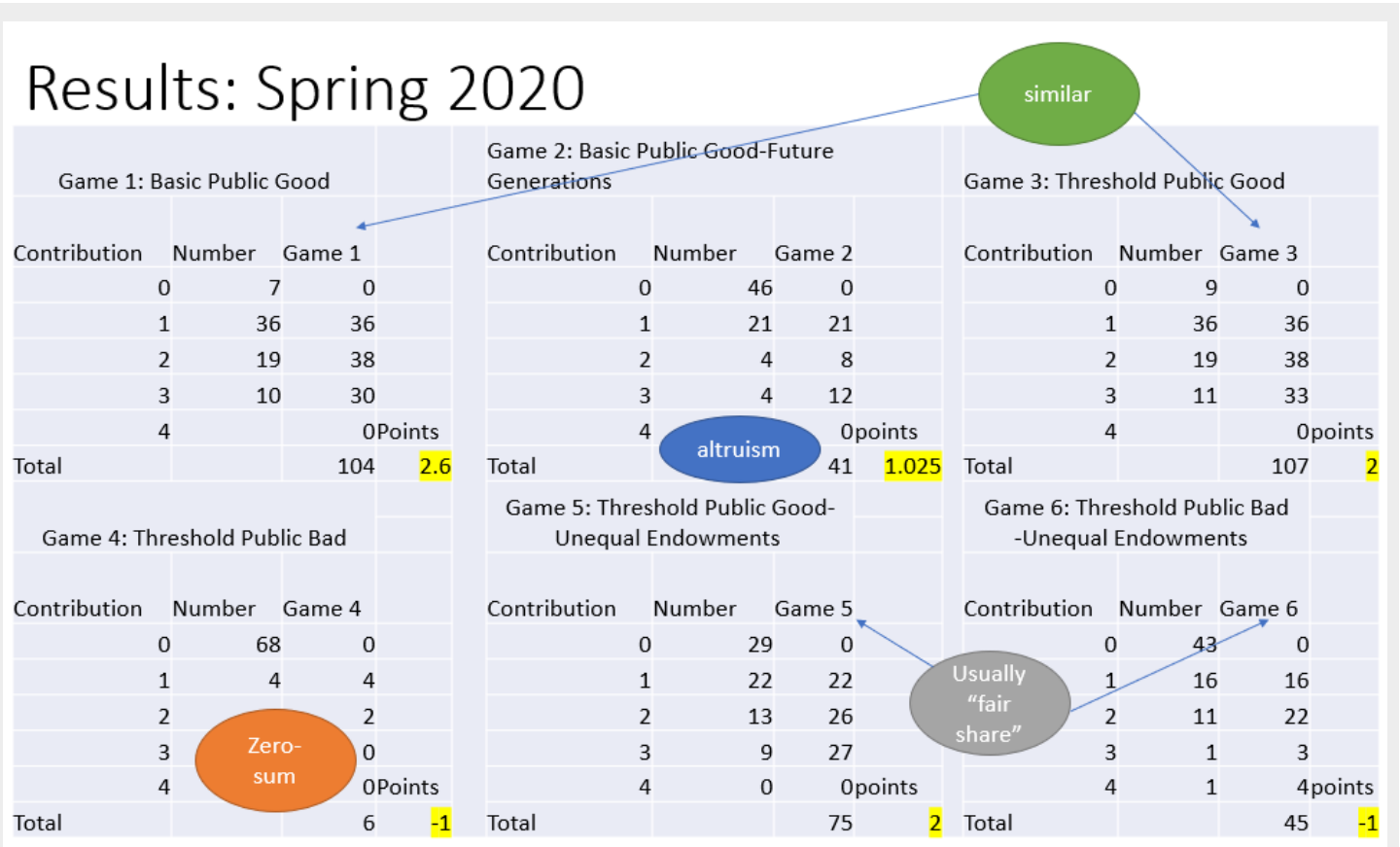

Figure 1. Game Results and Discussion Points

would be a free-for-all in Game 6, as they had written off all attempts at coordination (although they were pretty close to compliance in Game 5).

Students at the lower-level undergraduate level are often not able to come up with rules that are enforceable and suitable for the classroom setting. One semester a class wanted the instructor to punish students who did not behave as decided by the group by not giving any bonus points to the defectors, or as they called them—cheaters. Ultimately, it is up to the professor to decide what you can enforce on behalf of the students.

Within the PowerPoint supplement, there is a link on slide 9 (click on the dice) for random dice to choose the binding game, which is what decides which game will be binding and thus how many bonus points students will actually receive, if any. If Game 1 is chosen randomly as the binding game, students are typically delighted because this is always the best game for everyone. On the other hand, if one of the threshold public bad games are randomly chosen, students are very resistant because these are typically the worst games for students. For a class worth 400 points, 2–6 bonus points is a fair scenario (~1 percent). If your class is out of more points, such as 1,000, then summing up the bonus points across all games may be appropriate and would likely be welcomed by the students.

4.2 Virtual Implementation

This exercise can be played either synchronously or asynchronously. If you play these games synchronously (via zoom, TopHat, etc.), you can use a Google Sheet or a workbook in another program that you share with your students for each student to keep track of their contributions. They would need to copy and paste this table into a Word document or Excel file on their own computer as this sheet is view-only. You can then have them upload the final table as an assignment in your learning management system (LMS). Additionally, you can distribute the endowments by name (e.g., last name A through E gets

1 endowment in Game 5, and 4 endowment in Game 6), such that there is an even distribution of each endowment in Games 5 and 6. You can use whatever polling software you feel comfortable with and are using regularly with your students. It may be preferable to have access to who answered what so you can calculate their bonus points instead of relying on their self-reported bonus points. The key is that you must poll in such a way that you have quick access to the distribution of responses to input into the results Excel file (Supplement 5) and display to students with a screen-share. Overall, the implementation and discussion prompts will not differ significantly for a synchronous implementation compared with a face-to-face implementation.

For asynchronous implementation, the games that do not require coordination can be played within one assignment, while the games requiring coordination can be played over several days or weeks with a combination of assignments and discussion posts. To induce free-riding behavior, student contributions must be made privately, which can be facilitated by a normal assignment in the LMS or in a survey (Qualtrics, Google Forms, etc.). For the games that allow coordination, discussions within the LMS can be used. Specific criteria around what students should include in their discussion is a must. For example, students may be required to propose a rule by a certain date and then vote on the best rule by another date using the "like" or "comment" feature within the discussion. Once a rule has been voted on (majority rules or highest votes wins), this rule will be communicated to students although behavior will still be at the discretion of the student. A debriefing video is recommended for each game where the professor discusses the behavior of the students in the game and connects that behavior to real-world climate change negotiations, such as the Paris climate talks.

5 Activity Statement

After the activity is completed, either in a face-to-face, synchronous online, or asynchronous online setting, a brief discussion should revolve around the following questions:

1) Which game was the most difficult and why?
2) Which game do you think most closely resembles global climate talks?[4]
3) Were there any aspects of climate change and climate change governance that were not incorporated in the game?

Students typically find that the final games are the most challenging because differing endowments presents a special challenge as they do not necessarily match the proclivity to contribute to the public good. Additionally, coordination is very challenging as they must consider more than just net welfare on aggregate. Students note that the sustainability game and the threshold public bad game with differing endowments most closely resemble climate talks.

For the homework assignment (Supplement 2), students are asked to identify global contributions to climate change, mitigation efforts, and the poverty/climate change interaction (homework key available as Supplement 6). Next, they are tasked with identifying how a threshold level of spending could be met, analyzing the results of a hypothetical outcome in terms of welfare, and finally discussing the dynamics of climate negotiations using the terms they learned in the games. The style of questioning presented in the homework could also be extended to exams in either a multiple-choice or open-ended format to further test SLOs. Students need not participate in the public good game to do this homework. If they do not participate, it might be useful to include an example scenario in their notes. Within the supplemental material, there is a climate change Concept Map that was developed for use in an "Economics of Resource Use" class for the climate change section of the course (Supplement 4).

[4] Information about the Paris climate talks may be useful to introduce the idea of climate negotiations: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

6 Conclusion

In summary, the series of six public good games provide an opportunity to discuss complex climate change negotiations and economic behavior in a fun and educational way. Students get to experience the free-rider problem firsthand as well as explore issues related to equity and fairness. Exposure to other fields of economics (behavioral and political economy) is a bonus within this activity. It is easy to implement in a 50-minute class period, although a longer period can feature more discussion and more opportunity for successful coordination.

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