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Contents

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4. Teaching and education commentaries (e.g. notes on pedagogy, evaluations of teaching effectiveness, evaluation and review of applied economics textbooks, curriculum development and educational methodology).

Teaching and Educational Methods

Teaching by the Case Method to Enhance Graduate Students' Understanding and Assessment of Wicked-Type Problems: An Application Involving the Bears Ears National Monument

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Abstract
This paper presents the results of a teaching project designed to enhance graduate-level agricultural and applied economics students' understanding of wicked-type problems, and the limitations of benefit-cost analysis (BCA) as an evaluation criterion for such problems. We employed the case method, a participatory, student-centered approach to teaching, wherein students work in groups to evaluate a case. The case used for this study focused on a wicked-type problem at the time that this study was being implemented, namely determining "What is the 'socially optimal' or preferred size of the Bears Ears National Monument?" The effectiveness of the case method in achieving expected student learning outcomes was assessed through the application of a sign test and a Wilcoxon signed rank test to students' responses on a pre- and post-survey. Student learning outcomes were further assessed using the grades received by students on an individual and group assignment. Overall, results suggested the case method is an effective tool for advancing students' understanding of wicked-type problems, but not necessarily for teaching students about the limitations of BCA as an evaluation criterion for such problems. It appeared students may have already been familiar with the limitations of BCA, prior to participating in the study.

1 Introduction

Graduates of agricultural and applied economics programs should be equipped with the skills and knowledge necessary to address real world problems. One way to achieve this is to implement a curriculum that makes use of interactive, student-centered approaches to teaching and learning economic concepts and analysis techniques (Becker 2000). Academia has made progress in this area, noted by efforts to shift away from traditional chalk and talk instructional methods toward more active and interactive approaches to teaching and learning (e.g., games, labs, classroom discussions, and experiments; Watts and Becker 2008). However, there remains a need to educate students on how to go about analyzing and providing solutions to wicked-type problems (Batie 2008).

Wicked-type problems are characterized as being complex, ill-structured problems often too difficult to approach using standard reductionist analytical tools and techniques (Rittel and Webber 1973; Klamer 2007; Batie 2008). Wicked-type problems emerge almost daily in the field and sub-fields of agricultural and applied economics. Examples include complex problems related to public lands management, food security and poverty, climate change, and federal farm bill policies that affect agribusiness operations and many other sectors of the economy. As of 2008, however, the skills necessary to undertake and properly examine such problems were sparsely being included as part of the applied economics curriculum (Batie 2008). Students at the time were found to be thoughtlessly applying models, not examining possible alternative criteria with which to evaluate complex problems, or reflecting on the nature of the science when assessing complex problems (Klamer 2007; Batie 2008).

Our independent review of the literature revealed several recent attempts to get agricultural and applied economics students to think critically, carefully, and "outside the box" when applying economic concepts and conducting economic analysis to solve complex problems; for example, see Hertel (2020), Riley (2020), Simmons (2020), and Lacy et al. (2020).[1] However, the same literature review did not reveal any formal attempts to teach (or procedures for teaching) students how to undertake and examine complex problems deemed to be wicked in nature from the perspective of an applied economist (i.e., using their economics "toolkits").

Recently, Morreale and Shostya (2021) provided an organizational framework for teaching students enrolled in an undergraduate capstone course how to manage the complexities presented by social policy problems. In another recent study, Hoffman et al. (2021) examined how reflective engagement approaches to learning contribute to students' understanding of wicked-type problems. While the Hoffman et al. (2021) study does address methods for teaching students about wicked-type problems, the study focused on the use of reflective engagement as a teaching strategy and does not focus on teaching practices specific to applied economics (Hoffman et al. 2021).

We contribute to the literature on teaching methods applied to wicked-type problems, by first describing and presenting the components of a teaching project designed to enhance graduate-level agricultural and applied economics students' understanding of: (1) wicked-type problems including their characteristics; and (2) the limitations of using standard reductionist analytical techniques, namely benefit-cost analysis (BCA) as an evaluation criterion for such problems (see Section 3). Second, we present the results of an analysis conducted to assess the effectiveness of the case method approach to teaching in meeting the teaching project's main objectives as they relate to a set of expected student learning outcomes (see Sections 4 and 5).

The case method is a participatory, student-centered, problem-based, approach to teaching and learning, wherein students are presented with a case and asked to provide recommendations as to potential solutions (Carlson and Schodt 1995; Carlson 1999; University of Illinois Board of Trustees et al. 2020). For this teaching project, the case presented to students was focused on the complex nature of the decision to designate and subsequent actions taken to resize the Bears Ears National Monument (BENM).[2] Role playing as members of private consulting firms, students were tasked with examining the case and providing recommendations for a wicked-type problem needing to be addressed, namely determining "What is the 'socially optimal'[3] or preferred size of the BENM?" Choices as to what size of the BENM should be considered "socially optimal" or preferred were confined by the size designations of the BENM established by the time that the teaching project had begun (Spring 2018): ~1.35 million (M) acres or ~0.2 M acres.

While not without criticism (e.g., see Shugan 2006; Foster and Carboni 2009), the case method approach to teaching has been shown to promote more effective learning and enhance long-term retention of the subject matter (Bruner 1991; Christensen, Garvin, and Sweet 1991). By allowing students to develop the framework used to provide a solution to the case presented, the case method approach to teaching builds a capacity for critical thinking (Bruner 1991) and improves student engagement inside of the classroom (Nkhoma, Sriratanaviriyakul, and Quang 2017). Following the case method, students who participated in this teaching project took an active role in evaluating the case. The instructor and teaching

[1] This list of recent research by no means represents an exhaustive list of attempts to get students to think outside the box in applying the science of applied economics. It does, however, point to progress made in the field and sub-fields of agricultural and applied economics, noted by recent publications in Applied Economics Teaching Resources (AETR).
[2] For more background information on the Bears Ears National monument, see Section 2.
[3] We put "socially optimal" in quotes as we are not necessarily referring to the strict definition of a "social optimum" from economic theory such as a Pareto Efficient solution or the solution to a constrained social welfare maximization problem as in the classic article by Bator (1957).

assistant acted only as the facilitators, providing students with some background information on the case, developing assignments, and answering questions as needed (Bruner 1991).

The effectiveness of the case method was assessed in terms of students having gained an understanding of wicked-type problems and the limitations of using BCA to assess and provide solutions to such problems, following the criteria outlined by the expected student learning outcomes using the results of a sign test and a Wilcoxin signed rank test. Both tests were applied to responses received by students on a pre- and post-survey administrated as part of the study conducted for this teaching project and described in more detail later in this paper.[4] Responses from students are considered collectively and individually, by each semester that the study conducted for this teaching project was implemented. The effectiveness of the case method in terms of meeting expected student learning outcomes was also assessed using grades received on an individual take-home assignment, as well as grades received on, and recommendations provided by students during final oral presentations.

Overall, our results suggest teaching by the case method positively impacted students' understanding of wicked-type problems in terms of meeting four of the five expected student learning outcomes. The case method, as it was applied for this study, however, did not have a significant effect on students' understanding of the limitations of using BCA to assess and provide solutions to wicked-type problems. The result is perhaps due to students already being familiar with BCA limitations prior to participating in the study conducted for this teaching project.

2 Wicked Nature of Assessing the "Socially Optimal" or Preferred Size of the BENM

The BENM is located in San Juan County, Utah. It was established via presidential proclamation in December 2016. Originally, the BENM encompassed approximately 1.35 M acres of federally managed land. In December 2017, however, a decision by the administration at the time resulted in the BENM being resized to include just over 0.2 M acres (Turkewitz and Friedman 2017). Four years later the question of what size the BENM should be was once again up for debate, as a new administration has established plans and is actively pursuing a review of the 2017 decision to resize the BENM (Gessner 2021; Maffly and Podmore 2021; McCombs and Whittle 2021).[5]

The original decision to designate and the subsequent decision to re-size the BENM were both based on the results of formal reports prepared by Secretaries of the Department of the Interior (DOI) at the time, Jewell (2013 to 2017) and Zinke (2017 to 2019), respectively. Reports prepared included assessments of the environmental and economic impacts resulting from the decision to establish and then reduce the size of the BENM (Jewell and Vilsack 2016; Zinke 2017). To provide a proper assessment, consideration had to be given to the interest of multiple stakeholder groups including: (1) local Native American tribes who frequent the area to collect traditional herbs and visit sacred sites; (2) local ranchers, miners, and timber harvesters who rely on the area for economic productive purposes; and (3) industries including recreation and tourism who derive economic benefits from increased visitation to the BENM (Jewell and Vilsack 2016; Zinke 2017).

As would be expected with any wicked-type problem, the views, values, opinions, and beliefs of what BENM size or footprint should be considered "socially optimal" or preferred varied by stakeholder group (Horn and Weber 2007; Batie 2008). For example, the decision to designate the Bears Ears area as a national monument in 2016 was supported by members of the inter-tribal coalition, given the

[4] Supporting literature for questions included on the pre- and post-survey included but were not limited to Batie (2008) and Rittel and Webber (1973).

[5] On inauguration day, the current president ordered the current Secretary of the Interior, "to in consultation with the Attorney General, the Secretaries of Agriculture and Commerce, the Chair of the Council on Environmental Quality, and Tribal governments, to conduct a review of the monument boundaries and conditions that were established by each previous presidential proclamation and determine whether restoration of the monument boundaries and conditions that existed as of January 20, 2017, would be appropriate" (Biden 2021).

monument status provided an additional layer of protection to cultural and historical artifacts in the area (Larsen 2016). While local lawmakers agreed that cultural and historical artifacts contained within the Bears Ears area deserve protection, they disagreed with the 2016 decision to designate the area as a national monument, stating "local officials were better suited to care for, preserve, and manage sacred artifacts within the site than the federal government" (Larsen 2016).

Under the original 2016 designation, the U.S. Forest Service (USFS) was not permitted to issue any new permits or leases for livestock grazing, timber harvesting, or mining which left many local ranchers and miners concerned over how the national monument status might end up compromising the land uses they had already built their businesses around (Buhay 2017). Furthermore, while designed to offer an additional layer of protection to the area, land use restrictions brought on by the national monument status raised concerns from many Utah residents. Of primary concern for the Utah residents was that the designation would cause long-term economic harm by not allowing for extraction of economically valuable and feasible resources, such as uranium, which could provide revenue to the state (Buhay 2017; Quinlan 2017).

Last, while the original designation of the BENM in 2016 still permitted recreational activities, many people felt the seasonal, service-industry jobs supported by the recreation and tourism industry would not compare to year-round opportunities for employment that could be possible in the absence of the national monument designation (Buhay 2017). Others suggested increased recreation and tourism visits to the area brought about by the 2016 national monument designation could yield positive economic benefits for the area, but noted that as a national monument, the federal government would be responsible for providing resources to the area to support increased recreation and tourism (Zinke 2017).

The discussion above highlights the need for an interdisciplinary, cross collaborative approach to assessing and providing recommendations as to which size of the BENM should be considered "socially optimal" or preferred. Thus far, attempts to determine a solution as to the "socially optimal" or preferred size of the BENM have only resulted in other problems and issues. For example, following the 2016 decision to designate the Bears Ears as a national monument, Utah Attorney General, Sean Reyes announced plans to partner with the Utah Governor's office, the federal and state legislators, and San Juan County, to file a lawsuit challenging the 2016 designation decision (Kaufman 2016). Following the 2017 decision to reduce the size of the BENM, five members of the inter-tribal coalition filed a lawsuit against members of the administration at the time, citing an "unlawful attempt to revoke and replace a national monument of major historic and scientific importance in violation of the United States Constitution and the Antiquities Act of 1906" (Campbell 2017).

Determining the "socially optimal" or preferred size of the BENM represents a wicked-type problem for multiple reasons. First, increasing or decreasing the size of the BENM has complex and mixed effects on the various stakeholder groups involved. Second, as with any wicked-type problem, the consequences of BENM management actions are not able to be fully realized until after a designation and the rules governing that designation are in place. For example, there is considerable risk (e.g., the potential for looting and vandalism) and uncertainty involved in allowing or preventing economic activities to occur within and around the BENM. Third, there are no easy solutions for the BENM sizing problem as there is literally no "one size fits all" solution, and each candidate for a "socially optimal" or preferred size may generate additional problems including legal, ethical, and political problems.

Thus, when assessing and providing recommendations as to the "socially optimal" or preferred BENM size, students need to carefully consider the wicked nature of the problem being presented. Although it would be convenient to determine which size of the national monument should be considered "socially optimal" or preferred following a simple BCA decision rule, such as "approve the original size of national monument (1.35 M acres) over the current size (0.2 M acres) if the net present value (NPV) is greater than zero," a decision rule such as this on its own might not be satisfactory. However, as suggested by Klamer (2007) and Batie (2008), the methods underlying BCA represent an analytical framework that most students are familiar and comfortable with applying. Moreover, what students may lack is a deeper understanding of the role of the economist in addressing and identifying alternative criteria with which to assess problems that are wicked. Using the case method as a pedagogical means for teaching, we introduce students to the wicked nature of such a problem as determining the "socially optimal" or preferred size of the BENM, and the limitations of only using BCA to assess and provide recommended solutions for such a problem.

3 Implementing the Case Method Approach and Expected Student Learning Outcomes

To implement the case method, at the start of the semester, students were randomly divided into groups, referred to for the purpose of the teaching project, as hypothetical "private consulting firms." In their role, playing as members of their respective private consulting firms, students were presented with their "scope of work," which included a description of the case and informed them that their firm had been selected to assess the change in the size of the BENM on different resource areas using alternative quantitative and qualitative assessment methods (more detail provided below).

Students were instructed that at the end of the semester they would, together with the other members of their group (i.e., the other colleagues at their firm), present the results of an assessment and provide recommendations as to the "socially optimal" or preferred size of the BENM to an interagency BENM task force. The course professor (instructor) and teaching assistant role played as members of the interagency BENM task force. The reason for specifying an interagency task force as the "client" in this case is that the BENM is jointly managed by the Bureau of Land Management under the U.S. DOI, and the USFS under the U.S. Department of Agriculture.

Before starting on their group (consulting firm) work, students received verbal instructions on the policy/decision-making process wherein the role of a professional economist is to provide information and professional advice to the people who have the authority to make policy and management decisions, such as public land managers, the United States Congress, and the President of the United States (POTUS). The role of the professional economist as an objective analyst and purveyor of information to facilitate the policy and management process, as described by Bergstrom and Randall (2016, Chapters 4 and 22), was emphasized to students throughout the semester. In this role, professional economists are aware of politics and political pressure and influence but are not political and do not apply political pressure or influence themselves.

It was made clear to students that economic analysis is only one input into public policy decisions, such as setting the size of the BENM, and that such decisions typically consider the "triple bottom-line" of economic, environmental, and ethical/social effects. It was also made clear to students that the ultimate decision as to the "socially optimal" or preferred size of the BENM would be made by the POTUS under the authority granted to them via the United States Antiquities Act.[6]

Table 1 includes a list of the case method teaching materials used for this project.[7] The materials are designed to walk students through how to assess a wicked-type problem from the perspective of an applied economist. Together the materials provide an outline of how to conduct an economic assessment of a policy or management problem or issue, such as determining the "socially optimal" or preferred size of the BENM. Pre- and post-surveys were used to assess students' understanding of wicked-type problems and the limitations of using BCA to assess and provide solutions to such problems, both before and after participating in the study.

[6] Recently, President Biden appointed a multistakeholder type of "task force" to review the designation of the BENM with different sizes under the Obama and Trump Administrations to ultimately provide him with input and advise on his ultimate decision of what size he will keep or change for the monument.
[7] To access copies of the course materials, see the Teaching Note.

Table 1. List of Case Method Teaching Materials Used for Wicked-Type Problems Teaching Project[a]

Case Method Teaching Materials	Description of Case Method Teaching Materials
1. Consent Form and Pre-Survey	The consent form provided important information about the study being conducted and requested for the students' agreement to participate and have their data collected. The pre-survey provided a list of declarative statements about wicked-type problems, the limitations in using benefit-cost analysis to assess and provide solutions to such problems, as well as students' preparedness in assessing such problems. The pre-survey was used to assess students' understanding prior to participating in the study.
2. Virtual Information Packets	Virtual information packets included research studies and general information related to the Bear's Ears National Monument including the controversy surrounding the decisions to designate and then resize the national monument, as well as general information on wicked-type problems.
3. Four Case Method Exercise Worksheets	The four case method exercise worksheets introduced key concepts related to conducting an economic assessment including: (1) identifying goods and services supported by an area of interest; (2) the "with" and "without" principle; (3) theoretically appropriate welfare measures for changes in market and nonmarket goods and services; and (4) market and nonmarket empirical valuation techniques, decision-making criteria, and potential quantitative and qualitative analysis tools available to applied economists.
4. Individual Take-Home Assignment	The individual take-home assignment was an assignment wherein students were tasked with conducting a benefit transfer application to assign values to the changes in goods or services supported by the area of interest (i.e., the Bears Ears National Monument [BENM]) between the two competing sizes of the BENM being evaluated. Results were used to inform final oral presentations.
5. Mid-Semester Check-in Progress Report Memo	The mid-semester check-in progress report was an assignment wherein students were asked to report progress on their final oral presentations including providing a list of the changes in ecosystem goods and services identified by their group, the theoretically appropriate welfare measures for assessing changes in the goods and services identified by their group, and their associated willingness-to-pay or willingness-to-accept compensation measures.
6. Final Oral Presentation Assignment	The final oral presentation assignment provided instructions for completing and presenting the final oral presentations including the form of the presentation, required presentation outline, the number of changes in goods and services needing to be identified by each group, and the time limit for the presentations.
7. Individual Peer Evaluation Form	The individual peer evaluation forms were filled out by each student for each member of their group. They provided an assessment of students' progress and performance by other students, specifically members of their group.
8. Post-Survey	The post-survey was identical to the pre-survey and used to assess students' understanding after participating in the study.

[a] Copies of all items and more information can be found in the Teaching Note.

Virtual information packets were provided to students via the course website and made available following the class period wherein the pre-surveys were completed by the students. The information included in each virtual information packet provided was identical. Case method exercise worksheets were completed by students with other members of their group (private consulting firm) on predesignated case method exercise days.[8] The case method exercise worksheets also provided a medium with which students could collect the data and other information necessary to complete their final oral presentations.

For their final oral presentations, members of each private consulting firm were required to evaluate the difference between the "with" and "without" net economic value of eight separate changes in ecosystem goods and services supported by the BENM area, considering two separate states-of-the-world (e.g., two separate policy scenarios):

> *State-of-the-world A*: The "without" policy scenario state-of-the-world, which we define as the current (e.g., year 2020) size of the BENM equal to ∼0.2 M acres;
>
> *State-of-the-world B*: The "with" policy scenario state-of-the-world, which we define as the subsequent size of the BENM equal to ∼1.35 M acres,[9]

and determining which state-of-the-world represented the "socially optimal" or preferred size of the BENM. Students were in charge of researching and identifying the types of goods and services supported by the BENM on their own and then choosing eight changes to analyze. The only stipulation on the eight changes in ecosystem goods and services chosen to be analyzed was that at least one change had to be identified for each of the six categories outlined in the case method exercise worksheets: (1) Recreation; (2) Wilderness; (3) Timber or Minerals; (4) Grasslands; (5) Waterways; and (6) Ceremonial/Historical/Cultural.

Given the time and budget constraints of this project, to complete their individual take-home assignments, students relied on secondary data from the 2016 Updated Recreation Use Values Database (RUVD) from Oregon State University, the Environmental Valuation Reference Inventory (EVRI), and other sources obtained via their own literature reviews. Results from the benefit transfer applications were used to inform a BCA to be conducted by each group (private consulting firm) assessing a change in the size of the BENM going from State-of-the-world A to State-of-the-world B. The results of the BCA were to be presented during the group's final oral presentations. Presentations were to be prepared and presented as a formal policy brief to members of the BENM interagency task force at the end of the semester.

A review of the BENM characteristics presented in Section 2 provides support for the potential difficulty in using only one analysis technique, such as BCA, to determine whether State-of-the-world A or State-of-the-world B should be considered "socially optimal" or preferred. To meet the suggestions of Klamer (2007) and Batie (2008), students were tasked with identifying and applying at least two other quantitative or qualitative analysis techniques, in addition to BCA, to assess which state-of-the-world should be considered "socially optimal" or preferred. Following the case method, the students had full autonomy over deciding which additional analysis techniques would be used by their groups. The only stipulation was that at least one of the techniques had to be quantitative and at least one had to be

[8] Case method exercise days were determined by the instructor and teaching assistant prior to the start of the semester. Students were informed at least one week in advance of the date.
[9] We purposely chose the generic "State-of-the-world A" and "State-of-the-world B" terms to help students objectively assess the problem at hand of determining the "socially optimal" or preferred size of the BENM, rather than (hopefully) being distracted one way or the other by political feelings and allegiances.

qualitative (e.g., social justice analysis).[10]

Analysis techniques chosen were to be discussed during each group's final presentation (formal policy brief) in terms of how the techniques were used, including caveats and limitations, to recommend the "socially optimal" or preferred size of the BENM. To assist students in understanding that "socially optimal" or preferred size can mean different things to different people, especially non-economists, over the course of the semester students were introduced to different types of decision-making criteria typically taught in an applied welfare economics course including Pareto Efficiency, Pareto Improvement, Maximum Value of Social Welfare (Well-Being), and Potential Pareto Improvement.

To track the progress of each group in completing the requirements for their final oral presentation, the mid-semester check-in progress report was assigned. To motivate students to participate in their groups and discourage the free-rider problem, following the final oral presentations students completed individual peer evaluations for each member of their groups prior to presenting with their groups. The results from the individual peer evaluations were factored into each student's individual final oral presentation assignment grade. Individual peer evaluations focused on student effort, participation, cooperativeness, and most importantly communication.

All of the teaching materials described above and listed in Table 1 are available to instructors of agricultural and applied economics (or one of its sub-fields) who are interested in teaching students how to address wicked-type problems using the case method. Instructors who adapt this teaching project for their courses can change the terminology if so desired to better suit their course structure and preferences. For example, perhaps using the term "socially preferred" may help avoid confusion with the strict meaning of "socially optimal" from economic theory. Interested instructors could also modify the case being used, by adopting a different wicked-type or complex problem to be addressed by students.

Expected student learning outcomes from participation in the study included a gained understanding of:

L1: the general complexity presented by wicked problems and the characteristics common among problems considered to be wicked in nature;

L2: how proposed solutions to a wicked problem may differ based on the viewpoints of the different stakeholder groups being considered, and how when tasked with addressing a wicked problem, it is important to manage and consider the viewpoints of the multiple stakeholder groups and where those stakeholder groups assign value;

L3: an improved ability to assess wicked problems including how the application of economic principles can and cannot be used to inform decision making regarding wicked problems;

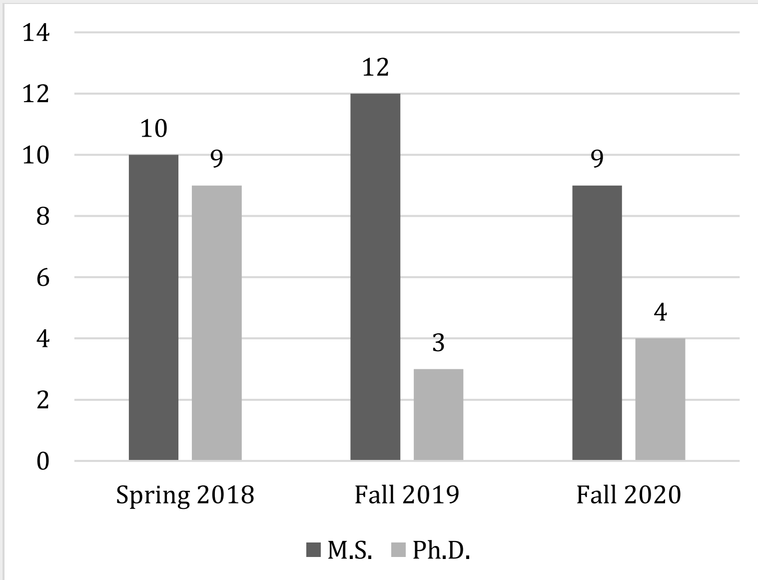
L4: recognizing the limitations of traditional economic assessment methods, namely as BCA and identifying alternative assessment methods; and

L5: how to undertake applications that involve the integration of both quantitative and qualitative analysis techniques during the decision-making process for a wicked-type problem.

[10] Our goal with respect to allowing them to choose the criteria is two-fold. First, as graduate-level economists in training, it is imperative that they can adequately choose from a set of evaluation criteria. Second, by presenting the results from two or more criteria, students should be able to see how the criteria chosen can influence results and policy recommendations.

4 Study Design, Data Collection, and Empirical Approach

The study conducted as part of this teaching project was implemented three times (during three separate semesters: Spring 2018, Fall 2019, and Fall 2020) in a graduate-level applied economics course taught in the Department of Agricultural and Applied Economics at the University of Georgia.[11] Study participants included 47 graduate students. Nineteen students participated in Spring 2018, 15 students participated in Fall 2019, and 13 students participated in Fall 2020. Figure 1 provides a count of the number of M.S.



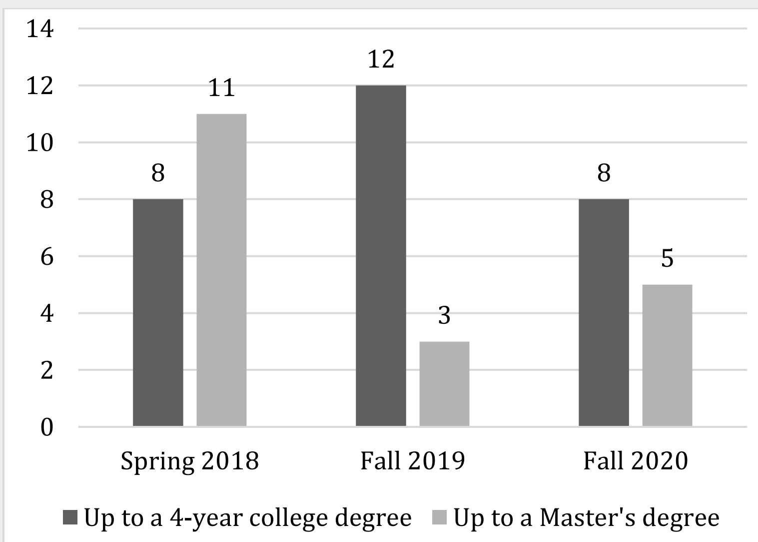


Figure 1. Number of M.S. and Ph.D. Students Participating in the Teaching Project by Semester and Number of Students Having Completed up to a 4-Year College Degree or Master's Degree by Semester

and Ph.D. students who participated in the study during each semester, as well as the highest degree completed by students who participated in each semester.[12]

[11] The course is designed to introduce students to economic valuation theory and techniques with applications primarily to natural resource and environmental policy and management issues and problems. The course is open to graduate students both inside and outside of the department. Having passed a graduate-level microeconomic theory course is a prerequisite to enroll.

[12] While we could potentially use these responses to determine the number of M.S. students who are in the process of competing their second M.S. degree or the number of Ph.D. students who had previously completed or not completed an M.S. degree, university human

In Spring 2018 and Fall 2019, in-person classes were held and hard copies of all case method teaching project materials (see Table 1), excluding the virtual information packets, were provided to students. In Fall 2020, in accordance with the university's COVID-19 guidelines, classes were held virtually via the Zoom online conferencing platform, and all classroom materials were provided to students electronically.[13] On the first day of each semester, during which this teaching project was being implemented, students were informed of the study and asked, following university human subjects research protocol, whether they agreed to participate in the study. All students enrolled in the course consented to participate in the study.[14, 15]

Students were then asked to complete a pre-survey. The pre-survey provided students with the following definition of wicked problems: "A wicked policy problem is a problem that is difficult or impossible to solve due to incomplete or contradictory knowledge and the number of stakeholders involved (e.g., people with opposing value, beliefs, and opinions). Wicked policy problems are often interconnected with other problems." Students were then asked to state whether they "strongly agreed," "agreed," "neither agreed nor disagreed," "disagreed," or "strongly disagreed" with a series of true statements related to wicked problems.

The pre-survey also provided students with the following definition of BCA: "Benefit-Cost Analysis (BCA) is an organizational framework used to identify, quantify, and compare the costs and benefits of a proposed policy or project. The final decision 'rule' is informed by a comparison of the total costs and benefits of the particular policy or project of interest." Students were then asked to state whether they "strongly agreed," "agreed," "neither agreed nor disagreed," "disagreed," or "strongly disagreed" with a series of false statements about the ability of BCA in addressing and providing a solution to a wicked problem.

The pre-survey also included a series of questions related to whether the responding student was familiar with wicked-type problems prior to participating in the study, and whether they had previously received formal training on how to assess wicked-type problems or utilize BCA in a previous course. A series of sociodemographic questions were also included in the survey. Over the course of the semester students were presented with the case method teaching materials outlined in Table 1. Following the completion of their final oral presentations, each student was provided with a copy of the post-survey. The post-survey was identical to the pre-survey. Table 2 provides a complete list of all questions included on the pre- and post-survey.

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subjects research protocol prevents us from matching student responses to personally identifiable information not already included in the survey. For future iterations of this study, we suggest including an additional question that asks students to reveal if they are an M.S. or Ph.D. student.

[13] The teaching note provides information on how the course and case method teaching materials were delivered in person vs. online across the three semesters.

[14] While all students consented to participate in the study, during the first semester (Spring 2018) one student who consented to participate dropped the course. Data for this student are not included in the study.

[15] Approval to conduct the study was obtained from the University of Georgia Institutional Review Board. Following university human subjects research protocol, students were not required to consent to having their data collected as part of the course. However, all students enrolled in the course were required to complete all the assignments associated with the study (see Table 1) since assignments were part of the graded requirements for the course.

Table 2. List of Questions Included on the Pre-Survey and Post-Survey Used to Assess Students' Understanding of Wicked-Type Problems, the Limitations of Benefit-Cost Analysis in Assessing and Providing Solutions to Such Problems, and Students' General Familiarity with Wicked-Type Problems Prior to and after Participating in the Teaching Project

Question #	Label	Statement
		Questions Related to Wicked-Type Problems
1	Recognize	The term "wicked problems" is not well recognized or discussed in the field of applied economics.
2	Simple	The solutions to wicked policy problems can be boiled down to a simple calculation (e.g., net present value calculation).
3	Disciplines	Wicked policy problems often span multiple disciplines.
4	BetterWorse	Solutions to wicked problems are not true-or-false, but better or worse.
5	Exhaustive	Wicked problems do not have an exhaustive set of potential solutions, nor is there a well-described set of permissible operations that may be considered when reaching a solution.
6	Assumption	It is important to consider what assumptions realistically hold when solutions to wicked problems are determined.
7	Present	The solution to a wicked policy problem could be influenced by how the problem is presented.
8	Imperative	It is imperative the graduate students studying applied economics receive formal training on how to deal with, account for, and solve wicked policy problems.
9	Training	Prior to this study, you received formal training on how to solve wicked policy problems in either an economics, applied economics, or other course taught here at the university.
10	Familiar	Prior to this study, you were familiar with wicked policy problems.
		Questions Related to Benefit-Cost Analysis
11	Appropriate	Benefit-cost analysis is an appropriate and effective tool that can be used to reach a conclusion regarding whether or not to pursue an economic policy or project involving a wicked problem.
12	Rely	No matter the context of the problem at hand, an economist can and should always rely on the results of benefit-cost analysis to support their policy recommendations.
13	Only	As a graduate student in applied economics, you should plan to analyze any economic policy or project using only benefit-cost analysis.
14	Leading	The results of a benefit-cost analysis exercise should always be the leading factor in the decision of whether or not to approve an economic policy or project involving a wicked policy problem.
15	Identify	When a conducting benefit-cost analysis, it can be difficult to identify and measure all relevant commensurable benefits and costs that can be monetarized.
16	Sufficient	You have received sufficient training on how to solve policy problems using benefit-cost analysis in either an economics or applied economics course here at the University of Georgia.

Question #	Label	Statement
		Sociodemographic Questions—Response Options in Parentheses
17	Gender	Which most accurately describes your gender? (Male =1; Female = 0)
18	Age	What is your age?
19	Schooling	What is the highest level of schooling you have completed? (2-year college degree = 1; 4-year college degree = 2; Master's degree = 3)
20	Career	Which career path most accurately represents your plans after graduation? (Private Sector = 1; Academia = 2; Federal Government = 3; Other = 4)
21	Hours	How many hours a week on average do you spend studying outside of school? (1–5 hours = 1; 6–10 hours = 2; 10–15 hours = 3; 15–20 hours = 4; More than 20 hours = 5)
22	Professional	Are you a member of a professional economics organization? (Yes = 1; No = 0)
23	Environmental	Are you a member of an environmental group or organization? (Yes = 1; No = 0)

A sign test and a Wilcoxon signed rank (WSR) test were applied to student responses on the pre- and post-surveys to assess whether the case method, as it was applied, was an effective tool for enhancing students' understanding of wicked-type problems in terms of meeting the expected student learning outcomes outlined above, including a gained understanding of the limitations of using BCA to assess and provide solutions to such problems. Both the sign test and Wilcoxon signed rank test are used frequently to analyze paired observation data (i.e., observations from the same individual at two different points in time; Wilcoxon 1945; Snedecor and Cochran 1989; Rosner, Glynn, and Lee 2006).

To implement both tests, responses by each student i to each question j in Table 2 were coded as follows: "strongly disagree" = 1; "disagree" = 2; "neither agree or disagree" = 3; "strongly agree" = 4; and "disagree" = 5.[16] The term d_{ij} was defined as the difference between any matched pair of responses, x from student i, to question j such that,

$$d_{ji} = (x_{preji} - x_{postji}). \tag{1}$$

The sign of the difference for any matched pair of responses by each student i was estimated following (2)

$$sgn(d_{ji}) = \begin{cases} - \quad if\ (x_{preji} - x_{postji}) < 0 \\ 0 \quad if\ (x_{preji} - x_{postji}) = 0 \\ + \quad if\ (x_{preji} - x_{postji}) > 0 \end{cases}. \tag{2}$$

The sign test examines the equality of matched pairs by observation to a series of questions (Snedecor and Cochran 1989). Making no further assumptions regarding the distribution of individual responses, the sign test can be used to investigate whether differences in responses to an individual question between the pre- and post-survey can be observed.

[16] See Figures 1a through 16a in the appendix for an overview of the frequency of responses of "strongly disagree," "disagree," "neither agree or disagree," "strongly agree," and "disagree" on the pre- and post-survey together, when the class was taught in person (Spring 2018 and Fall 2019), when the class was taught online (Fall 2020), and when responses across all three semesters (Spring 2018, Fall 2019, and Fall 2020) are considered together.

Following the sign test, the null hypothesis that the median of differences in responses between the pre- and post-survey to a single question is zero, can be tested against the one-sided alternative hypothesis that the median of differences in responses is positive (i.e., H_0: median of $(x_{preji} - x_{postji}) = 0$ vs. H_A median of $(x_{preji} - x_{postji}) > 0$); the median of differences in responses is negative (i.e., H_0: median of $(x_{preji} - x_{postji}) = 0$ vs. H_A median of $(x_{preji} - x_{postji}) < 0$); or tested against the two-sided alternative hypothesis that the median of differences in responses is different from zero (i.e., H_0: median of $(x_{preji} - x_{postji}) = 0$ vs. H_A median of $(x_{preji} - x_{postji}) \neq 0$). Results of the sign test are presented in terms of the number of times (frequency) in which a response on the pre-survey exceeded a response on the post-survey (i.e., $\sum_{i=1}^{n} sgn(d_{ji}) > 0$); a response on the pre-survey did not exceed a response on the post-survey (i.e., $\sum_{i=1}^{n} sgn(d_{ji}) < 0$); or a response on the pre-survey did not differ from a response on the post-survey (i.e., $\sum_{i=1}^{n} sgn(d_{ji}) = 0$).

On the pre- and post-survey, questions 1 through 7 represent true statements about wicked-type problems. Following the sign test, more negative differences in responses to each question 1 through 7 between the pre- and post-survey lead to a rejection of our first null hypothesis (H_{01}) in favor of our first alternative hypothesis (H_{A1}) that the case method is an effective tool for enhancing students' understanding of wicked-type problems. The first null hypothesis (H_{01}) we tested is related to expected student learning outcomes L1, L3, and L4.[17]

Questions 11 through 14 represent false statements about the applicability of BCA in assessing and providing solutions to wicked problems. Following the sign test, more positive differences in responses to each question 11 through 14 between the pre- and post-survey led to a rejection of our second null hypothesis (H_{02}) in favor of our second alternative hypothesis (H_{A2}) that the case method is an effective tool for teaching students about the limitations of BCA in assessing and providing solutions to wicked-type problems. The second null hypothesis we tested is related to the expected student learning outcome L2.

For the WSR test, we considered the absolute value of the signs of d_{ji} from (2) and let r_i represent the signed rank as follows:

$$r_i = sgn(d_{ji}) * rank(|d_{ji}|)\,. \tag{3}$$

The WSR test statistic, W was then calculated as,

$$W = \sum_{i=1}^{n} r_i \tag{4}$$

for each question. Following the WSR test, if the absolute value of W exceeded the critical value at the pre-designated 0.05 level of confidence, we failed to reject our null hypotheses in favor of our alternative hypotheses, supporting the case method as an effective tool for enhancing students' understanding of wicked-type problems including a gained understanding of the limitations of BCA in assessing and providing solutions to such problems.[18]

During their final presentations, each group was asked to state why determining the "socially optimal" or preferred size of the BENM may represent a wicked-type problem. As such, responses to this question and the grades received on the final oral presentations were used to further assess whether students gained an understanding of wicked-type problems through participation in the study and whether expected student learning outcomes L1 through L4 were met. Moreover, during their final oral

[17] Based on the way student responses are coded, a negative difference in a response between the pre- and post-survey, implied that the student's response was closer to "agree" or "strongly agree" on the post-survey than it was on the pre-survey.

[18] Responses to questions 8, 9, 10, 15, and 16 were not evaluated using a sign test or a WSR test because these questions refer to student's perceived familiarity with wicked problems and BCA and preparedness in applying and utilizing BCA.

presentations, students were asked to discuss the advantages and limitations of each additional criteria chosen by their group to evaluate the problem, including an explanation as to why additional criteria were chosen based on the wicked nature of the problem being addressed. Expected student learning outcome L5 was assessed using responses to the above questions, as well as grades received by the students on their final oral presentations.

5 Analysis Results and Discussion

Table 3 presents the summary statistics for responses by students to questions on the pre- and post-survey. Overall, approximately 62 percent of the students who participated in the study identified as being male, while 38 percent identified as being female. Across the three semesters, the age of student participants ranged from 21 years old to 36 years old, and students spent an average of 11 to 15 hours a week studying outside of school. Compared to when the course was taught in-person (Spring 2018 and Fall 2019), more students who participated in the online version of the course (Fall 2020) were members of an environmental or professional economics organization. Overall, most students planned to pursue a career in academia upon graduation.

Review of the pooled responses on the pre-survey indicated prior to participating in the study, 33 (~70 percent) of the students agreed or strongly agreed with the statement in question 8 that "It is imperative the graduate students studying applied economics receive formal training on how to deal with, account for, and solve wicked policy problems." Of the 33 students who agreed, 18 had completed up to a four-year college degree, and 15 had completed up to a master's degree. After participating, 40 (~85 percent) of the students agreed or strongly agreed with the statement in question 8. Only 2 of the 33 students who agreed or strongly agreed with the statement in question 8, prior to participating in the study, did not agree or strongly agree with the same statement after participating.[19]

Across the pooled responses, 39 (~80 percent) of the students disagreed, strongly disagreed, or neither agreed nor disagreed with the statement in question 10 that "Prior to this study, they were familiar with wicked policy problems." Of these 39 students, 27 (~69 percent) indicated they also had not yet received sufficient training on how to solve policy problems using BCA, as observed by their responses to question 16. Across the pooled responses, only 13 (28 percent) students indicated prior to this study, they had received formal training on how to solve wicked policy problems in either an economics, applied economics, or other course taught at the university, as observed by their responses to the statement included in question 9. Of these 13 students, 3 (23 percent) indicated they were a member of a professional economics organization; 1 (8 percent) indicated they were a member of environmental organization; and 9 (69 percent) indicated they were neither a member of a professional economics or an environment organization.

Table 4 provides the results of sign test applied to student responses on the pre- and post-survey for all semesters (pooled), for semesters when the course was taught in-person (Spring 2018 and Fall 2019), and for semesters when the course was taught online via Zoom (Fall 2020). Results of the sign test (see columns labeled as M1 in Table 4) applied to questions 1 through 7 suggest when responses by all students are considered (i.e., pooled responses) more negative differences than positive differences in responses are observed for all but one question—question 1, which stated: "The term 'wicked problems' is not well recognized or discussed in the field of applied economics." Results were robust across different coding strategies used for responses.[20]

[19] The two students who did not agree or strongly agree with the statement in question 8 after participating in the study but did agree or strongly agree with the statement in question 8 prior to participating in the study changed their response to "neither agree nor disagree" after participating.

Table 3. Summary Statistics for Responses by Students to Questions on the Teaching Project Pre- and Post-Surveys[a]

	Pre-Survey Response Means				Post-Survey Response Means					Sociodemographic Means			
Question Label	Pooled	Spring 2018	Fall 2019	Fall 2020	Pooled	Spring 2018	Fall 2019	Fall 2020	Question Label	Pooled	Spring 2018	Fall 2019	Fall 2020
Recognize	3.30	3.53	3.20	3.08	2.83	2.68	3.13	2.69	Gender	0.63	0.63	0.73	0.59
	(1.08)	(1.02)	(1.21)	(1.04)	(1.01)	(0.89)	(1.13)	(1.03)		(0.49)	(0.50)	(0.46)	(0.52)
Simple	2.89	2.37	4.33	2.00	2.83	3.79	1.87	2.54	Age	25.43	26.26	24.73	25.00
	(1.37)	(1.07)	(0.82)	(0.91)	(1.40)	(1.18)	(1.06)	(1.20)		(3.02)	(4.09)	(2.15)	(1.58)
Disciplines	3.66	2.53	4.47	4.38	4.47	4.42	4.53	4.46	Schooling	2.40	2.58	2.20	2.38
	(1.26)	(1.12)	(0.64)	(0.51)	(0.58)	(0.61)	(0.64)	(0.52)		(0.50)	(0.51)	(0.41)	(0.51)
Better Worse	3.53	2.68	4.20	4.00	4.15	4.32	4.07	4.00	Career	2.19	2.21	2.13	2.23
	(1.20)	(1.29)	(0.77)	(0.58)	(0.75)	(0.67)	(0.96)	(0.58)		(0.85)	(0.79)	(0.99)	(0.83)
Exhaustive	3.38	3.11	3.73	3.38	3.60	3.63	4.07	3.00	Hours	3.17	3.68	2.73	2.92
	(1.03)	(1.24)	(0.70)	(0.96)	(1.01)	(1.01)	(0.70)	(1.08)		(1.17)	(1.25)	(0.88)	(1.12)
Assumption	3.55	2.63	4.33	4.00	4.49	4.47	4.47	4.54	Professional	0.43	0.21	0.40	0.77
	(1.21)	(1.30)	(0.49)	(0.71)	(0.59)	(0.70)	(0.52)	(0.52)		(0.50)	(0.42)	(0.51)	(0.44)
Imperative	4.02	4.16	4.00	3.85	4.30	4.26	4.13	4.54	Environmental	0.30	0.05	0.07	0.92
	(0.90)	(0.83)	(1.07)	(0.80)	(0.72)	(0.73)	(0.74)	(0.66)		(0.46)	(0.23)	(0.26)	(0.28)
Present	3.45	2.53	4.27	3.85	4.30	4.26	4.20	4.46					
	(1.33)	(1.26)	(0.88)	(1.07)	(0.69)	(0.65)	(0.86)	(0.52)					
Training	2.34	2.05	2.40	2.69	2.55	2.37	2.33	3.08					
	(1.22)	(1.13)	(1.40)	(1.11)	(1.12)	(1.16)	(1.23)	(0.76)					
Familiar	2.66	2.58	2.67	2.77	2.91	2.74	2.73	3.38					
	(1.26)	(1.12)	(1.50)	(1.24)	(1.19)	(1.15)	(1.28)	(1.12)					
Appropriate	3.74	3.89	3.67	3.62	4.00	4.11	3.73	4.15					
	(0.82)	(0.88)	(0.90)	(0.65)	(0.63)	(0.57)	(0.70)	(0.55)					
Rely	2.45	2.58	2.20	2.54	2.32	2.26	2.27	2.46					
	(0.88)	(0.96)	(0.77)	(0.88)	(0.96)	(0.99)	(0.80)	(1.13)					
Only	2.09	1.79	1.93	2.69	2.00	1.95	2.20	1.85					
	(1.00)	(0.79)	(1.03)	(1.03)	(1.12)	(1.03)	(1.37)	(0.99)					
Leading	2.66	2.74	2.33	2.92	2.79	2.79	2.80	2.77					
	(0.81)	(0.81)	(0.62)	(0.95)	(0.88)	(0.85)	(0.94)	(0.93)					
Identify	4.26	4.26	4.27	4.23	4.28	4.16	4.40	4.31					
	(0.57)	(0.56)	(0.59)	(0.60)	(0.77)	(0.90)	(0.83)	(0.48)					

Table 3 continued.

Question Label	Pre-Survey Response Means				Post-Survey Response Means			
	Pooled	Spring 2018	Fall 2019	Fall 2020	Pooled	Spring 2018	Fall 2019	Fall 2020
Sufficient	2.83 (1.17)	2.53 (1.02)	2.80 (1.32)	3.31 (1.11)	3.98 (0.71)	4.00 (0.75)	3.73 (0.70)	4.23 (0.60)
N	47	19	15	13				

[a] Pre- and post-survey question responses recorded on a Likert scale. Summary statistics for sociodemographic indicators are only provided for pre-survey responses. Standard errors in parentheses. Pooled responses are for Spring 2018, Fall 2019, and Fall 2020 aggregated.

Table 4. Results for the Sign Test Applied to Student Responses on the Teaching Project Pre- and Post Surveys[a]

Question #	Label	Count $sgn(d_{ji}) > 0$		$p-value$		Count $sgn(d_{ji}) < 0$		$p-value$		Count $sgn(d_{ji}) = 0$		$p-value$	
Pooled Responses (N = 47)		**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**
1	Recognize	19	16	0.04	0.01	9	5	0.98	1.00	19	26	0.09	0.03
2	Simple	18	13	0.63	0.71	19	15	0.50	0.43	10	19	1.00	0.85
3	Disciplines	4	2	1.00	1.00	20	16	0.00	0.00	23	29	0.00	0.00
4	Better Worse	7	1	0.99	1.00	18	13	0.02	0.00	22	33	0.04	0.00
5	Exhaustive	8	6	0.98	0.85	17	9	0.05	0.30	22	32	0.11	0.61
6	Assumption	3	0	1.00	1.00	24	15	0.00	0.00	20	32	0.00	0.00
7	Present	7	3	1.00	1.00	22	19	0.00	0.00	18	25	0.01	0.00
11	Appropriate	4	11	0.99	0.03	13	3	0.02	0.99	30	33	0.05	0.06
12	Rely	12	5	0.50	0.62	11	5	0.66	0.62	24	37	1.00	1.00
13	Only	13	5	0.26	0.36	9	3	0.86	0.86	25	39	0.52	0.73
14	Leading	8	9	0.95	0.21	15	5	0.11	0.91	24	33	0.21	0.42
2018–2019 (In-Person) (N = 34)		**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**
1	Recognize	14	13	0.06	0.02	6	4	0.98	0.99	14	17	0.12	0.05
2	Simple	15	13	0.43	0.50	13	12	0.71	0.66	6	9	0.85	1.00
3	Disciplines	3	2	1.00	1.00	18	16	0.00	0.00	13	16	0.00	0.00
4	Better Worse	5	0	1.00	1.00	16	12	0.01	0.00	13	22	0.03	0.00
5	Exhaustive	2	1	1.00	1.00	13	8	0.00	0.02	19	25	0.01	0.04
6	Assumption	2	0	1.00	1.00	18	12	0.00	0.00	14	22	0.00	0.00
7	Present	7	3	0.99	1.00	17	16	0.03	0.00	10	15	0.06	0.00
11	Appropriate	4	6	0.83	0.25	6	3	0.38	0.91	24	25	0.75	0.51
12	Rely	8	2	0.40	0.81	6	3	0.79	0.50	20	29	0.79	1.00
13	Only	5	4	0.87	0.06	8	0	0.29	1.00	21	30	0.58	0.13
14	Leading	4	7	0.99	0.09	12	2	0.04	0.98	18	25	0.08	0.18

Table 4 continued.

Question #	**Label**	**Count $sgn(d_{ji}) > 0$**		**$p - value$**		**Count $sgn(d_{ji}) < 0$**		**$p - value$**		**Count $sgn(d_{ji}) = 0$**		**$p - value$**	
2020 (Online) (N = 13)		**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**
1	Recognize	5	3	0.36	0.31	3	1	0.86	0.94	5	9	0.73	0.63
2	Simple	3	0	0.91	1.00	6	3	0.25	0.13	4	10	0.51	0.25
3	Disciplines	1	0	0.88	1.00	2	0	0.50	1.00	10	13	1.00	1.00
4	Better Worse	2	1	0.69	0.75	2	1	0.69	0.75	9	11	1.00	1.00
5	Exhaustive	6	5	0.38	0.11	4	1	0.83	0.98	3	7	0.75	0.22
6	Assumption	1	0	0.99	1.00	6	3	0.06	0.13	6	10	0.13	0.25
7	Present	0	0	1.00	1.00	5	3	0.03	0.13	8	10	0.06	0.25
11	Appropriate	0	5	1.00	0.03	7	0	0.01	1.00	6	8	0.02	0.06
12	Rely	4	3	0.75	0.50	5	2	0.50	0.81	4	8	1.00	1.00
13	Only	8	1	0.02	0.94	1	3	1.00	0.31	4	9	0.04	0.63
14	Leading	4	2	0.50	0.81	3	3	0.77	0.50	6	8	1.00	1.00

[a] Columns labeled as M1 include results of the sign test when responses by students are coded as follows: “strongly disagree” = 1; “disagree” = 2; “neither agree or disagree” = 3; “strongly agree” = 4; and “disagree” = 5. Columns labeled as M2 include the results of the sign test when responses by students to question 1 through 7 of “strongly agree” or “agree” were assigned a value of 1 and responses of “strongly disagree,” “disagree,” or “neither agree nor disagree” were assigned a value of 0; responses of “strongly agree” or “agree” to questions 11 through 14 were assigned a value of 0 and responses of “strongly disagree,” “disagree,” or “neither agree nor disagree” were assigned a value of 1.

The number of students whose responses on the post-survey exceeded responses on the pre-survey to questions 3, 4, 5, 6, and 7 by highest degree completed at the start of the study is outlined in Figure 2. The number of students whose responses on the post-survey exceeded responses on the pre-survey to questions 3, 4, 5, 6, and 7, who indicated they were members of a professional economics organization, or an environmental organization are presented in Figure 3. When the course was taught in-person (Spring 2018 and Fall 2019), the same results hold with the exception that more negative differences than positive differences in responses were not observed for question 2, which stated: "The solutions to wicked policy problems can be boiled down to a simple calculation." When the course was taught online (Fall 2020), more negative differences than positive differences in responses were observed, but results did not hold across the different response coding strategies used. Following the results of the sign test applied to pooled responses to questions 1 through 7, we rejected of our first null hypothesis (H_{01}) in favor of our first alternative hypothesis (H_{A1}) that the case method is an effective tool for enhancing students' understanding of wicked problems meeting expected student learning outcomes L1, L3, and L4.

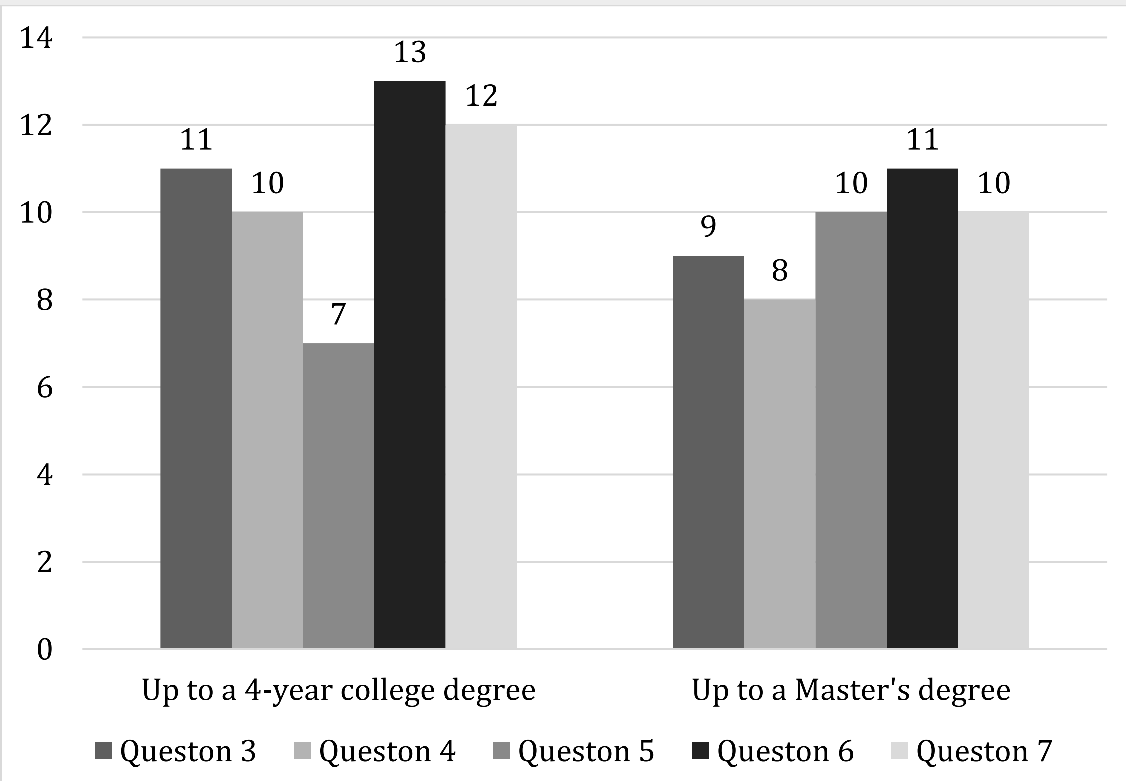

Figure 2. Number of Students Participating in the Teaching Project Whose Responses on the Post-Survey Exceeded Responses on the Pre-Survey to Questions 3, 4, 5, 6, and 7 by Highest Degree Completed

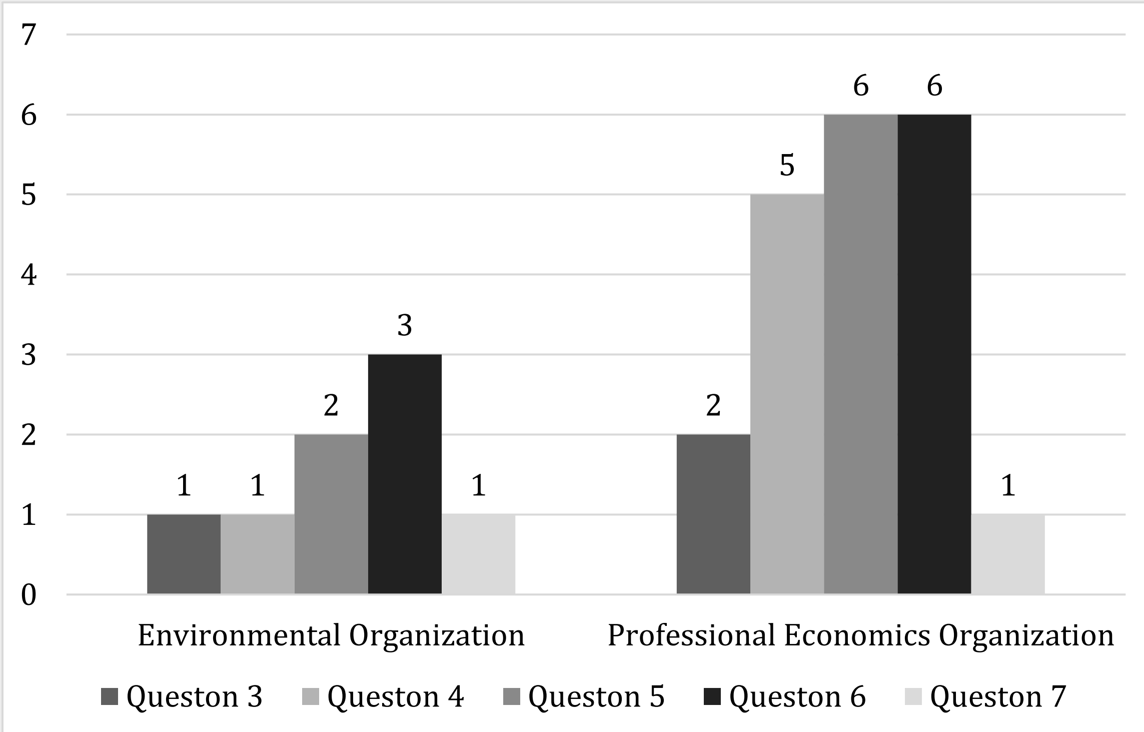

Figure 3. Number of Students Participating in the Teaching Project Whose Responses on the Post-Survey Exceeded Responses on the Pre-Survey to Questions 3, 4, 5, 6, and 7 Who Indicated Being Members of a Professional Economics Organization or an Environmental Organization

Results of the sign test applied to questions 11 through 14 (see Columns labeled as M1 in Table 4) indicate when student responses were considered together, more positive differences than negative differences in responses were observed for only two questions—question 12, which stated: "No matter the context of the problem at hand, an economist can and should always rely on the results of benefit-cost analysis to support their policy recommendations" and question 13, which stated: "As a graduate student in applied economics, you should plan to analyze any economic policy or project using only benefit-cost analysis," but results are not robust across different coding strategies used.[20] When only the in-person responses (Spring 2018 and Fall 2019) were considered, more positive differences than negative differences in responses were observed for Question 12. The same result held true when the class was taught online (Fall 2020).

Thus, we failed to reject our second hypothesis (H_{02}) in favor of our second alternative hypothesis (H_{A2}) that the case method, as it was applied for this study, is an effective tool for enhancing students' understanding of the limitations of BCA for assessing wicked problems and conclude expected student learning outcome L2 was not met. Further examination of the responses to questions 11 through 14 on the pre-survey indicate that most students were familiar with the limitations of BCA in assessing and providing solutions to wicked problems prior to participating in the study. Had students not been familiar with BCA limitations before participating in the case study, we speculate that perhaps participation in the case may have significantly increased students' understanding of BCA limitations.

The results of the WSR test applied to student responses on the pre- and post-survey are included in Table 5. Results from the WSR test indicate teaching by the case method positively impacted students'

[20] As a robustness check, a second sign test was also applied to student responses to questions 11 through 14. For the second sign test, responses of "strongly agree" or "agree" to questions 11 through 14 were assigned a value of 0 and responses of "strongly disagree," "disagree," or "neither agree nor disagree" were assigned a value of 1. For the second sign test, positive differences in responses to questions 11 through 14 led to a rejection of our second null hypothesis in favor of our second alternative hypothesis.

understanding of wicked problems as measured by their responses to questions two through seven. More specifically, based on these results, we can again reject the first null hypothesis (H_{01}) at the 0.05 level of significance in favor of the first alternative hypothesis (H_{A1}). However, the results from our WSR test again reveal that the case method may not be an effective tool for teaching students about the limitations of BCA in assessing and providing solutions to wicked problems. Thus, we again failed to reject our second null hypothesis (H_{02}) in favor of our second alternative hypothesis (HA2).

Table 6 provides an overview of average student performance on the individual take-home assignment, individual peer evaluation form, and the final oral presentations. Student performance, on the individual take-home assignment, as measured by the grades received, ranged from a D minus (62 percent) to a perfect score (100 percent). When all three semesters are considered together the average grade received was 92 percent. Grades on the individual take-home assignment were significantly higher when the course was taught in-person compared to online. Individual peer evaluation grades received followed a similar pattern. Overall, final oral presentation grades received ranged from 84 percent to 100 percent. When the course was taught online, all students received a grade above 95 percent. During final oral presentations when asked why the BENM may represent a wicked-type problem, themes common across team responses included "it is a complex scenario," "there is no clear-cut solution as to what the socially optimal size is," and "it involves the interests of many diverse stakeholders." Team responses indicate after participating in the study, students were familiar with the types of characteristics common among wicked problems.

Alternative quantitative and qualitative analysis techniques chosen by students and presented during their final oral presentations included but were not limited to ethical stewardship, voting to reach a collective decision, cost-effective analysis, multicriteria analysis, maximum social well-being, social product maximization, and ranked choice. Based on the identified alternative criteria chosen to evaluate the wicked problem and discussions during the final oral presentations, it was determined that through participation in the study, students learned how to undertake applications involving the integration of both quantitative and qualitative analysis techniques, as suggested by the identified alternative criteria chosen to evaluate the wicked problem and discussions during the final oral presentations.

Table 5. Summary of Results for the Wilcoxon Signed Rank Test Applied to Student Responses on the Teaching Project Pre- and Post-Surveys[a]

Question #	Label	Count of Positive Ranks		Count of Negative Ranks		Ties		Z Statistic		$p = value$	
Pooled Responses (N = 47)		**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**
1	Recognize	19	16	9	5	19	26	2.23	2.40	0.0256*	0.0164*
2	Simple	18	13	19	15	10	19	0.08	-0.38	0.9404	0.7055
3	Disciplines	4	2	20	16	23	29	-3.51	-3.30	0.0005*	0.0010*
4	Better Worse	7	1	18	13	22	33	-2.60	-6.14	0.0094*	<0.001*
5	Exhaustive	8	6	17	9	22	32	-1.55	-0.78	0.1218	0.4386
6	Assumption	3	0	24	15	20	32	-4.20	-3.87	<0.001*	<0.001*
7	Present	7	3	22	19	18	25	-3.25	-3.41	<0.001*	<0.001*
11	Appropriate	4	11	13	3	30	33	-2.50	2.14	0.0245*	0.0325*
12	Rely	12	5	11	5	24	37	0.41	0.00	0.6805	1.0000
13	Only	13	5	9	3	25	39	0.71	0.71	0.4769	0.4795
14	Leading	8	9	15	5	24	33	-1.26	1.07	0.2080	0.2850
2018–2019 (In-Person) (N = 34)		**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**
1	Recognize	14	13	6	4	14	17	1.98	2.18	0.0477*	0.0290
2	Simple	15	13	13	12	6	9	0.66	0.20	0.5126	0.8415
3	Disciplines	3	2	18	16	13	16	-3.53	-3.30	<0.001*	<0.001*
4	Better Worse	5	0	16	34	13	0	-2.82	-5.17	0.0047*	<0.001*
5	Exhaustive	2	1	13	8	19	25	-2.78	-2.33	0.0055*	0.0196*
6	Assumption	2	0	18	12	14	22	-3.73	-3.65	<0.001*	<0.001*
7	Present	7	3	17	16	10	15	-2.74	-2.98	0.0062*	0.0029*
11	Appropriate	4	6	6	3	24	25	-0.79	1.00	0.4480	0.3173
12	Rely	8	2	6	3	20	29	0.71	-0.45	0.4804	0.6547
13	Only	5	4	8	0	21	30	-0.98	2.00	0.3291	0.0455
14	Leading	4	7	12	2	18	25	-1.84	1.67	0.0657	0.0956

Table 5 continued.

Question #	Label	Count of Positive Ranks		Count of Negative Ranks		Ties		Z Statistic		$p = value$	
2020 (Online) (N = 13)		**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**	**M1**	**M2**
1	Recognize	5	3	3	1	5	9	1.02	1.00	0.3072	0.3173
2	Simple	3	0	6	3	4	10	-1.22	-1.73	0.2232	0.0833
3	Disciplines	1	0	2	0	10	13	-0.58	-	0.5637	-
4	Better Worse	2	0	2	0	9	13	0.00	-3.42	1.0000	<0.001*
5	Exhaustive	6	5	4	1	3	7	0.96	1.63	0.3352	0.1025
6	Assumption	1	0	6	3	6	10	-1.94	-1.73	0.0522	0.0833
7	Present	0	0	5	3	8	10	-2.22	-1.73	0.0263*	0.0833
11	Appropriate	0	5	7	0	6	8	-2.65	2.24	0.0082*	0.0253*
12	Rely	4	3	5	2	4	8	0.00	0.45	1.0000	0.6547
13	Only	8	1	1	3	4	9	2.12	-1.00	0.0343*	0.3173
14	Leading	4	2	3	3	6	8	0.41	-0.45	0.6824	0.6547

[a] (1) Columns labeled as M1 include results of the Wilcoxon Signed Rank Test when responses of “strongly disagree” = 1; “disagree” = 2; “neither agree or disagree” = 3; “strongly agree” = 4; and “disagree” = 5 are used. Columns labeled as M2 include the results of the Wilcoxon Signed Rank Test when responses of “strongly agree” or “agree” to questions 1 through 7 were assigned a value of 1 and responses of “strongly disagree,” “disagree,” or “neither agree nor disagree” were assigned a value of 0 and responses of “strongly agree” or “agree” to questions 11 through 14 were assigned a value of 0 and responses of “strongly disagree,” “disagree,” or “neither agree nor disagree” were assigned a value of 1. (2) *Statistically significant α = 0.05.

Table 6. Summary of Student Performance by Measures Used to Further Assess Students' Understanding of Wicked-Type Problems and the Limitations of Traditional Valuation Techniques, Namely Benefit-Cost Analysis in Assessing Such Problems (N = 47)

Item		Pooled	Spring 2018 n =19	Fall 2019 n = 15	Fall 2020 n = 13
Individual Take Home Assignment	Minimum	62	80	80	62
	Maximum	100	100	100	100
	Median	94	90	98	92
	Average	92	91	96	88
Individual Peer Evaluation	Minimum	3.9	4.8	5	3.9
	Maximum	5	5	5	5
	Median	5.0	5	5	5
	Average	4.9	5	5	4.7
Final Oral Presentation Assignment	Minimum	84	84	100	98
	Maximum	100	100	100	100
	Median	100	96	100	100
	Average	98	95	100	99

6 Concluding Remarks

Using the case method, we presented students in a graduate-level applied economics course with the wicked-type problem or question, namely "What is the 'socially optimal' or preferred size of the BENM?" Throughout each semester, during which the teaching project for this study was being implemented, students were presented with a suite of classroom materials consisting of four in-class case method exercises, an individual take-home assignment, a mid-semester check-in progress report memo, and instructions for a final oral presentation. The classroom materials were designed to guide students through the process of conducting an economic assessment of a policy or management problem or issue including how to (1) identify the policy or management issue(s) of interest; (2) identify changes in goods and services related to the policy or management issue(s); (3) define theoretically appropriate welfare change measures associated with the identified changes; and (4) identify and implement economic valuation techniques for quantifying welfare change measures identified.

Following a traditional approach to teaching economic analysis, students were divided into groups and presented with two policy scenarios (i.e., two separate states-of-the-world reflecting the size and management of the BENM) and asked to provide recommendations as to which state-of-the-world should be considered "socially optimal" or preferred following the decision criteria of BCA and the decision criteria of two alternative analysis techniques as chosen by their group, at least one of which needed to be qualitative in nature. Their assessments and recommendations were to be presented at the end of the semester in the form of a final oral presentation (final policy brief), which included a discussion of the wicked nature of the problem.

Expected student learning outcomes (L1 through L5) were assessed using responses on a pre- and post-survey, and the grades received by students on an individual take-home assignment and final oral presentation. Our quantitative analysis results showed that the case method had a positive impact on students' understanding of wicked-type problems, but not necessarily on their appreciation of the limitations of BCA in assessing and providing solutions to such problems. It appeared that students were mostly already aware of the limitations of BCA for assessing policy and management decisions, perhaps from previous undergraduate and graduate economics courses.

While quantitative analysis results support the hypothesis that the case method is an effective means for enhancing students' understanding of wicked-type problems, it is important to note that there are multiple observable and unobservable factors that may be contributing to these results, which we are unable to fully account for given the limitations of the data. For example, it could be the case that students were enrolled in another course (or multiple courses) during the same semester that introduced them to wicked problems (e.g., an environmental economics or policy course). It is also possible that students were exposed to wicked problems through news outlets (e.g., Members in the News Announcements from the Agricultural and Applied Economics Association) or other sources (e.g., seminars or presentations at the university and elsewhere).

As a result, the conclusions should be considered in light of the case method having a positive, but not necessarily causal effect on students' understanding of wicked-type problems. Nevertheless, through exposure to the case method, students gained the practical experience necessary to work individually and as part of a group to assess and offer solutions to complex, multidimensional problems. Such experience and skills are imperative given that graduates in economics face a world where career opportunities are contingent upon being able to interact with a diverse group of stakeholders including lobbyists, politicians, and other practitioners of science (Bergstrom and Randall 2016; Karunaratne, Breyer, and Wood 2016).

Another limitation of our data analysis is that the sample size was relatively small and composed of a unique, specialized group of students. Thus, self-selection bias could have occurred since to be eligible to participate in our study, students first had to register and take the particular graduate course in which the study conducted as part of this teaching project occurred. Instructors who plan to make use of these course materials should consider the impacts of range restriction and survivor bias in cases where students do not agree to participate or choose to withdraw from participation during the study. Throughout the three semesters of our study, however, we had only one student withdraw from the course and study.

If an instructor is interested in using responses on the pre- and post-survey to draw conclusions about the effectiveness of the case method in enhancing students' understanding and assessment of wicked-type problems and/or the limitations of BCA to assess and provide solutions to such problems, then special consideration should be given to the size of the sample and student access to outside materials when completing the pre-survey before drawing casual conclusions. Last, questions designed to measures students' potential gained understanding of additional quantitative analysis techniques and other economics methods were not built into the pre- and post-survey. If this is of interest to instructors who make use of the course materials, we suggest including additional questions related to analysis techniques and other methods discussed throughout the semester.

In response to the COVID-19 pandemic, many universities were forced to transition to online instruction. This increase in online instruction training and experience could result in an increase in online instruction in the future even when the pandemic is over. Most colleges and universities have been expanding online learning anyway, regardless of the pandemic. Thus, there will be a need for instruction that can be adapted to both in-class and online delivery formats that engage students with the course material while simultaneously preparing them for careers in their field. The classroom materials developed for this teaching project can easily be adapted for online instruction including online breakout group meetings.

As Batie (2008) and Stephenson (2003) point out, addressing wicked problems does not equate with abandoning the science. Many of the same tools and concepts used by applied economists to address tame problems can be used to address wicked problems. Specifically, applied economists can apply traditional economic analysis methods to assess potential trade-offs associated with one policy alternative over another for a wicked problem. The value of such analysis, however, is likely to be enhanced if consideration is given to the values underlying the dispute, and if the implications and limitations of such an analysis effort are identified. Our study makes an effort to get students to do just that.

As wicked problems continue to proliferate in the field and sub-fields of agricultural and applied economics, it is critical that graduates of these programs are aware of them, understand the limitations of traditional economic assessment methods such as BCA in assessing such problems, and gain new insight on the process and skills necessary to effectively assess and provide solutions to complex problems facing society using a variety of quantitative and qualitative techniques more effectively. Our experience in conducting the teaching project described in this paper suggests that applied economics students are not generally familiar with wicked-type problems and are interested in learning more about these problems and how to deal with them. Based on our overall positive teaching project experience, we recommend the case method as a means for providing students with the hard and soft skills needed to effectively assess and provide potential solutions to wicked-type problems and issues. These skills include effectively working individually and in groups, identifying affected stakeholders and how they are affected by a problem, quantifying benefits and costs, and integrating quantitative and qualitative assessment tools to offer more holistic policy and management recommendations.

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Appendix

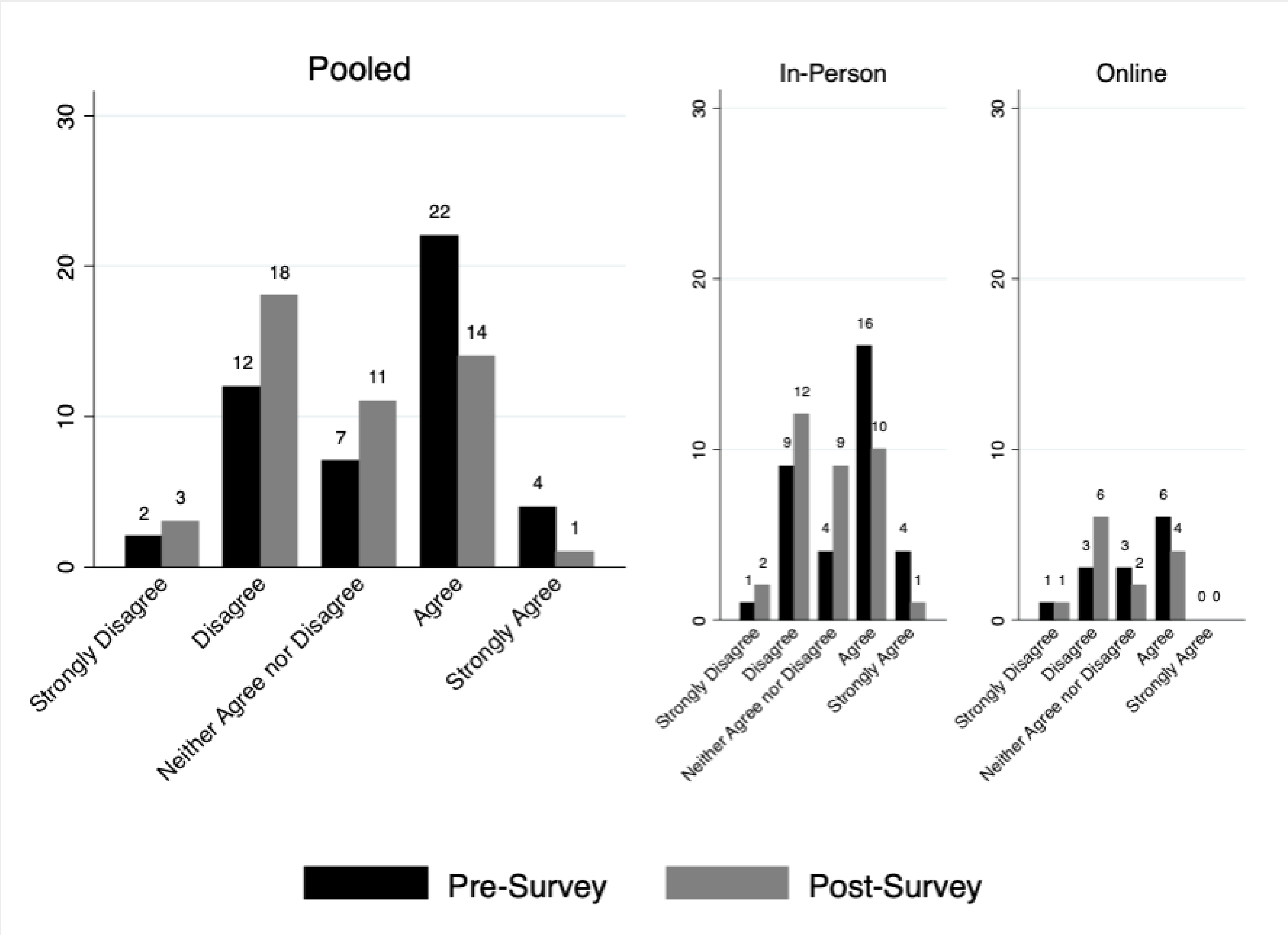

Figure 1A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 1, which stated: "The term 'wicked problems' is not well recognized or discussed in the field of applied economics."

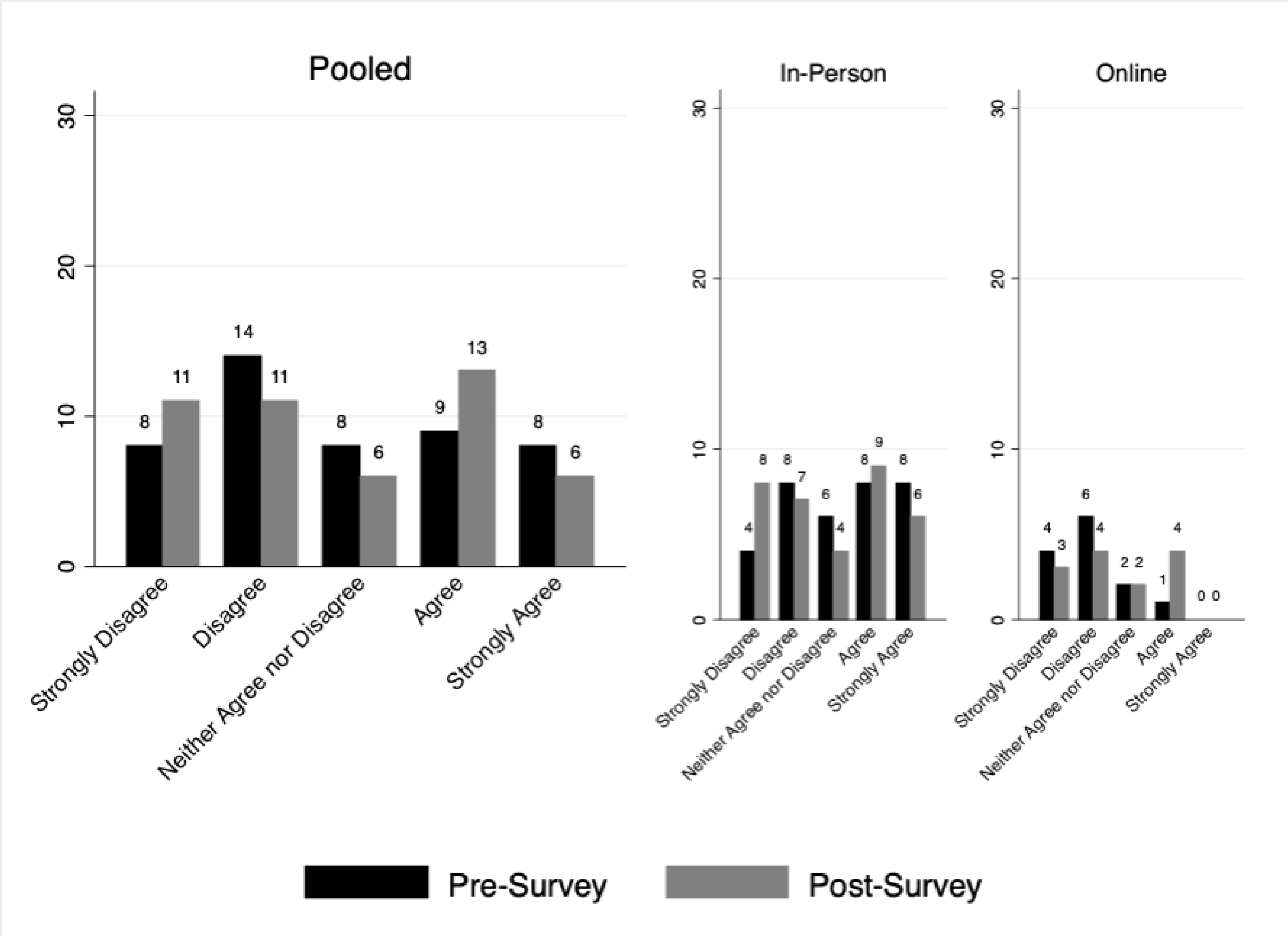

Figure 2A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 2, which stated: "The solutions to wicked policy problems can be boiled down to a simple calculation (e.g., net present value calculation)."

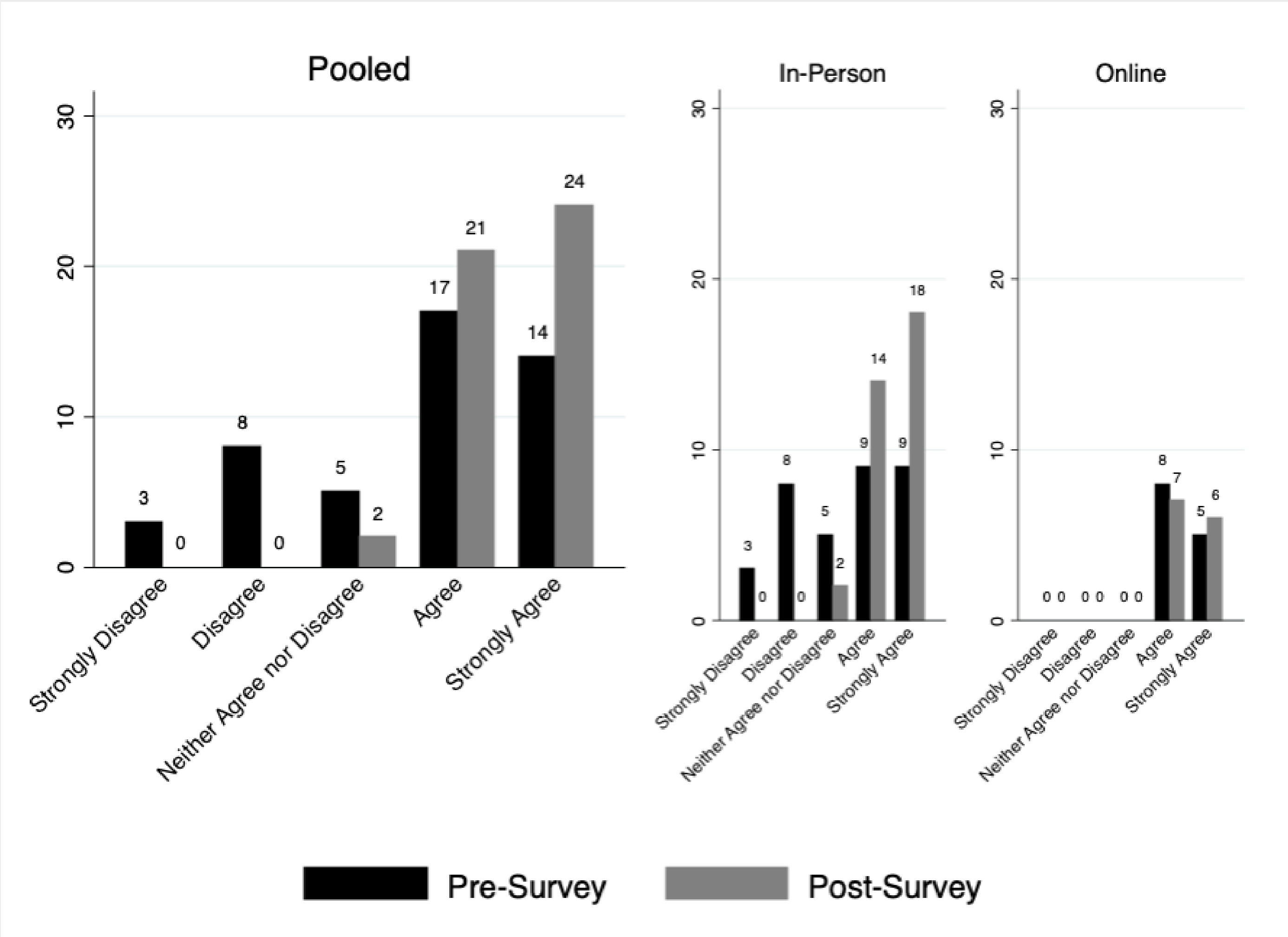

Figure 3A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 3, which stated: "Wicked policy problems often span multiple disciplines."

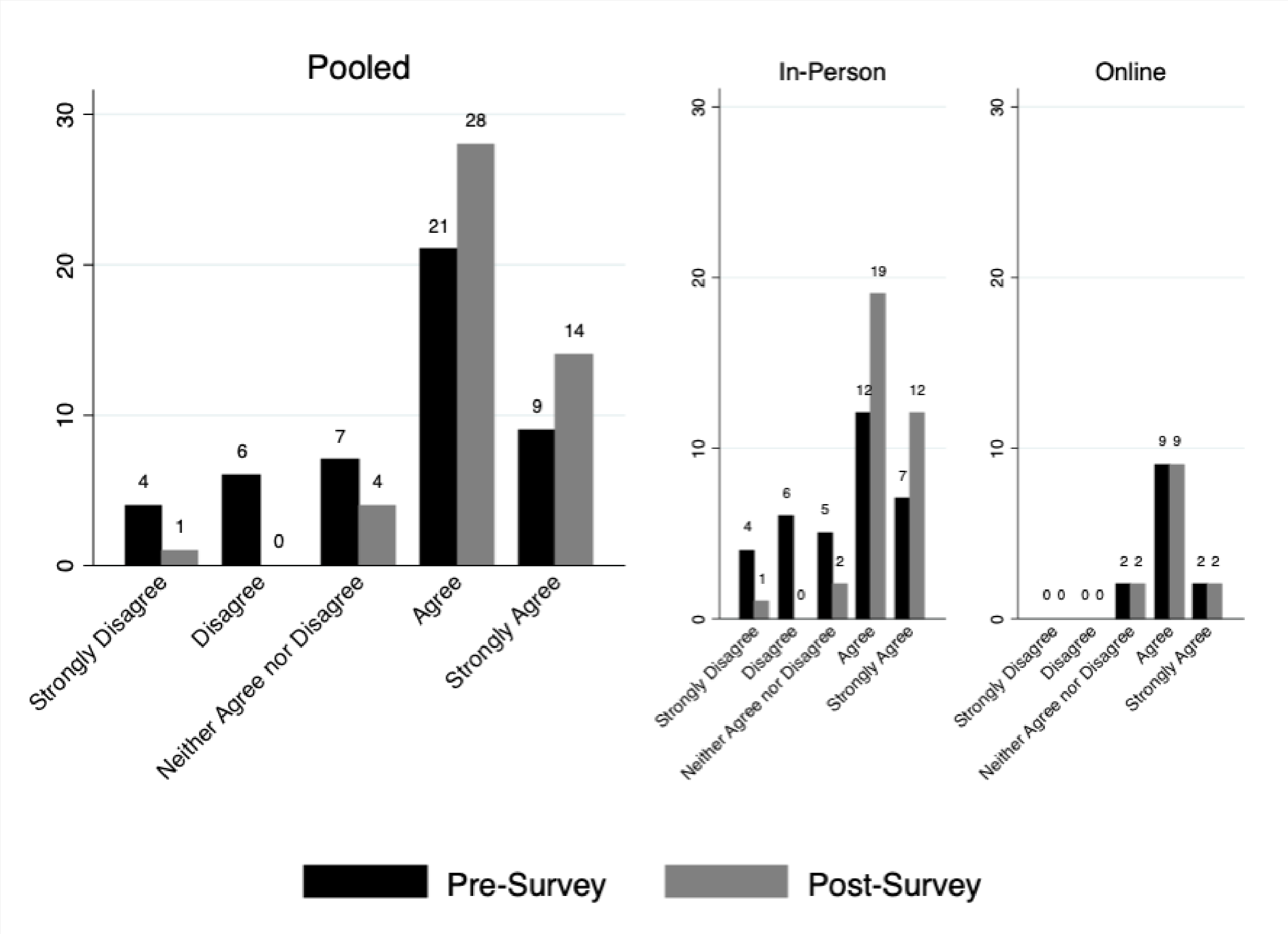

Figure 4A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 4, which stated: "Solutions to wicked problems are not true-or-false, but better or worse."

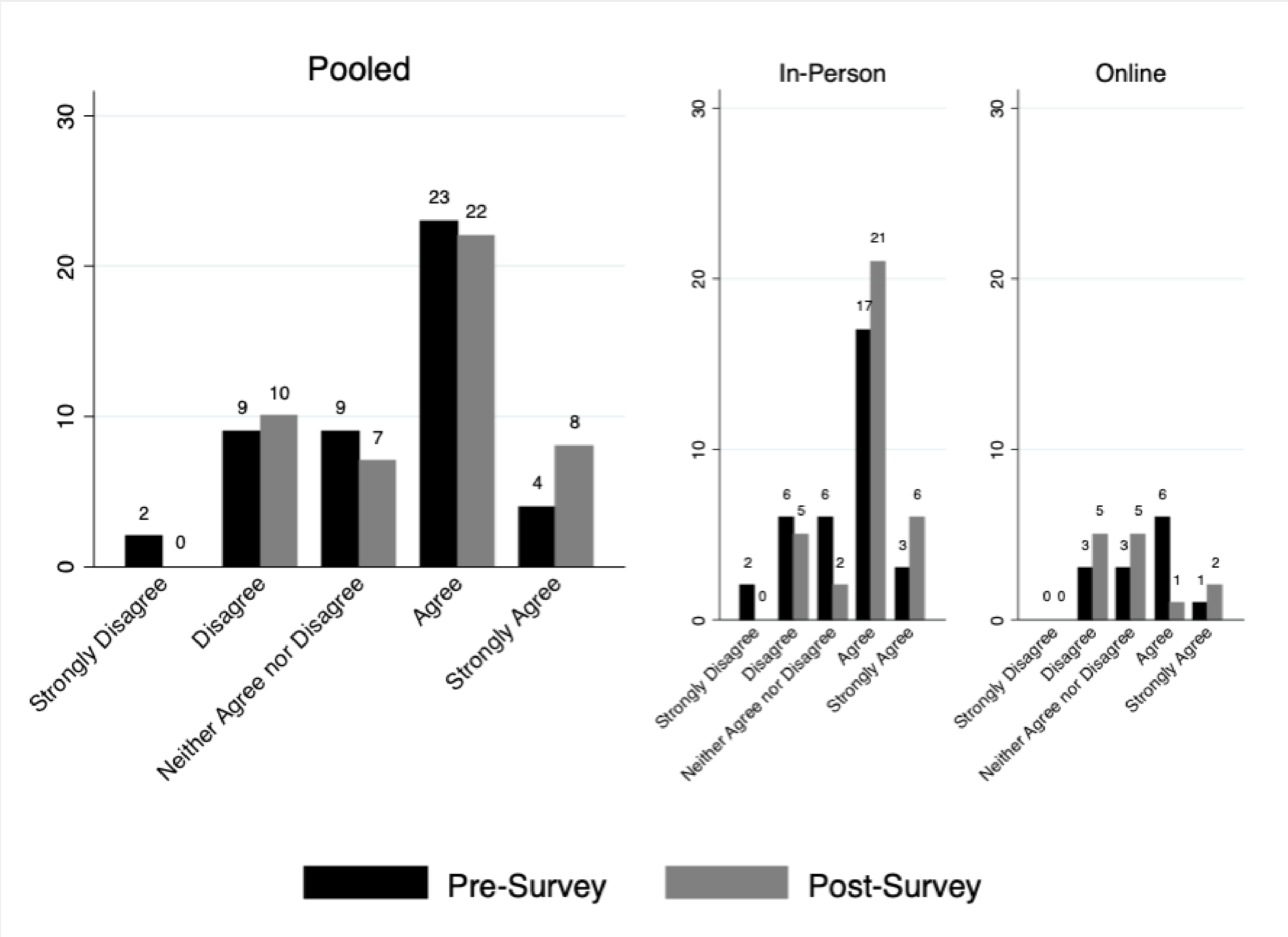

Figure 5A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 1, which stated: "Wicked problems do not have an exhaustive set of potential solutions, nor is there a well-described set of permissible operations that may be considered when reaching a solution."

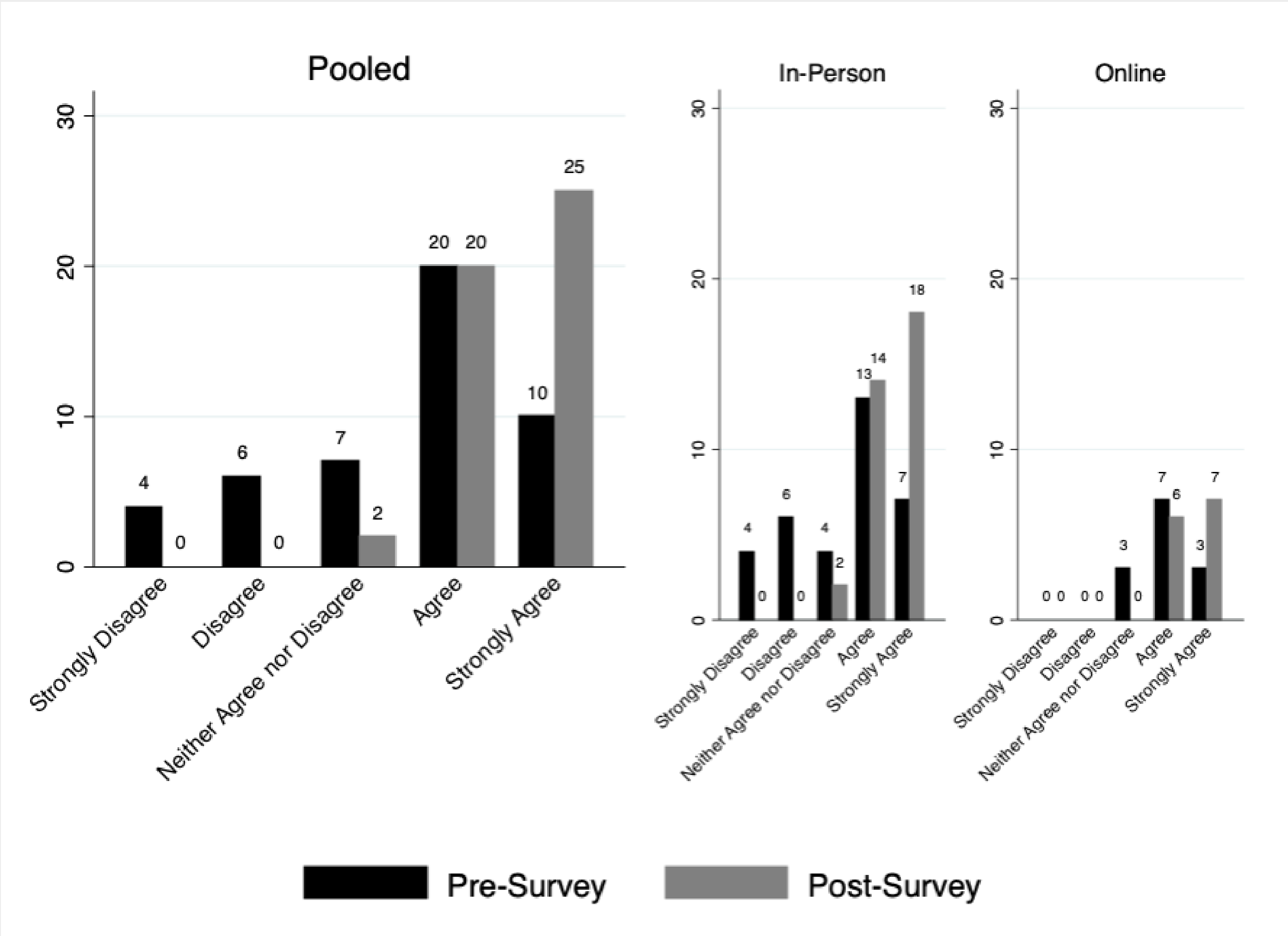

Figure 6A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 6, which stated: "It is important to consider what assumptions realistically hold when solutions to wicked problems are determined."

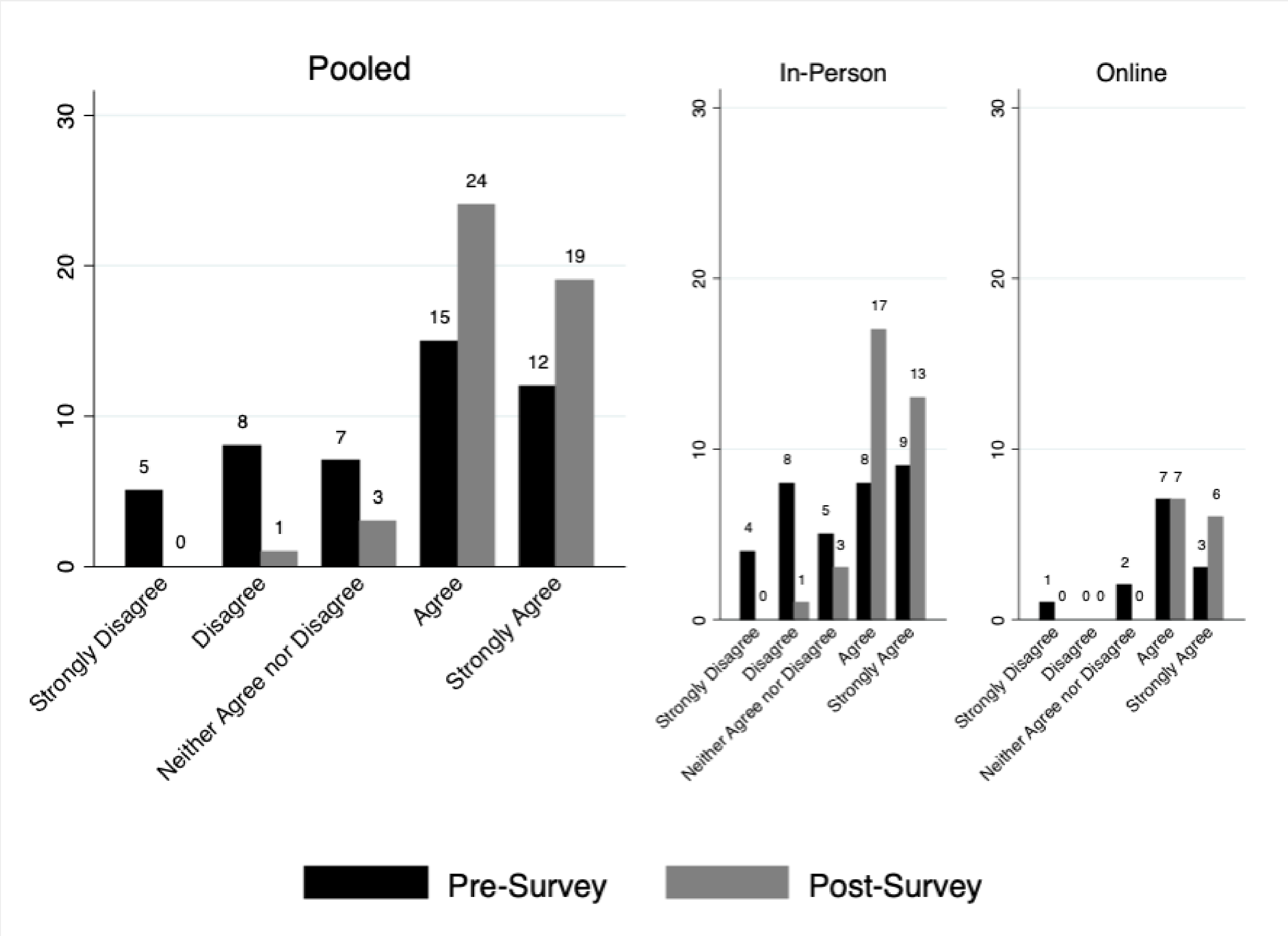

Figure 7A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 7, which stated: "The solution to a wicked policy problem could be influenced by how the problem is presented."

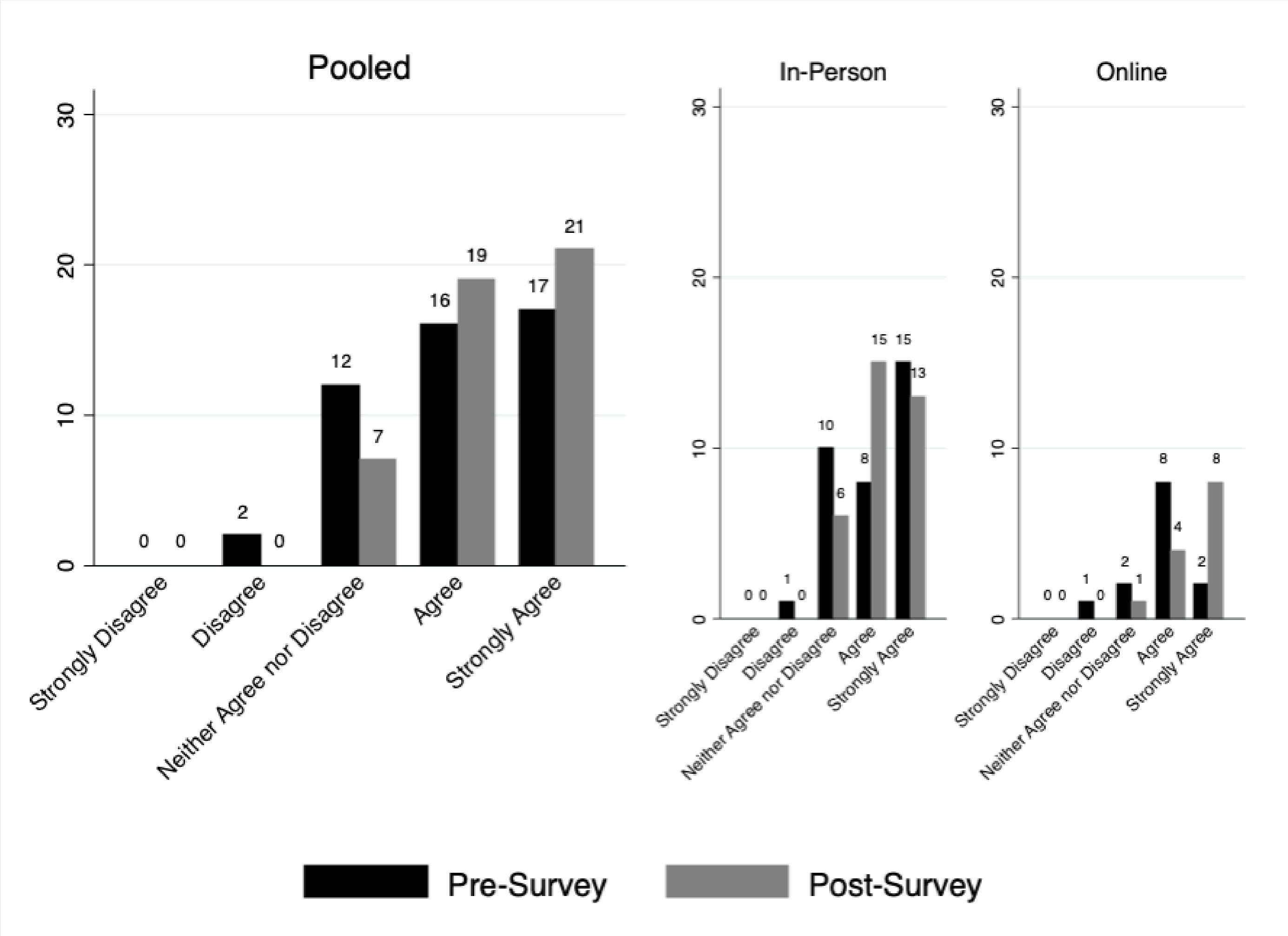

Figure 8A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 8, which stated: "It is imperative the graduate students studying applied economics receive formal training on how to deal with, account for, and solve wicked policy problems."

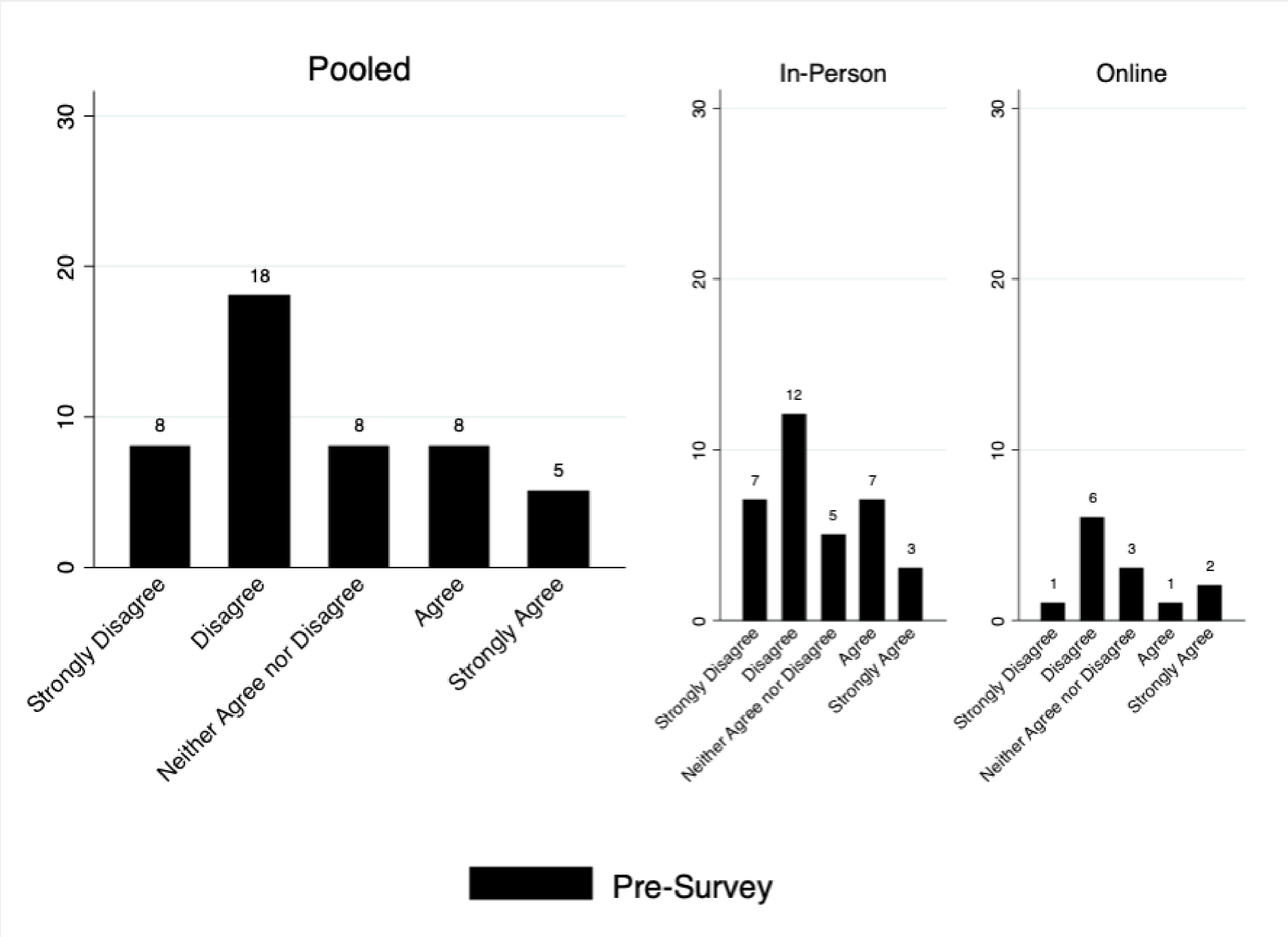

Figure 9A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 9, which stated: "Prior to this study, you received formal training on how to solve wicked policy problems in either an economics, applied economics, or other course taught here at the university."

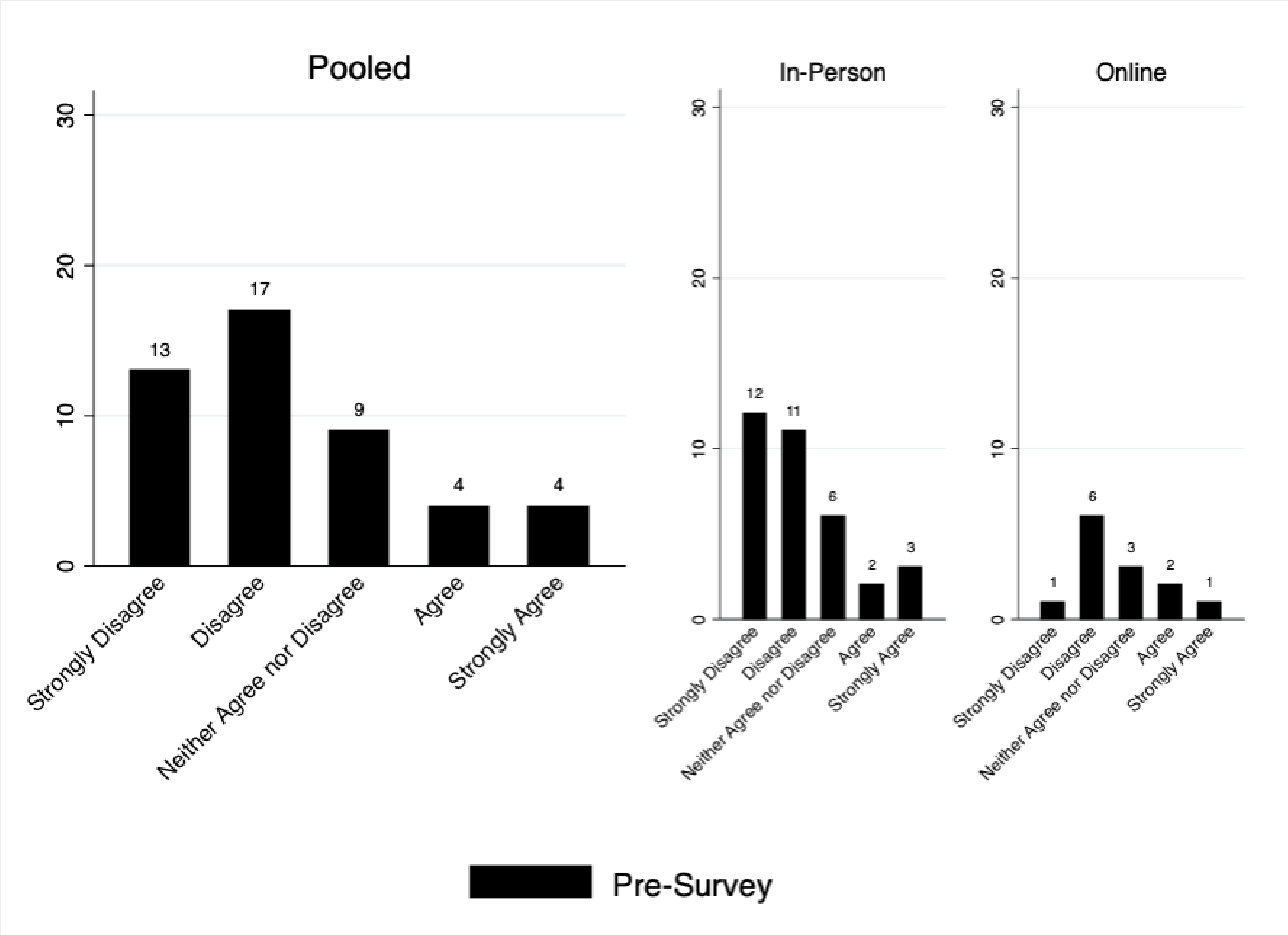

Figure 10A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 10, which stated: "Prior to this study, you were familiar with wicked policy problems."

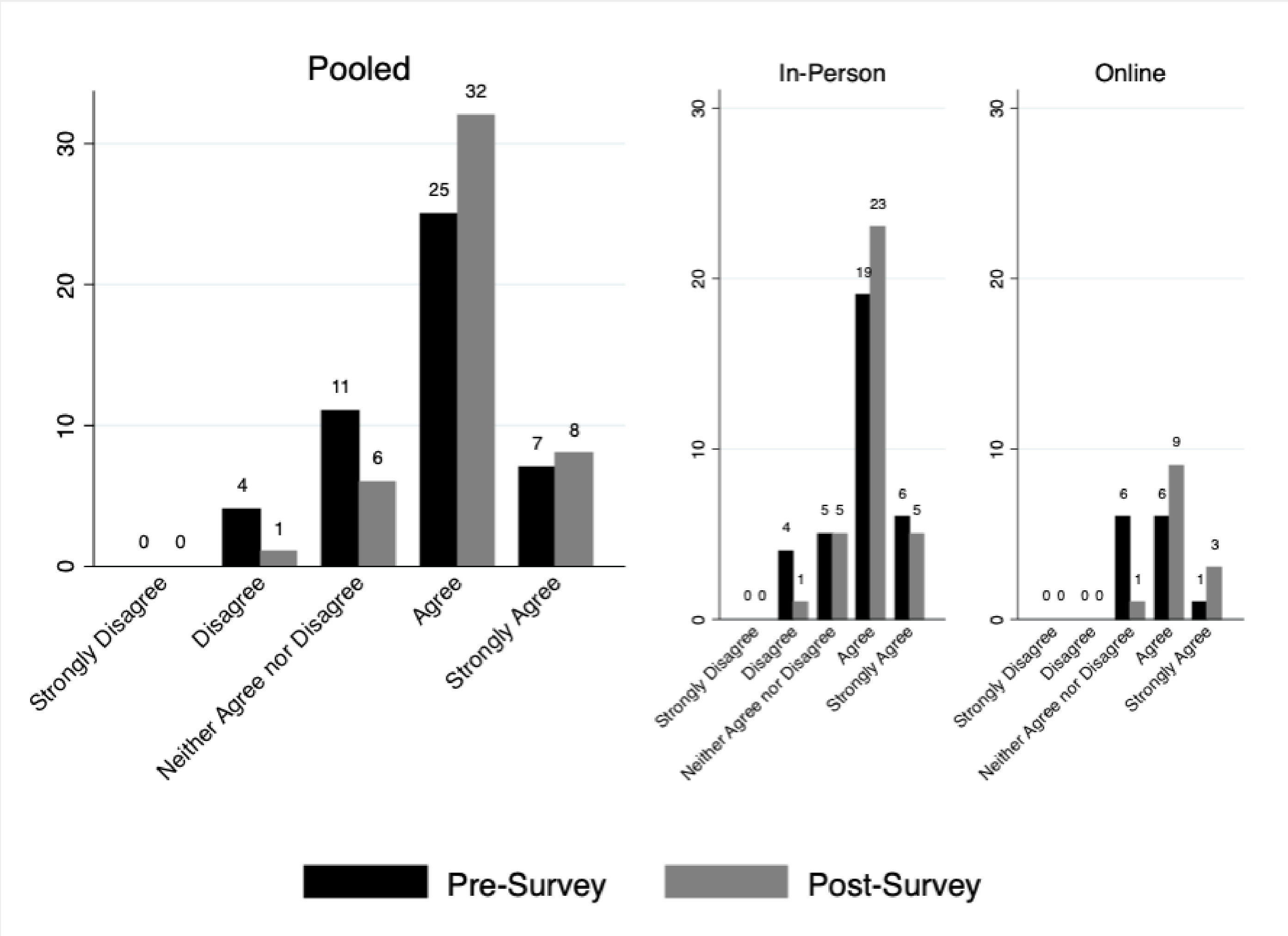

Figure 11A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 11, which stated: "Benefit-cost analysis is an appropriate and effective tool that can be used to reach a conclusion regarding whether or not to pursue an economic policy or project involving a wicked problem."

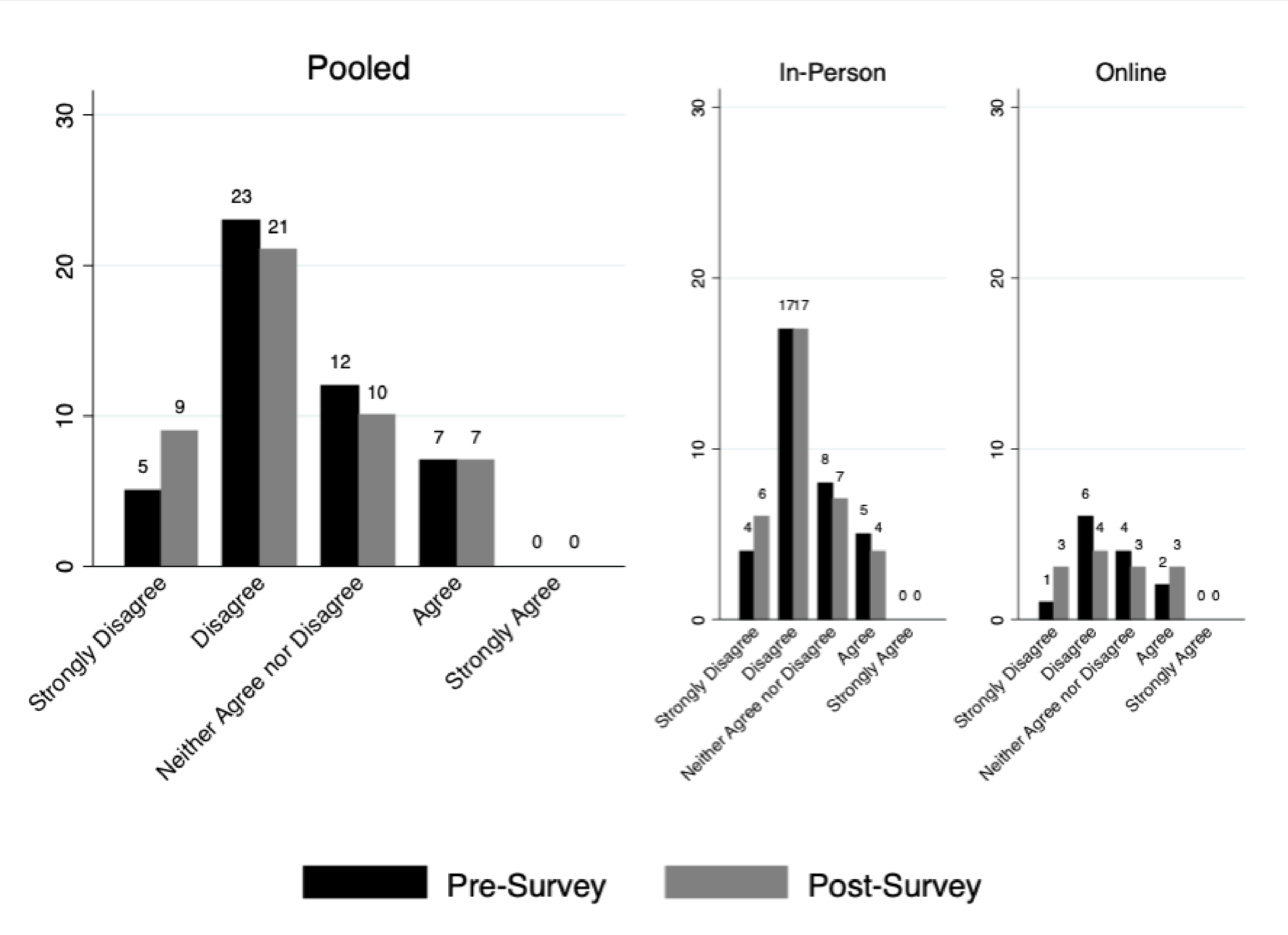

Figure 12A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 12, which stated: "No matter the context of the problem at hand, an economist can and should always rely on the results of benefit-cost analysis to support their policy recommendations."

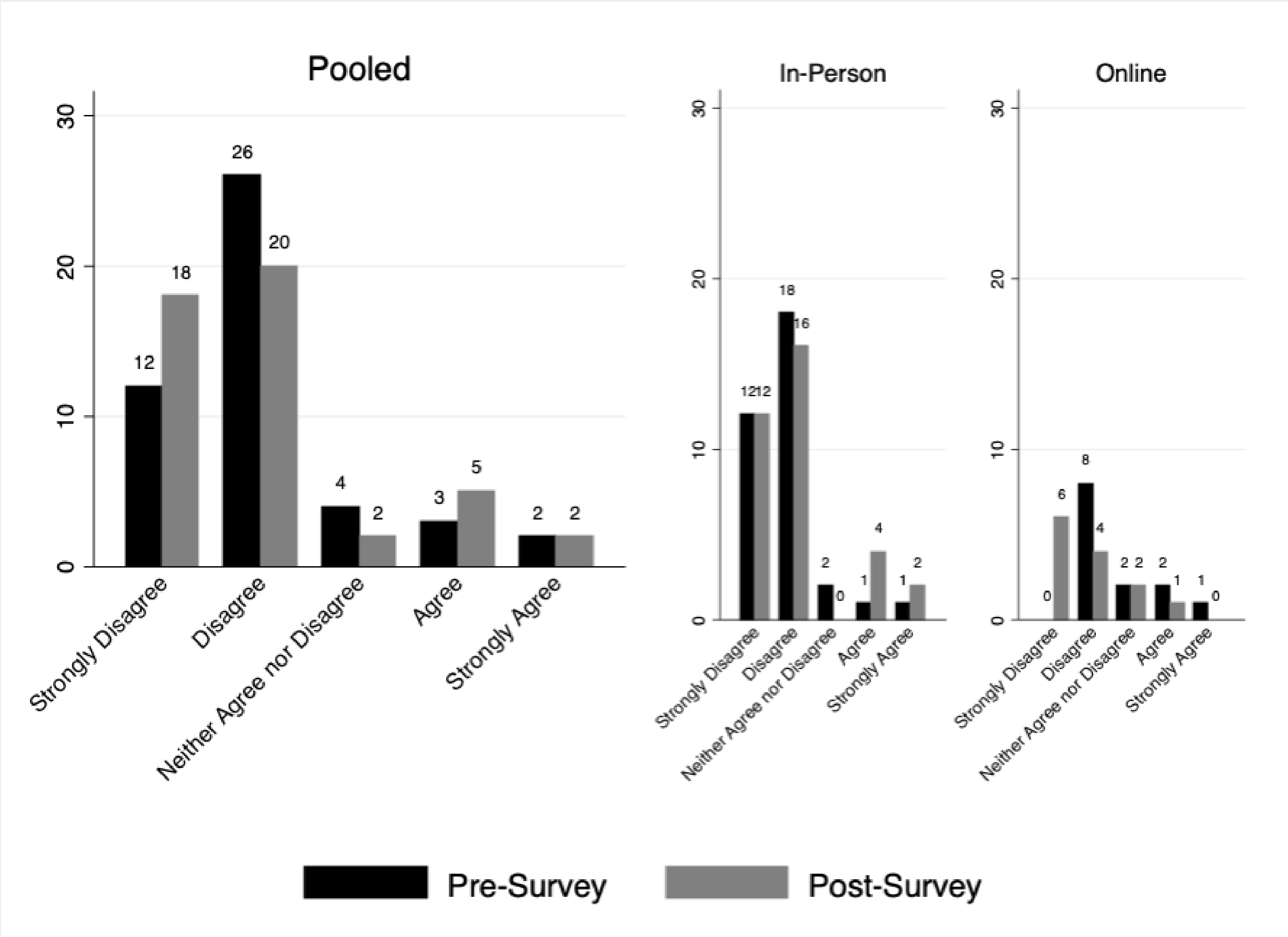

Figure 13A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 13, which stated: "As a graduate student in applied economics, you should plan to analyze any economic policy or project using only benefit-cost analysis."

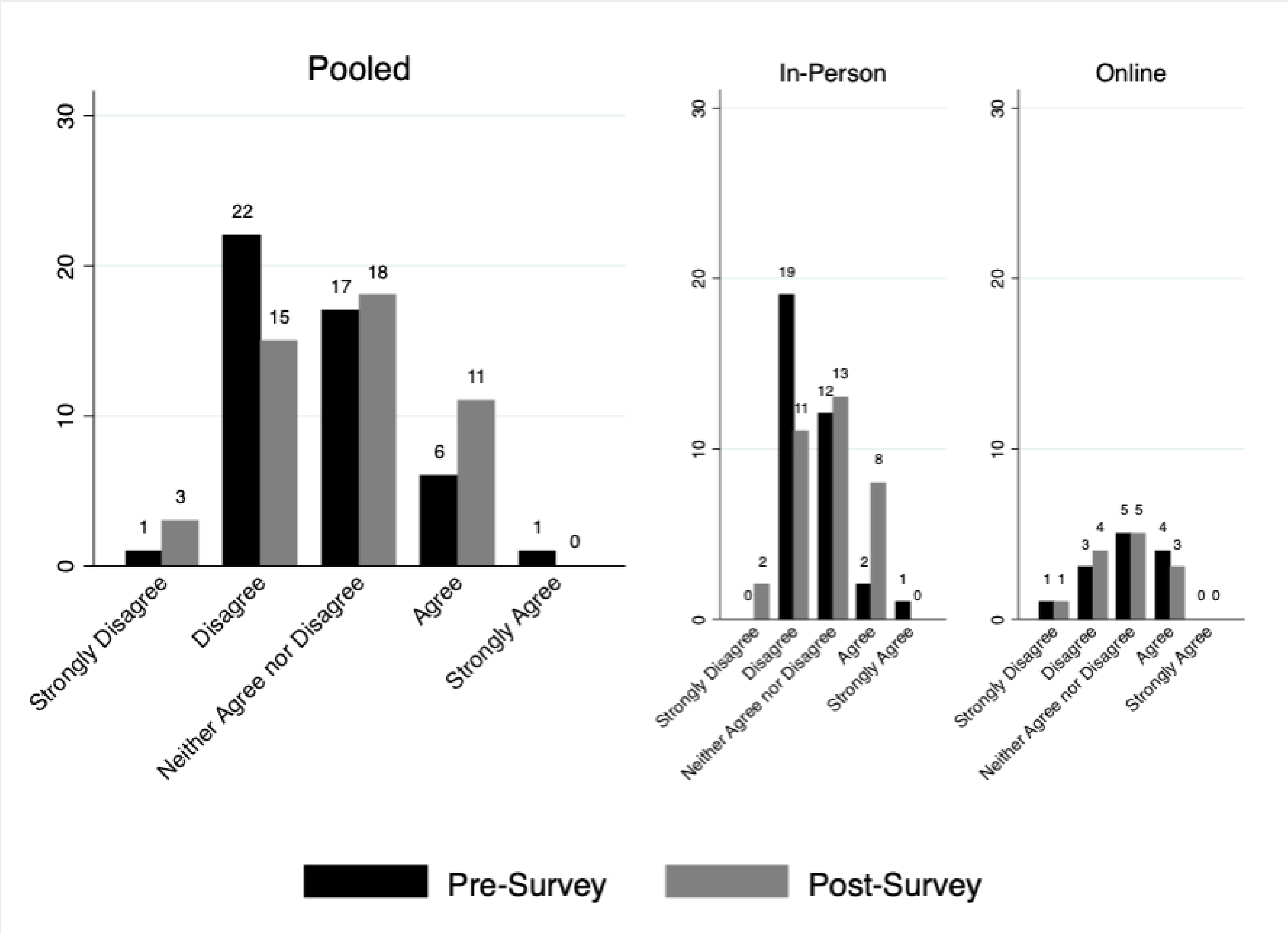

Figure 14A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 14, which stated: "The results of a benefit-cost analysis exercise should always be the leading factor in the decision of whether or not to approve an economic policy or project involving a wicked policy problem."

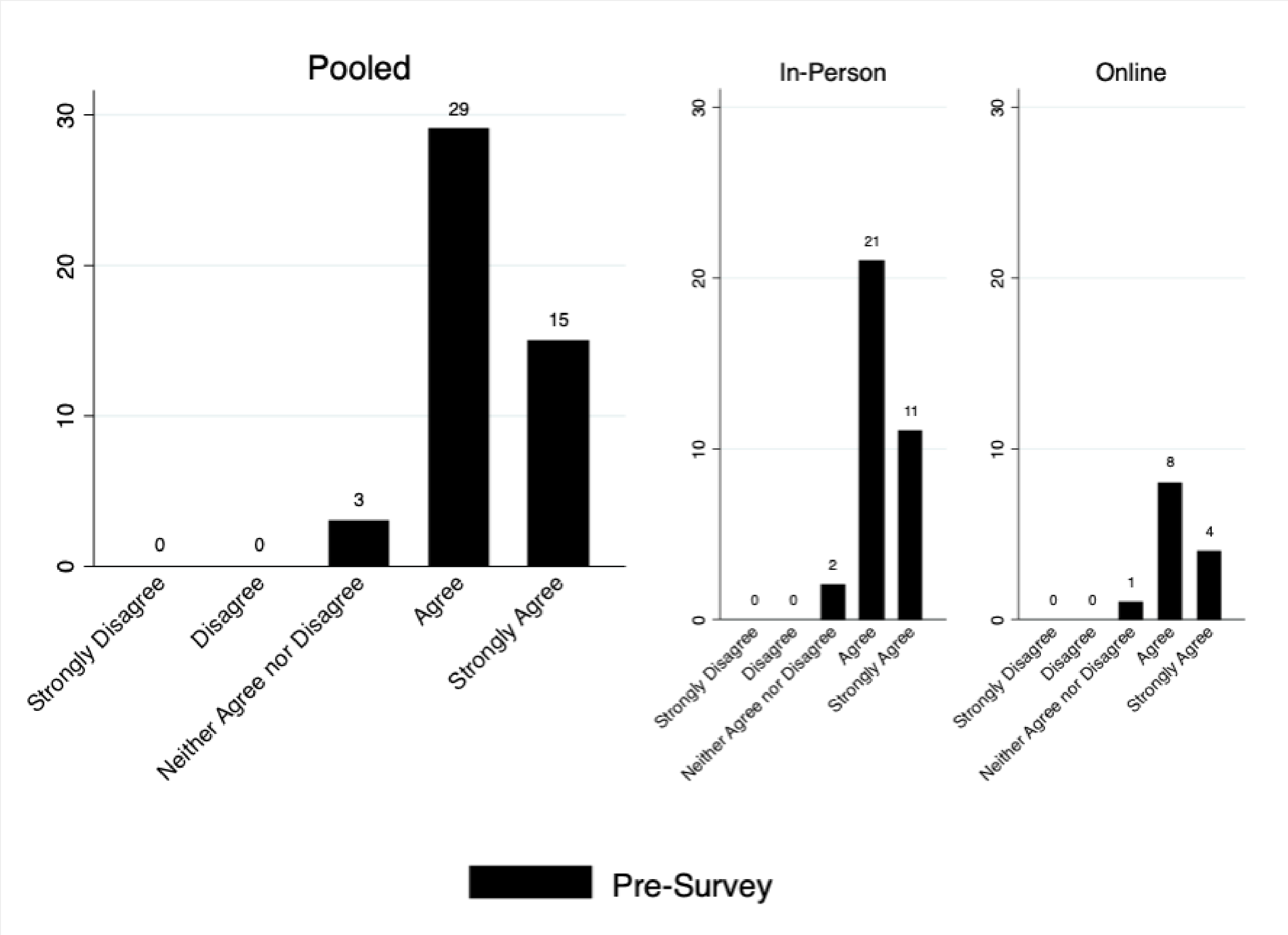

Figure 15A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 15, which stated: "When a conducting benefit-cost analysis it can be difficult to identify and measure all relevant commensurable benefits and costs that can be monetarized."

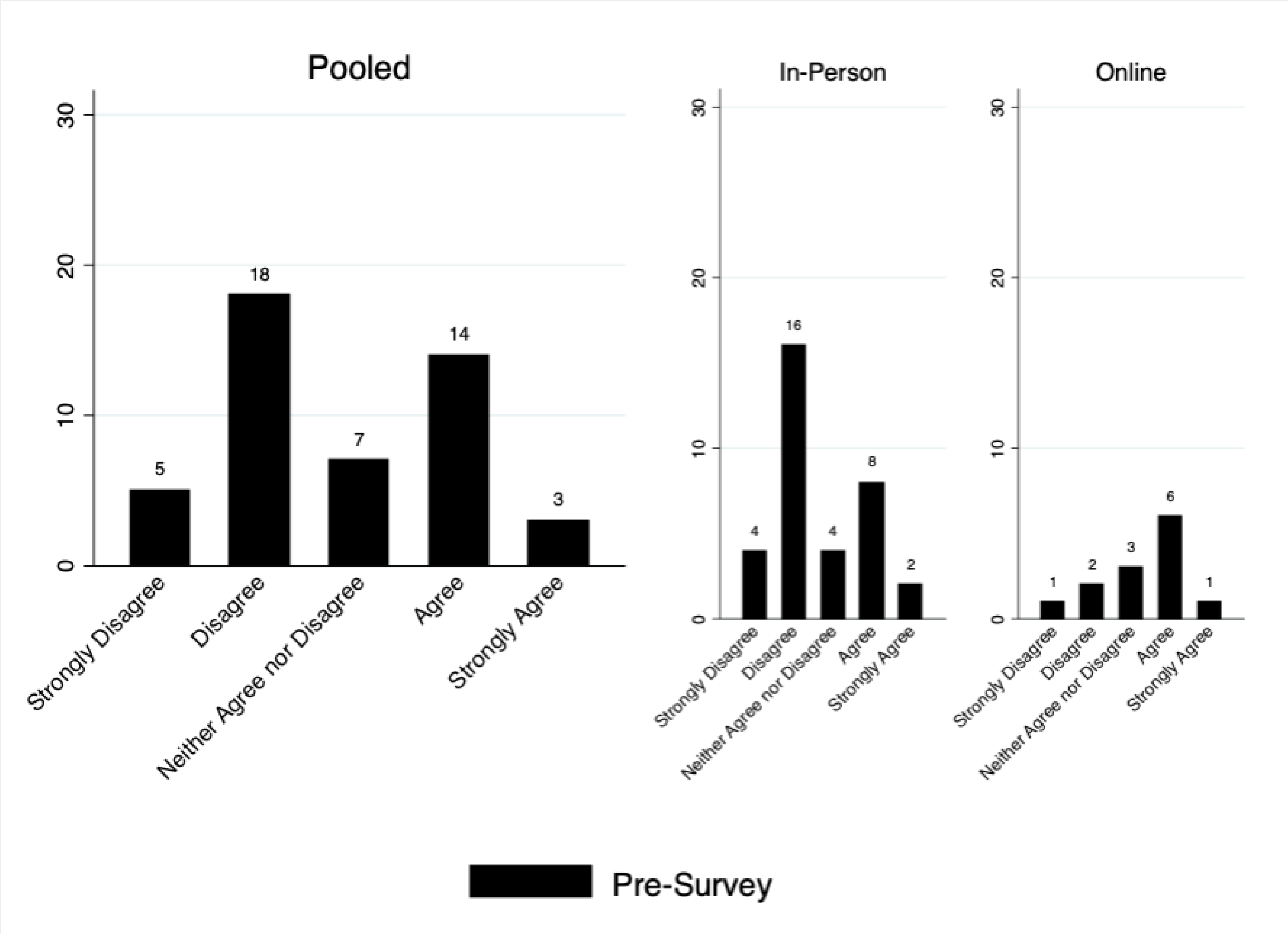

Figure 16A. Frequency of pooled (Spring 2018, Fall 2019, and Fall 2020), in-person (Spring 2018 and Fall 2019), and online (Fall 2020) responses by students to question 16, which stated: "You have received sufficient training on how to solve policy problems using benefit cost analysis in either an economics or applied economics course here at the University of Georgia."

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Teaching and Educational Methods

Seeds of Learning: Uncertainty and Technology Adoption in an Ecosystem-Based Adaptation Game

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Keywords: Classroom game, climate change adaptation, ecosystem-based adaptation, payments for ecosystem services, technology adoption, uncertainty

Abstract
We introduce an interactive game exploring ecosystem-based adaptation (EBA) to climate change, with a focus on technology adoption and uncertainty. The game is useful in academic classes and training sessions for policy makers and stakeholders. Participants play the role of small-scale farmers in a developing country where their farming practices cause erosion that pollutes waterways, while at the same time climate change is making farmers more vulnerable to natural threats like flooding. The game gives participants a series of opportunities to adopt EBA practices: for example, a riparian buffer strip, low-till farming, and agroforestry. The practices differ in the uncertainty surrounding their effects on yields. The game deploys three policies to encourage adoption: a flat payment, a conservation auction, and a flat payment with a pilot bonus for early adoption. Players observe each other's choices and outcomes, which allows for social learning. Participants get a hands-on understanding of climate change's impacts, adaptation, ecosystem services, payment for ecosystem service programs, choice under uncertainty, social learning, adoption of new technology, learning spillovers, cost-effective conservation, and conservation auctions. We provide all materials necessary to run the game, a list of suggested readings, and ideas for discussions and assignments.

1 Introduction

Climate change is already affecting ecosystems worldwide (IPCC, 2014) and the people whose farming and livelihoods are supported by those ecosystems (e.g., Hoegh-Guldberg and Bruno, 2010). Low-income households in tropical developing countries are particularly vulnerable (Barbier, 2010, Barbier and Hochard, 2018). Some technologies and practices that can help reduce these vulnerabilities are referred to as ecosystem-based adaptation (EBA) practices, and use ecosystems to make human and natural systems more resilient (IPCC, 2014, USGCRP, 2018, World Health Organization, 2018). For example, buffer strips of preserved natural ecosystems alongside waterways and roads can fight erosion and protect water quality in the face of increasingly unpredictable precipitation patterns. EBA projects, including watershed management, forest restoration, and mangrove protection, are currently underway in almost sixty countries (Rizvi, et al., 2015). However, people are often hesitant to adopt these practices because adoption is typically costly. This hesitation is greater because many benefits are external to the adopter, and practices' effects on yields are uncertain from the adopter's perspective and, in some cases, not well understood by science.

In this paper, we present an interactive game that explores the adoption of EBA practices. Putting participants in the shoes of decision makers through games like this one, as discussed in Holt (1999), can help build a strong and nuanced understanding of economic models and the systems they represent. The key contributions of the game are to help participants understand how agents choose whether to adopt EBA practices and the hurdles these practices encounter, and to more generally to help participants explore topics surrounding adoption and diffusion of technology with uncertain net benefits. In the game, participants play the role of small-scale farmers in a developing country where policy makers are trying to promote EBA practices. In this role, they must decide, through a series of scenarios in which the policy incentives and the inherent types of uncertainty they face vary, whether to adopt an EBA practice. The structure of the game can easily be adapted to different contexts, such as water quality improvements in developed countries. This paper provides all the information and materials needed to play the game as we present it or to customize it.

This game is well suited to undergraduate and graduate classes in environmental economics, public economics, agricultural economics, environmental policy, environmental studies, international development, and public policy. The game can be used in classes on microeconomics, uncertainty, and information, as well.[1] It also works well in training and capacity-building workshops for policy makers, extension workers, and stakeholders. While it would be helpful for participants to have taken an introductory economics course, the game can be used with participants who have no economics training, including students in introductory and non-economics classes and non-academic stakeholders; in supplementary material we suggest accessible readings to help such participants engage with the game. This type of game may particularly benefit participants who have less economics background or who are intimidated by the mathematics in which economics is often expressed. This is because it allows them to learn about the incentives embedded in scenarios in an intuitive and experiential way. On the other hand, participants who have advanced economics training can use the game to explore and model interesting decision-making contexts in more technical detail. We have, to date, run this game with undergraduate students (who have taken principles of microeconomics), graduate students (with advanced economics backgrounds), and policy makers and stakeholders (with little to no economics background). While the time it takes to play the game has an opportunity cost, it covers many topics, and its immersive and interactive nature may increase the depth of learning, as interactive experiences often do (e.g., Ball, et al., 2006), potentially providing a favorable pedagogical benefit-cost ratio.

The game works best with ten to sixty participants. If played in one sitting, it could last from fifty minutes to two hours depending on how many periods the instructor runs and the intensity of the discussion during the game; alternatively, different treatments of the game can be spread across the semester to match the treatments to the course subject matter, in which case the game would take a small amount of time across each of multiple class sessions.[2] We provide a set of treatments that can be mixed and matched and repeated to the instructor's taste, providing active learning of topics including climate change adaptation, ecosystem services, decision making under uncertainty and (Knightian) ambiguity, payment for ecosystem service programs, cost-effective program deployment, conservation auctions, technology adoption and diffusion, information as a public good, social learning, and learning in a noisy environment. We also provide participant instructions (Appendix I) and, in supplementary material available for download, an Excel sheet for conducting the game, an instructor guide, two handouts with topical background for participants at different levels of technical detail and assumed knowledge, a list of readings that can be shared with different kinds of participants, a list of ways in which the game can be extended or modified, and slides for use with the game.

The paper proceeds as follows. In Section 2, we describe the game and treatments in narrative detail, though we leave the practical details to the instructor guide (supplementary material). In Section 3, we discuss the economic and policy context of the game. In Section 4, we present suggestions that can form the basis for class discussions or assignments. In Section 5, we discuss our experiences with the game. Finally, in Section 6, we conclude.

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[1] While economics graduate courses typically do not devote time to interactive exercises like this, we feel that is a missed opportunity, because games like this have many complexities that can be explored with rigor. This game may also be particularly useful in interdisciplinary master's degree programs because it can let policy-focused students learn from experience how incentives work without having to unravel complex mathematical derivations.

[2] This is reminiscent of Secchi and Banerjee (2019); we thank an anonymous reviewer for suggesting this.

2 The Game

In this game, participants learn firsthand about EBA programs and the challenges in deploying adaptation technology and methods, and about how uncertainty in outcomes can affect the adoption of new technologies. Each participant plays the role of a farmer whose livelihood depends on a harvest that is subject to climate risk and who can participate in EBA programs. Participants make decisions over a series of rounds, called "contract periods." We present six treatments that can be mixed and matched, with the option of repeating any treatment if desired. Each treatment introduces an element that renders the game more realistic, and thus more complex; the treatments generally build on each other. Table 1 outlines the treatments; the following sections explain the elements in more detail. The treatments are also described in the standalone participant instructions (Appendix I).

Our preferred way to conduct the game is to play each of the first four treatments for one round and the remaining two treatments in two repeated rounds each, as we describe in the following. That configuration requires about ninety minutes of total class time.[3]

If possible, we suggest that the instructor pay one or more participants an amount of money proportional to their earnings.[4] Real payment heightens attention and creates a lively atmosphere. Further, the incentive compatibility of payment-relevant decisions helps participants gain a stronger understanding of the underlying decision context and the incentives it creates, since they have "skin in the game." Holt (1999) provides a useful discussion of the benefits of using incentives in classroom games. We discuss payment mechanics in detail later on.

In what follows, we give a narrative explanation of the game and how to play it. Recall that we list some suggested ways to modify the game to explore different topics or shift the focus in supplementary material. We explain in extensive detail the practical elements of precisely how to conduct the game, with hints about how to prevent challenging situations and how to make the game go as smoothly as possible, in the instructor guide (in supplementary material).

2.1 Setup and General Conduct

Each participant plays the role of a small-scale farmer in a developing country where climate change is increasing the risks to agriculture from both drought and heavy rains. The periods vary in the policy being implemented and the type of uncertainty explored. In each period, each participant decides whether to adopt the EBA practice available that period, and has some resulting earnings (denominated in shillings, ₪) that represent net income for that period. The costs to adopt a practice are private and comprise explicit costs of adoption and an (often uncertain) opportunity cost in foregone yields. The benefits of adoption are public in that everyone in the community benefits from decreased erosion, which improves water quality.

A participant's earnings in each period depend on their decisions, the decisions of others, and chance, and their total earnings for the game are the sum of their earnings in each period. Specifically, at the start of the game, each person is given a randomly selected number from one to ten (we use playing cards) that determines their baseline returns from agriculture. Their Farming Value, used for earnings calculations, is the number they receive times 1,000₪. Their earnings, in a general sense, are given in Equation 1.

$$\text{Earnings} = \text{Farming Earnings} + \text{Government Payments} \tag{1}$$

Government payments vary from treatment to treatment. If present, they consist of a base adoption incentive (either a fixed 1,500₪, or an amount depending on participants' bids in the auction

[3] For shorter sessions we recommend playing the first two treatments and either following up with a detailed discussion or playing treatment 3 or treatment 4, depending on the desired focus.
[4] At some institutions, the instructor may need to seek permission to pay participants.

Table 1. Treatments and Learning Objectives

Period	EBA Practice	Incentive/Policy	Brief Description	Learning Objectives
1	Riparian buffer strips	No government involvement	Participants decide whether to adopt EBA[a] with no uncertainty about costs or benefits and no policy incentive to adopt	• Impacts of climate change • EBA • Subsistence agriculture in developing countries • Erosion and water quality • Provision of local public goods
2	Riparian buffer strips	Flat adoption subsidy	A fixed payment is offered for EBA adoption	• Payment for ecosystem services programs • Cost-effectiveness in pollution abatement
3	Riparian buffer strips	Conservation auction	Participation in the EBA program is determined by an auction	• Conservation and procurement auctions • Incentive compatible auction design
4	Low-till or no-till farming	Flat adoption subsidy; uncertain direct impact	Direct impact to the EBA adopter is uncertain; fixed payment for adoption	• Decision making under uncertainty
5	Agroforestry (border)	Flat adoption subsidy; uncertain but correlated direct impact	Direct impact to the EBA adopter is uncertain, but those impacts are correlated across participants; fixed payment for adoption	• Different forms of uncertainty • Learning spillovers in the adoption of new technology
6	Agroforestry (intercropped)	Flat adoption subsidy plus pilot bonus; uncertain but correlated direct impact	Direct impact to the EBA adopter is uncertain, but those impacts are correlated across participants; fixed payment for adoption plus bonus for early adoption	• Incentivizing learning about new technology

[a]EBA stands for ecosystem-based adaptation.

treatment) as well as, in the final treatment, a bonus for early adopters (a pilot bonus).

Farming earnings depend on the participant's Farming Value and are affected by whether the participant adopts the EBA practice as well as externalities from other farmers who do not adopt the EBA practice. Equation 2 shows how Farming Earnings are calculated:

$$\text{Farming Earnings} = \text{Farming Value} * (1 + \text{\# Adopters} * 5\%) - (\text{Adopt}) * \text{Direct Costs} \qquad (2)$$

where Adopt is a dummy equal to one if the participant themselves adopted the practice, and "# Adopters" is the number of participants in total who adopted it this period.

The Farming Value represents the basic suitability of this farmer's land to agriculture. The land's productivity is increased by every farmer's adoption of the EBA practice. The instructor can use examples to explain how such spillovers might arise. The story we tell is that these practices limit the impact of erosion on water quality in shared waterways in the face of the increase in intense rainstorms that comes from climate change.[5] In the game, for each farmer that adopts the EBA practice, the yield of every farmer in the group (including themselves) increases by 5 percent as the negative externality of nutrient runoff is abated. In reality, this ecosystem benefit will vary across different practices and will also be subject to uncertainty, but for simplicity, we keep it constant. Because these benefits are mostly external to the decision maker, the Nash equilibrium for most players in most situations in the game is to not adopt the EBA practice even though it will often be socially beneficial for everyone to adopt it. This divergence occurs because many benefits are external.

Direct Costs of adoption always include an explicit cost of 1,000₼ in the game. Additional direct costs arise because each practice also comes with an opportunity cost in the form of a yield reduction. With some EBA practices, this yield loss results from surrendering some land to filter strips; with other practices, it comes from increased weed growth or need for herbicides; and in some cases, it comes from interactions between the crops and trees used for agroforestry. In the first periods, this is a loss of 10 percent of base farming earnings. However, later periods demonstrate various kinds of uncertainty, as we will describe when we describe the treatments.

We summarize the payoff function's components in Table 2.

In advance of the game, we suggest sharing the instructions (Appendix I) and one of the handouts in the supplementary material as well as any additional desired readings (see supplementary material) with the participants. Before the game session, instructors should take time to familiarize themselves with the spreadsheet and the steps in the instructor guide (supplementary material), which includes instructions for modifying the spreadsheet to run treatments more or fewer times or to accommodate more or fewer participants.

Table 2. Elements of the Payoff Function

Name/Description	Value or Range	Description
Farming Value	Card number (1-10) times 1,000₼	Base earnings from farming if no one adopts the EBA[a]
# Adopters	0-N, where N is the number of participants	Number of people adopting the EBA including self
Yield improvement from reduced water pollution externality	1 + # Adopters * 5%	The amount by which yield is improved from everyone's adoption of the EBA
EBA practice adoption cost	1,000₼	The flat cost to adopt an EBA
Additional farming earnings reduction from adopting the EBA practice	Farming Value times: 10% for Treatments 1, 2, & 3; Weather Yield Effect for Treatment 4; Unknown Yield Effect for Treatments 5 & 6	How much the EBA reduces (or, if negative, increases) farming earnings, e.g., through land not planted or increased/reduced yield
Adoption incentive	1,500₼ in Treatments 2, 4, 5, and 6; depends on auction outcome in Treatment 3	The amount the government will pay to those who adopt the EBA
Pilot bonus	500₼	The added payment (in Treatment 6) for being an early adopter of the EBA

[a]EBA stands for ecosystem-based adaptation.

[5] You might need to explain to participants that while climate change will cause some places to be drier (and others to be wetter), a sudden rainstorm in a dry ecosystem can be quite damaging.

In the game session, in each period, the instructor should explain the decision environment, and then verbally elicit every participant's decision for that period. After each period, they should summarize to the participants how many people chose to adopt an EBA practice and show them the implications for participants' earnings that period.

After all of the periods, as we discussed, we suggest paying at least one participant. The spreadsheet is set up to choose 10 percent of participants randomly and to convert earnings into dollar amounts on the order of $2 to $10 (though the conversion rate to dollars can be changed in the spreadsheet if your game configuration would yield an undesirable pay range). Participants can also be paid in other ways if that is preferred; some alternatives are shared in the instructor guide (in supplementary material). Even if there are no payments for participation, participants tend to enjoy looking at everyone's earnings at the end of the game.

The game can be preceded by, interspersed with, or followed by discussions or assignments. When we play the game, we lead short discussions to debrief after each treatment and a more substantial discussion after the game is complete, linked to readings assigned before class and written assignments that follow the class.

2.2 Treatments

As discussed, the treatments are independent from each other, but they are mostly progressive in the sense that many build on each other. In particular, the fifth and sixth treatments are more intuitive if run together.

The first three treatments use riparian buffer strips (Hill, 1996) as their EBA technique. Farmers who adopt this practice leave a stretch of land unfarmed at the edge of the waterway, and turn that land into a quasi-natural ecosystem to provide a variety of ecosystem services such as habitat for species. However, the primary benefit of this practice to the community is that it reduces runoff into the waterway by filtering soil that is eroded by rainfall and filtering many chemicals that would otherwise pollute the water. Its primary cost is a reduction in the land available to farm. This land is often the farmer's most fertile land because of its location next to the water. In the game, the adoption of riparian buffers leads to a 10 percent decrease in yields, which is the opportunity cost of participating.

2.2.1 Treatment 1: No Government Involvement

This treatment is the simplest, and both sets a baseline and provides participants with experience in the decision environment. Earnings are as shown in Equation 3.

$$\text{Earnings} = \text{Farming Value} * (1 + \#\text{ Adopters} * 5\%) - (\text{Adopt}) * [\text{Farming Value} * 10\% - 1{,}000₼] \quad (3)$$

If we denote Farming Value (1,000₼ times the person's card) as FV, the private cost of taking a contract is $1{,}000 + 0.1 * FV$ ₼, while the private benefit is $0.05 * FV$ ₼; as a result, the net private cost is $1{,}000 + 0.05 * FV$ ₼, so profit-maximizing people will not adopt the practice. However, the external public benefit is 5 percent times the sum of all other Farming Values in the room. If cards are uniformly distributed from 1 to 10, then this is $5.5 * 1{,}000 * 5\% * (N-1)$₼$= 275(N-1)$₼. Thus, it is socially beneficial for someone to adopt as long as $275(N-1)$₼ ≥ $1{,}000 + 0.05FV$₼. If cards are uniformly distributed, then it will be socially beneficial for everyone to adopt if $N - 1 \geq \frac{1{,}000+50}{275}$₼, which requires $N > 4$. In this treatment, participants can learn about the negative externality caused by agricultural activity and can grapple with ideas about public good provision and ecosystem services.

It is worth pausing after this treatment to discuss why people made the choices they made. This can help clear up any confusion participants have about the game.

2.2.2 Treatment 2: Flat Adoption Subsidy

This treatment introduces the payment for ecosystem services scheme, using a flat payment of 1,500₼. Earnings for this treatment are as shown in Equation 4.

$$\text{Earnings} = \text{Farming Value} * (1 + \#\ \text{Adopters} * 5\%) - (\text{Adopt}) * [\text{Farming Value} * 10\% + 500₼] \quad (4)$$

The payment makes it privately optimal for a participant to take the contract if $1{,}500₼ \geq 1{,}000 + 0.05 * FV$ ₼. In other words, adoption is strictly optimal for everyone except those with a card of 10, and weakly optimal for them. We find it useful to have a payment that encourages full participation in this treatment, since later treatments that add uncertainty will decrease participation from this level. If the instructor prefers only partial participation, they can reduce the payment.

Is a flat payment realistic? In practice, some payment for ecosystem services schemes use flat payments. The prices are typically exogenous to the local decision makers because they are derived from national or global valuation estimates.

This treatment provides an opportunity to talk about the dual goals of efficiency and cost-effectiveness before introducing more complicating factors.

2.2.3 Treatment 3: Conservation Auction

In this treatment, payments and participation are based on a procurement auction. Auctions are common in conservation programs, including the United States Conservation Reserve Program (Hellerstein, 2017). In this treatment, participants submit bids for desired payment amounts, and the lowest 50 percent of the bids are accepted into contracts. All contracts are paid the value of the lowest bid *not* accepted. Earnings are therefore as given in Equation 5.

$$\begin{aligned}\text{Earnings} = \text{Farming Value} * (1 + \#\ \text{Adopters} * 5\%) - (\text{Adopt}) * [&\text{Farming Value} * 10\% \\ &+ \text{Auction Payment}]\end{aligned} \quad (5)$$

Since this is incentive-compatible, everyone should bid their true cost of adoption. If participants are purely self-interested, this is $1{,}000 + 0.1 * FV$ ₼. (The same amount of ecosystem services is always provided regardless of whether an individual takes up the contract since there is a set number of contracts; therefore, adoption no longer yields an added $0.05 * FV$ private benefit from increased ecosystem services.)[6]

Bidding in the auction is engaging and students enjoy it, but it is more complex than flat payments. It is possible to run all of the remaining treatments with auctions (which requires modifying the spreadsheet), but for simplicity, our materials implement them with flat payments.

2.2.4 Treatment 4: Uncertain Direct Effect

This treatment introduces a new EBA practice: low-till or no-till farming (Montgomery, 2007).[7] Low-till and no-till farming disturb the soil less than conventional tilling, and as a result, the soil is less erodible and requires less fertilizer as more nutrients stay in the soil. However, the undisturbed soil is more prone to weed growth. This treatment can be modified to represent weed growth as a flat cost (representing more time and effort spent weeding or more herbicides purchased), but we express it as a reduction in yield, which is likely as weeds crowd out the crop. Of course, weed growth depends on many factors, and in a good year, the net private effect of the reduced tilling and the weed growth can even be positive.

Therefore, we use this treatment to introduce uncertainty. The uncertainty in this treatment is

[6] If some bids are tied, depending on how ties are resolved, the number of contracts and thus the amount of ecosystem services may vary after all. The instructor guide discusses this in detail.

[7] It is possible to use the same EBA practice for all treatments and ask the participants to assume they are independent. We suggest using different practices to reduce behavioral spillovers across treatments and to introduce more examples of EBA practices.

simple: everyone in the community faces a common weather shock that determines how vigorous weed growth will be that year. That common shock, which we call the Weather Yield Adjustment, is equally likely to be -30 percent or +10 percent, which is a mean-preserving spread from the yield impact in the earlier treatments, but provides two possible outcomes that are quite different from each other. Earnings are given by Equation 6.

$$\text{Earnings} = \text{Farming Value} * (1 + \#\text{ Adopters} * 5\%) +/- (\text{Adopt}) * [\text{Farming Value} * (\text{Weather Yield Adjustment}) + 500₼] \quad (6)$$

On average, low-till farming and the riparian buffer strip have the same impact on yield: a decrease of 10 percent. Thus, risk-neutral agents will always take up contracts because the payment equals the expected cost of participating. However, as most people are risk-averse, some will not participate, especially those with higher cards.

2.2.5 Treatment 5: Uncertain but Correlated Direct Effect

In this and the next treatment, the EBA practices are forms of agroforestry (Branca, et al., 2011, Jose, 2009, Kiptot, et al., 2007).[8] In this treatment, trees are to be planted around crop fields as a border. In the sixth treatment, trees are to be interspersed throughout the crop field, a practice known as intercropping. In each case, the trees are native species and provide ecosystem benefits by reducing runoff into waterways. In addition, they may yield net positive or negative effects on crop yields. The negative effects occur because the trees take some land, water, and nutrients away from the crops. On the positive side, however, they provide a windbreak (reducing erosion), can hold soil, nutrients, and water in place (reducing runoff) so that crops can use them, and may also provide local cooling.

Farmers may be uncertain about how agroforestry will perform in their context. Treatments five and six both showcase two elements of this uncertainty: systemic and idiosyncratic. The total yield impact is the sum of these effects. Figure 1 shows these two elements, which we describe in detail next.

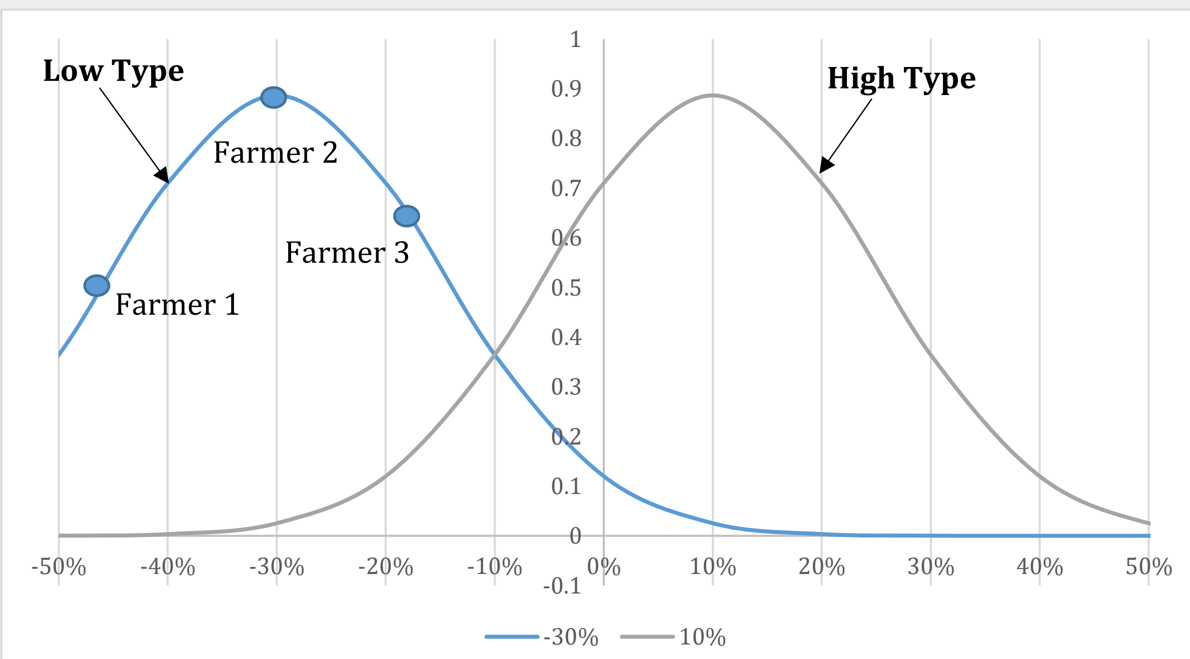

Figure 1. Systemic and Idiosyncratic Uncertainty in Yield Impacts

[8] Branca, et al. (2011) define agroforestry as "land use practices in which woody perennials are deliberately integrated with agricultural crops" and describe the ways in which such practices can improve land productivity.

Systemic uncertainty is represented in Figure 1 by whether a community is on the Low Type or High Type curve, which each represent a distribution of effects across participants that is equally likely, as each community is equally likely to be a Low Type or High Type in terms of yield impact. There is systemic uncertainty about the fundamental performance of agroforestry, particularly in any local area. Studies have found mixed evidence of agroforestry's impacts (Branca, et al., 2011, Kiptot, et al., 2007), depending on the trees used, how they are planted, and the local climate. In the game, the systemic uncertainty is equally likely to be -30 (Low) or +10 (High) percent.

Idiosyncratic uncertainty is represented in Figure 1 by the location of any given farmer on their community's distribution curve, as exemplified by Farmer 1, Farmer 2, and Farmer 3. The idiosyncratic uncertainty in agroforestry performance arises because land, soil, and microclimate properties can vary quite a bit even within a local area, causing agroforestry to perform differently on different plots of land. The practice's effect on yield, therefore, is an idiosyncratic disturbance (drawn from a normal distribution) away from the mean systemic effect (which is equally likely to be -30 percent or +10 percent). The idiosyncratic risk has characteristics of risk because participants know the shape of the distribution from which the disturbance is drawn, but also has characteristics of Knightian uncertainty (i.e., ambiguity) because participants do not know the probability of any particular disturbance since they do not know the standard deviation of the distribution, and further may have a hard time understanding a normal distribution. Earnings from Treatment 5 are given by Equation 7.

$$\text{Earnings} = \text{Farming Value} * (1 + \#\text{ Adopters} * 5\%) +/- (\text{Adopt}) * [\text{Farming Value} * (\text{Unknown Yield Effect}) + 500₼] \tag{7}$$

Because most people are risk averse and ambiguity averse, participants, especially those with higher card values, should become even less inclined to adopt a contract.

Because of the systemic element of risk, participants can learn from each other's experience with agroforestry, but because of the idiosyncratic element, any individual's outcome is imperfectly informative of any other individual's outcome. These concepts are difficult and require thorough explanation, especially with participants with less quantitative background. To enable social learning, we recommend playing this treatment twice, reminding participants that the same draws for both the systemic and idiosyncratic elements of risk will be used both times.

Because the agroforestry implementations differ, the mean and idiosyncratic effects may be different between this treatment and the following treatment, so they are separate independent draws for the two treatments, though they are the same for different rounds within a treatment.

2.2.6 Treatment 6: Uncertain but Correlated Direct Effect, with Pilot Bonus

This treatment, which uses intercropped agroforestry (described previously), builds on Treatment 5 by introducing a pilot bonus. This is an additional payment of 500₼ for people to adopt the practice in the first of the two paired rounds. Importantly, the same realizations for systematic and idiosyncratic risk hold for both of the paired rounds. Earnings from Treatment 6 are given by Equation 8.

$$\text{Earnings} = \text{Farming Value} * (1 + \#\text{ Adopters} * 5\%) +/- (\text{Adopt}) * [\text{Farming Value} * (\text{Unknown Yield Effect}) + 500₼ + (\text{First Round}) * 500₼] \tag{8}$$

where First Round is a dummy equal to one if this is the first round of this treatment.

Risk aversion and ambiguity aversion should again drive participants away from agroforestry. However, revelation of adopters' yield realizations provides information about the systemic element of risk that is valuable to everyone since the more adopters have been observed, the better everyone can guess what the systemic element is; information acts as a public good because yields are publicly visible. Because of this public good element, "experimentation" with the practice by community members is underprovided relative to what is optimal, and thus a subsidy for early adopters may be efficiency enhancing.

As with Treatment 5, we recommend running this treatment twice to allow for social learning. Participants' attention should be called to the fact that this treatment introduces a different practice that will have a different and independent draw for the systemic element of risk for any rounds done in this treatment rather than the same value as in Treatment 5.

3 Policy Context and Economic Underpinnings

In this section, we provide a general economics-based discussion of the topics addressed in the game, with instructors conducting the game as the target audience. Participants can learn from the handouts and additional readings (both of which can be found in supplementary material).

3.1 Climate Change

Climate change is a dramatic public goods problem. Greenhouse gases emitted anywhere in the world generate physical impacts that are already affecting the world and that are predicted to intensify over time (IPCC, 2014, USGCRP, 2018). According to the Intergovernmental Panel on Climate Change, "Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability" (IPCC, 2014). The human cost of climate change's impacts will be most significant in tropical and low-lying areas (IPCC, 2014), and low-income populations are particularly vulnerable (Barbier and Hochard, 2018).

While climate change's progression can be reduced by mitigation (abatement) of global net greenhouse gas emissions, there is general agreement that some impacts of climate change are now unavoidable, and thus communities and individuals must take action to lessen the damages from those impacts. These actions are broadly referred to as adaptation.

3.2 Adaptation and EBA

Adaptation comprises large-scale projects undertaken or funded by governments as well as actions taken by households or firms. Adaptation modes can be categorized into "hard adaptation," also known as grey adaptation, which includes the construction of flood barriers and other infrastructure (McGeehan and Hu, 2017), or "soft adaptation," which comprises social initiatives, policy initiatives, and EBA (also known as green adaptation).

EBA relies on natural features to reduce the impacts of climate change. For example, wetlands can buffer coastal areas to reduce flood risk during storm surges (Burley, et al., 2012). Restored or natural ecosystems alongside waterways or roads, particularly instead of development, can reduce vulnerability to the erosion and flooding that are rendered more likely by increased variability in precipitation, improving water quality.

Individual EBA projects (e.g., Rijal and Yansanjav, 2017, Twinomuhangi, 2017) have been developed by several United Nations initiatives, especially by the United Nations Environment Programme and the United Nations Development Programme. This work advances Sustainable Development Goal #13: "Take urgent action to combat climate change and its impacts." EBA projects, including watershed management, forest restoration, and mangrove protection, are underway in almost sixty countries (Rizvi, et al., 2015). Many EBA projects also provide other local and global ecosystem services; for example, agroforestry may reduce erosion from extreme weather while also absorbing carbon dioxide. Table 3 describes examples of EBA from the United Nations Development Programme's EBA Programme.

Table 3. Examples of EBA Projects

Nepal	Peru	Uganda
• Maintaining and restoring ecosystems along roads to reduce landslides • Restoring wetlands, springs, and ponds to ensure year-long drinking water supply • Soil nutrient management to increase soil moisture during dry periods	• Restoring water channels and reservoirs to support micro-watersheds and wetlands to secure provision of water for the reserve communities and downstream users • Grassland management to enhance pastoral livelihoods and increase resilience to drought and frost • Vicuña management to produce animal fiber for livelihoods and communal livestock management in natural grasslands	• Improved water retention through roadside drainage bunds and runoff retention drains • A gravity flow engineered irrigation scheme, combined with reforestation and soil and water conservation • Riverbank restoration to create a hybrid grey-green solution to catchment-scale water management • Tree planting using agroforestry to stabilize soil to reduce landslides

Source: (UNDP, 2015).

Adaptation typically provides benefits by reducing damage costs, though EBA may provide additional benefits through other ecosystem services such as the water quality benefits that appear in this game. Adaptation, including EBA, generally has costs as well; if it did not, the agent would have theoretically already taken the adaptation action.[9] Some costs are explicit, such as labor and resources used to restore an ecosystem that can buffer rainfall. However, some costs are opportunity costs: benefits foregone by taking action. For example, the opportunity cost of establishing a filter strip on a waterway is the crop yield that strip of land could have borne.

Are EBA decisions chosen by individuals likely to be economically efficient in the sense of maximizing net social benefits? It is efficient to take an adaptation action if the costs of the action are less than the benefits it provides, or if the marginal benefit of the last marginal adaptation step (e.g., the last inch of riverbank turned into a filter strip) just equals the marginal cost of that step. Thus we must consider whether the decision-making agent appropriately weighs all marginal costs and benefits. Some EBA is undertaken on public lands. In those cases, policy makers can evaluate total costs and total benefits and make the efficient decision.

Some adaptation actions require individuals or firms to change their behaviors. Some of the people most exposed to climate risks and thus most in need of adaptation are farmers, whose adaptation decisions this game focuses on. Farmers are already changing farming practices in response to climate change (Reed, et al., 2017), presumably because the benefits in mitigating yield losses outweigh the adaptation costs. However, farmers' EBA provides positive externalities to others inside and outside their communities. These benefits come in the form of ecosystem services (MEA, 2005) such as habitat provision, water filtration, limiting erosion, and local climate regulation. These are public goods or common pool resources because they are non-rival (e.g., a person can benefit from increased biodiversity without detracting from others' benefits) or congestible (e.g., a groundwater source that can be degraded by excessive extraction), and they are nonexcludable (e.g., no one can be stopped from enjoying reduced

[9] Some agents, particularly in markets with limited access to credit, may not have the capital to make up-front investments that would be privately optimal. Other policies, like grant programs, can help ease such constraints.

flooding). Because ecosystem services are positive externalities (modeled in our game by other farmers' improved crop yields), without policy intervention, people's tendency to focus on their own costs and benefits will cause them to do less EBA than would be efficient.

3.3 Policies to Promote Ecosystem Service Provision

Economists and policy analysts argue that policies like mandates, supports, or incentives are needed to achieve the efficient provision of public goods like ecosystem services.

Many such initiatives are payment for ecosystem service programs (Forest Trends, et al., 2008). Payments for ecosystem services monetize externalities by paying the providers of ecosystem services. These payments may be orchestrated by global organizations like the United Nations, private nonprofits like The Nature Conservancy, or directly by governments.

Theoretically, the size of the externality is calculated, and payment in the amount of the estimated externality is offered to the provider of the ecosystem services. This is a Pigouvian solution and should be both efficient and cost-effective. As noted previously, efficiency requires provision of the social welfare maximizing amount of ecosystem service (here, EBA). Cost-effectiveness requires that the costs of providing this amount of ecosystem service are as low as possible. A flat payment of the size of the externality is efficient and cost-effective because only, and all of, the land parcels for which adoption costs are low enough for adoption to be socially beneficial will adopt the practice. However, sometimes a target amount of ecosystem provision is chosen based on other factors, such as the wishes of stakeholders, and payments are set to achieve that amount. Alternatively, a flat payment may be determined based on the budget available. Either of these may not be efficient, but is still cost-effective.

The advantage of opt-in payment for ecosystem services systems over mandates that specify which parcels should adopt practices is that they let policy makers be ignorant of the true costs of participation for any individual since individuals make choices based on their private knowledge of their costs. If the policy maker knew the distribution of costs but couldn't attribute costs to individual parcels, mandates could achieve efficiency but not cost-effectiveness.

If policy makers have a fixed budget, or participation costs are so uncertain that they could not effectively target a flat payment, a conservation auction can achieve a cost-effective ecosystem service provision while eliciting information about participants' costs. Landholders submit bids consisting of a proposed action and payment. If all land would provide the same ecosystem benefits, the policy body can accept bids starting from the lowest until they meet the desired number of contracts or budget (if benefits vary, a weighting scheme can be used). If the auction is incentive compatible, bidders should bid their true participation costs, assuring cost-effectiveness. Conservation auctions are widely used worldwide, including in the United States Conservation Reserve Program and projects under the United Nations REDD+ Programme.

In the context of EBA, Wertz-Kanounnikoff, et al. (2011) demonstrate that a well-designed payment for ecosystem services system can address some of the key elements necessary to be successful, and that it can be cost-effective and equitable, but only in some situations, and even then, complementary policies must be used.

3.4 Uncertainty and Technology Diffusion

Many agricultural EBA practices are new. The effects these practices may have on yields may be uncertain (Doswald, et al., 2014), and the results from past research may leave it unclear how well they will work in local conditions. Worse yet, the changing climate makes past results a limited predictor of future performance. Information about how a technology works is essential to spreading new agricultural technologies in developing countries (Caeiro, 2019, Jack and Tobias, 2017, Pates and Hendricks, 2020), but the best available information still leaves farmers with uncertainty. People are generally averse to risk, and especially to what economists call ambiguity or true (Knightian) uncertainty, in which the odds of the outcomes cannot be quantified. New technology presents this more challenging kind of uncertainty, and thus people may refuse to adopt it. However, if people adopt it, their experience would let others learn about the technology's performance, so the information generated from experimentation is a public good. People, therefore, do not have the incentive to adopt the new technology as much as would be optimal, as shown in lab experiments (Raeburn, et al., 2016).

Therefore, if policy makers want households and firms to take the risky act of adopting a new technology so society can benefit from learning about the technology, policy makers must encourage that adoption. One possible solution is an adoption bonus: an additional payment, on top of the base payment for ecosystem services, to reward risk-taking by early adopters.

4 Discussions and Assignments Related to the Game

We prefer to conduct some discussion interspersed between treatments, followed by a robust discussion after the game. Alternatively, if the time for the game is short, participants can engage in conversations through online forums after the game. They can also be assigned writing or analytical exercises before or after the game session. Because the game has many features, the instructor can tune the discussion or assignments to complement the desired focus. In what follows, we provide suggestions for leading discussions and designing assignments, organized by topic.

4.1 General Prompts

We always like to start discussions by asking, "How did you make your decisions? How *should* people make their decisions?" If answers are public, participants can learn from each other, and these answers may open doors to the other topics described next.

Another broad prompt is, "What is missing from this game?" Ask for real-life complicating features, and discuss whether these features have policy implications. This is particularly fruitful if participants are policy makers or stakeholders, as it can help them envision how payments for ecosystem services or EBA might work in their setting.

We also like to ask, "What policy do you think is best to achieve the goals in this kind of setting?" Participants can identify policies from the game, real-life policies, or their own ideas.

4.2 Climate Change, Ecosystems, and Ecosystem Services

Ecosystem service provision and the fight against climate change can be understood through theories of public goods and externalities. If participants are analytically inclined (e.g., in a higher-level economics class), ask them to derive the equilibrium with self-interested agents and the socially optimal outcome. More generally, participants can discuss the *homo economicus* assumption of rational self-interest and why people might deviate from it, including mistakes, other-regarding preferences, and preferences for environmental stewardship.

More concretely, participants can discuss ecosystems and agriculture and how they interact, especially subject to climate change. Participants can brainstorm locally relevant examples of ecosystem services that affect agriculture and how human action can diminish or bolster those services. They can reflect on whether ecosystems should be valued beyond their instrumental value, and this discussion can cover alternative foundations for social decision making such as rights-based and obligation-based systems.

To begin discussions of climate change, participants can use the Intergovernmental Panel on Climate Change's latest Assessment Report (IPCC, 2014) to learn what impacts they can expect in their home country or region. Participants can be prompted to think about interactions between adaptation decisions and the amount of greenhouse gas mitigation that is optimal or expected. They can research the forms of adaptation that are available in different contexts and explore the potential for feedbacks between climate change and ecosystem service provision.

4.3 Payments for Ecosystem Services

Participants can link the incentive payments in the game to the externalities provided by adoption, and discuss whether this might be an efficient payment for ecosystem services scheme. Similarly, they can discuss cost-effectiveness in this setting and whether it was achieved when they played the game. Participants can identify sources of implementation costs and discuss whether universal adoption is efficient. They can compare the game's incentive-based payment for ecosystem services system to an alternative command and control policy. A discussion of how non-self-interested preferences may affect cost-effectiveness can also be fruitful.

It is useful to point out that the payments themselves do not enter into efficiency calculations, as they are a transfer. However, participants can discuss where the payment money comes from, such as taxation, which may generate inefficiencies through distorted incentives or administrative costs, as well as the potential redistributional (i.e., equity) effect of these transfers.

The game also provides room to discuss the contract payment mechanism. We like to ask, "What are the benefits of a flat payment versus an auction?" It's important to identify the potential informational advantage of the auction. In advanced academic settings, students can prove that *n*th-price procurement auctions are incentive compatible; in less technical settings, participants can discuss the intuition for this by noting that one's bid influences whether one wins the auction, but not how much one pays, as noted in the instructor guide (in supplementary material).

This game does not cover all issues regarding payment for ecosystem services programs. Dissanayake and Jacobson (2021) describe another game that focuses on additionality, verifiability, and community governance in the context of tropical deforestation. Alternatively, Dissanayake and Jacobson (2016) uses a game modeled on the United States Conservation Reserve Program to explore how ecosystem service costs and benefits may vary spatially.

4.4 Uncertainty, Information, and Technology

This game emphasizes risk and uncertainty and offers entry points to these topics from theoretical, behavioral, and policy-focused perspectives. In upper-level economics classes, students can discuss expected value, expected utility (and risk aversion), prospect theory (and loss aversion), and subjective expected utility (and ambiguity aversion) and how they would guide behavior here. Which of these theories best describe how people actually behave? Are there other biases we should consider? How should society make choices facing risk and ambiguity? It is also useful to discuss the merit of judging decisions ex ante rather than ex post.

It can also be productive to consider upside and downside risk separately since, in this game, information can unlock upside risk. The precautionary principle is also relevant. From an individual perspective, it might be precautionary to wait to observe others' outcomes. In the game, society has no reason to follow the precautionary principle, but if technologies (like gene modification) have substantial downside risks, then some would prescribe a precautionary approach of limiting adoption. Distribution of risk within society is also relevant: in the agroforestry treatments, each farmer naturally focuses on their own outcome, while society encompasses a portfolio of people with different outcomes. Social risk is lower than individual risk because of diversification, and individual risk-taking has positive social externalities.

The game can also spur discussion about the role of information. As noted, distributed information about costs is an argument for incentive-based systems over mandates, and for auctions over flat payments. Participants can also discuss how people learn new information; in higher-level economics classes, Bayesian learning and the formation and updating of priors can be discussed. Most centrally, participants can discuss information revelation and diffusion of a new technology, and how that feeds into efficiency in adoption and innovation. In the agroforestry treatments, information about a new technology is publicly revealed by adoption, so adoption provides an informational public good. The instructor can ask questions like: "What are the impediments to the diffusion of a technology?" "What are the respective roles of the private and public sectors in innovation and technology diffusion?" "Who captures the benefits of new technology? How do they capture it, and does this increase or decrease inequality?"

5 Our Experience with the Game

We have played the game once with a lower-level undergraduate environmental and resource economics class at a liberal arts school in the United States, once with graduate students in agricultural economics at a university in China, once in a seminar with economics faculty, and with policy makers and stakeholders from various countries at capacity-building training sessions held in Zambia and Uganda. Each time we have played the game, we found that participants engaged deeply with decision making and the context of the game. Only the first instance was conducive to a post-game survey. Out of the thirty-two participants, twelve completed an optional online survey. In this section, we discuss our experiences in general and responses from the survey.

Most survey respondents reported that the game helped them somewhat or very much learn about each of the main learning objectives: EBA (100 percent), payment for ecosystem services programs (100 percent), adaptation (92 percent), climate change (67 percent), risk and uncertainty (83 percent), auctions (67 percent), agriculture in developing countries (67 percent), and how agents learn about new technologies (58 percent). Further, all students said they enjoyed the game somewhat or very much and that the game was a good use of time, and they recommended its future use.

When asked what their takeaways were, many students reflected on how incentives drove participants' choices. One student said, "One takeaway was that even though I really wanted to do adaptation because I knew that it would be good environmentally, for most rounds it did not make economic sense to do it so most of the time I did not adopt. Another takeaway was that the people with the lowest cards adopted most of the time, which to me shows that lower-income farmers bear the burden of adaptation, which is not necessarily how I believe it should be."

Participants also reflected in nuanced ways about the considerations they now thought were important in designing payment for ecosystem services programs, with many commenting about equity and fairness, such as this student: "Ethical implications! Why will program participants decide to take part? Is it fair? Also, how can you support lower-income firms/people in the case of bad luck, like in the second half of the game?[10] It seems like it would make sense to encourage participation by offering a safety net for those who need it." When asked if the game changed how the participants think and feel about the kinds of families the participants are playing the roles of, many said the game helped them understand the decision-making scenario but also highlighted issues of fairness, like this student: "Definitely. It shows how directly impacted these rural households in developing countries can be, and how EBA can help them and incentivize them to protect the environment and adapt to challenges from climate change, while also not losing all their returns/money."

This feedback, while only from one session, provides evidence that the game is effective at achieving the learning objectives presented in Table 1. Informal feedback and discussions from the other instances of playing the game, including with the policy makers, reflected similar positive outcomes. Overall, participants felt the game was a good use of time and that it allowed an in-depth exploration of issues surrounding EBA adoption. For the policy makers, for instance, one primary reflection was that the game let them better understand the constraints farmers face when they make environmental decisions. Only a few of them had thought about the trade-offs that farmers and communities face, especially regarding yield uncertainty. Participants were struck by the importance of accounting for risk aversion when trying to implement a program of this type. Participants generated some of the discussion ideas we provide in the preceding section, including questions about the distribution of costs and benefits.

We now provide a few lessons we have learned about playing the game, though we give these and

[10] This time the game was played, the realized common effect was large and negative.

many other tips in the instructor guide (in supplementary material). One lesson is that since the treatments build in complexity, discussions between treatments help participants understand basic concepts before they are used again. This is why we recommend interspersed discussion over a single cumulative final discussion. Another is that the auction is challenging for participants to understand, but can be made clearer by writing some hypothetical bids on the board, stacked vertically in increasing order, and then showing which bids would be accepted and what payment they'd receive. Finally, the nature of the uncertainty in the later treatments can be hard for participants to grasp; indeed, the purpose of the game is to help participants grasp these concepts. We find it useful to build plots on the board to demonstrate the correlated uncertainty: we lay out a bell curve and then demonstrate draws from it (dots on the line) that may represent values of different participants in the room, and then another bell curve with another set of dots that could hold in another scenario, effectively building up a graph like that in the instructions and Figure 1.

6 Conclusion

In this paper, we present a game that can be used to engage students and practitioners with the mechanics of environmental policies, the theory that underlies those policies, features of human behavior, and ethical and practical questions that arise in environmental policy. The game puts participants in the role of small-scale farmers in developing countries deciding whether to adopt EBA practices. Participants get a hands-on understanding of climate change and adaptation, ecosystem services, payment for ecosystem service programs, choice under uncertainty, social learning, adoption of a new technology, learning spillovers, cost-effective conservation, and conservation auctions. While the game's application is specific, many concepts demonstrated in the game have broad implications. In our experience with the game, the immersion it provides in a variety of topics renders the use of time well worth it, and our participant feedback supports this assessment. We hope that you find this interactive exercise useful for your teaching, training, and capacity-building activities.

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Appendix I. Participant Instructions

Seeds of Learning: Ecosystem-Based Adaptation Interactive Game Instructions

You are a small-scale farmer in a rural region of a developing country. You are a subsistence farmer: your crops feed your family, and thus your crop yield is crucial to your family's well-being. Climate change is causing an increase in extreme precipitation and temperature patterns where you live. As a result, the agriculture that you and your neighbors practice is increasingly threatened by hazards such as drought, flooding, and extreme heat.

Your government would therefore like to encourage some people in your community to adopt ecosystem-based adaptation (EBA) practices to reduce erosion and improve water quality, soil quality, and agriculture in your area. EBA practices include changes to landscape configuration (terraces, contours, and bunds), different ways of working the soil (e.g., low-till or no-till), different inputs (improved seeds, mulch, organic fertilizer instead of traditional, and reduced fertilizer use), agroforestry, intercropping, and preservation of small strips of land along waterways to filter runoff (riparian buffer strips). Over a series of periods (each of which represents a growing season), the government will offer conservation contracts; the contract in each period will offer you a payment if you adopt the EBA practice the government proposed for that period.

Each practice requires you to put in a lot of work to implement it. We represent this as an adoption cost of 1,000₼ (your country's currency, which is known as shillings). Each practice reduces erosion, and each (in ways we will describe) affects your crop yield directly and affects everyone in the community indirectly by improving the ecosystem.

The direct effect on your yield comes from reduced erosion and other features of the practice; for example, some practices reduce the amount of your land you can grow crops on. The net direct effect may be positive or negative, and may be a known amount or may be uncertain. The direct effect depends on the specific practice, and will be described in each contract period.

Your adoption of an EBA practice provides ecosystem services because reduced erosion reduces sedimentation and pollutants in waterways and diminishes the force of flowing water. Thus, if one person adopts any EBA practice, other farms have improved water and soil quality and themselves experience less erosion. Specifically, each person's adoption of any EBA practice increases the yields of everyone in the community by 5%. For example, if 10 farmers adopt a practice, everyone's yields go up by 10*5% = 50%. We'll call this the *ecosystem yield increase rate*. If you are an adopter, this indirect effect is additional to the direct effect the practice has on your yield.

We will play through several contract periods, with specific circumstances changing in ways that we will describe in the following. In each year, your earnings are the sum of your *farming earnings*, your *adoption costs*, and your *government payments*. You were handed a card at the start of today's session. Your *Farming Value*, the value of the crop yield you get if no one adopts an EBA practice, is 1,000₼ times the value on your card. Your *farming earnings* come from your *Farming Value*, adjusted by direct and indirect effects from the conservation practices you and your neighbors adopt. The *adoption costs* are 1,000₼ if you adopt the practice and 0₼ if you do not. The *government payments* vary across contract periods: there is either no government payment, a flat payment for adopters, or a payment based on an auction (which we will describe later).

In each contract period, you must make a decision: whether to adopt the EBA practice (or what bid to make in an auction to determine who adopts the practice). Your earnings for that period depend on your decision and the decisions of the other people in the community.

The table below translates the possible per-period earning ranges in this game into ways a low-income family in a situation like this might experience those levels of earnings.

Per-Period Earnings	Your Family's Experience
Less than 2,000₼	Family is hungry; it cannot afford basic necessities; health suffers; children are removed from school at a young age.
2,000₼ to 5,000₼	Basic necessities are met; can afford some schooling for children, but a life shock (e.g., major illness) can push the family into deep need.
5,000₼ to 10,000₼	Basic necessities and health are covered; children can attend school.
Above 10,000₼	Can save money or start a business; children can attend university.

Your earnings for the whole session are the sum of your earnings in each period. To ensure that each person makes thoughtful decisions, at the end of the game we will randomly choose one or more people (the instructor will announce how many) and pay them an amount based on their total earnings (the sum of earnings for all periods converted to dollars by dividing by 10,000₼/$).

Contract Period 1: No Government Involvement

The EBA practice the government would like you to adopt is a riparian buffer strip: keeping an uncultivated buffer of land along river banks. Adoption directly *reduces* your yield by 10%.

The government is offering no payment.

Therefore, if you adopt the practice, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%) – Farming Value * 10% – 1,000₼

If you do not adopt the practice, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%)

Contract Period 2: Flat Adoption Subsidy

The EBA practice is again a riparian buffer strip, and its direct effect on your yield if you adopt it is to *reduce* your yield by 10%.

The government will pay 1,500₼ to each person who enters a contract to adopt the EBA practice. Since adoption costs 1,000₼, this means that if you adopt, in addition to your farming earnings you get 1,500₼ – 1,000₼ = 500₼.

Therefore, if you adopt the practice, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%) – Farming Value * 10% + 500₼

If you do not adopt the practice, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%)

Contract Period 3: Conservation Auction

The EBA practice is again a riparian buffer strip, and its direct effect on your yield if you adopt it is to *reduce* your yield by 10%.

The government will pay for adoption of an EBA practice, but now it will choose conservation contract recipients and the subsidy amount based on a conservation auction.

Therefore, if you adopt the practice, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%) – Farming Value * 10%
– 1,000₼ + Government Payment

If you do not adopt the practice, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%)

As noted, contracts will be awarded this period through an auction. Instead of declaring whether you'd like to adopt the adaptation practice, you will instead declare a bid. The government asks you to bid the minimum amount of money you'd be willing to accept to adopt the practice. Once everyone has made a bid, the government will rank the bids and will accept the lower half of them (all bids asking for up to the median bid). The government payment for all accepted bids will be the lowest bid that was *not* accepted. For example, if the bids were 1₼, 2₼, 3₼, 4₼, and 5₼, bids 1₼, 2₼, and 3₼ would be accepted, and the payment for all of them would be 4₼.

Contract Period 4: Uncertain Direct Effect

The EBA practice is now low-till farming. This practice has different direct effects on your yields in different years because the effects depend on the weather, although it has the same ecosystem-based water and soil quality benefits for everyone in every year (5% increase times the number of adopters in the community). In a good year, the practice will increase yield by 10%, but in a bad year, it will decrease yield by 30%. Good years and bad years are equally likely (50% chance). We call this amount the *Weather Yield Adjustment*. Everyone will have the same *Weather Yield Adjustment* (in percent) in this contract period. We will use the random number generator in Excel to determine the weather this year and thus the effect on everyone's yields, but only after everyone has made their decision.

The government will pay 1,500₼ to each person who enters a contract to adopt the EBA practice. Since adoption costs 1,000₼, this means that if you adopt, in addition to your farming earnings you get 1,500₼ – 1,000₼ = 500₼.

Therefore, if you adopt the practice, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%) +/– Farming Value * (Weather Yield
Adjustment) + 500₼

If you do not adopt the practice, your earnings are:

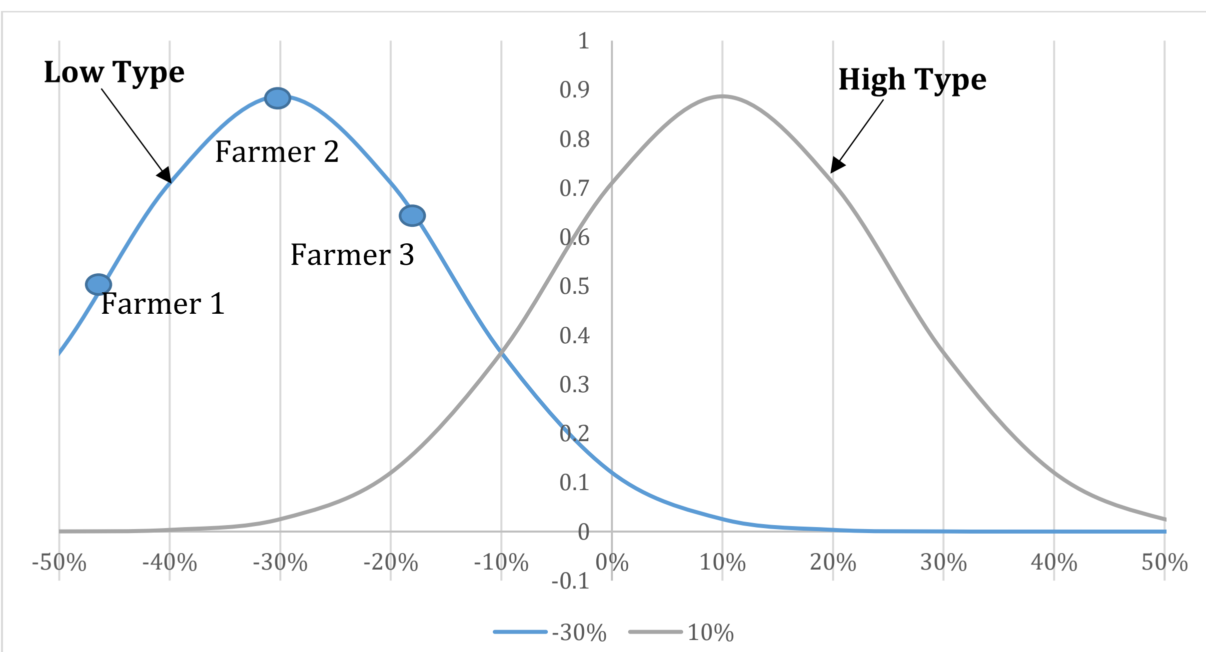
Earnings = Farming Value * (1 + # Adopters * 5%)

Contract Periods 5A & 5B: Uncertain but Correlated Direct Effect

The EBA practice is now agroforestry, with trees planted in borders surrounding the crops. This practice takes land away from cropping, and the trees will use water and nutrients that the crops would otherwise use. On the other hand, the trees will provide a windbreak and will anchor the soil, and thus reduce erosion. The trees may also provide local cooling and may make water more available to your crops. Studies have found varying effects of these benefits on yields; the results also may depend greatly on factors like the soil type, elevation, and gradient of the land. Scientists do know that agroforestry will generate the same water and soil quality benefits as the other practices (5% increase times the number of adopters in the community), but the direct effect on adopters' yields could be to *increase or decrease* your yield by an amount we will call the *Unknown Yield Effect*.

This Unknown Yield Effect will vary from field to field, but the general tendency will be the same across all fields in a local area. To be precise, the Unknown Yield Effect will be normally distributed around some mean (average) value, and that mean value will be either -30% (Low Type) or +10% (High Type). Both are equally likely; that is, each is 50% likely. This means that there is a high chance of getting values that are close to the mean and a small chance of getting values that are more different. Therefore, if you see someone else's yield effect from agroforestry, that tells you something about how it will work on your land, though your exact effect will probably be different. In other words, you don't know the effect agroforestry will have on your farming until you try it; you don't even know the precise mean value of the distribution of possible effects, but can learn about it from seeing others' yield effects.

The following figure will help you visualize these random effects. There are two lines on the figure (Low Type and High Type); each represents one the way that farmers' values for agroforestry might be distributed in a local area. The height of the line shows how common a value is in the given community. The mean of the distribution is where the line peaks. As you can see, each distribution has a different mean (average) but has some values larger and some smaller than the mean. Everyone in your community will have a value from the same distribution, but you don't know yet which distribution applies in your community. Not only that, you don't know where on the distribution your own personal effect will be. For example, if your community has a Low Type distribution, you could be more like Farmer 2, than Farmer 1, or Farmer 3.



We will use Excel's random number generator to determine the mean effect and each person's individual effect, but both will be hidden; only the Unknown Yield Effect for people who adopt agroforestry will be revealed.[11]

The government will pay 1,500₼ to each person who enters a contract to adopt the EBA practice. Since adoption costs 1,000₼, this means that if you adopt, in addition to your farming earnings you get 1,500₼ – 1,000₼ = 500₼.

We will play this treatment for two periods, and you need <u>not</u> make the same decision in both periods. Your Unknown Yield Effect will stay the same across the two periods! That is, we'll use Excel to come up with random numbers at the beginning of period 5A, and those numbers will apply to both 5A and 5B.

In each period, if you adopt the practice, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%) +/– Farming Value * (Unknown Yield Effect) + 500₼

If you do not, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%)

<u>Contract Periods 6A & 6B: Uncertain but Correlated Direct Effect, with Pilot Bonus</u>

The EBA practice again uses trees, but in this case through intercropping. That is, you are being encouraged to plant trees at regular intervals within your crop fields. The benefits and costs of intercropping with trees are similar to those of planting tree borders around crop fields. However, the net effects are again uncertain and may be entirely different from the effects of the tree borders: both the costs and benefits are distributed broadly rather than concentrated around the edges of the field. Different plots of land will respond differently to intercropping as compared to agroforestry, because the two systems perform differently in response to different sizes, shapes, and elevation patterns on a plot of land. As a result, there is the same kind of uncertainty about intercropping's effects on yields as there was for border agroforestry. There is some unknown mean effect, which will be either -30% (Low Type) or +10% (High Type). Both are equally likely; that is, each is 50% likely. Again, everyone has a personal difference in effect drawn from a distribution with that mean, and your personal value is your Unknown Yield Effect. We will determine both the mean and the individual effects with Excel's random number generator. Both the mean and the personal difference will be different from the values you saw with border agroforestry.

The government will pay 1,500₼ to each person who enters a contract to adopt the EBA practice in each period. Since adoption costs 1,000₼, this means that if you adopt, in addition to your farming earnings you get 1,500₼ – 1,000₼ = 500₼.

What's different now is that the government is offering an additional pilot bonus of 500₼ to people who adopt the conservation practice *in the first period*. The goal is to help everyone learn more about the effect of this practice.

We will play this treatment for two periods, and you need <u>not</u> make the same decision in both periods.

[11] Don't worry that your earnings might go negative; we are truncating the distribution so that cannot happen.

Your Unknown Yield Effect will stay the same in both periods! That is, we'll use Excel to come up with random numbers at the beginning of period 6A, and those numbers will apply to both 6A and 6B.

In each period, if you adopt the practice, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%) +/− Farming Value * (Unknown Yield Effect) + 500₼ + Pilot Bonus

where the Pilot Bonus is 500₼ in the first period, and 0 in the second period.

If you do not, your earnings are:

Earnings = Farming Value * (1 + # Adopters * 5%)

Recording Sheet

Name: ____

Your Card Value: ____________ Player: ________________

Note: The column references here refer to the columns of this recording sheet, not the earnings spreadsheet we'll use in class!

A	B	C	D	E	F	G	H	I	J	K	L	M
Period	Treatment	Farming Value	Bid	Adopt?	Ecosystem boost rate	Ecosystem yield effect	Direct Adoption Effect (%)	Direct Adoption Effect Amount	Farming Income	Adoption Cost	Government Payment	Total Income
		Card value * 1000 ₼		Y=1 / N=0	(from spreadsheet)	C * F		C * H	C + G + I	1000 ₼ if adopt	1500 ₼ or bid if adopt	J - K + L
1	No government	₼			%	₼	-10%	₼	₼	₼	₼	₼
2	Flat subsidy	₼			%	₼	-10%	₼	₼	₼	₼	₼
3	Auction	₼	₼		%	₼	-10%	₼	₼	₼	₼	₼
4	Uncertain	₼			%	₼	%	₼	₼	₼	₼	₼
5A	Uncertain but correlated	₼			%	₼	%	₼	₼	₼	₼	₼
5B	Uncertain but correlated	₼			%	₼	%	₼	₼	₼	₼	₼
6A	Pilot bonus 1	₼			%	₼	%	₼	₼	₼	₼	₼
6B	Pilot bonus 2	₼			%	₼	%	₼	₼	₼	₼	₼

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Teaching and Educational Methods

Managing a Multiuse Resource with Payments for Ecosystem Services: A Classroom Game

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Abstract
This article presents a classroom experiment that introduces students to the concept of payment for ecosystem services (PES) applied to a multipurpose renewable forest resource. Through a natural resource management game, students can analyze how PES programs may alter the individual and group harvest decisions and stocks of both components of the multipurpose resources. Participants can choose between harvesting whole trees for timber, harvesting leaves for fodder, or some combination of both. In each round, students choose the quantity of both resources to harvest for profit. Students complete the experiment with and without the PES program to enable comparison of decisions across management regimes. The outcome (usually complete forest removal) at the end of the game helps demonstrate the tragedy of the commons in the absence of conservation policies.

1 Introduction

Finding the right balance between biodiversity conservation and human well-being is crucial for the preservation of the earth in general and communities' sustainable development (Haines-Young and Potschin 2010; McShane et al. 2011). The complexity of this debate lies in the following question: how do we preserve forest richness while meeting the needs of local communities who depend on them for their livelihoods? With climate change and growing world population, this question is becoming more challenging. An obvious response could be a win-win approach that enhances humans' needs while reducing the impacts on the ecosystems. Payments for ecosystem services (PES) have the potential of providing such dual benefits (Food and Agriculture Organization 2012). Although there is no agreed-upon definition for PES, the definition proposed by Wunder (2005, p. 3) is widely cited and stipulates that PES is "(a) a voluntary transaction where (b) a well-defined environmental service (ES; or a land-use likely to secure that service), (c) is being 'bought' by a (minimum one) ES buyer, (d) from (minimum one) ES provider, (e) if and only if the ES provider secures ES provision (conditionality)." The Heredia Declaration on Ecosystem Services[1] provides a concise and short definition stating that PES are fund-services provided by nature (Farley and Costanza 2010).

The classroom game presented in this article introduces students to the PES concept and its impacts on individual and group decisions. The game expands from a single forest product to two forest products received from the same species of tree. Many tree species, both in tropical and temperate forests, can provide multiple harvestable products (Myers 1988; Alexander, McLain, and Blatner 2001). An example is *Gliricidia sepium*, which provides timber, fuelwood, fodder, and green manure for agricultural crops (Simons and Stewart 1994).

[1] "A consensus statement signed by international and local experts outlining the mechanisms for successfully implementing PES at the global, regional, and local level."

This game is also flexible enough to accommodate any classroom format and size, as well as a broad range of education levels. It was implemented in undergraduate and graduate microeconomics courses in an agricultural and resource economics department during 50- and 100-minute class periods. The number of students per class ranged from ten to thirty students.

The learning objectives for the classroom game are to (1) calculate individual and group profit-maximizing harvest decisions based on a profit function; (2) illustrate the tragedy of the commons (Hardin 1968) in the absence of conservation policies for multipurpose resources; and (3) analyze how PES alter harvest decisions and stocks of timber and nontimber resources. While there are several games depicting the tragedy of the commons available for instructors to choose from, the game presented in this manuscript adds payments for ecosystem services as one approach to slow down overharvesting in the commons. Moreover, the game looks at more than one harvestable product, which mimics the real use (i.e. multipurpose) of forests in various ecosystems. It also has the potential to capture the ecological dynamics between timber and nontimber products during a classroom game.

2 Some Common Pool Resources (CPR) Games

CPR games have become a key teaching tool in applied micro and environmental economics classes to demonstrate firsthand the tragedy of the commons to students. Sophisticated examples of the CPR game for the classroom (Murphy and Cárdenas 2004; Secchi and Banerjee 2019) and for field research (Handberg and Angelsen 2016; Ngoma et al. 2020) have been developed to test a variety of different important institutional changes to the classic CPR problem, including the number of resource users, communication methods, and regeneration rates. However, all of these games are limited by focusing on a single harvestable resource (e.g., timber). This limitation ignores that common-pool resources may provide multiple products. For example, trees in a forest may provide timber in addition to food, medicine, and fodder created from the same resource. We extend this game to allow for the harvest of multiple products from the CPR in the context of a forest where individuals can harvest trees and leaves. This game illustrates how the availability of additional products for harvest may change the dynamics of a classic CPR.

Table 1 presents six CPR experiments played by students, which are similar in design and/or procedures to the game presented in this manuscript. The table summarizes the key features of those experiment designs, their main contributions, and their applications to the real world. To avoid any complications from combination or sequence of treatments that could affect students' strategies and overall outcome of the exercise, in our game, we implement one control (an unregulated CPR as in Murphy and Cárdenas 2004) and one treatment (a threshold-based PES scheme).

PES contracts can be designed using a linear payment or a threshold-based payment (Climate Investment Funds 2019). A linear payment contract will pay individuals a given amount per unit of tree surviving at the end of a designated period. The threshold payment contract will pay individuals a predetermined amount if the number of trees living at the end of a designated period meets or exceeds the threshold. These two PES contract designs were used in August 2017 in Burkina Faso under the Gazetted Forests Participatory Management Project for REDD+ implemented by the African Development Bank. Under the linear payment, a group of five community members received US$0.62 per tree surviving at the end of a given period. The threshold-based contract paid US$238 for 400 or more trees, US$185 for 300 to 400 trees, or US$62 for less than 100 trees. The theoretical economic prediction of suing these contract types suggests that threshold payments have the potential to induce more cooperative efforts (Climate Investment Funds 2019). This is because of the fact that they are likely to prevent collective action failure and create a coordination game. The treatment design used in this game represents a threshold-based PES scenario.

We also focus on two harvestable products (trees and leaves) unlike experiments presented in the table where the decisions are made for one resource (trees, fishes, or water). The decision making in our game is about the units of products to harvest (similar to Bednarik et al. 2019 and Secchi and Banerjee

Table 1. Classroom CPR Games in the Literature

Resource (References)	Level of decisions	Key features of designs	Game procedures	Findings/contribution	Applied to real world
FORESTS **(Dissanayake and Jacobson 2019)**	Individual and/or group decisions	Ability to commit contract fraud, uncertainty in earnings, auction payment, and community-level decision making.	10 to 60 students Adjustable number of rounds 45-90 minutes	No specific finding because the game is designed to cover many topics such as PES programs; climate change; cost-effectiveness; etc.	No
FORESTS **(Bednarik et al. 2019)**	Individual decisions	Treatments with rainfall intensity, flood losses due to cut trees, and communication.	5 students 20 rounds Session of 70 minutes	Adding flood risk to the game does not change the overharvesting outcome.	No
FORESTS **(Murphy and Cárdenas 2004)**	Individual decisions	Three treatments: an unregulated CPR, an imperfectly enforced externally imposed regulation, and communication for self-governance. Finite repeated game with undisclosed number of rounds.	8 students Simultaneous decisions 15 to 20 rounds split between the three treatments in a 75-minute class	Regulation induces a more self-interested behavior. Communication enables perfect or near-perfect compliance by all group members.	Yes
FISHERIES **(Secchi and Banerjee 2019)**	Individual decisions	Full information feedback, nonbinding communication.	5-10 members Dynamic sequential setting Played for multiple rounds throughout the semester Allotted time of 5 to 10 minutes per class period	Peer punishment improves group performance and prevents self-interested behaviors.	No

Table 1 continued.

Resource (References)	Level of decisions	Key features of designs	Game procedures	Findings/contribution	Applied to real world
WATER **(Farolfi and Erdlenbruch 2020)**	Individual decisions	Factorial design (communication/no communication) × (high surface water availability/low surface water availability).	Group of 15 players Run in 1.5 and 2.5 hours 10 rounds	Communication between resource users is conducive to more cooperative resource use. Resource scarcity might not increase the likelihood of cooperation.	No
NATURAL RESOURCES (Kumakawa 2018)	Groups (paired) decisions	Four treatments based on matching setup and feedback information. Endowment of money to be split between market and savings.	Simultaneous decisions 20 rounds in each pair 2 hours to complete each treatment	Cooperation in CPR games is derived from participants' strategic behavior for future rewards not from a sense of intimacy with other community members.	No

2019) to mimic reality, unlike the decisions on the number of months to spend extracting the resource (Murphy and Cárdenas 2004).

3 Game Setup

We present a classroom extraction game (e.g., Gardner, Ostrom, and Walker 1990; Murphy and Cárdenas 2004; Ostrom and Nagendra 2006; Holt et al. 2012) where students make individual decisions over harvesting two different products from a common pool resource: trees and leaves. Played in groups of five, individuals will participate in two stages of the game each lasting 10 rounds. Stage 1 is conducted with no PES program, and Stage 2 is conducted with a PES program. During each round, students decide the quantity of trees and/or leaves to harvest from the forest, which initially has fifty trees.[2]

To implement this game, we construct a game board where students can see the entire resource stock from which they may harvest. In Figure 1, we present a representation of our board where green magnets represent the fifty trees available for harvest, and clear magnets represent the reachable leaves of fifty trees available for harvest.[3] Students are provided with background information on the use of forests in tropical ecosystems with the associated consequences on multipurpose species populations and the concept of payments for ecosystem services (see Appendix A: Game Instructions/Student

[2] For instructors using a different group size, we recommend setting the starting stock of trees equal to ten times the number of players in each group.
[3] For an alternative approach that does not require a magnetic whiteboard or additional supplies, we also include an Excel representation in the Supplementary Materials.

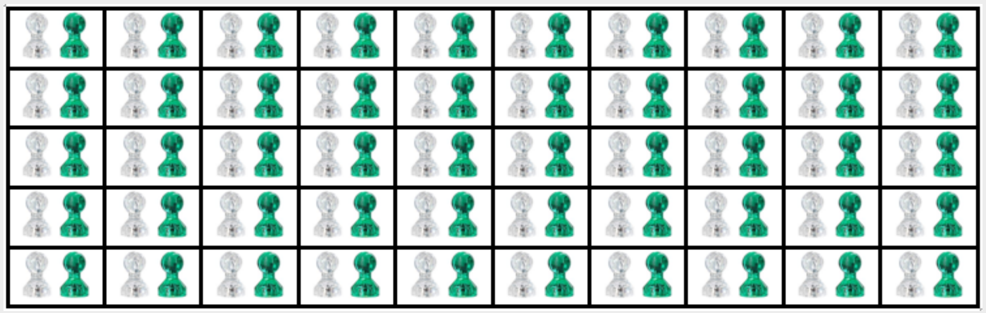

Figure 1. Game Board with Magnets Representing the Forest for a Group of Five Students

Handout). In addition, depending on the course level (i.e. for graduate students), a reading assignment of articles on PES programs may be assigned.[4]

All players are provided payoff tables showing the profit in tokens that can be earned based on the quantities of trees and leaves harvested and a decision sheet to record their payoffs (see Table 1 in Appendix A: Game Instructions/Student Handout).

During the game, students make their decisions simultaneously. When the stock size is low, if the players in the group submit harvest decisions that are greater than the remaining number of trees or leaves, the moderator/instructor will evenly divide the available resource among the five players, and any remainder will be discarded.

The game consists of two parts: (i) ten rounds of the control where players are given no additional information besides the context of the experiment and the general information about how to play the game, and (ii) ten rounds of the treatment where the stock of trees is reset to the same starting stock as part (i). At the end of each round in part (ii), all students receive a bonus payment for ecosystem services if 70 percent of the initial (prior to round 1) stock remains. The bonus is set at 500 tokens per student and is independent of any earnings from the individual student's actions during that round. Students are aware of the number of rounds they will be playing in the control and the treatment. The instructor could withhold information on number of rounds to be played to mimic an infinitely repeated version of the game and avoid end-game effects.

The trees and leaves regenerate throughout the game. At the end of each round, for every five trees standing, one tree is added to the forest. All leaves harvested during a round regrow for the next round. The game continues for ten rounds or until there are no more trees remaining. The total time for the game when playing with five students per group is approximately 45 minutes. Larger groups may require more time to work through each round. The earnings in the game are denoted in tokens. If desired, the instructor could convert the total earnings into bonus points at a pre-announced rate or award them based on the student's profit in a randomly chosen round.[5]

4 Instructor and Student Tasks

When conducted in person, the instructor will need the following resources to carry out the game:

1. Game Instructions (See Appendix A: Game Instructions/Student Handout)
2. Game board, options include:

[4] See Appendix D: Suggested Reading List.

[5] The instructor could use a rate of 0.0005 where 2,000 tokens earned in the game will correspond to 1 bonus point. The Excel workbook has a built-in tool for randomly choosing a round to award students. See the "Round chosen for payment" sheet in the "Payoffs Calculation" Excel file (available upon request to the editor).

- Magnetic white boards: The necessary size depends on the number of players in a group, which determines the size of the initial stock. We use a 26- × 34-inch board for an initial stock of fifty trees.
    - Whiteboard tape is useful to separate the board into slots that will contain the trees and leaves.
    - Two different colors of magnets should be used to represent the resources. Each slot on the whiteboard must fit two of the magnets.
- Chalkboard or dry erase board: The easiest way to use an existing classroom board would be to use two different color Post-it notes to represent the two resources. Alternatively, the instructor could use two different colored pieces of chalk or dry erase markers and mark/erase each slot as required for regeneration and harvest.
- Excel file: In both in-person and online classrooms, the instructor can use the provided Excel file[6] projected in the classroom or shared in the course's learning management system.

3. A computer with the payoff calculations Excel file to record students' earnings
4. Payoffs tables (Table 1 in Appendix A: Game Instructions/Student Handout) for students
5. Decision recording sheets for students (Tables 2 and 3 in Appendix B: Student Decision Recording Sheet)
6. Snacks or any other incentives if playing the game for prizes other than bonus points (optional)

The instructor's tasks are to:

1. Present the game instructions
2. Assign students to groups
3. Collect decisions each round and record them into the Excel spreadsheet
4. Determine if the conservation threshold is met for PES and communicate this to students
5. Using the spreadsheet, determine regrowth of trees and communicate new stock to students

At each round, the students must (i) decide the quantity of timber and/or leaves to harvest; (ii) submit their decisions to the instructor (without sharing with other students) and record on their own decision recording sheet; and (iii) calculate their profit (including PES if applicable). The game is designed to accommodate different course levels (introductory, intermediate, and higher) with some variation in students' tasks. With an introductory level course, the instructor can provide the students with the decision recording spreadsheet containing all formulas. Students will merely enter their harvest choices at each round and automatically see their earnings (no calculations required). In an intermediate level course, the instructor can provide students with the price and cost functions. The students will have to determine their profit function and earnings. For a higher-level course, the students can create their own PES schemes to implement in treatment rounds.[7]

[6] The editor will share them upon request.
[7] PES schemes can be designed around one or multiple dimensions, such as the amount provided (high vs. low), the payment mechanisms (lump sum vs. recurrent payments; individual vs. group payments), the payment forms (vouchers exchanged for goods vs. direct cash transfers), and so on. In a graduate level course, students can be asked to explore those dimensions to come up with a variant of the treatment phase presented in this paper.

5 Game Outcomes

Across all courses in which the game was played, thirty-five students played the game. On average, the forest was depleted after the fourth round during the control rounds. The main strategy used by students was that of a profit maximizer. As in a finitely repeated game, they start by harvesting on average four units of trees, which quickly lead to the extinction of the resources. In the treatment rounds, the game extended on average to the eighth round (Figure 2). The trend is the same for the leaves (Figure 3) since their harvest is contingent on standing trees. By the third round in the treatment, the quantity of trees harvested decreased from an average of 3.5 units to 1.5 units (Figure 2). Meanwhile, the quantity of leaves harvested increased from an average of 2 units to 3.5 units and stayed around an average of 2.5 units for the remaining rounds (Figure 3). This change of focus in the game results helped to point out that for multipurpose species, the use of PES could shift the pressure from one product to another. Therefore, to be effective, PES ought to include all harvestable products in their design.

In the best-case scenario, we would expect the resource to remain by the tenth round under the PES treatment. However, this was not the case for various reasons. Several reasons include:

- Students were aware of the number of rounds of play at the beginning of the game. While they sustained low harvests in the early rounds, the impending end of the game disincentivized cooperation in later rounds.[8]
- While some players reduced their harvesting rate, others were free riding on their conservation actions. As a result, the "altruistic" players retaliated by readjusting their strategy.
- Several unexpected strategies occurred during the game, as well. For instance, one player was overharvesting trees based on their own profit, receiving negative profit, with the hope of forcing the rest of the group to harvest less for a continued bonus gain throughout the treatment rounds in the game. This attempt never succeeded.

To keep the activity simple, we did not account for the ecological dynamic between the two products in the regrowth mechanism of the game. This could be an interesting addition to use in higher level courses, where tree regeneration would depend on the stock of leaves.

Given that the activity is around natural resources, a common curveball observed was that some students behaved altruistically in the control rounds, which reduced the observed effect of the PES treatment. The strategies used generally generate a lively debate about altruistic behavior versus self-interest. In theory, to earn more during the treatment rounds, players must cooperate, and each player must harvest below the Nash equilibrium and trust the other players will have the same strategies. A larger magnitude of the reward at the end of the game would hinder such altruistic behavior if the instructor preferred to illustrate a truly noncooperative game.

[8] To better understand interaction in an ongoing resource management scenario, the instructor may want to focus analysis on rounds from the middle of the game before any end-of-game effects take hold.

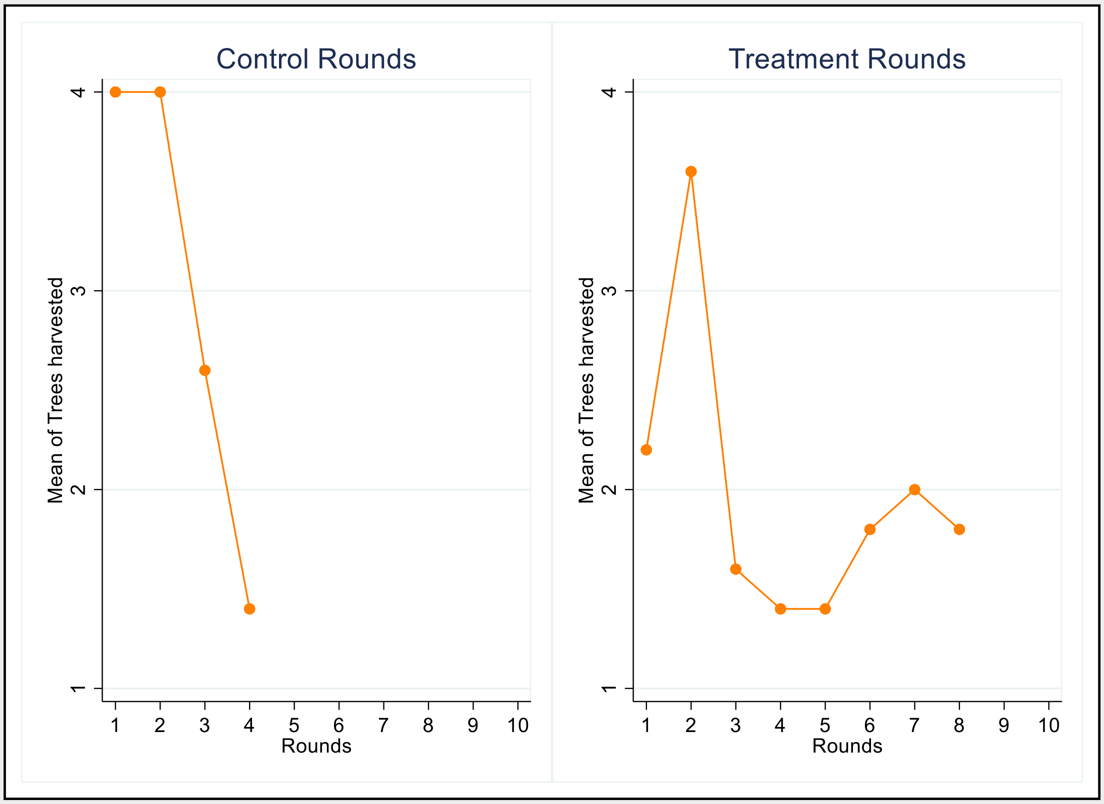

Figure 2. Average Harvest Trends of Trees

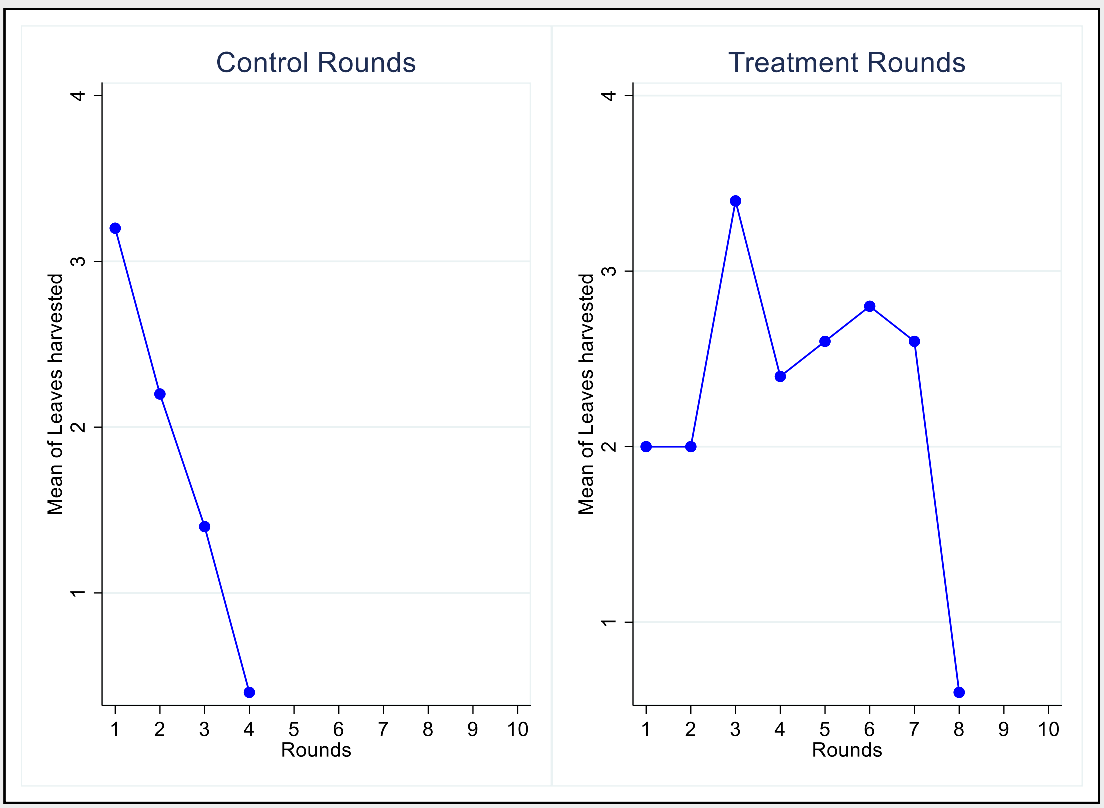

Figure 3. Average Harvest Trends of Leaves

6 Conclusion

This activity creates the opportunity for students to understand the rationale behind and some of the challenges of payments for ecosystems services. In addition, it introduces the students to the concept of multipurpose species, which is common in many ecosystems. Through the exercises, the students get to analyze how individual and group harvest decisions can affect species population dynamics and create environmental challenges. They are also exposed to the implementation of a PES scheme, leading to their assessment of how the approach can be effective or not. We believe the debriefing questions (see Appendix C: Post-Game Activities) offer a great platform for encouraging critical thinking and reaching the learning objectives. The game was successfully implemented in-person, but it can be easily adapted to an online classroom.[9] The game also has the potential to fit in various course levels. Different formats can be designed around the PES scheme for the treatment rounds. The PES could be based on proportional individual payments rather than group equal payments. It could also include a lump sum disbursement rather than recurrent payments throughout the rounds.

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[9] We have provided supplementary materials to run the game online using video conferencing software. The editor will share them upon request.

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Appendix: Game Materials

This appendix contains the following documents

A. Game Instructions/Student Handout
B. Student Decision Recording Sheet
C. Post-Game Activities
D. Suggested Reading List
E. Forest Resource Spreadsheet for Instructor
F. Payoffs Calculation Spreadsheet for Instructor
G. Payoffs Calculation Spreadsheet for Student

The Excel spreadsheets for Appendices E, F, and G are available upon request online through AETR.

Appendix A: Game Instructions/Student Handout

Overview:

In tropical ecosystems, forests are used for both their timber products and nontimber products (i.e. fruits, leaves, barks, seeds, etc.). Various species are harvested for both timber and nontimber products, and the harvest of one product could affect the other. For instance, overharvesting of leaves can influence the growth of the tree or overharvesting the seeds/fruits could affect the species' population dynamic. Species in these multiharvest situations are under higher human pressures.

In this game, students harvest from the same forest resource. Each tree in this forest produces two different valuable products: timber and leaves. During each round of the game, each student must choose the quantity of both resources to harvest for profit. The forest is a renewable resource, meaning that trees and leaves can grow back. The game also integrates a payment for ecosystem services (PES), which compensates the entire group of forest users if certain conservation targets are met in a given round.

Time estimate: 30–45 minutes to play

Number of participants: 5 players[10] and 1 moderator

Student learning objectives:

1. Calculate individual and group profit-maximizing harvest decisions
2. Graph group harvest decisions and resource stocks over time
3. Demonstrate the tragedy of the commons in the absence of conservation policies for multipurpose resources
4. Analyze how PES may alter the individual/group harvest decisions and stocks of both timber and nontimber resources

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Introduction:

We are going to participate in a natural resource management game, where you will earn money from harvesting from a forest. Each group will have 5 people who will make decisions on their own about how to use the forest resource. Each group will also have 1 moderator.

The trees in this forest produce two different valuable products that can be harvested to earn points. The first product is the timber from a tree. Timber is a valuable production material used to build and produce other wooden products. The second product is the leaves from a tree. Leaves are a valuable material that can be used as mulch, biomass, or even as an ingredient in animal feed/fodder.

Forest setup and harvesting:

The forest from which you harvest has a beginning stock of 50 trees. Each tree is represented by two colored markers or colored Excel cells. One color represents the timber and the other represents the leaves on the tree.

During each round of the game, you will individually and privately select the quantity of trees to harvest and the quantity of trees from which to harvest leaves. If you harvest a tree, you automatically harvest the leaves, too. However, it is possible to only harvest the leaves without harvesting the tree.

[10] Note, this game can be easily adapted for different numbers of players. We recommend setting the initial stock of the forest (i.e. number of trees) equal to the number of forest managers multiplied by 10. The PES threshold should then be set to 70 percent of this value, rounded to the nearest whole tree.

Payoffs:

Table 1 shows your earnings in points based on the number of trees and the number of leaves you choose to harvest.

Table 1: Payoffs from harvesting leaves and trees

Timber		Leaves	
Units	**Net Profit**	**Units**	**Net Profit**
1	600	1	40
2	1,100	2	80
3	1,400	3	110
4	1,600	4	130
5	1,500	5	150
6	1,300	6	140
7	1,200	7	140
8	800	8	120
9	200	9	120
10	-500	10	100

For example, in a given round if you choose to harvest two trees with leaves and harvest leaves from three additional trees, you would then have harvested a total of 2 units of timber for 1,100 points and 3 units of leaves for 110 points. Your total earnings in this round would be 1,210 points.

Submitting harvest decisions:

Without talking to other members of your group, you will decide the number of trees you would like to harvest and the number of leaves to harvest. Submit these to your moderator without revealing your decisions to others.

You are free to make any harvest decision you would like. Harvesting additional units of trees and leaves will earn different profit according to the payoff tables (**Table 1**).

If the players in the group submit harvest decisions that are greater than the remaining number of trees or leaves, the moderator will evenly divide the available resource among the 5 players, and any remainder will be discarded.

Stages of game and forest regrowth:

There will be two stages of this game, each consisting of 10 rounds. You can think of a round as equivalent to a year or harvesting season.

The forest will grow at the end of each round. For every 5 trees standing (with or without leaves), 1 tree will be replenished and added back to the game board. Any leaves harvested grow back during the next round.

If there are less than 5 trees remaining, no additional trees will grow, and the game ends.

End of round:

At the end of each round, the moderator will show you the forest and announce:

1. Total number of trees harvested
2. Number of trees from which leaves were harvested by the group
3. Number of trees in the forest after regrowth

If you have read and understand all of the instructions above, you may now begin Stage 1 of the game. Use the decision sheet (Table 2 in Appendix B: Student Decision Recording Sheet) to record all of your decisions in the game and track your earnings.

Stage 1 will last for 10 rounds or until the resource is depleted, whichever comes first.

Payments for ecosystem services and forest management:

Now suppose that because of concerns about resource depletion, the government has decided to implement a payment for ecosystem services (PES) program, which rewards groups of forest managers for not overusing the forest.

The PES program works as follows. In addition to earnings from your individual harvest decisions, the government is offering a bonus payment of 2,500 points to be split equally among all players if there are **at least 35 trees** still standing at the end of a round.

Each player in the group will receive an equal share, which amounts to an individual payment of **500 tokens.** If there are less than 35 trees still standing at the end of a round, there will be no bonus payment.

For example, suppose that each of the participants in your group harvests 2 trees. At the end of the round, the moderator would announce that 10 trees (2 trees × 5 managers) were removed, leaving 40 trees in the forest. Since the remaining number of trees is greater than the 35 trees threshold, each member will earn an additional 500 tokens on top of the 1,100 tokens profit they make from each harvesting 2 trees.

All other characteristics of the forest, payoffs, and rules of the game remain the same.

If you have read and understand all of the instructions above, you may now begin Stage 2 of the game. Use the decision sheet (Table 3 in Appendix B: Student Decision Recording Sheet) to record all of your decisions in the game and track your earnings.

Stage 2 will last for 10 rounds or until the resource is depleted, whichever comes first.

Appendix B: Student Decision Recording Sheet

Table 2: Forest Manager Decision Sheet (Stage 1)

ROUND NO.	QUANTITY OF TIMBER HARVESTED	QUANTITY OF LEAVES HARVESTED	EARNINGS FROM TIMBER	EARNINGS FROM LEAVES	TOTAL EARNINGS
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Table 3: Forest Manager Decision Sheet (Stage 2)

ROUND NO.	QUANTITY OF TIMBER HARVESTED	QUANTITY OF LEAVES HARVESTED	EARNINGS FROM TIMBER	EARNINGS FROM LEAVES	PES BONUS	TOTAL EARNINGS
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Appendix C: Post-Game Activities

Individual and group data analysis:

1. Graph your individual harvest decisions for trees and leaves over the rounds of the game. Create a separate graph for Stage 1 and Stage 2. Place units harvested on the vertical axis and rounds on the horizontal axis.
2. Using data collected from your group, calculate and graph the average group harvest for trees and leaves over the rounds of the game. Create a separate graph for Stage 1 and Stage 2. Place units harvested on the vertical axis and rounds on the horizontal axis.
3. Using a new graph, plot the stock of trees in the forest over the rounds of the game for Stage 1 and Stage 2.

Discussion questions:

1. How did individual and group decisions compare to what you might expect based on traditional microeconomic theory? What might explain any divergences?
2. How well did groups sustain cooperation in Stage 1 vs. Stage 2 of the game? Why?
3. How might the government make the PES program more effective? What would be the tradeoffs associated with these changes?
4. Other than forests, what types of environmental and natural resource problems do you think could be managed using PES programs? What might be some of the challenges?

Appendix D: Suggested Reading List

1. Hardin, G. 1968. “The Tragedy of the Commons.” *Science* 162(3859):1243–1248.
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Teaching and Educational Methods

Making Learning about Climate Change Fun and Interactive

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JEL Codes: A13, A22, C91, D91, H41, P26, Q54, Q58
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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

Results: Spring 2020

similar

Game 1: Basic Public Good

Contribution	Number	Game 1	
0	7	0	
1	36	36	
2	19	38	
3	10	30	
4		0	Points
Total		104	2.6

Game 2: Basic Public Good-Future Generations

Contribution	Number	Game 2	
0	46	0	
1	21	21	
2	4	8	
3	4	12	
4		0	points
Total		41	1.025

altruism

Game 3: Threshold Public Good

Contribution	Number	Game 3	
0	9	0	
1	36	36	
2	19	38	
3	11	33	
4		0	points
Total		107	2

Game 4: Threshold Public Bad

Contribution	Number	Game 4	
0	68	0	
1	4	4	
2		2	
3		0	
4		0	Points
Total		6	-1

Zero-sum

Game 5: Threshold Public Good-Unequal Endowments

Contribution	Number	Game 5	
0	29	0	
1	22	22	
2	13	26	
3	9	27	
4	0	0	points
Total		75	2

Usually "fair share"

Game 6: Threshold Public Bad -Unequal Endowments

Contribution	Number	Game 6	
0	43	0	
1	16	16	
2	11	22	
3	1	3	
4	1	4	points
Total		45	-1

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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Research Article

What does the pandemic mean for experiential learning? Lessons from Latin America

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JEL Codes: A20, A29,
Keywords: Agricultural sciences, educational plans, experiential learning, online education

Abstract
This study presents survey evidence of Latin American college students' perceptions of the switch from in-person instruction toward online instruction due to the COVID-19 pandemic. Three key findings emerge that present a negative outlook for higher education in programs that rely heavily on experiential learning. First, undergraduate students are not fully satisfied with the quality of online education received during the pandemic, especially the quality of experiential learning-based courses. Second, students perceive lower teaching quality independently of the course type as the main factor affecting learning. Third, students who experienced adverse stress and other limitations during the pandemic expressed difficulties in learning and have concerns about their educational paths, although just a small group expressed intentions to switch careers. These findings may affect long-term education in agricultural and applied sciences and show that remote education has not been successfully addressed in many countries of this region.

1 Introduction

The COVID-19 pandemic has created a crisis in the education system, forcing universities to put in place short-term solutions to address school closures, such as moving from face-to-face learning to remote instruction. However, very few universities were adequately prepared to move to a large-scale virtual education model (Houlden and Veletsianos 2020; Mitchell 2020). Thus, the pandemic has negatively affected teaching quality and student learning at most universities and colleges. This is concerning news for Latin America, which since the early 2000s, has faced an unprecedented growth in enrollment and access rates as a result of national policies, scholarships, and student loan programs (Ferreyra et al. 2017).

Many educational programs—including business and finance, agricultural sciences, music, and engineering—use experiential learning as a complementary component to theoretical curricula. For example, in agricultural sciences, activities such as hands-on laboratory experiments, fieldwork assignments, and field trips provide a unique opportunity for students to develop metacognitive skills—essential in developing critical thinking[1] (Magno 2010). Canceling or postponing practical activities may have detrimental effects on students' competencies (Baker, Robinson, and Kolb 2012) and mental health (Elmer, Mepham, and Stadtfeld 2020).

Students' limited access to high-quality education are exacerbated by the income inequality gap present in most Latin American countries (Mitchell 2020). Evidence also suggests that academic stresses may affect the career trajectory of Latino college students (Turkewitz 2020). Before the pandemic, agricultural science programs worldwide were already facing multiple challenges, including a declining

[1] Metacognitive skills are abilities for organizing and guiding one's own learning process. Among them are task orientation, goals preparation, monitoring a successful implementation of a plan, and evaluating task outcomes.

trend in enrollment rates, limited resources, difficulties keeping up with global trends, and balancing experiential learning with traditional class settings (Mulder and Kupper 2006; David and Bell 2018).

Online education has endured many challenges during the pandemic, which compounds the pressure facing agricultural programs. First, students and faculty dealt with fatigue of experiencing only online instruction during quarantine (Chakraborty et al. 2020; Mishra, Gupta, and Shree 2020). This alone could dissuade students from enrolling or returning to virtual lessons (Anemona 2020; Lederer et al. 2020). Second, there is a widespread perception that online courses have lower quality of engagement (Jaschik 2020), which could discourage students from engaging in virtual platforms. Notably, for courses with experiential components, fewer laboratory sessions and no field trips likely magnify this belief. Finally, the pandemic has shed light on intergenerational inequalities as many students did not have access to internet during lockdowns (Edelin 2020), which may affect students' mental health and student retention (World Bank 2020).

Emerging literature indicates that although school programs adapted pedagogy and activities to positively shift student perspectives about online learning during the pandemic (Leif, Moore, and Heath 2021), these efforts failed to replicate the experiential learning experience that occurs in the classroom (Danyluk, Kapoyannis, and Kendrick 2021). This shows the need to develop instructor's training and educational tools to impart experiential components in an online format (Liguori and Winkler 2020).

Despite reports and media coverage of education reforms post-COVID-19 and emerging evidence of the pandemic effects on social and applied sciences (see e.g., Pruitt, Tewari, and Mehlhorn 2020; Danyluk et al. 2021; Holderieath et al. 2021; Leif et al. 2021), to our knowledge no research has explicitly explored (i) the opinions and attitudes toward instruction quality during the pandemic for students enrolled in courses that integrate experiential learning components, (ii) the differences in perception of instruction quality when compared to theoretical courses, or (iii) how students' experiences with virtual learning during lockdowns have affected their learning experience and outlook about their educational plans, including their intent of switching academic programs. To address these topics, we focus on how agricultural science education as experiential learning has been a valued component in this multidisciplinary field (Knobloch 2003). This information is relevant for university administrators and program advisors as they work toward reforms in higher education in the post-pandemic world. The outcomes of this study are also significant for applied science programs—such as music, business, engineering, medicine—that offer practical experiences in their curriculum.

Data suggests that practitioners and overall the education community have not met a consensus on how to adapt instruction in a fast-changing world (Li and Lalani 2020; UNESCO 2020). The sudden shift in 2020 to virtual learning exacerbates concerns about the role of education technologies, such as synchronous online meetings, guided videos, tutorials, among others, in the development and quality of instruction. This article explores the students' perception of theoretical courses and contrasts the results with experiential learning classes. More precisely, data were collected in 2020 to examine how Latin American students pursuing an undergraduate degree in agricultural sciences: (1) perceive the switch from traditional in-person instruction to virtual learning; (2) contrast their attitudes toward the changes in different courses—varying in their teaching methodologies; and (3) learn about their perceptions regarding their future educational plans, including how online learning has changed their opinion with respect to their current major.

The outcome of the study aims to enhance the understanding of how online education was perceived by undergraduate students in two large universities in Latin America and how this may represent an opportunity for improvement of current teaching models in experiential-based academic programs.

2 Survey and Sample Characteristics

2.1 Survey Objectives and Sample

Data were collected during October 2020 to examine how Latin American students pursuing an undergraduate degree in agricultural sciences perceive the switch to virtual learning, contrast their perceptions in different courses, and learn about their perceptions regarding their educational plans.

Specifically, for the first two objectives, two types of courses are addressed: (I) *Theoretical Learning Courses* (TLC)—which offer a traditional theoretical-based setting where the instructor provides lectures face-to-face and students participate in discussions and class activities, and (II) *Experiential Learning Courses* (ELC)—which require either fieldwork or in-person labs.

To fulfill these objectives, a survey was conducted with undergraduate students from two universities: (i) Zamorano University, an agricultural-focused university in Honduras known for its diverse student body from 29 countries, with an average enrollment of 1,200 undergraduate students. This university offers a couple of unique characteristics: all students live on campus, and they must participate in daily learning-by-doing activities such as working in the crop fields, feeding cattle, packing vegetables, measuring water quality, among other activities.

(ii) The Pontifical Catholic University of Chile, one of the top universities in Latin America, with an enrollment of more than 25,000 undergraduate students from which about 880 students pursue an agricultural or forestry degree in the Faculty of Agronomy and Forestry Engineering. Students need to complete different activities related to crop and animal production throughout the school years.

An important distinction between both universities is the amount of time devoted to experiential learning, especially fieldwork. The academic program at Zamorano allocates an equal amount of time to practical activities and traditional theoretical settings. The agricultural program at the Chilean university generally allocates more time to theoretical lessons in the classroom, although 60 percent of the courses involve activities in the lab or field. Both universities suffered cancellation of all experiential learning activities during the lockdown. Therefore, surveying these two universities located in two different regions of Latin America and with different curricula provides a more comprehensive analysis.

2.2 Survey Development and Administration

The survey was designed based on previous research of students' satisfaction with online learning and emerging evidence regarding students' learning experiences amid the COVID-19 pandemic (Swan 2001; Rapanta et al. 2020). Participants were limited to undergraduate students who enrolled at both institutions prior to the pandemic, as they were taking the two types of courses and experienced the shift to virtual learning during the first term of the 2020 academic year.

It is important to note that, during the first wave of the pandemic, both universities employed synchronous online teaching supported with asynchronous learning resources (i.e., recorded videos, forums, and simulations). All experiential learning activities (fieldwork, lab sessions, and field trips) were canceled.

Prior to the data collection, a small investigatory process was conducted with students and faculty at both universities to test the survey.[2] In order to protect students' information and confidentiality, no identifiable information was collected except for their email addresses. To minimize any discomfort to participants and avoid potentially biased responses, respondents were informed that providing their contact information was voluntary, with the only purpose of compensation, and that the data would be anonymized, and personal identifying information removed.

The survey was designed in Typeform to be self-administered on students' electronic devices. Five surveyors conducted online interviews to support the data collection. The surveyors were senior

[2] The Pontifical Catholic University of Chile Human Research Ethics Committee and authorities of each university approved the study.

undergraduate students at Latin American universities, which allowed them to better relate to the participants and convey the importance of honest responses in the anonymous. All undergraduate students (about 2,080 people) were invited to participate in the online study using both email and social media invitations (Jorrat 2020). As compensation, each participant had a 10 percent chance to win a gift card worth approximately US$8.00.

The survey questions covered four key aspects: educational plans, perceptions of learning and teaching quality, well-being and learning environment, and sociodemographic information. Students were asked to evaluate both learning and teaching components for the two types of courses: ELC and TLC. We requested respondents to provide examples of each course type to determine whether students could differentiate them. Most respondents were able to correctly classify the courses.

Literature suggests that respondents who believe the survey to be inconsequential are more likely to give trivial answers (Sandorf, Aanesen, and Navrud 2016). Thus, a short script at the beginning of the questionnaire was included to promote truthful responses. An explanation of the relevance of the study was offered, including its potential implications for higher education. A 5-point Likert-scale was included at the end of the survey to verify if respondents perceived it as trustworthy: "*How likely do you think it is that university authorities will use the survey results in the management of education?*" where responses ranged from "*extremely unlikely*" to "*extremely likely*." As a robustness check, a second analysis was completed, which excluded the data from respondents who believed the survey to be inconsequential.[3] Results were similar in both cases.

A total of 141 students (about 7 percent of undergraduate students) fully completed the survey process, which lasted approximately 20 minutes.[4]

2.3 Survey Summary Statistics

Table 1 reports the descriptive measures of factors that were investigated, including perceptions of teaching quality, effort, well-being, and learning environment, based on survey responses. Particularly, a 5-point Likert scale[5] was used to ask students about their perception of how instruction quality and learning difficulty changed due to the pandemic for ELC and TLC.[6]

The summary statistics in Table 1 show that, independently of the type of course, the quality of teaching and course organization was perceived to be better before the pandemic. This is consistent with the belief that online learning carries a stigma of being lower quality than in-person instruction (Hodges et al. 2020). The case is stronger for ELC (average = 4.6) than TLC (average = 3.6) as students strongly agreed that the quality of teaching of ELC and experiential learning would have been better in the absence of COVID-19, which shows that misconception of virtual instruction is more dramatic for courses that integrate hands-on applications.

In regards to mental health status in Table 1, on average, respondents indicated a neutral sentiment to the statement: "*My mental health has worsened during the pandemic*" (average = 3.5). Furthermore, more than half of students reported low internet speed (62 percent) and lack of a study place (54 percent) as factors that have affected their learning environment. In terms of

[3] Specifically, those who answered "*extremely unlikely*" to the debriefing question were excluded in the robustness check.
[4] Some students skipped a few sociodemographic questions (i.e., household size). In this case, we imputed nearly 18 percent of missing values of the variable household size using predictions from a regression of reported values on individuals' characteristics. Overall, regression results are robust when excluding missing values. It is possible that those students who were unsatisfied with online instruction were more likely to participate in the study. Nonetheless, students were offered the possibility of winning a gift card when participating in the survey; therefore, they also had other reasons for participating.
[5] For the 5-point Likert scale, responses ranged from "strongly disagree" to "strongly agree."
[6] Four satisfaction statements were asked to compare with a situation without the pandemic: (1) "Teaching quality for ELC would have been better (without pandemic)," (2) "Teaching quality for TLC would have been better," (3) "Course organization would have been better," and (4) "Experiential learning would have been better."

Table 1. Summary Statistics

Variable	Description	Type	Mean	*SD*
Teaching quality for TLC	Quality for originally theoretical face-to-face courses would have been better without the pandemic	L5	3.61	1.17
Teaching quality for ELC	Switching ELCs to online settings during the pandemic were perceived with lower teaching quality	L5	4.62	0.70
Course organization	Course organization before the pandemic was better	L5	4.15	0.95
Experiential learning	Quality of courses with experiential learning pre-pandemic was better	L5	4.94	0.32
Poor mental health	Mental health has worsened	L5	3.46	1.34
Slow Wi-Fi	Low internet speed (if =1)	BIN	0.62	0.48
No study place	Lack of a place to study (if =1)	BIN	0.54	0.50
Financial support	Family receives financial support (if =1)	BIN	0.24	0.44
Relocation	Student relocated due to pandemic (if =1)	BIN	0.13	0.34
School years	Number of years in college	NUM	2.86	1.09
Household size	Family members in the household	NUM	4.52	1.57
Zamorano	Student is from Zamorano University (if =1)	L5	0.46	0.50

Note: TLC refers to Teaching Learning Courses whereas ELC indicates Experiential Learning Courses.
The type of variables presented are:

-Qualitative variables measured using the 5-point Likert scale (L5), values range from 1 to 5, where 1 = strongly disagree and 5 = strongly agree.

-Binary variable (BIN), where 1 means that the statement is occurring, 0 = otherwise

-Quantitative continuous variable (NUM)

SD refers to one standard deviation from the mean.

sociodemographics, the majority are juniors and seniors (60 percent), and about one quarter have families that receive government financial support (24 percent).

2.4 Survey Limitations

The survey has the following limitations. Although the study has a representative sample size for the study, it is possible that many students that had technical difficulties (e.g., internet connection) could not participate in the survey. The study also surveyed students that were enrolled in both universities in October 2020. Many students may have changed their degrees between March and October 2020. However, as expressed in the 2020 Zamorano report, less than 5 percent of its students dropped school. Furthermore, participation of eligible students was lower than in teaching evaluation surveys (7 percent vs. 26 percent). Considering that the average response rate for teaching evaluation surveys decreased by 27 percentage points over the 2019–2020 period and that both universities were conducting several surveys throughout the academic period of 2020, the low response rate in our study might not be surprising. Nonetheless, different approaches may be needed to encourage students to participate in times when in-person surveys are not possible. For instance, providing students additional incentives to participate or encouraging participating students to motivate their peers to take part in a survey might improve participation.

3 Learning Experience and Educational Plans

Since one of the aims of the study is to better understand students' learning experience during the pandemic, questions regarding their perceptions of learning quality were included in the survey. Using a 5-point Likert scale, participants were asked to rate the extent to which they agree or disagree with the following two statements contrasting a situation without the pandemic: (1) "*I would have experienced less difficulty in learning the course material*" and (2) "*The learning quality, in general, would have been better*." Students were asked to evaluate these statements for both types of courses (TLC and ELC). Responses to these questions are displayed in Figure 1.

For ELC, about half of respondents (47 percent) strongly agreed that learning became more challenging due to the pandemic. In contrast, only one-quarter (27 percent) of students strongly perceived this was the case for TLC. Regarding learning quality and experience, students predominantly expressed that they strongly agreed about the detrimental effects of the pandemic for both types of courses (i.e., 64 percent for ELC vs. 44 percent for TLC). However, it is possible that the shift to virtual learning translates into an increase in learning difficulty depending on the adaptability of the students to online classes (Xu and Jaggars 2013). Interestingly, the difference in perception between ELC and TLC in learning difficulty (20 percent) and quality (20 percent) are consistent, which may suggest that this difference may be partially attributed to the experiential components that students missed due to the pandemic.

The survey also included questions exploring students' change in attitudes toward online learning and educational plans due to the pandemic. Specifically, three statements were considered: (1) "*I feel willing to take more online courses in order to complete my core curricula while studying from home*," (2) "*I feel more willing to take online elective courses while studying from home*," and (3) "*I am more likely to change degree.*" The first two statements reflect attitudes toward online education, while the last one reveals plans about overall education path choices.[7] Responses to these questions are presented in Figure 2.

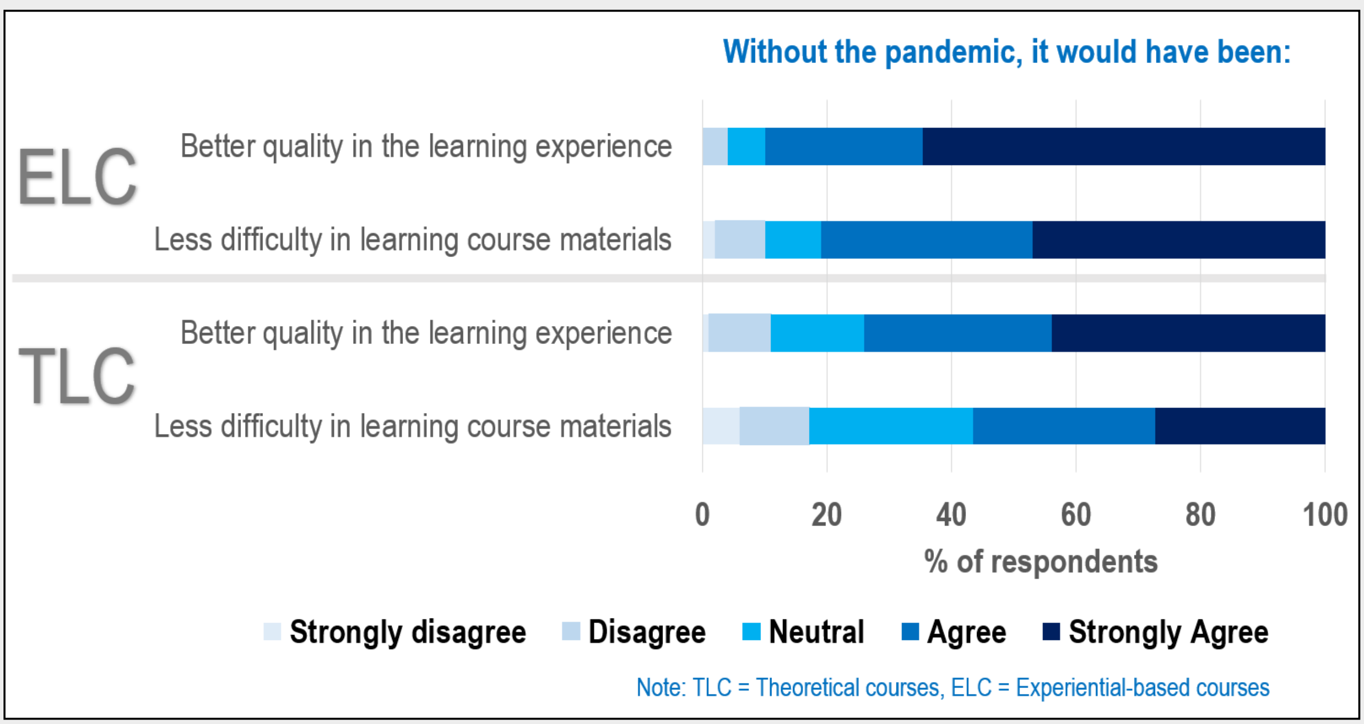

Figure 1. Perceptions of Learning Experience

[7] Questions regarding likelihood of changing or dropping from college were also asked to provide robustness to our analysis.

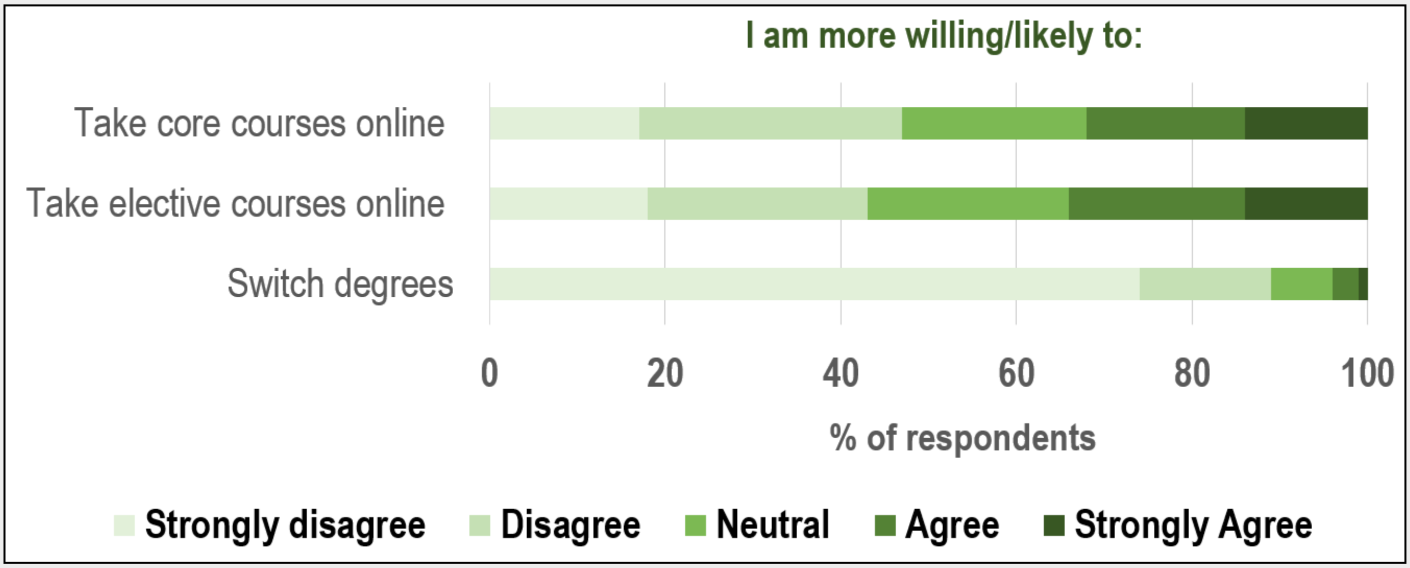

Figure 2. Perceptions of Educational Plans Regarding Future Courses and Career Path

Figure 2 displays that about 30 percent of students would be willing to take additional online courses in their careers. This percentage might not be surprising, given that the majority of students had difficulties with internet connection (62 percent of students faced low internet connection) and finding an adequate place to study (about 54 percent expressed this limitation).

Interestingly, only a small portion of participants (5 percent) stated that they would likely switch degrees, which was expected given that 60 percent of respondents are juniors and seniors. This is in line with previous results from a recent poll that indicated that about 4 percent of students are no longer sure if they will complete their degree or take a gap year (Remote Internships 2020). Likewise, less than 5 percent of students from Zamorano University decided not to continue their studies (S. Morales, personal communication, May 4, 2021), which has been the case for many other colleges across the continent. Consistently, a Fall 2020 report indicated that undergraduate students' enrollment decreased by 3 percent in the United States due to the coronavirus[8] (Douglas-Gabriel 2020).

4 Determinants of Learning Experience and Educational Plans

This section discusses factors influencing students' opinions of their learning experiences, teaching quality, and educational plans. Econometric analysis was applied to the qualitative responses presented in Figures 1 and 2.[9] Covariates for the regressions analysis were selected based on existing and new literature indicating that factors such as depression (Islam et al. 2020) limited physical resources (Edelin 2020), and socioeconomic aspects influenced students learning experience during lockdowns (Mitchell 2020).

[8] It is possible that some students switched to a nonagricultural major prior to the data collection, and, therefore, they were unable to participate in the survey.

[9] As a robustness check, we tested the possibility of interviewer bias and strategic answering to please the interviewer by including a dummy variable in the models (i.e., equal to 1 whenever the survey was administered by a surveyor, and 0 otherwise in all regressions). The lack of statistical significance of the coefficient on the surveyor dummy variable in all except one regression indicates that interview bias and strategic answering were likely not a significant problem of concern for this study.

4.1 Challenges toward Learning

The pandemic exacerbated the challenges faced by students toward learning, as expressed in Figure 1. Thus, an ordered logistic model (McCullagh 1980) was used to understand how mental health status, technical issues (i.e., low internet speed, lack of study place), demographic aspects, and school years aggravated the difficulties in learning the course materials for both TLC and ELC.

Tables 2 and 3 present the coefficient estimates and corresponding odds ratios, respectively for the two ordered logit models. Using a one-tailed test under an asymptotic normal distribution assumption for a large number of observations (n = 141), only three factors were found to be significant. The results suggest that for theoretical courses, students perceived that poor mental health exacerbated the challenges of learning during the pandemic. Likewise, Zamorano students perceived this issue more drastically, with odds of 2.18 times more likely to perceive difficulty in learning than students from the University of Chile. Interestingly, for both types of courses, students felt that relocating was an important factor that increased the difficulty in learning. The odds of experiencing learning difficulty for these students are, on average, twice larger than from those students who did not relocate.

Table 2. Ordered Logit Model Coefficient Estimates Assessing Learning Difficulty

	Theoretical Learning Courses	Experiential Learning Courses
Poor mental health	0.201*	0.122
	(1.66)	(0.97)
Slow Wi-Fi	-0.083	-0.457
	(-0.23)	(-1.26)
No study place	0.173	-0.323
	(0.56)	(-0.98)
Financial support	0.417	0.345
	(0.14)	(0.91)
Relocation	0.706’	0.822’
	(1.42)	(1.55)
School years	-0.202	0.048
	(-0.18)	(0.26)
Household size	-0.020	-0.002
	(-0.19)	(-0.02)
Zamorano	0.781*	0.553
	(1.87)	(1.26)
Cut-off point 1	-2.223*	-3.377**
	(-2.22)	(-2.93)
Cut-off point 2	-1.043	-1.732
	(-1.07)	(-1.68)
Cut-off point 3	0.339	-0.952
	(0.35)	(-0.94)
Cut-off point 4	1.662	0.657
	(1.72)	(0.65)
Log likelihood	-201.503	-169.715
Pseudo R^2	0.039	0.016

Note: T-statistics are in parentheses and * $p < 0.05$, ’ $p < 0.1$
P values are based on a one-tailed test asymptotic normal distribution (n = 141) with H_0: $\beta_j = 0$ and H_1: $\beta_j > 0$ for j = slow Wi-Fi, no study place, relocation, school years, household size, or Zamorano students; or H_1: $\beta_j < 0$ for j = financial support. P values are based on a two-tailed test asymptotic normal distribution for cut-off points.

Table 3. Odds Ratios for the Ordered Logit Model Assessing Learning Difficulty

	Theoretical Learning Courses	Experiential Learning Courses
Poor mental health	1.223*	1.130
Slow Wi-Fi	0.319	0.230
No study place	1.190	0.724
Financial support	1.519	1.412
Relocation	2.026’	2.277’
School years	0.817	1.049
Household size	0.981	0.998
Zamorano	2.183*	1.739

Note: * $p < 0.05$, $'$ $p < 0.1$
P values are based on a one-tailed test asymptotic normal distribution (n = 141) with H_0: $\beta_j = 0$ and H_1: $\beta_j > 0$ for j = slow Wi-Fi, no study place, relocation, school years, household size, or Zamorano students; or H_1: $\beta_j < 0$ for j = financial support.

4.2 Quality of Learning

Students expressed concerns about learning experience and quality due to the pandemic. Thus, we used an ordered logistic model to assess learning quality, regressing this qualitative variable on teaching quality and control variables (i.e., to account for mental health, technical issues, logistics, and demographic information). The results (presented in Table 4) and the odds ratios (in Table 5) show that for both types of courses—ELC and TLC—teaching quality is statistically significant in explaining students’ satisfaction toward learning quality. Its positive coefficient in both models indicates that respondents who agree with the statement “*Teaching quality would have been better without the pandemic*” are more likely to agree that “*Learning would have been better without the pandemic*.” Thus, students who were unsatisfied with the quality of instruction are more likely to agree that learning in a virtual format is of lower quality, therefore, more challenging compared to in-person instruction. Their odds of having more negative attitudes toward learning quality are higher by 3.9 and 2.4 times for ELC and TLC, respectively, compared to respondents who were satisfied with their quality of instruction. Thus, when comparing the differences in odd-ratios between both course types, it seems that perception of teaching quality played a more critical role for courses with experiential-learning components.[10] Although these results are correlational in nature, they relate to previous work indicating that learners’ prior experience with teaching style is a predictor of their satisfaction with experiential learning (Zhai et al. 2017).

Zamorano students perceived that experiential learning suffered a significant decrease in quality due to the lockdown, with their odds of perceiving a lower teaching quality being 2.6 times larger compared to students from the Chilean university. This was expected, as they devote half of the day to learning-by-doing activities. Interestingly, students without financial support expressed more discomfort with the learning quality of ELC during the pandemic, but this was not the case for TLC. This suggests that students who financially support their education by themselves or through family assistance were more concerned about the lack of experiential learning than theoretical learning. Likewise, there is suggestive evidence that undergraduate students in their first years of education perceived that the lockdown impacted the overall learning experience of theoretical courses.

[10] A side test for the difference in the coefficients of teaching quality for both TLC and ELC was conducted. The results show that the estimate of teaching quality in ELCs is significantly higher than for its respective TLC counterpart.

Table 4. Ordered Logit Model Coefficient Estimates Assessing Learning Quality

	Theoretical Learning Courses	Experiential Learning Courses
Teaching quality	0.857***	1.358***
	(4.97)	(5.16)
Poor mental health	0.146	-0.0487
	(1.13)	(-0.33)
Slow Wi-Fi	0.0476	-0.360
	(0.13)	(-0.85)
No study place	0.395	-0.101
	(1.16)	(-0.26)
Financial support	-0.282	-0.853*
	(-0.73)	(-1.98)
Relocation	0.155	0.877’
	(0.31)	(1.36)
School years	-0.291’	0.155
	(-1.51)	(0.73)
Household size	-0.0286	-0.131
	(-0.25)	(-1.07)
Zamorano	0.271	0.967*
	(0.60)	(1.87)
Cut-off point 1	-1.908	2.131
	(-1.44)	(1.49)
Cut-off point 2	0.439	3.290*
	(0.38)	(2.31)
Cut-off point 3	1.649	5.308***
	(1.43)	(3.56)
Cut-off point 4	3.283**	---
	(2.79)	
Log likelihood	-159.892	-111.910
Pseudo R^2	0.125	0.154

Note: T statistics are in parentheses and *** $p < 0.001$, * $p < 0.05$, ’ $p < 0.1$
P values are based on a one-tailed test asymptotic normal distribution (n = 141) with H_0: $\beta_j = 0$ and H_1: $\beta_j < 0$ for j = slow Wi-Fi, no study place, relocation, school years, household size; or H_1: $\beta_j > 0$ for j = teaching quality, financial support, Zamorano students. *P* values are based on a two-tailed test asymptotic normal distribution for cut-off points.

4.3 Educational Plans

The third set of ordered logistic regressions was specified to investigate the determinants of educational plans (presented in Figure 2) among Latin American students. Three variables (i.e., willingness to take core or elective courses online and likelihood of changing academic careers) were regressed against selected variables that comprise course organization, experiential learning opportunities—lab or fieldwork, mental health, technical issues, and sociodemographic characteristics.

The coefficient estimates[11] (shown in Table 6) and the corresponding odds ratios (shown in Table 7) suggest that a well-organized core course would strongly demotivate students from taking it online. For students that felt that a course was not well organized due to the pandemic, the odds of taking more core online courses are 33 percent lower than their counterpart. Interestingly, experiential learning perceptions did not affect participants’ opinions about their curriculum planning for both elective and

[11] It is not clear whether explanatory variables have a positive or negative influence on educational plans; therefore, we use a two-tailed test assuming asymptotic normal distribution (n = 141).

Table 5. Odds Ratio for the Ordered Logit Model Assessing Learning Quality

	Theoretical Learning Courses	Experiential Learning Courses
Teaching Quality	2.355**	3.887***
Poor mental health	0.149	0.140
Slow Wi-Fi	1.049	0.698
No study place	1.485	0.904
Financial support	0.755	0.426**
Relocation	1.167	2.402
School years	0.747'	1.168
Household size	0.972	0.877
Zamorano	1.311	2.631*

Note: *** $p < 0.001$, * $p < 0.05$, ’ $p < 0.1$. P values are based on a one-tailed test asymptotic normal distribution ($n = 141$) with H_0: $\beta_j = 0$ and H_1: $\beta_j < 0$ for j = slow Wi-Fi, no study place, relocation, school years, household size; or H_1: $\beta_j > 0$ for j = teaching quality, financial support, Zamorano students.

core courses. This means that the course structure primarily influences students’ attitudes toward taking virtual classes. This finding further reinforces that efforts to maintain instruction quality are necessary, particularly considering the prospect of online learning as a significant part of the education system in a post-COVID-19 world. In addition, this finding may prove challenging to move core courses in applied sciences to virtual settings.

On the other hand, participants who perceived that their mental health deteriorated or relocated during the pandemic are less likely to take more core online courses to complete their major. For these respondents, the odds of taking more online courses are 31 percent and 66 percent lower than their counterparts, respectively. Likewise, students from large households are more unlikely to take core courses virtually, which may be attributed to not having an appropriate place to study or proper internet connection, as large families tend to be poorer (Wodon et al. 2001) and, therefore, fewer resources per child are available, including time and guidance (Downey 1995).

In terms of career paths, only a small portion of students showed willingness to change their current careers. For those who expressed this intention, results indicate that respondents who expressed they had poorer mental health during the pandemic would be more likely to switch degrees. Furthermore, students from larger households are 1.4 times more likely to change careers after the pandemic. Likewise, Zamorano students were about 3.9 times more likely to switch degrees compared to those in the Chilean university.

5 Conclusions

This study highlights the difficulties faced in education due to the switch from experiential learning toward online instruction in Latin America during the COVID-19 pandemic. Three key findings emerge that present a more negative outlook for higher education during the pandemic and potentially post-pandemic. First, the survey results suggest that a sudden switch toward virtual platforms has negatively affected both theoretical and ELCs. Second, students’ negative impressions of teaching quality were the primary factor influencing their views regarding their learning experience. Compared to theoretical learning-based courses, the teaching quality of ELCs was a more important factor affecting perceived learning. Third, the article also remarks that the negative effect of the pandemic on mental health may have an adverse impact on the students’ education planning and career path, which is supported by previous work (Zheng et al. 2021). Yet, the relationship between mental health and career choice of college students seems to be inconclusive (Gray et al. 2021). Furthermore, participants who reported mental health issues expressed that they were unlikely to take further core courses in a virtual setting.

Table 6. Ordered Logit Model Coefficient Estimates Assessing Educational Plans

	Dependent Variable		
	Taking online a core course	**Taking online an elective course**	**Change degree**
Course organization	-0.399*	-0.244	0.0187
	(-2.36)	(-1.38)	(0.08)
Experiential learning	-0.155	-0.530	-0.321
	(-0.36)	(-1.21)	(-0.51)
Poor mental health	-0.369**	-0.231	0.521**
	(-3.05)	(-1.96)	(2.92)
Slow Wi-Fi	0.183	0.440	0.400
	(0.53)	(1.25)	(0.78)
No study place	-0.510	-0.348	0.496
	(-1.62)	(-1.09)	(1.13)
Financial support	-0.641	-0.388	0.100
	(-1.68)	(-1.06)	(0.19)
Relocation	-1.074*	-0.367	0.566
	(-2.06)	(-0.75)	(0.87)
School years	0.0743	0.119	-0.153
	(0.42)	(0.68)	(-0.68)
Household size	-0.203’	-0.156	0.335*
	(-1.88)	(-1.52)	(2.50)
Zamorano	-0.512	-1.042*	1.363*
	(-1.20)	(-2.45)	(2.41)
Cut-off point 1	-6.863**	-7.069**	3.934
	(-2.86)	(-2.93)	(1.20)
Cut-off point 2	-5.203*	-5.645*	5.271
	(-2.19)	(-2.37)	(1.60)
Cut-off point 3	-4.181	-4.559	6.685*
	(-1.77)	(-1.93)	(2.00)
Cut-off point 4	-2.933	-3.305	8.475*
	(-1.24)	(-1.40)	(2.43)
Log likelihood	-206.350	-211.392	-101.423
Pseudo R^2	0.070	0.057	0.142

Note: *T* statistics are in parentheses and * $p < 0.05$, ** $p < 0.01$, ’ $p < 0.1$
P values are based on a two-tailed test asymptotic normal distribution ($n = 141$).

Table 7. Odds Ratio for the Ordered Logit Model Assessing Education Plans

	Dependent Variable		
	Online course other degrees	**Online course other degrees**	**Change degree**
Course organization	0.671*	0.783	1.019
Experiential learning	0.857	0.588	0.725
Poor mental health	0.691**	0.794	1.684**
Slow Wi-Fi	1.200	1.552	1.492
No study place	0.600	0.706	1.641
Financial support	0.527	0.678	1.105
Relocation	0.341*	0.693	1.761
School years	1.077	1.127	0.858
Household size	0.816’	0.856	1.399*
Zamorano	0.599	0.353*	3.909*

Note: * $p < 0.05$, ** $p < 0.01$ P values are based on a two-tailed test asymptotic normal distribution (n = 141). P values are based on a one-tailed test asymptotic normal distribution (n = 141) with H_0: $\beta_j = 0$ and H_1: $\beta_j < 0$ for j = slow Wi-Fi, no study place, relocation, school years, household size; or H_1: $\beta_j > 0$ for j = teaching quality, financial support, Zamorano students.

These results imply that, in the short term, virtual classes may not be the best substitute for traditional courses with learning-by-doing components and further suggest that educational programs in applied sciences need to be proactive in improving the teaching methods and active learning used in online education. Practitioners and college administrators would need to invest significant resources in order to recreate the hands-on learning experience delivered by in-person instruction in virtual settings. Furthermore, efforts are needed to support and improve the technical challenges faced by students and educators for an optimal online learning experience. These efforts should be devised with an equity lens by offering both online and on-campus support and targeting marginalized collegiate populations (Lederer et al. 2020).

Concerning elective courses—which students are more willing to take online—incorporating a blended approach that integrates both classroom and online learning could be an attractive alternative in the post-pandemic education system of applied sciences (Martínez-Caro and Campuzano-Bolarín 2011; Gregory and Di Trapani 2012).

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Teaching and Educational Methods

Learning about Consumer Demand from Student Surveys

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Abstract
Active learning can help students to grasp abstract economic concepts and become acquainted with quantitative data analysis. This paper describes how a survey of willingness to pay for pizza that is designed, executed, analyzed, and interpreted by students can motivate learning about consumer demand. The approach, which can be adapted to other consumption goods, builds understanding of consumer demand from the level of the individual to the market.

1 Introduction

For students to "think like an economist" is the goal of most economics teachers. This goal bundles several learning objectives, notably: (1) how economic decisions involve a desired objective but scarce resources for reaching it, (2) how individual decision makers respond to incentives—prices in particular—and (3) how market behavior reflects the aggregation of individual decisions. Students who "get" these ideas are well on their way to thinking like an economist.

Introductory and intermediate microeconomics texts tend to express market demand with graphs and equations, often backed up by numeric examples. Many textbooks include a section on individual consumer choice between two goods, employing the constructs of the budget constraint and the indifference curve (Baye and Prince 2017). In my experience as a teacher, the conceptual leap from individual choice between two goods to market demand for one good can be hard for many students to make. Many students will memorize graphs and try to regurgitate them on exams. Memorization is not thinking like an economist.

A secondary goal for teachers of applied economics is to build quantitative skills that equip students to meet the rising demand for data analytics (Gillespie and Bampasidou 2018). Upper-level undergraduate classes are increasingly offering opportunities for students to work with "big data" (Elliott and Elliott 2020). However, before students can perform thoughtful data analysis, they need to "get" the underlying economic ideas.

How can a teacher narrow the gap so that the conceptual leap from consumer choice to market demand is more easily bridged? Experiential learning from personal experience yields better economic learning outcomes than passive, "chalk and talk" teaching (Eber 2003; Hawtrey 2007), and classroom experiments constitute one way to generate insights from personal experience (Holt 1999). Particularly for ideas related to consumer demand, experiential learning should be easy: we are all consumers who make choices daily. Experiential learning may be especially valuable for students of business management who intentionally chose a very applied field when they could have chosen a more abstract field like mathematics or economics.

Although the economic literature is loaded with studies based on student data, remarkably few involve student learning from the data that they themselves provided. One large body of economic education studies reports surveys of student preferences about pedagogic approaches (Thomas and Galambos 2004). A related literature explores what features students seek from the university experience (Bruno and Campbell 2016). A large literature in experimental economics relies upon students as research subjects. Apropos of the application in the current article, at least one such study estimated student willingness to pay for pizza (Louviere and Islam 2008), an eminently relatable consumption item. But the study's purpose was to compare methods for eliciting willingness to pay; its audience was researchers, not students.

The few published examples of classroom experiments to generate consumer demand data come from the early years of active learning in economics. The first published case is excellent. In it, Weidenaar (1972) offers a versatile experiment where students are invited to submit purchase contracts to buy apples. The exercise allows construction of a demand schedule and establishment of a market-clearing price when the instructor brings a fixed quantity of apples to the next class. The experiment also enables a lesson in how the instructor, as monopolist, can choose the quantity to supply that maximizes their revenue.

The 1990s and early 2000s saw a flush of pedagogic innovation in economics using classroom games and experiments (Holt 1999; Bergstrom and Miller 2000; Brauer and Delemeester 2001; Eber 2003). Many individual games and experiments from that period are inventoried online at the sites "Games Economists Play" (Delemeester and Brauer 2000) and "Computer Programs for Classroom Games" via the VeconLab (Holt 2012) or in the newsletter *Classroom Expernomics*[1]. One demand experiment examines willingness to pay for an ice-cold soft drink on a hot versus a cold day (Brock 1992), allowing construction of a demand curve and illustration of a shift. Another reported in Eber (2003) involves estimating student price elasticity of demand for candy bars (Hill 2001). In a textbook that is still in print, Bergstrom and Miller (2000) offer a collection of experiments, including two for constructing demand and supply functions in hypothetical settings.

This article expands upon the approach of Weidenaar (1972) and others to eliciting student willingness-to-pay by explicitly building up from individual consumer demand to market demand and by using a student-designed survey of willingness-to-pay for pizza. It draws upon students' own stated preference data to help them build intuition about demand concepts. The approach can be extended to offer quantitative exercises for demand analysis that students can connect to themselves. The article proceeds to describe learning objectives, the process of developing a demand survey with students, how analyzing the results of past surveys met the learning objectives, and how students of undergraduate managerial economics responded to this approach.

2 Learning Objectives

The learning objectives underpinning introductory demand analysis for a private good can be divided between the individual level and the market level. At the individual level, students should learn how a consumer's willingness to pay for a good arises from both their preferences and their budget to shape that individual's demand schedule. At the market level, students should learn how individual consumer demand schedules build market demand and how movements along a demand curve differ from shifts in a demand curve.

These conceptual learning objectives can easily be connected to objectives for learning about basic quantitative demand analysis. A core learning objective at this level is how to graph market demand using a spreadsheet program. For more advanced learners, quantitative analysis objectives include how to conduct a regression analysis, how to use the resulting demand function to compute own-price elasticity of demand, and how a substitute or complement product can shift market demand. A potential learning objective for highly motivated students is to compare functional forms for fit with the data and with demand theory.

[1] Archived at https://academic.marietta.edu/people/delemeeg/expernom/.

Apart from objectives for learning outcomes, process objectives matter as well. Evidence is strong that many students learn more readily via active learning processes that communicate meaning at a personal level (Hawtrey 2007). For students in managerial business programs, the opportunity to build market research skills adds to the appeal of conducting a survey.

3 Survey Design and Data Collection

This exercise was developed in a junior-level, undergraduate class in managerial economics for students majoring in agribusiness management, food industry management, and environmental economics and management at Michigan State University. The exercise evolved over three years.

The design began when the author invited students to help design market research on student consumption of a common food. The class unanimously identified pizza as a food that all students consume. As the market research was to be conducted via a stated preference survey, the next step was to define the product traits with care, so that survey respondents would understand the hypothetical market (Champ, Boyle, and Brown 2003). Students discussed the type of pizza product, location of purchase, timing of purchase, prior consumption, and available budget.

The initial class in 2018 set a standard for future class surveys by defining the product as pepperoni pizza with mozzarella and tomato sauce, divided into slices that were eighths of a 16-inch pizza. The purchase took place at a pizzeria at 8:00 p.m. after the buyer had not eaten since noon. Prices were arranged above and below local norms, including $0.25, $0.50, $1.00, $1.50, $2.00, and $3.00 per slice. The next year's class added a substitute in consumption: peanut butter and jelly sandwiches (PBJs) at two price levels. The 2018 class identified gender as a potentially relevant consumer trait but decided that budget questions were too sensitive to include. After discussion of results, the 2019 class added gluten intolerance and vegetarianism.

In the survey, each student records the number of pizza slices that they would buy at each of the six pizza prices, while holding constant the price of PBJs, first at $0.50 and then at $2.00 each. In 2018, students completed the original, one-page paper survey form in class. Starting in 2019, the surveys were conducted online using Qualtrics software (see Supplemental Materials).

Using the survey format here requires scant added class time, though advance discussion of what to include increases student buy-in at the analysis stage. Data analysis takes about two hours of instructor time outside of class, with suggested approaches included in the Excel workbook available in the Supplemental Materials. The additional in-class teaching time needed for this survey approach is small because the alternative is typically to teach the material with artificial data examples from a textbook or from other sources.

4 Pizza Survey Results by Learning Objective

I have now conducted the pizza survey with three classes (Fall 2018, Fall 2019, and Fall 2020). The first two were the most actively involved in its design. Although survey completion is voluntary, response rates are high, in part because students received a participation point for completing the survey. Given that the survey's goal is to advance learning objectives, the results are reported and discussed by learning objective.

4.1 Individual Demand

In order to convey ideas about individual choices, it can be helpful to select instructive cases and invite students to debrief. Examples of instructive cases can be ones close to the median that represent typical behavior as well as ones near the high and low consumption extremes. As some students are shy or sensitive about discussing their choices, the author would touch base with selected students ahead of time. He would present the responses of a willing student, showing how many slices of pizza they would buy at each price. The instructor or another student would then interview the student about why they made their choices. Inviting students to tell their stories can elucidate revealing thought processes. Most classes have at least one student who is willing to buy 40 or more slices. When I asked one student how he could possibly eat that many, he replied that at a price of $0.25/slice, he would stock up for later. Lessons learned: Satiation need not limit demand if storage is possible, and consumers may stock up (but that will affect subsequent demand). In the same class, another student would buy no pizza at any price. She explained that she was gluten intolerant. Lesson learned: Price is not the only driver of demand; other factors can be powerful constraints or motivators.

Individual demand curves illustrate how preferences and budgets shape downward-sloping individual demand schedules. The curves in Figure 1 illustrate more typical choices than the extremes cited above. For example, Student 22 in 2019 preferred only to eat pizza fresh and hot, so even at low prices they would not buy more than the four slices that they could eat at one sitting. This student's behavior exemplifies the concept of diminishing marginal utility; despite falling prices, they opted not to consume more than four slices. Student 24 in the same figure would stock up on cheap pizza and eat it later. Here, the availability of storage (and maybe roommates) explain why that individual's choices seemed inconsistent with diminishing marginal utility.

4.2 Aggregate Demand

Lessons about aggregate demand can be easy extensions from the individual level. Data from selected individual students illustrates how individual demand schedules can be summed horizontally to generate aggregate demand for the group. In Figure 1, the combined curve displays the summation of the individual demands by Students 22 and 24.

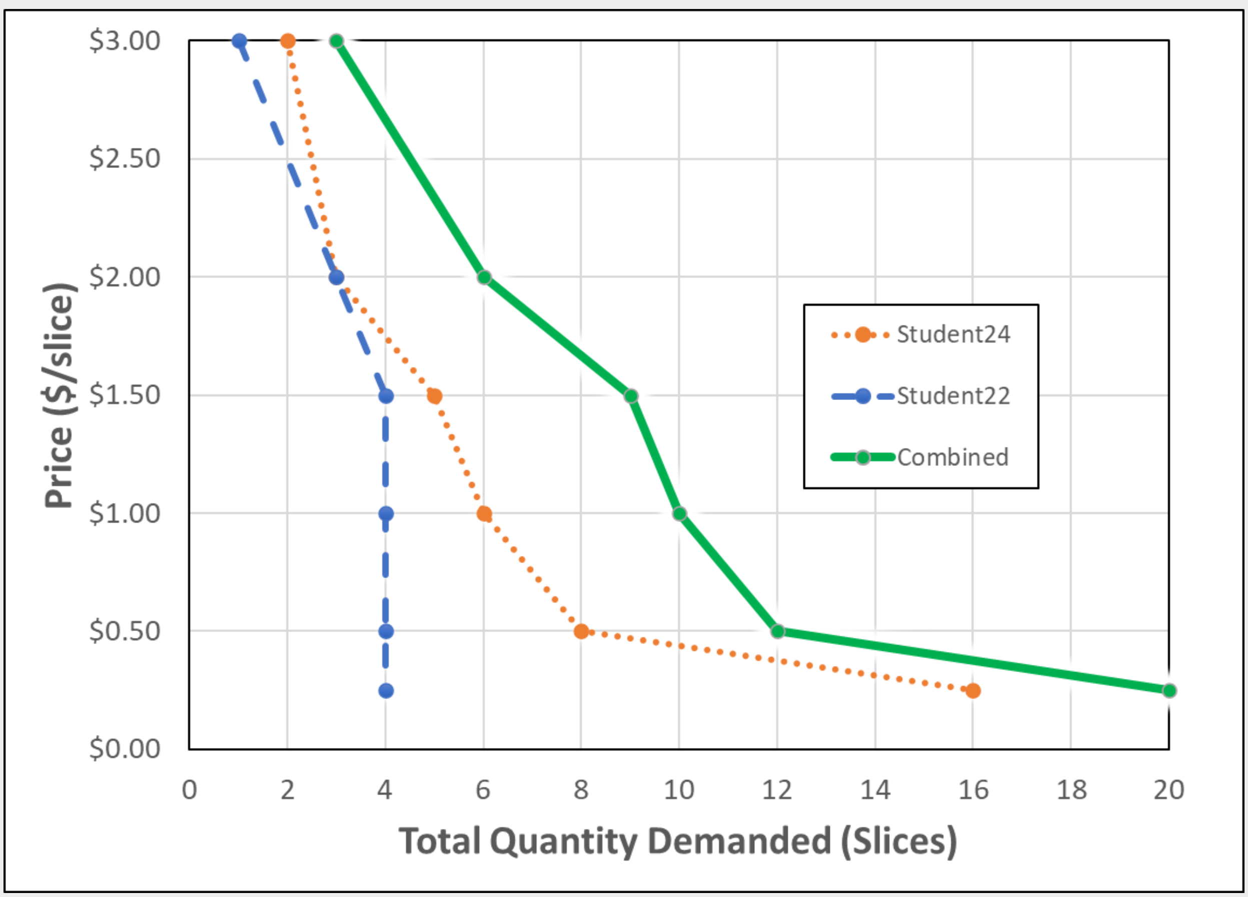

Figure 1. Individual Demand Curves of Two Students Sum Horizontally to Combined Demand (2019 Class)

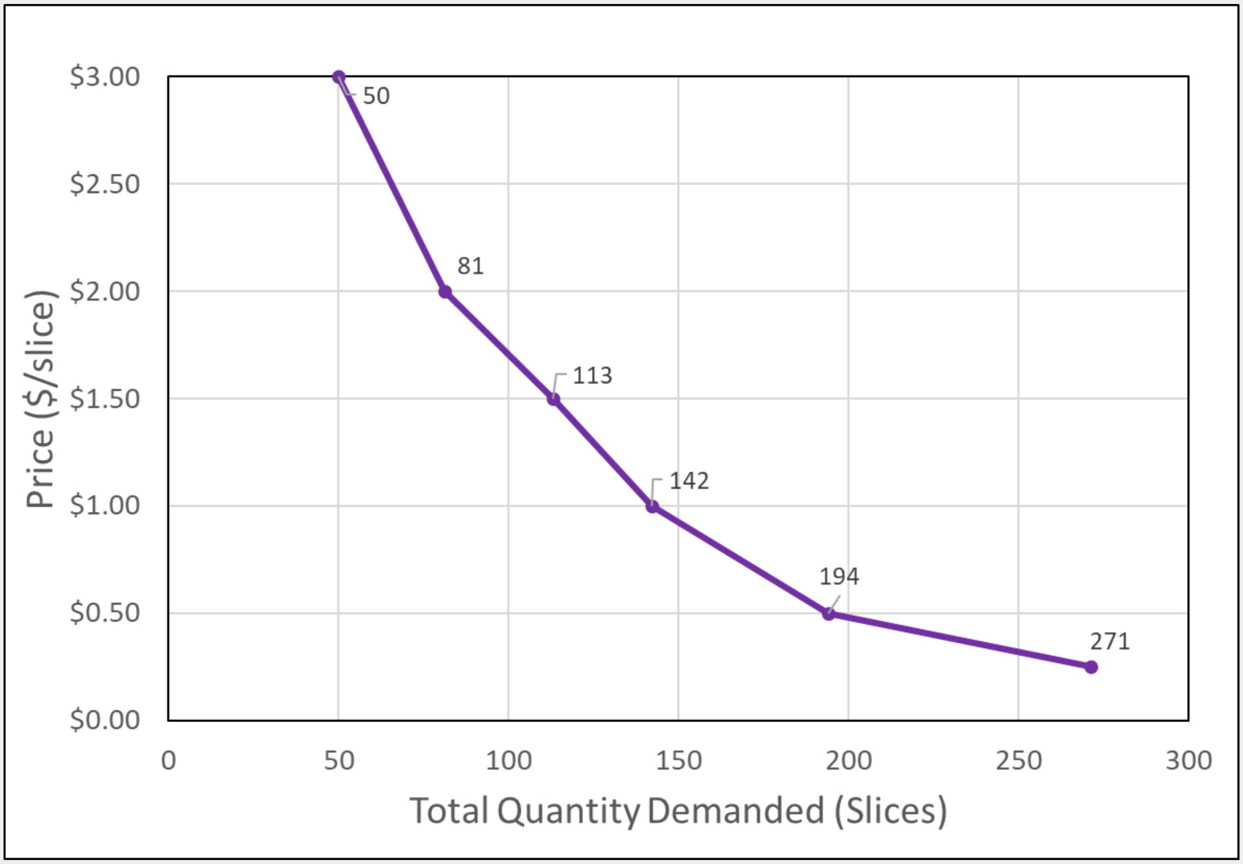

Figure 2. Aggregate Class Demand for Pepperoni Pizza at 8:00 pm if PBJ Price Is $2.00 (2019 Class)

From this two-person "market," it is an easy conceptual next step to aggregate all students in the class to define a small market. As instructor, I invite students to imagine an entrepreneur who wishes to open a pizzeria by analyzing the demand of students in the class. Summing pizza quantity demanded horizontally across the entire class while holding constant the price of PBJs as a consumption substitute generates six demand points, as shown in Figure 2. I invite students to interpret what they see. Typically, they will note that the points are not in a straight line (unlike demand curves in most undergraduate textbooks). This creates an opportunity to measure differences in arc elasticities, comparing one pair of demand points at high prices with another pair at low prices. For example, the data from Figure 2 show that the own-price arc elasticity of demand between the highest priced two points is -1.18, whereas between the two lowest priced points it is -0.50.[2] As price falls, demand becomes less elastic (setting the scene for future lessons on how firms with market power should set prices to maximize profit).

The demand curve in Figure 2 also carries a teaching opportunity about consumer surplus. Pick any particular price, say $1.00 per pizza slice, and the graph reveals the area of consumer surplus. By measuring and discussing it, students begin to grasp the notion of aggregate social welfare on the consumer side.

The important distinction between movement along the demand curve and a shift in the demand curve can be illustrated with student data on what happens to the demand for pizza in response to a change in the price of a related good. Figure 3 illustrates the leftward shift in student demand for pepperoni pizza when PBJ prices fall from $2.00 to $0.50. Students can readily see that demand changes,

[2] Arc elasticity between the two highest priced points in Figure 2 is $(\Delta Q/Q)/(\Delta P/P) = (-31/65.5)/(1/2.5)$. Between the two lowest priced points, it is $(-77/232.5)/(0.25/0.375)$.

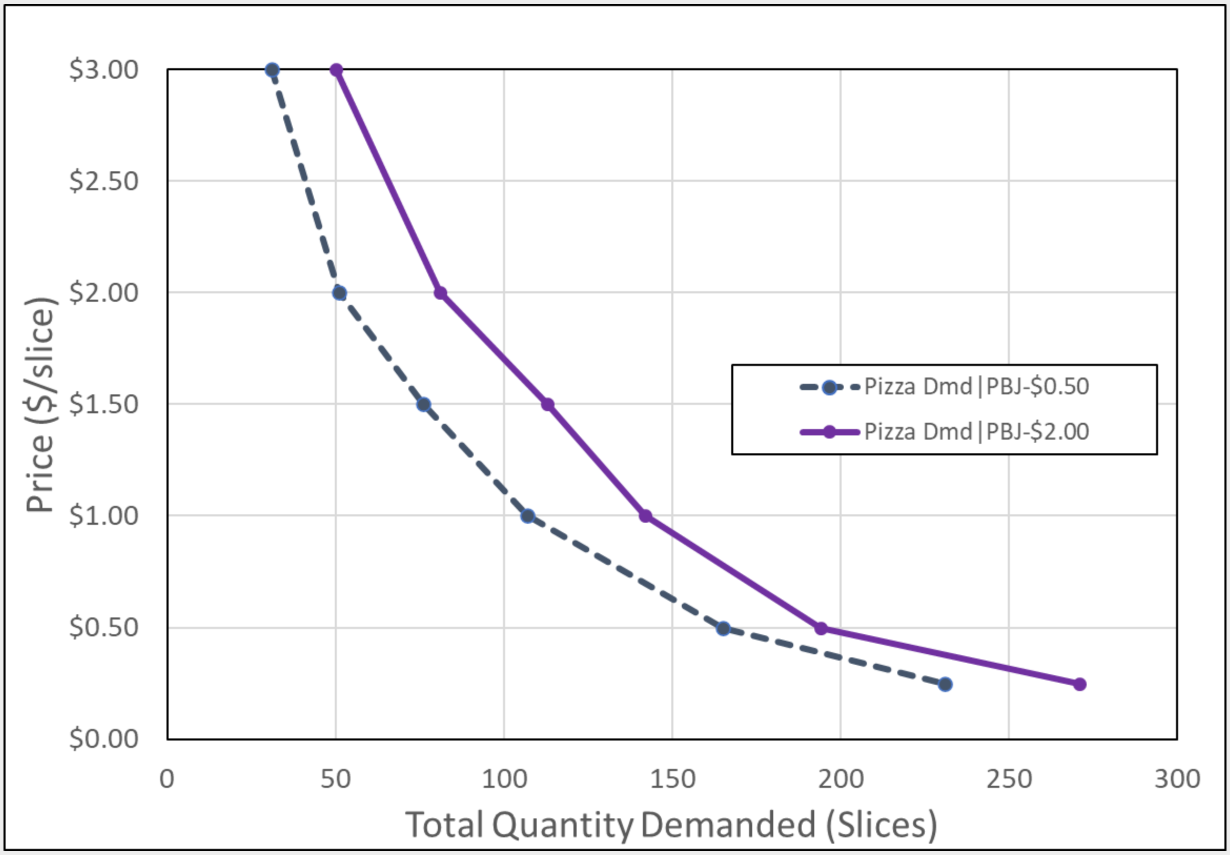

Figure 3. Aggregate Demand for Pepperoni Pizza at Two PBJ Prices (2019 Class)

even though the price of the pizza stays constant. Asked to interpret why pizza demand seems to shift out when PBJ prices rise, students will eventually hit upon the economic concept of substitutes in consumption.

4.3 Introduction to Regression Analysis

The very small size of the aggregate, class-level data set makes it easy to introduce the intuition behind regression analysis. The six demand points for pizza slices while holding the PBJ price constant facilitate discussing the shape of the demand curve. What do we expect a demand function to look like? Is it linear? Curvilinear? What kind of slope?

Many spreadsheet programs can run linear regressions. One common example is Microsoft Excel, with the (free) Data Analysis add-in. For students who are unfamiliar with regression, it can be helpful not just to demonstrate how to run a simple regression, but also to show how to calculate predicted values and to plot a fitted curve against the original data points. I typically invite students to compare linear, quadratic, and logarithmic functional forms where quantity demanded depends only on the price of pizza slices.

In three years of pizza surveys, the classroom demand curves have never been linear. Asked if the data points are randomly scattered around the fitted curves, students will note that the linear function underestimates demand at both high and low prices. That observation sets the stage for introducing curvilinear forms. Although the quadratic form sometimes fits the data over the observed range better than the logarithmic, the latter tends to fit quite well (with adjusted R^2 values of 0.91 to 0.99).

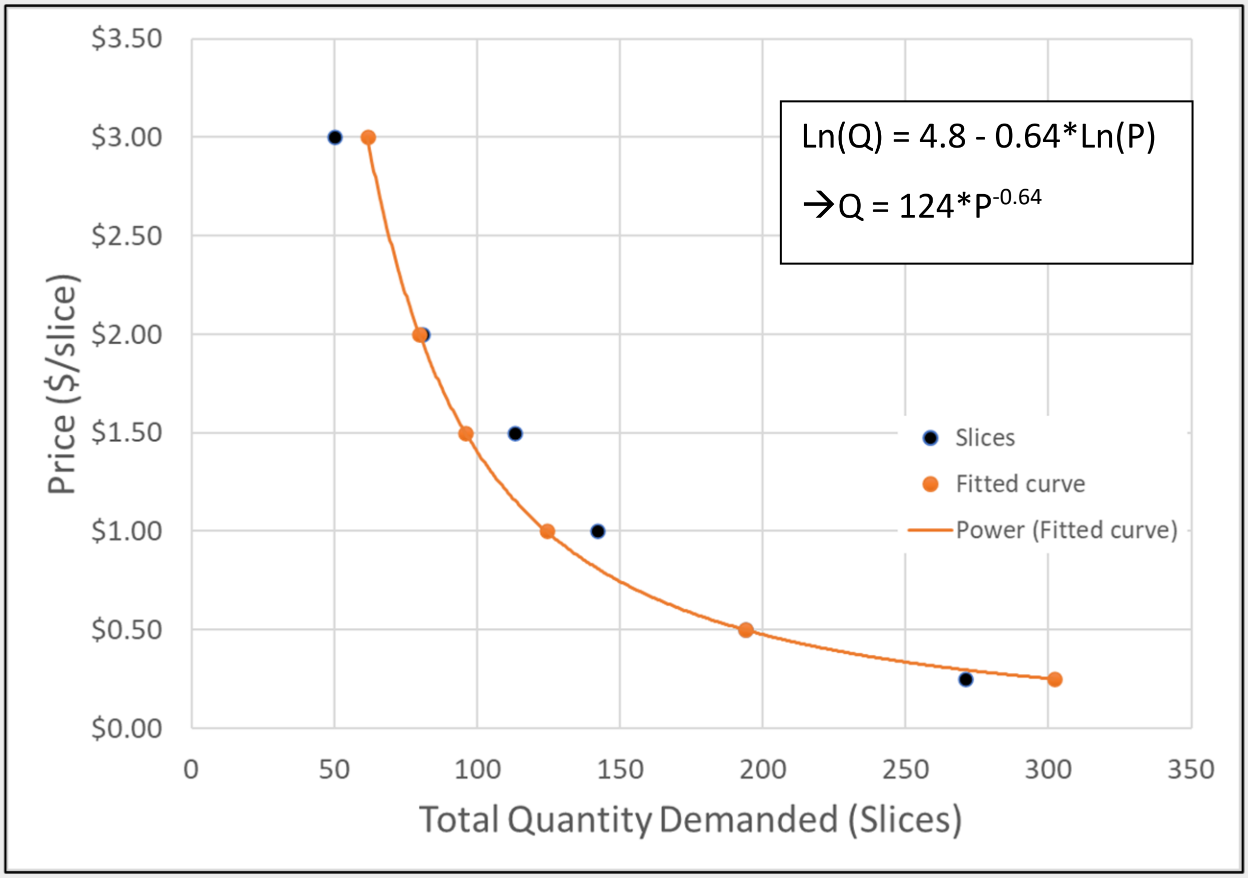

Figure 4. Fitted Logarithmic Curve of Class Aggregate Demand for Pepperoni Pizza as a Function of Own Price (Holding PBJ Price Constant at $2.00; 2019 Class)

The logarithmic form in Figure 4 enables introducing the concept of a demand function with constant elasticity. The simple, log-log demand functions have yielded own-price elasticities of demand of -0.80 (2018 class with no PBJ price) and -0.64 and -0.66 (when PBJ prices were included in the survey, but not in the regression model).

A logical extension of estimating demand only as a function of own price is to include the price of a substitute—representing the kind of data behind Figure 3. The log-log regression based on the prices of both pizza slices and PBJs from that data set (2019 class) yields an own-price elasticity of demand for pizza of -0.71 and a cross-price elasticity of pizza demand in response to PBJ price of +0.23 (both coefficient estimates with p values under 0.01). This result can support a subsequent lesson about cross-price elasticities for substitutes (positive in sign) versus complements (negative in sign). The Excel workbook in Supplemental Materials provides the data and graphs from the 2019 class survey.

5 Discussion and Conclusion

The purpose of this article is to share a teaching technique, not to provide a formal evaluation of its effectiveness. With that caveat, this instructor found it much more fun to teach these concepts by inviting students to interpret their own data. Students certainly appeared more motivated than when discussing artificial data sets.

Students were most enthusiastic in the first two years when they actively engaged in planning the surveys. Their involvement at the design stage yielded two unexpected benefits. First, it clearly motivated greater interest in the data. Second, the process of relying on consumer demand theory to inform the survey design helped students to "think like an economist" even before they interpreted results. In 2020, while teaching online due to COVID-19, I chose to save time by skipping the survey design step. With wisdom of hindsight, that decision sacrificed both an important learning opportunity and a degree of student enthusiasm.

For instructors who wish to mine student data for market research nuggets, much more is possible. Students can explore segmenting the market by gender, budget, or age. They can add questions about demand response to non-price promotions, like “buy-one-get-one-free” deals. In senior undergrad or graduate classes, students can compare demand studies based on real local pizza prices to the stated-preference survey here, perhaps discovering how much harder it is to estimate market demand when prices of related consumption goods are not held constant.

The key takeaway message is that involving students in the design, execution, data analysis, and interpretation of a commonly consumed good can greatly motivate learning about consumer demand. Pizza is the good that my students identified, but other students would identify other goods with similar advantages for learning demand concepts and how to conduct basic data collection and analysis. Whatever the product, engaging in market research is a fun, motivating, and instructive way to teach about consumer demand.

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