Applied Economics Teaching Resources

AAEA Agricultural & Applied Economics Association

Teaching and Educational Methods

Making Business Statistics Come Alive: Incorporating Field Trial Data from a Cookstove Study into the Classroom

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JEL Codes: A22, I15, O12, O13, Q56
Keywords: Classroom integration, climate change, health, poverty, randomized controlled trial, teaching statistics

Abstract
This paper describes how to incorporate data from a randomized controlled trial in rural Uganda into teaching an undergraduate business statistics course. The semester-length classroom exercise includes discussions and brainstorming sessions, which allow students to imagine how they would execute a field experiment and analyze the data. Students become familiar with one data set as they use it to supplement textbook examples of hypothesis testing, analysis of variance applications, and simple linear regression. The article discusses the background of the sustainability challenge of 2.8 billion people in the world cooking with solid fuels, the rollout and schedule of integrating field-experiment data into the classroom, and student evaluations of the exercise. The target audience is undergraduate statistics students and/or instructors interested in demonstrating how textbook statistics are used to better understand a real-world sustainability challenge.

1 Introduction

As instructors, how do we make required classes interesting for students? Can we engage students who may feel they are forced to be in a required class (as opposed to an elective they choose)? Is there a way to make statistics come alive for students who say they don't like statistics? Personally, how do I teach statistics in a way that is fun for me? As a new faculty member, these were the questions I asked myself when I was assigned to teach multiple sections of undergraduate business statistics. In this paper, I outline my attempt to answer these questions by integrating data from a development economics experiment from Uganda into the classroom.

The course I was assigned to teach is called "Statistical Decision Making" and is the second of two semester-length classes, which compose the statistics requirement for undergraduate business majors at Fordham University. The recommended textbook for these two courses is Introduction to Business Statistics by Ronald M. Weiers (Weiers 2010). Typically chapters 1–7 (topics from the visual description of data to continuous probability distributions) are covered in the first semester, and the second course covers chapters 8–16 (topics from sampling to linear regression). The majority of students taking the second-semester course are sophomores.

Because numerous sections of this class are offered every semester, there were teaching materials (including PowerPoint slides and practice questions) available within the department. As a new faculty, I did not want to alter the core of what was already being taught, but I did want to develop lectures that incorporated statistics in action with real world (nontextbook) applications. Additionally, pedagogical literature suggests that incorporating experimental design into statistics courses leads to better learning outcomes, especially as data science skills become more important to potential employers (Anderson-

Cook and Dorai-Raj 2001; Blades, Schaalje, and Christensen 2015; Hardin et al. 2015; Rossman and Chance 1999).

For these reasons, I made the reimagining of a field experiment I was a part of in Uganda a recurring part of the class. In this paper I show how—as the statistical concepts in the textbook grew more complex—I used the field experiment data as the basis of empirical examples of the statistical techniques successively presented in the textbook chapters.

2 Cookstove Experimental Problem Background

Around 40 percent of the world's population (2.8 billion people) cook on traditional cookstoves that burn solid fuels such as wood, charcoal, or animal dung (Bonjour et al. 2013). The burning of these solid fuels is associated with many sustainability challenges. For example, the smoke from these stoves kills approximately 4 million people each year (Lim et al. 2012), as well as contributes to deforestation (Bailis et al. 2015) and global warming (Bailis, Ezzati, and Kammen 2005; Bond, Venkataraman, and Masera 2004; Ramanathan and Carmichael 2008). Furthermore, the time costs of gathering fuel and the burden of diseases caused by breathing in cook fire smoke typically falls on women and children, potentially increasing existing gender inequalities (Patrick 2007; Edwards and Langpap 2012).

2.1 A Potential Solution

The safest cooking for consumers requires cleaner fuels such as gas or electricity (which is typical in most of the developed world). However, because of limited infrastructure, high costs, and related supply chain challenges (Lewis and Pattanayak 2012; Rehfuess et al. 2010), these cleaner fuels are not readily available for much of the 2.8 billion people that use solid fuels in developing countries. Therefore, one option that may be beneficial (at least until infrastructure improves) is fuel-efficient cookstoves. These cookstoves are designed to use the same types of solid fuels, but are engineered to burn more completely and create less smoke (because of an insulated burning chamber and better air flow), reducing some of the associated environmental and health risks.

2.2 An Adoption Puzzle

While fuel-efficient cookstoves may reduce the amount of fuel necessary to cook (saving the user time and/or money collecting or purchasing fuel, while reducing health risks from less smoke emissions), this does not necessarily mean that fuel-efficient cookstoves will be adopted readily by any given culture or people group. In fact, leading research about the adoption of fuel-efficient cookstoves notes that given the potential benefits of cookstoves, most regions continue to adopt fuel-efficient stoves at "puzzlingly low rates" (Mobarak et al. 2012). It is this adoption puzzle that is the focus of the field experiment that I used in the classroom to illustrate various statistical concepts as the semester progressed.

2.3 The Field Experiment

The randomized controlled trial that is the focus of the class exercise (Beltramo et al. 2015b) was executed in the Mbarara region of southwestern Uganda. In this experiment we examined two central hypotheses: (1) if low willingness to pay for a cookstove was because of low awareness of the health, economic, and time-savings benefits of fuel-efficient cookstoves and/or (2) if low willingness to pay was because of limited access to financing.

We held sales meetings in 36 different communities in Mbarara. About 60 participants came to each sales meeting. When participants arrived (the meetings were usually held on a soccer field), each participant completed a survey on their cooking practices, household socio-demographics, employment,

and other information. After the intake survey was completed, we randomly assigned participants to one of four groups corresponding to one of the four informational marketing messages: (1) health benefits of the new stove, (2) time and money savings of the new stove, (3) both of those messages combined, and (4) a control group with no informational message. Each of the four groups went to a different corner of the soccer field, and an enumerator delivered their informational message using a script and flipcharts. The control group held a discussion—led by an enumerator with flip charts—on common cooking practices while the other groups received their informational marketing messages.

Once the messages were delivered, everyone came back to a central area, and saw a demonstration of the Envirofit G3300 stove, cooking common local dishes. The manufacturer of the Envirofit reports that it reduces biomass fuel consumption by up to 60 percent versus a three stone fire, reduces smoke and harmful gasses by up to 80 percent, reduces cooking time by 50 percent, and has a product lifespan of 5 years (Envirofit Inc. 2014). We then ran two sealed second-price auctions for the Envirofit G3300. In both auctions, everyone who wanted to bid wrote his or her bid on a piece of paper and put it in an envelope. The winner of the auction won the stove but paid the price of the second highest bidder (see additional details on the auction setup in Beltramo et al. (2015b)).

The two auctions differed in the terms offered. One offered a typical "cash and carry" offer, which means that the highest bidder would pay the second-highest bid, and at the time that the payment was made, the buyer would receive the stove. The second auction required the winner to pay the second-highest bid for the stove, but that total was due over four equal weekly installments. The buyer received the stove when the first of the four payments was made. The vast majority of participants placed bids on both the "cash and carry" and the "pay over time" offers.

2.4 Results of the Field Experiment

More than 2,100 people participated in the auctions for the Envirofit stove. An overview of the results of the field experiment was that there were no statistically significant differences in average bids when comparing average bids between the four randomly assigned informational messages. This suggests that a lack of information about the time savings or health benefits of clean cooking technologies does not appear to be a barrier to willingness to pay (i.e., demand).

Interestingly, however, we found that when participants bid on the pay over time offer (four equal payments spread over four weeks), they bid an average of 40 percent higher than when they bid on the cash and carry offer (pay all at once). This appears to lead to the broader conclusion, that at least in this setting, relieving liquidity constraints is much more important than relieving informational constraints (Beltramo et al. 2015b; Levine et al. 2018). These findings have important implications for how organizations such as the Global Alliance for Clean Cookstoves allocate scarce resources to promote the adoption of fuel-efficient cookstoves and would suggest that resources should focus on financing and relieving liquidity constraints rather than informational marketing campaigns. We executed other field experiments in this Ugandan context as well, while those experiments are not the topic of this paper, readers can consult them to delve deeper into the topic of cookstoves, the local background, and/or the results (Beltramo et al. 2015a; Beltramo et al. 2019; Harrell et al. 2016; Simons et al. 2014; Simons et al. 2017). Next, I describe how I integrated the field experiment examining how informational marketing messages affected willingness to pay into the classroom.

3 Classroom Integration

In the "Statistical Decision Making" course, we cover chapters 8–16 of Weiers (2010). The main topics for the semester are sampling distributions and estimation, hypothesis testing, and an introduction to linear regression. The reimagining of the cookstove field experiment fits nicely into these broad topics, as

designing the field experiment allows students to recreate a real-life sampling exercise. It also provides real-world data to do many different hypothesis tests, and the underlying data set can also be used when introducing simple regression analysis.

3.1 Overview of the Semester Plan

To create the setting to challenge students to develop policies for fuel-efficient cookstove demand, I first conduct a large brainstorming exercise. The two key questions for the brainstorming exercise were: "What are the biggest problems facing the world today?" and "Why do we study statistics?" This is a fun and engaging exercise as we write all of the students' suggestions on the board. Once 15–20 ideas are up on the board, I group the items and narrow the discussion toward poverty, health, and climate change–related issues. This follows with an open-ended discussion as to why we study statistics. My intention in discussing both of these questions as part of the same conversation is for students to begin to grapple with the larger question of how do we know what we say we know, and can statistics help us be more confident in what we know?

Next, I present the following scenario to the classroom. The Global Alliance for Cookstoves, which has the ambitious 10-year goal to foster the adoption of clean cookstoves and fuels in 100 million households, approaches our class and asks for help with the following:

- What is the best way to create demand for fuel-efficient cookstoves?
- How can we know that we have created demand?
- Design a program and data collection plan that will give us evidence to answer these questions.

Once these questions are posed to the class, we break into small groups to discuss/brainstorm further. Each group comes up with their best ideas and then I write each of those ideas up on the board.

Generally some group recommends some type of informational marketing lessons to teach about the benefits of the stoves and/or a group recommends some type of financing to make the stoves more affordable. Building upon the student recommendations, I describe what we did in the field (laid out in Beltramo et al. (2015b) and the supplementary teaching notes).

At this point, I illustrate the mechanism of the second-price auction. I bring freshly baked brownies to the classroom and auction them off using the same sealed second-price auction mechanism that we used in the field. By doing this I show students that the researcher can map out the entire demand curve based on all the bids that were submitted while only selling one cookstove (or set of brownies).

Next, I detail how I used the cookstove auction data collected in Uganda to give students the opportunity to practice the statistical techniques learned in the course (e.g., t-test vs. population means, t-tests with two sample means, hypothesis tests with two samples, ANOVA tests with more than two samples, etc.). The data I used in the classroom is provided in the supplementary teaching materials (described in detail in the next section). Additionally, data and code has been deposited online with other related publications (e.g., Beltramo et al. 2015b; Simons et al. 2018).

3.2 Semester Schedule

Detailed teaching notes and sample PowerPoint slides are provided in the supplementary materials, which outline how the cookstove experiment is integrated into the course. See Table 1, for a summary of how the topics of the chapters in Weiers (2010) and the topics illustrated with the cookstove data line up.

Table 1. Integration of Cookstove Study by Topic

Ch.[a]	Topic	Integrating the Cookstove Study	Supplementary materials provided
---	Introduction	Large brainstorming exercise asking "What are the most important problems facing the world today?" and "Why do we study statistics?"	None—chalkboard-based classroom discussion
8	Sampling Distributions	Show YouTube video from the Global Alliance for Cookstoves (GACC). Introduce the premise of the field experiment—the GACC has approached our classroom and asked us to design a study to answer: (1) What is the best way to create demand for fuel-efficient cookstoves? and (2) How can we know that we have created demand?	Stove Preliminary Setup Slides.pptx
9	Estimation from Sample Data	Describe the field experiment from Beltramo et al. (2015b). In the experiment, we tested four informational marketing messages: (1) good for your health, (2) saves time and money, (3) both messages combined, (4) no message (control group) to see if lack of information was a barrier to willingness to pay for a cookstove. We also tested financial constraints, by allowing participants to bid both on cash and carry offer (get stove at the same time you pay full amount) and a pay over four weeks offer (get stove with first payment, then additional three installment payments one week apart). In class, we do a sealed second-price auction for some homemade baked goods; this allows the students to go through the same bidding procedure as the participants in the field experiment.	Experimental Rollout.pptx
10	Hypothesis Tests with Sample Mean or Proportion	How representative is the sample of 2,100+ respondents that was gathered in rural Uganda? I found population level information about Uganda (from World Bank, Uganda Communications Commission, Uganda Bureau of Statistics) on self-employment, cell phone ownership, age of household head, and household size. Then we use hypothesis tests to compare the sample means from the Uganda cookstove data with these population figures.	Hypothesis Tests—sample vs population.pptx

Table 1. Continued

Ch.[a]	Topic	Integrating the Cookstove Study	Supplementary materials provided
11	Hypothesis Tests with Two Sample Means or Proportions	Now we can answer one of the main questions we designed the experiment to answer, is there a difference in mean bids between the control group, which did not receive any information, and the mean bid for the group that received information on the health benefits of the stoves? Students choose the appropriate test and then calculate the appropriate z or t statistic to test that hypothesis. They can do hypothesis tests with any two of the four informational marketing treatments. However, they do not yet know how to compare all four at the same time.	Hypothesis Tests—two samples.pptx
12	Analysis of Variance Tests	Once we have learned ANOVA, we can compare the mean bid of all four informational marketing messages. Students create the hypothesis, calculate the F-test statistic associated with the ANOVA analysis, and use it to decide whether the average bids were statistically significantly different between informational marketing messages or not.	ANOVA—means of four samples.pptx
13	Chi-Square Applications	I did not use the cookstove data for a chi-square example, though data is provided so an instructor could create a topical example if desired.	None
14	Nonparametric Methods	I did not use the cookstove data for a nonparametric methods example, though data is provided so an instructor could create a topical example if desired.	None
15	Simple Linear Regression and Correlation	In the ANOVA chapter, we examined the difference of the mean bid between the four informational marketing messages. Next, we analyze if there is a different average bid for those who bid on the pay now versus the pay over time offer. To do this, I show the students how we could model this with a hypothesis test (like in Ch. 11), or we could show it with a basic regression setup. After we have introduced the concept of a basic regression (Ch. 15), we run a simple linear regression to see the difference between the average bid of pay now versus pay over time bids.	Regression—difference in payment offers.pptx
16	Multiple Regression and Correlation	Show students that we can add variables to the right hand side of the regression (move from simple linear regression to multiple linear regression). In this way, we can answer questions like what is the difference in average bids between the two payment offers while controlling for age, gender, and/or family size. I also have additional slides prepared to wrap up various questions students may have raised over the semester regarding cookstove adoption and use (based on Beltramo et al. 2015b; Beltramo et al. 2019; Levine et al. 2018; and Simons et al. 2017).	Conclusion—stove adoption and use.pptx

[a] Chapters are out of the textbook by Weiers (2010).

3.3 Student Responses

In general, students enjoy the experience of going through the cookstove study throughout the semester. The majority of students say they like the integration in that it brings real data into a course that often just uses textbook examples. Some meaningful student quotes about the course and integrating the cookstove study include:

> *I just wanted to reach out and say thank you for a great semester! You made stats more than just bearable . . . you made it fun! I am someone who dreads math but got lucky having you as a professor. I appreciated your real world material as it made the content more meaningful. I am an individual who always wants to make a positive impact, so I was happy to see that even in fields like statistics, you can change the world.* —Sophomore

> *I transferred to Fordham exactly for courses like this that combine social justice initiatives with academia. As evident by my grade, I hate numbers. However, I hope for a career that will help change the world, and you showed me that data and stats are essential to this mission.* —Junior

> *To me, being able to learn about a chapter, then look at a formula and map out how you used this specific formula while you performed your studies made the class much more interesting. This was not only good review for the class, but it also showed that the information we were going over was very powerful and can make a serious impact on the lives of millions of people throughout the world. For the majority of classes I've had at Fordham, one of the biggest drawbacks for me is the inability to relate the material to something that I know will be useful once I graduate. However, you were able to present the material in a way that proved what we were learning is useful and is actually used when analyzing data after performing experiments.* —Sophomore

> *Cookstoves made my least favorite subject a highly tolerable subject.* —Sophomore

Although these comments from students are encouraging, not all students were completely on board with the exercise. Some student comments were critical about the exercise. The most common critical comment was that students felt the example dragged on too long (i.e., the whole semester) or was not applicable to their immediate experience.

> *Would like more interesting/applicable problems. Slightly redundant slides/examples.* —Sophomore

Additionally, it seemed most students were interested in the topic, but some wanted to know the results of the experiment immediately as opposed to the schedule where little by little was revealed as we covered additional topics in the textbook.

3.4 Discussion

In response to these critiques, I began to group and condense the cookstove material. I have taught this cookstove integration in ten sections of this course, and the first couple of times I taught it, I tried to mention the cookstove example (even very briefly) in every class meeting. I have since pooled the cookstove material with the plan of discussing it more in depth when I discuss it, but only once per chapter (once every two to three class periods as opposed to every class meeting). Although this still does not solve the issue if a student simply does not find the example interesting or compelling, it does make the material feel less disjointed. When students say they want to know the results of the field experiment immediately, I generally pivot the discussion saying that the experience of research is slow and that we will uncover the results as we learn additional statistical techniques to do so.

3.5 Extensions

At the end of the semester, I like to take a full class session to review what we learned through the integration of the cookstove experiment into the course. When doing this, students generally ask many questions that fall outside of the scope of the informational marketing experiment described in Beltramo et al. (2015b). Some of those questions usually are: We saw in the cookstove examples that informational marketing was not effective in increasing demand, but that an offer to pay over time was effective. Was there anything else you found to be effective to raise demand for the cookstoves? Do people use the new cookstoves once they receive them? Did the donors appreciate your study? How did they use the information you created? and other questions. To address these questions, I describe the related studies that we performed in Uganda on creating demand for cookstoves and how stoves are used over time by the households (Beltramo et al. 2015a; Beltramo et al. 2019; Levine et al. 2018; Simons et al. 2017).

This also allows for a discussion of the history of cookstove programs more broadly in the developing world. The progress of these programs has been uneven (Barnes et al. 1994; Gill 1987; Maes and Verbist 2012; Smith et al. 1993), with critiques suggesting that programs failed because of a lack of linking the cooking technology with the explicit needs of the cooks that use the devices. Framing an in-class discussion with this historical context of mixed success can be the basis of an in-depth discussion on cookstoves and the challenge of sustainability topics more generally.

If time allows, another valuable discussion is around the interpretation of a negative statistical finding. For example, in the data used in the classroom exercise, there was no statistically significant difference between bids across the four informational marketing messages. How should researchers interpret this? Does this mean that participants already knew the benefits of fuel-efficient cookstoves? Does it mean that many of them were not fully convinced of the benefits outlined in the marketing messages? Were their interests in cookstoves generally low and their bids did not properly reflect their true valuation? Was the sample large enough to provide statistical power? In the context of the hypothesis tests developed, are negative findings equivalent to no result? A broader discussion incorporating these questions gives the instructor an opportunity to demonstrate how to carefully assess the meaning of negative and null findings.

4 Conclusion

In this paper and the supplementary teaching materials, I describe how to integrate a development economics field experiment about an important sustainability issue into the ongoing structure of an undergraduate business statistics course. I found that doing this made the course more fun to teach for me, and more engaging for the students as well. Part of this was likely because this was a research topic I am passionate about. However, another part was that the field data collected fit very nicely into the typical structure of a statistics course where the topics get incrementally more complex as the course progresses. This allowed students to become familiar with one data set and to focus their mental energy

on the statistical concepts as opposed to using that energy to learn a different data set as progressively more complex statistical techniques were introduced. Last, this exercise allowed students to grapple with the challenges of experimental design and see how statistics were used to better understand a real-world sustainability challenge.

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Acknowledgement: I thank Theresa Beltramo, Garrick Blalock, Stephen Harrell, and David Levine as collaborators on the cookstove study in Uganda. Furthermore, I thank the Center for Integrated Research and Community Development (CIRCODU) who executed the data collection in Uganda. The success of the project depended greatly on its managers—Joseph Arinieitwe Ndemere, Juliet Kyaesimira, Vastinah Kemigisha—and field supervisors—Innocent Byaruhanga, Fred Isabirye, Michael Mukembo, Moreen Akankunda, and Noah Kirabo. Last, thank you to Linda Dennis, two anonymous reviewers, and the editor for many useful comments on the manuscript. Material in the manuscript has been reviewed and approved for human subjects by the Committee and Office for the Protection of Human Subjects at UC-Berkley (Protocol # 2010-06-1665).

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