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Using the Becker-DeGroot-Marschak Mechanism to Teach Willingness to Pay and Consumer Surplus

The Becker DeGroot Marschak (BDM) mechanism is a widely-used technique to elicit subjects' willingness to pay for ordinary consumer and environmental goods. In this article, I show an application of the BDM mechanism to teach the concepts of willingness to pay and consumer surplus in introductory economics classes. The procedure is easy to implement, even in courses with large enrollments, and it actively engages all students. Evidence suggests this technique improves learning outcomes.

Jens Schubert †

†University of Delaware

1. Introduction

Bringing economic concepts to life in large-enrollment introductory courses is an ongoing challenge for instructors. The traditional chalk-and-talk lecture format is currently the preferred method of instruction in introductory economics courses (Asarta, Chambers, & Harter, 2021), but instructors need to adopt more innovative pedagogical strategies that engage students (Picault, 2019). Effective pedagogy not only identifies and communicates clear learning goals, but also helps students "achieve these goals through activities that promote active, engaged learning" (Barkley & Major, 2016). In-class experiments are one way to actively involve students in their learning. Emerson and English (2016) find that classroom experiments yield positive learning gains. In addition, providing monetary incentives for classroom experiments can increase student learning outcomes (Rousu et al., 2015). Nonetheless, many classroom experiments either engage only a small subset of the students, or their implementation is too challenging in large-enrollment courses.

A pit market is a common in-class activity to engage students in the topics of demand and supply and consumer and producer surplus.[1] The activity works well in classes of up to 50 students. However, in large classes (100+ students), most students become passive observers rather than active participants. Further, a pit market is much harder to implement in large classes; the logistics and preparatory work required can deter instructors from adopting it. An alternative burgeoning practice is using media to teach economics principles, which engages students by providing relevant content (Picault, 2019). For example, Geerling, Mateer, O'Roark, & Sackett (2018) use a scene from the movie *Bourne Identity* to highlight the concepts of consumer and producer surplus. Using media and popular culture work well to emphasize economic concepts by relating them to students' day-to-day lives, and can be easily implemented in large courses. However, it remains a challenge for large-section instructors to move all enrolled students (not just a subset) from being passive observers of media to being active participants during class. The interactive learning activity described in this article bridges this gap.

This classroom activity employs the Becker DeGroot Marschak mechanism (Becker, DeGroot, & Marschak, 1964) to teach the concepts of willingness to pay and consumer surplus. In the activity, the instructor sells a $10-bill to students, and all students become potential buyers. First, students assess their value for the $10-bill; then the instructor elicits students' values using the incentive-compatible BDM mechanism. Next, the instructor determines the random buying price, students calculate their potential earnings, and the instructor selects some students at random for payment. By using an in-class response system (e.g. Learning Catalytics, Poll Everywhere, Socrative), the instructor can assess student learning in real-time. The activity is easy to implement and engages all students, even in courses with large enrollments. I conducted the activity with 250 students in one of my sections of Introduction to Microeconomics. The activity significantly increased learning compared to a section without the activity, students noted that the activity brought the underlying concepts to life in a post-activity survey, and the students reportedly felt that they gained a better understanding of the material.

The article proceeds as follows. First, I describe the interactive learning activity in the form of an implementation guide for instructors. Then, I summarize my findings from a recent semester. The last section concludes.

[1]Bergstrom & Miller (2000) describe how to implement a pit market activity, and Dickie (2006) presents an example of a pit market to teach demand, supply, and market equilibrium.

2. Procedures

This in-class activity uses the BDM mechanism to elicit students' values for a $10-bill. The exercise demonstrates the concepts of willingness to pay and consumer surplus. By the end of the activity, students will be able to: (1) differentiate between willingness to pay and price, (2) calculate consumer surplus, and (3) understand the BDM mechanism for valuation of a good. The activity takes between 30 to 45 minutes, depending on the level of post-activity discussion and debrief. The instructor needs a $10-bill and some smaller denomination money (fives, one-dollar bills, and coin change). There are several advantages to using a $10-bill instead of an ordinary consumption object (such as a university-branded mug). First and most importantly, a $10-bill has a homogeneous and unambiguous value across all student participants, which allows the instructor to: (i) evaluate whether students submit the correct bid, (ii) evaluate whether students calculate consumer surplus correctly, and (iii) easily determine the appropriate bid range: between $0 and $10. (With an ordinary consumption item, students will have heterogeneous homegrown values for the item, which makes it impossible for the instructor to assess whether they are bidding their true value and whether they are calculating their consumer surplus correctly. Additionally, setting the appropriate bid range can be challenging with homegrown values, potentially introducing other confounds such as anchoring and likelihood calculations of successful bidding.) Second, students do not need any money to participate in the activity – the instructor can simply pay them the difference between $10 and the random price. Once students have learned the mechanism and understand how to determine willingness-to-pay and consumer surplus, the instructor could then introduce a second activity with an ordinary consumption good.

To draw the random price for the BDM, the instructor may prefer a physical random price generator such as a bingo cage with balls numbered zero through 10 for the dollar amount, and zero, 25, 50, and 75 for the cent amount of the random price. The activity consists of the following main steps:

1) Define consumer surplus.
2) Offer a $10-bill for sale.
3) Introduce the BDM mechanism including a check-for-understanding quiz.
4) Elicit values for the $10-bill.
5) Calculate earnings and randomly select students for actual payout.
6) Debrief and assess learning.

<u>Define Consumer Surplus</u>

Start the lesson by defining consumer surplus.
Definition. Consumer surplus (*CS*) is the difference between the highest price a consumer is willing to pay (*WTP*) for a good or service, and the actual price (*P*) the consumer pays.

<u>Offer a $10-Bill</u>

Show students a $10-bill and ask them: *How much are you willing to pay for a $10-bill?* Provide students with a general overview of the activity: *Today, you have the chance to buy a $10-bill from me. I will ask you how much you are willing and able to pay for a $10-bill. Then, I will draw a price at random between $0 and $10. If the random price, P, is less than what you stated you are willing to pay, you get the $10-bill and you pay me the random price, P. For convenience, I will pay you ($10 - P), which will be your earnings. Thus, you do not actually need any cash to participate. I will choose some of you at random for payment.*

Explain the BDM Mechanism

The BDM mechanism is equivalent to a second-price auction against a random bidder. Thus, the optimal strategy is for students to bid their true value for the $10-bill. (The BDM mechanism, like a second-price auction, is demand-revealing; bidding one's true value is the weakly dominant strategy.) Nonetheless, the mechanism is not trivial and subjects in laboratory and field experiments do not always bid optimally (see for example Bohm, Linden, & Sonnegard, 1997; Noussair, Robin, & Ruffieux, 2004; Rutström, 1998). Students therefore require training to familiarize themselves with the mechanism to arrive at their optimal bid for the $10-bill. Plott & Zeiler (2005) show that with robust experimental procedures, differences between willingness to pay and willingness to accept for ordinary goods of known value disappear. The procedures described here follow the Plott & Zeiler (2005) methods: explanation of the optimal strategy, practice, and incentive-compatible value elicitation.

Instructions

Your task is to submit a bid to buy a $10-bill.
If your bid (WTP) is accepted, you get $10 and you pay the random buying price. To make things easy, I will simply pay you $10 less the random buying price. Using a bingo cage, I will draw the buying price from a range of $0 to $10 in $0.25 increments.

- *If your bid is greater than or the same as the random price (WTP ≥ P), then you buy the $10-bill and you pay the random price; your earnings will equal $10 less the random buying price, ($10 - P).*
- *If your bid is less than the random price (WTP < P), then you do not buy the $10-bill; your earnings will equal $0.*

Your best strategy is to bid your true value for the $10-bill! If you do bid your true value, there is no downside risk for you in this activity. The worst that can happen is that you earn $0, when either (1) you do not buy the $10-bill (WTP < P), or (2) when the random buying price equals your bid (WTP = P). In either case, you will be just as well off as before. For example, if you bid $10 and the random buying price comes out as $10, you buy the $10-bill for $10. (You pay me nothing and I pay you nothing.)

However, there are many possibilities for you to earn money in this activity. For example, if you bid $10 and the random price is $0, you buy the $10-bill for $0 - and you earn the difference, $10! For any random price less than your bid, you earn money. Since the buying price is completely random, to maximize your chance of earning money, simply bid your true value for the $10-bill.

How do you determine your bid? Start with the minimum possible price ($0) and ask yourself: "Do I want to buy the $10-bill for $0?" (If you do, your earnings would be $10 – $0 = $10). Then, increase your bid: "Do I want to buy the $10-bill for a price of $0.25?" (If you do, your earnings would be $10 – $0.25 = $9.75). You will eventually reach a price at which you are just as well off as not buying the $10-bill. Alternatively, you can start with the maximum possible price ($10) and ask yourself: "Do I want to buy a $10-bill for $10?" (If you do, your earnings would be $10 – $10 = $0). Then, work your way down: "Do I want to buy for a price of $9.75?" and so on. It is your best strategy to bid a price at which you feel just as well off buying the $10-bill as not buying it.

Understanding Quiz

Assess your students' comprehension of the random buying price procedure by asking several understanding questions. For best practice, the instructor should use the same in-class

response system (e.g. Learning Catalytics, Poll Everywhere, Socrative) that is used for regular in-class participation. To incentivize students to carefully think about the BDM mechanism, participation credit should be tied to correct answers.[2] The following four questions are designed to help students understand the BDM procedures and why bidding their true value is the optimal strategy to maximize earnings. (An asterisk denotes the correct answer. The bids and buying prices are examples that can be varied.) The instructor should ask one question at a time and discuss the correct answer before moving on to the next question.

1. *A student bids $4.50; the random buying price is $5.50. Will the student buy the $10-bill?*
   a. *Yes, the student will buy the $10-bill and pay $4.50.*
   b. *Yes, the student will buy the $10-bill and pay $5.50.*
   c. *No, the student will not buy the $10-bill because her bid of $4.50 is less than the random buying price of $5.50.**
2. *A student bids $4.50; the random buying price is $5.50, which is greater than the student's bid. Thus, the student does not buy the $10-bill for $5.50. If the student had bid more than $5.50, then _____*
   a. *the student would have bought the $10-bill and paid $5.50 for it.**
   b. *the student would not have bought the $10-bill and thus paid nothing for it.*
   c. *the student would have bought the $10-bill and paid more than $5.50 for it.*
3. *A student bids $10; the random buying price is $5.50. The student _____*
   a. *will buy the $10-bill and pay $10 for it.*
   b. *will buy the $10-bill and pay $5.50 for it.**
   c. *will not buy the $10-bill.*
4. *A student bids $10; the random buying price is $5.50. The student buys the $10-bill for $5.50. How much does the student earn? [Enter your answer in dollars, rounded to the nearest cent.] $4.50**

The majority of students should answer these questions correctly before moving on to the practice round. The instructor might want to prepare a second version of questions one through four, just in case. (The appendix contains a second version of the Understanding Quiz with alternate questions.)

Random Price Draw

To determine the random price, the instructor could use a bingo cage so students can visualize the randomness of the price selection. (The bingo cage also adds to students' excitement about the outcome of the price draw. A bingo set with cage can be purchased from various retailers, such as Amazon, Target or Walmart, for about $30.) Place the bingo cage on the document camera or projector so that students can see the draw. Determine the price in two draws. The first draw determines the dollar amount; the second draw determines the cent amount. First, load the bingo cage with balls numbered zero through 10. Spin the cage and draw a ball - show the ball to the students and announce the dollar amount. If the drawn ball is the number 10 ball, the random price procedure concludes. If the drawn ball is a number smaller than 10, load the bingo cage with balls numbered zero, 25, 50 and 75. Spin the cage and draw a ball. Again, show the ball to students and announce the cent amount. (Alternatively, the instructor could draw the cent amount in 10-cent increments, using bingo balls numbered zero through nine, with the zero-ball representing zero cents, the one-ball ten cents, and so on. This method would only require one set of balls.)

[2] In my class, I used the regular in-class response system for the BDM experiment. For each question, I assigned one participation point for answering and one participation point for answering correctly.

Elicit Values

Before conducting the decision that counts, conduct one or two practice rounds to clarify any remaining misconceptions. Begin by announcing the practice round.

Practice

How much are you willing to pay for a $10-bill? [Enter your answer in dollars, rounded to the nearest cent.]

Using the response system, collect all students' practice bids. Then, draw the random buying price for practice. Note that some students will have submitted a practice bid lower than $10. Use the practice buying price to reiterate the optimal strategy and why bidding below the value is not optimal. For example, if the practice random price is $4.25, stress that all students who bid more than $4.25 would have bought the $10-bill at the random price of $4.25, and thus would have earned $5.75. Emphasize that by bidding less than $4.25, students forego the earnings of $5.75. Again, ask your students: *What is a $10-bill worth to you?* Some of your students will yell out "10 dollars" at this point of the activity. Reiterate that by bidding their true value for the $10-bill, they not only ensure that they do not overpay for the $10-bill, but also secure any potential earnings if the random price is less than their true value. Answer any remaining questions about the pricing mechanism.

Binding Decision

Announce the binding round. Conduct the binding value elicitation for the $10-bill using the response system.
How much are you willing to pay for a $10-bill? [Enter your answer in dollars, rounded to the nearest cent.]

Collect all students' bids for the $10-bill. Draw the random buying price. By now, students are bustling with excitement, especially if the drawn random price is low.

Calculate Earnings and Payout

Next, let your students calculate their earnings. First, students need to determine whether they purchased the $10-bill or not. If they submitted a bid greater than the random price, then they purchase the $10-bill and pay the random price, *P*. Ask students to calculate their earnings (*CS*) as follows:

$$CS = \begin{cases} \$10 - P, & P \leq WTP \\ \$0, & P > WTP \end{cases}$$

Then, randomly select one (or multiple) student(s) for actual payout.[3] Verify the selected students' earnings calculations and pay them their earnings.

Debrief and Assess Learning

Students who bid less than the random buying price are genuinely frustrated with

[3] I randomly selected two students for payout in my large lecture of 250 students. In large classes, the instructor may want to prepare the class roster in an Excel workbook and use the *rand()* function to draw students randomly for payout.

themselves when they realize that bidding the value of the $10-bill would have resulted in significant earnings. Give your students the opportunity to reflect on the activity by answering a short, open-ended question in the response system: *What was your thought process when you decided how much to bid for the $10-bill?*

Next, complete the lesson by showing students how to calculate consumer surplus when given consumers' willingness to pay for a good. For example, you can show a table with three consumers' willingness to pay for a glass of lemonade (e.g. Emily's *WTP = $1.50*, Ethan's *WTP = $1.25*, Elijah's *WTP = $1.00*). Ask your students: *What do we need to calculate the consumer surplus in the market for lemonade?* Students will answer that they need the price of a glass of lemonade. State a price (e.g. *P = $1.10*). Using your response system, ask your students to calculate the consumer surplus for one (or more) of the consumers in the table (e.g. *If the price of a glass of lemonade is $1.10, what is Emily's consumer surplus?*

3. Findings

I conducted the activity in one of my large-enrollment, in-person sections of Introduction to Microeconomics in 2021. A total of 238 students completed the activity. Students in the course represent a variety of different majors, with about three-fourths of the students pursuing a business degree. (About 90 percent of the students are freshmen.) Following the procedures described above, I implemented the $10-bill activity before exposing students to worked examples of consumer surplus or any lecture material related to the concept.

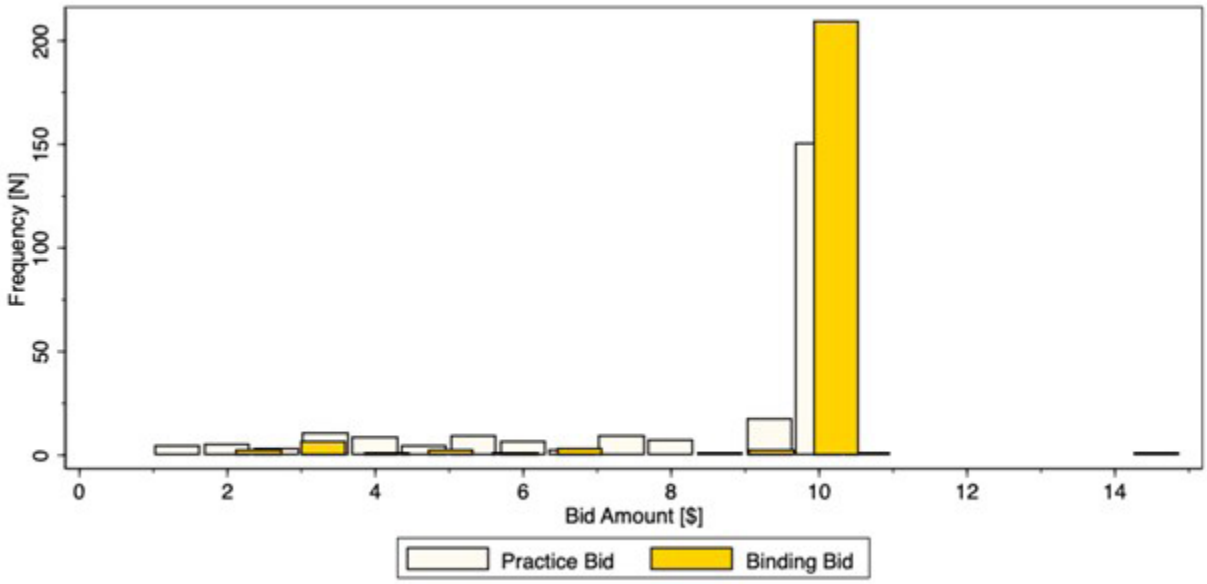
Table 1: Summary Statistics of Check-for-Understanding Quiz

	Question 1	Question 2	Question 3	Question 4
Did Not Answer	11 (4.62%)	3 (1.26%)	-	1 (0.42%)
Answered Incorrectly	22 (9.24%)	43 (18.07%)	6 (2.52%)	3 (1.26%)
Answered Correctly	205 (86.13%)	192 (80.67%)	232 (97.48%)	234 (98.32%)

Table 1 shows the summary statistics for the Understanding Quiz (see instructions above). On all four understanding questions, at least 80% of the students answered correctly. I asked one question at a time, and I explained the correct answer before asking the next question. Thus, the correctness rate increased as more students caught on. Figure 1 shows the distribution of the practice bids and the binding bids. During the practice round, 153 students (64.29%) bid the optimal amount. During the binding round, 221 students (92.86%) bid optimally. I selected two students at random for payment.[4]

[4] The random buying price was $6.00. The two students selected at random both bid higher than $6 and thus earned $4 each.

Figure 1: Frequency of Practice Bids and Binding Bids.



Next, I assessed learning by asking a concept check question (the "*If the price of a glass of lemonade is $1.10, what is Emily's consumer surplus?*" question from above). Two-hundred-twenty-two students (93.28%) correctly calculated the consumer surplus.

In a different section of the same course (also with about 250 students), I presented the lecture material and worked through examples, but I did not conduct the $10-bill activity. I then asked the identical concept check question as above. Using the $10-bill activity, student learning outcomes improved by 9.34% (2.87% standard error), on average, compared to student learning outcomes in the standard lecture (see Table 2). The difference in the correct answer rate is statistically significant at the one percent significance level (Wilcoxon rank-sum test, $z=3.23$, $p<0.01$). This result shows that student learning outcomes improve significantly with the interactive $10-bill activity compared to traditional methods.

Table 2: Correctness Rate for Consumer Surplus Concept Check Question, by Type of Lecture

	Standard Lecture	$10-Bill Activity
Incorrect Answers	40 (16.06%)	16 (6.72%)
Correct Answers	209 (83.94%)	222 (93.28%)

Note. The difference in the correctness rate between Standard Lecture and $10-Bill Activity is statistically significant at the one percent significance level (Wilcoxon rank-sum test, $z=3.23$, $p<0.01$).

To assess students' experiences, I conducted a brief post-activity survey. (In total, 123 students completed the survey). On a Likert-scale from one (strongly disagree) to five (strongly agree), 94.31% of the respondents either agreed or strongly agreed that "*the $10-bill activity made the concept of consumer surplus a lively learning experience.*" In response to "*I am confident that I understand the concept of consumer surplus*", 80.49% of respondents either agreed or strongly agreed.

In summary, the $10-bill activity significantly increases student learning outcomes and enhances active student participation.

4. Conclusion

In this article, I present a classroom application of the BDM mechanism to teach the concepts of willingness to pay and consumer surplus. Using the BDM mechanism to sell a $10-bill gives instructors the opportunity to employ an interactive learning activity that engages all students in introductory-level courses. All students are familiar with the item of a $10-bill, and there is no ambiguity about its true value. The $10-bill activity is easy to implement and does not require special software. The instructor only needs a $10-bill (and some small denomination bills and coin change) and a random number device for the price-draw. The activity clearly demonstrates the difference between willingness to pay and price. Students not only enjoy the activity, but also achieve significantly better learning outcomes.

The BDM mechanism can also be easily employed to teach the concepts of willingness to accept and producer surplus. Instead of selling a $10-bill, the instructor could buy a $10-bill from students. Students would submit an offer (state their willingness to accept) to sell a $10-bill to the instructor. The instructor would then draw a random price from $10 to $20 (to match the possible earnings range of the willingness to pay task). If the random price is higher than a student's offer, the student will sell to the instructor and earn the difference between the random selling price and ten dollars. If the random price is less than a student's offer, the student does not sell and does not earn anything.

Later in the semester, the instructor can refer to the "$10-bill activity" when teaching the topics of price elasticity and game theory. Students will recognize that the demand for a $10-bill is perfectly elastic. At prices less than or equal to 10 dollars, the quantity demanded for a $10-bill is infinite; at prices above ten dollars, the quantity demanded drops to zero. Likewise, it will be easier for students to discern dominant and dominated strategies when they recall their optimal strategy in the $10-bill activity.

Future work could compare the BDM to a pit-market activity or use of media and popular culture to teach consumer surplus. It is possible that a combination of these pedagogies could yield even better learning outcomes. In the meantime, the BDM activity described here can be easily implemented in large-section courses.

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Appendix

1. Alternative Understanding Quiz

1. *A student bids $7; the random buying price is $9. Will the student buy the $10-bill?*
   a. *Yes, the student will buy the $10-bill and pay $7.*
   b. *Yes, the student will buy the $10-bill and pay $9.*
   c. *No, the student will not buy the $10-bill because her bid of $7 is less than the random buying price of $9.**
2. *A student bids $7; the random buying price is $9, which is greater than the student's bid. Thus, the student does not buy the $10-bill for $9. If the student had bid more than $9, then _____*
   a. *the student would have bought the $10-bill and paid $9 for it.**
   b. *the student would not have bought the $10-bill and thus paid nothing for it.*
   c. *the student would have bought the $10-bill and paid $7 for it.*
3. *A student bids $10; the random buying price is $9. The student _____*
   a. *will buy the $10-bill and pay $10 for it.*
   b. *will buy the $10-bill and pay $9 for it.**
   c. *will not buy the $10-bill.*
4. *A student bids $10; the random buying price is $9. The student buys the $10-bill for $9. How much does the student earn? [Enter your answer in dollars, rounded to the nearest cent.] $1,00**