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Lecture Capture Learning: Do Students Perform Better Compared to Face-to-Face Classes?

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Running Head: Lecture Capture Versus Face-to-Face

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Abstract:

Online learning has become more prevalent in colleges and universities as new technology is introduced. One such technology is lecture capture, which allows a live lecture to be recorded and packaged with classroom media and delivered online to many more students than a traditional face-to-face class. This paper studies the selection process and educational outcome differences between students enrolled in a lecture capture and a face-to-face course in economic principles. Students could select either course format, both with the same instructor and course requirements, without capacity restrictions. We find that students' attitudes toward online learning are the chief determinant of their choice of class over demographics, opportunity cost measures, or past online experiences. Additionally, our findings suggest that lecture capture students perform as well as those who take a face-to-face course when not accounting for self-selection. When selection is taken into account, lecture capture is not significantly worse than face-to-face.

1. Introduction

Colleges and universities are finding new ways to deliver courses to students utilizing technologies that are constantly evolving. Part of the effort is to accommodate a broader student demographic, one that is more mobile and technologically savvy, more likely to work while enrolled in school, and more eager to seek alternative settings for education than a traditional campus classroom. Also, tighter fiscal constraints facing institutions of higher learning have made the implementation of online learning one way to improve cost efficiency. An increasingly popular approach to delivering online courses is the use of lecture (video) capture technology, in which classes are taped in front of students in a live class, and then made available online to many more students.

The discussion regarding the effectiveness of online classroom delivery extends beyond pedagogical issues; it has become a prevalent topic of debate within academic departments in which faculty hold different beliefs about the effects of online learning. The issue pits those who desire to introduce new classroom technologies that a growing number of students and faculty demand against those who argue that such methods of instruction yield poorer student learning outcomes and lack the human interaction necessary for the full academic experience. The evidence provided by each side is still rather limited, and the interpretation of studies is subject to the biases that each side of the debate hold.

Once primarily limited to non-traditional colleges, the use of online course delivery methods such as lecture capture has now become mainstream. Figlio, Rush, and Yin (2013) found that in 2010, virtually every university with 15,000 students or more offered some form of online course. Unlike online courses of the past, lecture capture technologies have evolved to

allow students to view lectures as if sitting in the front row of an actual class. Students see everything presented in class along with the professor on a single screen.

This paper studies the comparative outcomes of students choosing to enroll in traditional face-to-face courses versus lecture capture format courses in economic principles. Unlike many prior studies on the subject, this study focuses on the selection process of the students in choosing to enroll in a traditional face-to-face section or a lecture capture section of the same course. Further, both sections were taught by the same instructor and on the same days, and students from both sections completed identical exams and assignments simultaneously throughout the semester. Finally, the size of our sample is larger than prior studies, which allows for specifications that are more extensive.

This paper has two main goals. First, we study the selection process by analyzing the factors that determine which course format students choose and the reasons for doing so. Second, we study the outcomes from each subset of students using a variety of assessment tools. Under the ideal environment of free choice among students to select from two formats without capacity restrictions, our findings provide a unique contribution to the literature and provide valuable guidance to institutions implementing or considering online delivery methods in their course offerings.

2. Literature Review

The use of external-delivery courses has been in existence for decades. Prior to the Internet, some universities offered correspondence courses, where students study lecture material independently and deliver completed coursework via the postal service. In the 1970s, institutions such as the University of Florida began using “TV-replay” courses by taping lectures in a classroom, then replaying the taped lecture over and over throughout the week. This format

evolved into public access television replay where lectures were broadcasted on a local television channel, and finally into the online lecture capture format used today. Colleges and universities across the nation are adopting the lecture capture format, both in large scale as well as small scale with the increasing availability of commercial lecture capture software.

The empirical research comparing student outcomes between lecture capture and traditional course delivery is limited both in numbers and in scope. Most studies on online learning focus on distance learning courses (e.g., Brown and Liedholm 2002); however, distance learning differs from lecture capture in the delivery of course material and the media-rich technology inherent in the latter. A summary of early studies on the effects of online learning is found in a U.S. Department of Education report prepared by Means et al. (2010).

Several recent studies have analyzed the effectiveness of lecture capture and hybrid courses. Figlio, Rush, and Yin (2013) focused on learning outcomes between a "live" section of economic principles and a lecture capture section. Selection was controlled by randomly placing students into an "only live" and "only online" group, allowing learning outcomes based on student performance to be compared, controlling for various personal characteristics. The authors found that the "live" group performed modestly better than the online group, particularly for certain subgroups including Hispanic students, male students, and lower-performing students.

Subsequent studies by Joyce et al. (2014) and by Bowen et al. (2014) compared traditional and hybrid courses in economics and statistics, respectively, comparing outcomes in courses with multiple face-to-face lectures each week with hybrid courses that met only once per week. In each study, students in all sections had complete access to online resources, but not the lectures themselves, which were not recorded. Therefore, these studies analyzed the effect of class time on performance and whether online resources serve as an effective substitute for class

lecture. Their results showed that traditional courses performed only slightly better than hybrid courses, suggesting that the cost savings to students and universities from using online and hybrid formats justifies their growing use.

In each of the three papers above, students were randomly placed into traditional and online sections to control for selection. Their findings all suggest that the advantage of traditional face-to-face classes in achieving greater learning outcomes is not substantial, and that the use of online technologies is a practical substitute especially when facing resource constraints.

Given that substantial differences were not found between face-to-face and online courses, the question then becomes which format best meets the needs of students. One reason why selection is a difficult issue to measure empirically is because classroom capacity restrictions often force students into online sections. If enrollment restrictions in each format were high enough to avoid reaching capacity, then the selection issue would itself be an interesting issue to study. Existing studies looking at this issue have typically used small samples.

Gratton-Lavoie and Stanley's (2009) study allowed students to choose between an online and face-to-face version of the same class. Although the results of their study provide some interesting results on how selection of class format influences learning outcomes, their study included only 58 students in the online (distance learning) section and 98 students in the face-to-face section. Another study by Flores and Savage (2007) estimated student demand and performance using lecture capture within a small class of 39 students. Students could watch lectures online using Tegrity Cart technology which allows instructors to record lectures and sync with classroom media. Their findings based on student questionnaires found that students were willing to pay on average about $90 to have the option to download lectures, and students

who watched the online lectures performed better. Their study showed that replay of lectures can improve learning outcomes; however, their study does not evaluate whether lecture capture in lieu of attending a face-to-face class would have the same effect.

Euzent et al. (2011) conducted a study that more closely resembles our approach in terms of selection. Large lecture capture and face-to-face sections taught by the same instructor over two semesters provided a large sample. The authors evaluated student performance based on exams and assignments, and used instructor evaluations and a post-course questionnaire to evaluate student attitudes. Their findings found no significant difference in student performance between formats, and that student perceptions of lecture capture were very positive. However, their study did not investigate the factors driving students to select one format over another.

In our paper, we build upon the existing studies of the effectiveness of lecture capture and face-to-face courses by utilizing a large set of variables collected over the course of the study using a large sample of students. Therefore, we are able to seek results that prior studies have been unable to achieve due either to limitations in the course setup or the lack of adequate observations. Our data allow us to evaluate the choices students make in selecting a lecture capture course over a traditional face-to-face course and to examine differences in learning outcomes between the two types of course delivery.

3. Lecture Capture vs. Traditional Face-to-Face Courses

A brief discussion of the conceptual differences between our version of a lecture capture class and a face-to-face class is warranted. A lecture capture class is recorded in a specialized classroom with up to 40 students attending the live recording. The recorded lecture can be watched via live streaming or can be viewed at any time after its recording. Exams and

assignments are completed online as well, so the student is not required to come to campus at any point during the semester.

The lecture capture delivery method has a number of advantages for students. In addition to not having to come to campus, lectures can be viewed at any time. Further, the student has the option of rewinding, pausing, or re-watching a lecture. Table 1 reports some results from a post-course questionnaire and details the use of lecture capture by students. While a third of students report watching the recorded lectures from beginning to end without stopping, the rest report taking a pause to take notes (66.8%) or to rewind (42.5%). In addition, the student also had the ability to fast forward through (presumably boring) parts (13.4%) or just skip around (6.7%). Finally, 15.7% of students reported watching a lecture more than once. The disadvantages of lecture capture include the lack of face-to-face contact with the instructor and the lack of interaction with classmates. Also, the flexible format encourages procrastination, as students sometimes wait until right before an exam to watch lectures.

<Table 1 here>

In comparison, the face-to-face class offers the advantage of seeing the instructor in person, as well as sitting in a room with classmates. The disadvantages are the fixed time period for the lecture and the inability to watch a missed lecture at a later time. However, one reason reported by students for choosing a face-to-face course was the inherent enforcement mechanism of a fixed class time period. A student who misses a lecture cannot watch it later, but instead must read the book, obtain notes from a classmate, view course materials online, or perhaps visit the professor and/or teaching assistant during office hours.

In this study, as many course conditions have been made the same across the groups as possible. The same instructor taught both sections using the same book. The assignments and

exams were the same and were administered in the same manner – online for both groups. Both sections had access to the same resources for the class (a university tutoring office, online course materials, study guide, etc.). The taping of the lecture capture section and the class period for the face-to-face section were back-to-back on the same days of the week. In short, the main differences, as noted above, are the fact that lecture capture allows for viewing lectures anytime and as many times a student would like, whereas the face-to-face version offers intangible benefits of seeing a live "show" with an audience but without the ability to repeat lectures as with lecture capture. Finally, it should be noted that in this study, the instructor, by design, merely repeated the lecture to both sections. Of course, questions asked by students varied between the lecture capture and face-to-face sections. (In lecture capture lectures, the instructor would typically answer submitted questions at the start of the subsequent lecture.)

4. Data

This paper focuses on the selection by students of a lecture capture course as well as learning outcomes using a rich dataset that allows us to address a number of important questions. First, what influences students to elect to take an economics class in a lecture capture format? We measure factors including personality type, work schedules, and perceived work avoidance. Second, do students learn more or less in a lecture capture format? We measure learning outcomes of students in each section as well as the allocation of study time between students in each format. Third, do student attitudes toward lecture capture change after taking a lecture capture course?

Data for this study were collected for two sets of students who were enrolled either in a lecture capture section or a face-to-face section of microeconomic principles during a single semester at a large public university with over 30,000 students. This university has a diverse

student population, reflecting a demographic trend across the country. A total of 344 students enrolled in the lecture capture section and 130 students enrolled in the face-to-face section.

Students in the lecture capture section were given an opportunity to attend the taping of the class in a classroom studio that holds up to 40 students. However, because all lecture capture courses are marketed as online courses, fewer than 30 students per class on average attended the taping (attendance was recorded for the purposes of this study), while the vast majority of students (over 80%) watched lectures exclusively online, either via live streaming or via the recordings. Only students who were registered for the lecture capture section were given access to the recorded lectures. Students enrolled in the face-to-face section were not given access to any recorded lectures from the other section, with no exceptions per college policy which charges students in the lecture capture section a $180 technology fee. Students in both classes were asked to volunteer to be part of this study. The participation rate in the lecture capture section was 85.8% while the participation in the face-to-face section was 96.9%.

The data for this study comprise three categories: 1) student background information collected via a pre-course and post-course questionnaire along with attendance data; 2) assessment data collected via an online pretest along with grades for all course assignments and exams; and 3) transcript data obtained from each student after the semester ended. In the following, we describe the data collection process for each category in greater detail.

The pre-course questionnaire contained questions used to collect demographic data, information on work and school schedules, variables aimed at predicting online learning achievement, and various measures of student attitudes toward economics. During the last week of the semester, a post-course questionnaire was given to obtain information on study habits, and opinions of the course delivery format.

Table 2 provides some basic demographic and academic information for the two groups: the face-to-face class and lecture capture class. The distance from campus variables and expected job hours are constructed from questions that had the students choose their response from ranges of values. The gender and race variables are self-reported from the pre-course questionnaire.

<Table 2 here>

Various assessment mechanisms were used to evaluate prior student knowledge. First, an online pretest consisting of 15 identical but randomized general microeconomic questions taken from the *Test of Economic Literacy* (TEL) national standardized exam was given to students during the first week of the semester. The scores from the pretest are reported in Table 2 for each section.

We also collected transcript data on each student at the end of the semester. Using the transcript data, we were able to ascertain whether students had previous economics courses, the number of credit hours they had completed or if they were new to the university, as well as their undergraduate grade point average.

The pre-course questionnaire included two sets of questions: a set of questions dealing with attitudes toward online learning and another set dealing with past experience with various online learning techniques. Table 3 shows the summary statistics for the online learning questionnaire. The online learning questions are from Bernard et al. (2004). Their original questionnaire consisted of 25 questions. Our subset of questions was selected so as to have questions representing the four factors identified by Bernard et al.: Confidence about Prerequisite Skills (S), Beliefs about Distance Education (B), Self-Direction and Initiative (I), and Desire for Interaction with the Instructor and Other Students (D). (Letter in parentheses identifies the questions in Table 3.)

<Table 3 here>

The prerequisite skills questions (S) focused on whether the student was comfortable communicating online or with written communication or whether the student had Internet access. Somewhat surprisingly, the responses to the skills questions were fairly uniform across two groups. This probably reflects the increasing acceptance and use of online communication. Despite comparable skills between the two groups, the beliefs about distance learning (B) differed significantly across groups. In general, neither of the groups thought learning at home and in class were the same; only 12.7% of face-to-face class students and 27.9% of lecture capture class students agreed or strongly agreed that learning was the same in class as at home on the Internet. Interestingly, the question with the greatest difference between the groups (and the most predictive power) was whether listening skills could be improved online as well as in class. The lecture capture group was much more likely to believe that listening skills could be improved using the Internet.

In terms of the questions focusing on self-direction and initiative (I), the self-discipline question exhibits an interesting pattern. The face-to-face class had a relatively high percentage of students marking "strongly agree" as well as "disagree." This seems to confirm two theories: disciplined students will make it to a live class and undisciplined students try to enforce discipline by signing up for a class they have to attend. Anecdotal evidence provided by students on a free response question supports these ideas – reasons for choosing a face-to-face class included acknowledging the likelihood of falling behind on viewing lectures, or that concentrating on coursework outside of the classroom would be difficult. Finally, in the two questions focusing on the student's desire for interaction (D), the face-to-face group was more

likely to view face-to-face student-instructor interaction as necessary for learning. No differences existed between the groups in terms of enjoyment of group work in general.

Table 4 summarizes the past experience of students with online learning. In general, the vast majority of students have had experience with some form of online learning. The percentage of students that reported taking a previous course in a lecture capture format was 24% in the lecture capture section and only 15% in the face-to-face section. The percentage of students that had experienced live streaming of courses online was higher in the face-to-face section than the lecture capture section (17% to 13%).

<Table 4 here>

During the semester, students took four exams, including a comprehensive final, that were given approximately four weeks apart. Each exam except for the final covered approximately four chapters of the textbook. And all assignments and exams were identical between the two sections. In fact, because all assignments and exams were given online, students from both courses completed all requirements of the course simultaneously. Therefore, no difference in the timing and administration of assignments and exams existed between the two sections of the course. Our performance measure is the point total for all exams, including the comprehensive final. To make the results easier to interpret, we standardized the exam point totals by subtracting the mean (over both classes) and dividing by the standard deviation. The raw results shown in Table 5, not adjusted for any sample selection, do not indicate any large differences in student performance between the sections – neither the means nor standard deviations differ significantly.

<Table 5 here>

Throughout the semester, data were collected on the extent to which lecture capture students viewed the online lectures (obtained via statistical extraction from the course management software), attendance in the studio taping for lecture capture, and attendance in the face-to-face section. A graduate assistant was assigned the task of collecting attendance data for each lecture in both sections. Attendance was taken at the beginning of class. Students were told that attendance itself would not result in any course credit. Attendance data were not made available to the instructor to avoid any grading bias based on class attendance.

Attendance data indicate that the lecture capture format results in more views of lectures than a face-to-face format. The face-to-face group attended, on average, 6.7 sessions (of a total of 19 non-test classes). The reported average is a bit low since stragglers, somewhat common in a late afternoon class, would not have been included in the attendance count taken at the beginning of class. While the number is not perfectly measured, the measure does give an indication of the student's motivation, with chronically late students receiving a lower attendance number. By the same token, while the average number of days students logged on to the video system was 11.9, the recording system does not tell us how long the videos were watched. (We also report the number of times a student logged on. This number was skewed by students logging in numerous times in a day. While this may reflect many viewings, it also may reflect dropped Internet connections or other technical difficulties.) Nonetheless, it would appear that the convenience of lecture capture was utilized by students.

Finally, students reported information in a post-course questionnaire. The numbers reported in Table 5 show that the hours spent at work, hours spent studying for the economics course, and hours spent studying for other courses were about the same between the two

sections. We also asked students if they liked the online exam format – both sections reported favorably. The lecture capture group was somewhat more likely to enjoy taking exams online.

5. Model and Results

In this section, we begin by presenting a selection model on the choice of course format. Then, we present a model on the determinants of learning outcomes, followed by a discussion of the estimation results from both models. Last, we address the results concerning student attitudes toward online learning.

Selection

A selection model is critical to explaining the type of student that would be attracted to the lecture capture format, an issue concerning many institutions of higher learning. We develop and test our selection model by estimating a number of specifications to explore the factors that most significantly impact the student's decision. The full model is described by (1), with different variables capturing each category of inputs listed.

Lecture Capture = f(Academics, Demographics, Measures of Opportunity Cost, Online Attitude Questions, Past Online Experience) (1)

The academic questions include a number of items to capture relevant aspects of the student's academic background that might influence their choice of course format. The pretest score is included because students who have prior knowledge of economics may feel more confident about taking an online version of the class. The same idea applies for the variable measuring whether the student had previously taken macroeconomic principles. Also, we included whether the course was required for their major and whether the student was new (i.e.,

just beginning at the university). The importance of the class may affect the student's choice of course format, while new students may not be familiar with or cognizant of lecture capture courses and therefore less inclined to register for one.

One academic variable *not* included was the student's undergraduate GPA. Interestingly, initial estimations found that the GPA (or any exponential versions) was not a predictor of whether a student took a lecture capture or face-to-face version of the course. The mean student GPA in the two formats was almost identical (2.84 to 2.81). This is, in some respects, an interesting comment on the selection process: it is not necessarily the weaker or stronger students – in terms of overall academic ability – who select one format over another. In addition, excluding this variable also helps identify the selection and educational output equations.

Demographic variables include gender, race and ethnicity. We have no *a priori* expectations on the influence of these variables on selection.

The selection equation also includes questions that measure the opportunity cost of attending a face-to-face version of the class. These include how much students intend to work and how far they live from campus, both of which increase opportunity cost. Each is represented by dummy variables, with the excluded categories being "not working" and those living within 25 miles, respectively.

The set of questions (Table 3) regarding attitudes toward online learning is included. These capture the student's beliefs about online learning, prerequisite skills, initiative, and desire for interaction. Each of these factors may influence a student's decision whether to choose a lecture capture course. In the questionnaire, the students responded to the questions using a five-choice scale from "strongly agree" to "strongly disagree." Instead of including an indicator variable for each possible response to each question, we created two variables for each question:

agree and disagree. The rationale is that some questions had very few or no students that strongly agreed or strongly disagreed. We therefore combined responses (such as strongly disagree and disagree) until we had approximately 10% in a group. Table 3 indicates the combinations we used for each variable by using boldface for the two extreme groups and regular font for the "middle" group (which is the omitted group in the estimations). We note that including these attitudinal variables from a survey given after the choice opens the possibility that students respond in a way that justifies their choice. However, we feel that students have fairly defined opinions that are not likely to dramatically change because of the choice itself. However, we do believe that experience over the semester-long course may change opinions.

A student's choice of a lecture capture course format is undoubtedly influenced by their past experience with lecture capture or other forms of online learning. A question on the pre-course questionnaire provided students an opportunity to indicate whether they had previously experienced online homework, quizzes, exams, chat rooms, and course management software. In addition, students indicated whether they had previous experience with lecture capture or online live streaming classes.

As noted above, we first estimate a variety of specifications of the selection model to investigate which variables provide the most explanatory power. We estimate first a model with all variables except the attitudes toward online learning. We then estimate the specification with only the attitudes toward online learning. In a third specification, we include all variables. Finally, we estimate a parsimonious version that includes only a subset of the variables of the full model. We use the parsimonious version to estimate the educational production function while accounting for selection.

Educational Production Function

The effect of the lecture capture format is measured through the estimation of (2), the production function.

Performance in Class = f(Academics, Demographics, Time Allocation, Lecture Capture) (2)

This specification of the learning equation is standard. The prescore measures a student's knowledge coming into the course, as does having past macroeconomics coursework. These, coupled with GPA, reflect the student's scholastic ability in economics and overall. We included gender, racial and ethnic variables as our demographic background control variables.

Since we collected self-reported data for the number of hours a student worked and studied, we include in our final specification these measures as estimates of the approximate amount of time a student has to devote to studies. Note that the job hours in the production equation is from the post-course questionnaire, and therefore represents actual hours worked. The selection job variable was collected at the beginning of the course, and therefore represents the student's anticipated hours, which impact (perhaps) the selection of the course type. We also include the number of times a student attended class – either in person (for both groups) or, in the case of lecture capture, by logging on to the recorded lecture online.

Estimation of Production Function with Selection

The two equations are estimated using a maximum likelihood estimator derived by Maddala (1983). Anstine and Skidmore (2005) and Coates et al. (2004) provide small-sample examples of the technique. The equations estimated are:

Test score = $X_j B + s C_j + e_j$

$C^* = Y_j D + u_j$

C^* is not observed directly. The decision to choose lecture capture (C_j) is found by:

$C_j = 1$, if $C^* > 0$

$C_j = 0$, otherwise

The error terms e and u are assumed bivariate normal and are correlated (ρ). If the errors are not correlated, each equation could be estimated separately.

In creating the specification for estimating the production function with selection, we sought to include variables in the selection equation that predicted participation in the lecture capture course, but that would not be correlated with student learning. Certainly, distance from campus is one of the variables, because it is unlikely that a student's location affects performance. We also include job hours, which are likely to restrict choice of the live section. While having a job *per se* does not impact learning, the time allocation of someone who has a job may impact learning. Therefore, we do two specifications of our production function. The first excludes job hours – since it is not clear that job hours alone will reduce learning – and the second includes job hours with self-reported time allocation variables.

We also include variables about past experience with online courses (previous lecture capture and live streaming courses) as well as attitudes toward online courses. We do not include these variables in the production function. It is interesting to note that the Bernard et al. (2004) paper from which the attitudinal items were drawn used the items to predict student performance; however, the authors noted that the variables did not account for a lot of the variance in posttest scores (8%). Initial estimations with our data indicated extremely small explanatory power of these variables on student performance. We suspect that part of the reason may be the difference

in delivery of online education from 2004 to the present. Lecture capture is much closer to an in-class experience, and so some of the student traits that may have previously impacted student performance online may be moderated in their effects. In short, these attitudinal variables are correlated with selection, but not performance. As noted earlier, we exclude GPA from the selection equation. We did not find any evidence that overall student performance changed a student's choice of course delivery.

We estimate four versions of the production function. The first is a regular regression with no selection modeled. We then estimate the production function with all variables except the ones reflecting time allocation, but control for selection using the parsimonious specification of our selection model. The third specification includes all variables, including the time allocation variables. The fourth specification excludes the variables measuring past online experiences as well as attitudes toward online learning. We exclude the attitudes and past online courses as a robustness check. In the case of attitudes, we do so in the event that students do change their opinions based on their choice as opposed to the choice being based on attitudes.

Results

Table 6 presents the estimation results of the four specifications of our selection model using a standard probit model.

<Table 6 here>

Overall, the results did not vary quantitatively or qualitatively across specifications. A student who had previously taken macroeconomics was significantly more likely to choose lecture capture (12% to 17%). While the prescore variable was not significant, its magnitude indicates that a high prescore student (75^{th} percentile) would be approximately 6% more likely to

take lecture capture as a low ability student (25th percentile). Together, these reflect an increased willingness to try a lecture capture format when the material covered is more familiar to a student. Students for whom the course is a requirement also had a preference for lecture capture. In terms of demographics, women were slightly more likely to choose lecture capture (6% to 8%). Hispanics were significantly less likely to choose lecture capture.

The variables capturing the opportunity cost of attending a face-to-face lecture had significant effects. Those who live long distances from campus, are, unsurprisingly, more likely to choose lecture capture (14%). The number of job hours did seem to encourage students to select the lecture capture course as compared to the omitted group of those who did not plan to work, although the magnitude was largest and significant for those who worked 1 to 20 hours a week.

Of the indicator variables that measured the student's past experiences with online learning, two were significant. A student who has taken a lecture capture course in a prior term is more likely to take another. Interestingly, students who have taken a live streaming course are less likely to take a lecture capture course. The discrepancy may perhaps be explained by the fact that live, unrecorded lectures can be easily missed, while lecture capture is always available.

Of the ten questions on attitudes toward online learning, three were strongly correlated with the student's decision to take a lecture capture course. The response to the question "I feel that I can improve my listening skills the same using the Internet as in class" was a strong predictor of whether a student chose lecture capture – more so than seemingly more direct questions such as "Learning is the same in class and at home on the Internet." Those that agreed to that question were 40% more likely to elect lecture capture than those who strongly disagreed. As noted earlier, those who strongly agreed that they were self-disciplined and those who

disagreed that they were self-disciplined were less likely to choose lecture capture. Not surprisingly, agreement with "I feel that face-to-face contact with my instructor is necessary for learning to occur" was negatively correlated with the lecture capture choice.

From a policy standpoint, it's important to summarize which variables are most likely to predict student choice. A comparison of the first two specifications provides some clarity. The specification with academic, demographic, opportunity cost, and previous online experience variables has a pseudo-r2 of 0.09. The area under the ROC curve, a summary measure of the predictive power of the model, is 0.69.[1] The specification with only the attitudes variables has a pseudo-r2 of 0.17 and an area under ROC of 0.78. In short, the results indicate that attitudes play a larger role in a student's decision to choose lecture capture than all of the other variable categories combined.

This result is significant as many economics departments consider adding more technology-delivered courses. Many of the arguments for technologies like lecture capture focus on the fact that it reduces the opportunity costs of attending class; for example, it allows the students flexibility to work around their work schedules and save time commuting. While these do play a role in a student's decision, more important is the student's attitude toward the technology. Therefore, although administrators cannot ignore the advantages of lecture capture technology, they also cannot ignore the fact that for some students this technology is not viewed as an acceptable alternative to face-to-face. The results also suggest that familiarity with the subject material (as evidenced by previous economics coursework) or with previous lecture capture coursework increases student acceptance of the technology.

Table 7 presents the estimation results from the education output equation with selection. Most of the variables influencing learning are in line with expectations. A higher prescore or

GPA, as expected, increased student achievement. Although race and ethnicity did not affect student achievement, gender did. Female students performed approximately 0.35 of a standard deviation lower than male students. This translates (roughly) to one grade level lower (e.g., B to B-).

<Table 7 here>

The third specification, which includes attendance and time allocation variables, provides results consistent with expectations. Live attendance, in particular lecture capture students who attended the tapings, is positively related to performance. Number of online class logins is also positively correlated with performance. Actual job hours worked, unsurprisingly, had a negative impact. One change that occurred when comparing the final specification to the other two specifications was the reduced effect of the new student variable. The new student variable likely captured, to some degree, a student's enthusiasm and dedication. Because attendance also captures student enthusiasm, it is reasonable that the new student coefficient would decrease.

The effect of lecture capture varies with the specification of the selection equation. In raw terms, the difference in exam scores was 0.08 in favor of the lecture capture format. Estimates from the regression model without selection reflect about the same size effect, with a 0.08 standard deviation improvement with lecture capture.

However, once selection is factored in, the estimated effect of lecture capture decreases. In the specifications with selection, the estimated rho is positive (0.23, 0.17, and 0.04). This means that the error terms between the equations are correlated and implies that OLS will overestimate the treatment effect. With the selection model, the effect of lecture capture ranges from -0.17 to 0.03. In any case, the standard errors on the coefficients are large, so none of the coefficients are significant in any of the specifications.

The final specification is a robustness check that excludes the variables measuring attitudes toward online learning and past experience with lecture capture or live streaming. As we noted earlier, this is to ensure that the survey responses to the attitudinal questions were not influenced by the selection of the course format as a way to justify a student's choice. Although the coefficient on lecture capture increased slightly, it remains insignificant and lower than the effect in raw terms without selection. All other variables showed no significant changes from previous specifications.

The Caveat

Overall, the results from this study suggest that lecture capture is perhaps nearly as effective (if not equivalent to) a face-to-face lecture. In fact, students in the lecture capture section became more likely to view online courses as equivalent to traditional face-to-face courses. Table 8 shows a comparison of the attitudes toward online learning questions that were asked in both the pre-course and post-course questionnaires. The results of only a few items changed. First, students in both the face-to-face and lecture capture sections reported being less "willing to actively communicate with my classmates and instructors online." More interestingly was that the lecture capture students were more positive in their response to "Learning is the same in class and at home on the Internet." The gain was strongly centered on students who had not already taken a lecture capture course. In short, those who were new to the technology were apparently convinced that it made the gap between a face-to-face and an online lecture less significant. While the absolute magnitude of the *Class Home Agree* variable (46.3% choosing strongly agree or agree) for those new to lecture capture still did not indicate agreement with the statement, the positive change seems to indicate that lecture capture is making the case. One can

easily imagine a time in the not-so-distant future when technological improvements to online learning will close the gap further.

<Table 8 here>

However, it should be remembered that this study was constructed to keep everything constant except for the delivery mechanism (face-to-face versus lecture capture). In fact, it could be argued that since the instructor is an award-winning instructor and director of the college's lecture capture courses, the lecture capture section was delivered as well as it possibly could be. Because the idea was to parallel what was being done in the lecture capture course, the face-to-face lecture was merely a live replication of the lecture capture lecture. Herein lies the caveat. One advantage of a face-to-face lecture is the opportunity to do more. This goes beyond the ability of students to ask questions. Some examples of what could be done include small group work, in-class experiments, role-playing as well as classroom response systems (see Buckles and Hoyt 2005, and Buckles, Imazeki, and Hoyt 2012). In fact, recent advances in classroom design, such as an active learning classroom, may enhance learning relative to a standard lecture setting. Although these classrooms incorporate technology, they also focus on group interaction and learning.

To the extent that some of the advantages of a face-to-face class are not exploited, this study does not constitute a comprehensive or fair comparison between types of course delivery. A fair test would pit one format against the other in a way that utilizes the best pedagogical techniques for each delivery system. However, the results of this study are perhaps more realistic in its assessment. As documented most recently by Watts and Schaur (2011), "chalk and talk" remains the primary mode of delivery in an economics classroom. To the extent that this remains

the same, this study suggests that the benefits of putting the lecture conveniently online may not come at a very high cost - if one exists at all.

6. Conclusion

This paper studies the selection process and learning outcomes of lecture capture and traditional face-to-face lecture formats for a microeconomic principles course. Using unique data collected in a large lecture capture section and a face-to-face section, our analysis was able to control for many important factors influencing the performance of students in each format.

The results show that a student's choice between a lecture capture and a face-to-face section depends on whether she has had a previous economics course, the distance she lives from campus, her past experience with online learning, and, most importantly, her attitude toward online learning. Our results show that attitude is more important in the selection process than variables capturing demographics, the opportunity costs of going to a face-to-face class, or past online experiences.

In terms of exam scores, the raw scores between the groups are almost the same. However, students in the face-to-face section were judged to perform better than students in the lecture capture section if self-selection is taken into account. None of the estimates were significantly different from zero.

The results of this study provide a contribution to the literature on economic education as well as for all disciplines using online course delivery. While the debate regarding face-to-face versus online instruction continues among the faculty, our results show that it also exists among the students – and just as faculty have strong views on the subject, so do students. While our results show that students do not yet believe that face-to-face is the same as online classes, chalk-

and-talk professors should be on notice that student's beliefs are changing, and that performance gaps, if any, are closing.

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Endnotes

1. The ROC curve plots the model sensitivity (the probability of predicting lecture capture if the actual choice is lecture capture) versus 1 – specificity (the probability of predicting face-to-face if the actual choice is face-to-face). Since these are functions of the choice of cutoff value to classify a prediction (a typical cutoff value is 0.5), the curve plots the values as the cutoff is varied from 0 to 1. The area under the curve can vary from 0.5 to 1.0, with 0.5 having no predictive value, and 1 perfectly predictive.

Table 1. Lecture Capture Student Use of Technology

How they watch:	
I watch lectures from start to finish, but will rewind and listen to certain parts again.	42.5%
I watch lectures from start to finish, but will pause on occasion to take notes.	66.8%
I watch lectures from start to finish without stopping.	33.6%
I sometimes fast-forward through certain parts of the online lecture.	13.4%
I tend to jump around to certain parts of the online lecture.	6.7%
I watch online lectures more than once.	15.7%
I never or almost never watched any of the online lectures.	6.0%
N	268

Table 2. Variable Means

Mean	Lecture Capture	Face-to-Face
Survey Variables:		
Female	54.9%	47.6%
Black	19.3%	18.3%
Asian	4.4%	4.8%
Hispanic	19.8%	26.8%
Course Required for Major	88.4%	79.2%**
Lives Far from Campus	18.6%	11.1%*
Expected Job Hours 1 to 20	44.4%	36.5%
Expected Job Hours over 20	35.6%	34.9%
Testing and Transcript Variables:		
Prescore (out of 15)	9.05	8.61
Previously Taken Macroeconomic Principles	34.4%	20.6%***
University Undergraduate GPA	2.84	2.81
New to University	18.3%	25.4%*
Observations	288 to 295	123 to 126

***Significantly different from Lecture Capture at 1% level.

**Significantly different from Lecture Capture at 5% level.

*Significantly different from Lecture Capture at 10% level.

Table 3. Attitudes toward Online Learning

Variable Name: Question Wording	Face-to-Face / Capture (Test if Same)	Strongly Agree	Agree	Neutral	Dis-Agree	Strongly Dis-Agree
Comf Online: I am comfortable communicating with others online. (S)	Face	**41.3**	41.3	**15.9**	**1.6**	**0.0**
	Capture (Same)	**41.5**	45.9	**11.9**	**0.7**	**0.0**
Comm Online: I am willing to actively communicate with my classmates and instructors online. (S)	Face	**36.5**	46.8	**15.1**	**1.6**	**0.0**
	Capture (Differ)	**40.8**	50.3	**6.8**	**2.0**	**0.0**
Comf Writ: I am comfortable with written communication. (S)	Face	**43.7**	46.0	**9.5**	**0.8**	**0.0**
	Capture (Same)	**46.1**	44.8	**8.5**	**0.7**	**0.0**
Inter Diff: Accessing the Internet for my studies is difficult for me. (S)	Face	**0.8**	**3.2**	**12.0**	48.8	**35.2**
	Capture (Same)	**0.7**	**4.4**	**11.9**	40.1	**42.9**
Class Home: Learning is the same in class and at home on the Internet. (B)	Face	**4.0**	**8.7**	18.3	45.2	**23.8**
	Capture (Differ)	**6.2**	**21.7**	31.3	33.0	**7.9**
List Skill: I feel that I can improve my listening skills the same using the Internet as in class. (B)	Face	**3.2**	19.8	25.4	**38.1**	**13.5**
	Capture (Differ)	**11.7**	45.0	25.8	**13.8**	**3.8**
Self Disc: In my studies, I am self-disciplined and find it easy to set aside reading and homework time. (I)	Face	**18.3**	39.7	18.3	**20.6**	**3.2**
	Capture (Differ)	**17.1**	51.9	19.5	**10.2**	**1.4**
Man Study: I am able to manage my study time effectively and easily complete assignments on time. (I)	Face	**19.8**	57.9	**11.9**	**10.3**	**0.0**
	Capture (Differ)	**23.6**	61.8	**10.2**	**3.8**	**0.7**
Enjoy Gr: As a student, I enjoy working with other students in groups. (D)	Face	**15.9**	34.1	23.8	**18.3**	**7.9**
	Capture (Same)	**13.6**	30.2	26.1	**21.4**	**8.8**
Face Nec: I feel that face-to-face contact with my instructor is necessary for learning to occur. (D)	Face	**25.6**	37.6	20.0	**13.6**	**3.2**
	Capture (Differ)	**5.8**	22.5	36.2	**29.4**	**6.1**

Variable abbreviations are shown in **bold**. Variables are grouped into Agree and Disagree as shown by **bold numbers** above. Whether the distribution between face-to-face and lecture capture differs significantly at a 10% level is shown in parentheses (Differ).

Question categories: Confidence about Prerequisite Skills (S), Beliefs about Distance Education (B), Self-Direction and Initiative (I), and Desire for Interaction with the Instructor and Other Students (D). N = 125-126 for Face-to-Face, 291-295 for Lecture Capture.

Table 4. Previous Experience with Online Coursework (in percent)

Mean	Lecture Capture	Face-to-Face
Online homework (completed and graded online) **OnHW**	93.2	88.1*
Online quizzes **OnQuiz**	90.5	87.3
Online tests **OnTest**	81.7	77.8
Chatrooms or discussion boards **Chat**	64.4	54.0**
Classes with previously recorded lectures (e.g., lecture capture) **Prev Capture**	24.4	15.1**
Classes with live lectures watched online **Live**	12.5	16.7
Classes which use Blackboard or other course management software **BlackB**	90.2	85.7
Observations	295	126

**Significantly different from Lecture Capture at 5% level.

*Significantly different from Lecture Capture at 10% level.

Variable abbreviations are shown in **bold**.

Table 5. Exam Totals, Attendance, and Post-Course Questions

Variable	Face-to-Face	Lecture Capture
Exam Total Mean (Standard Deviation); N = 120 and 275	-0.05 (1.05)	0.02 (0.98)
Attendance (N = 126 and 295):		
Days Attending Face-to-Face Lecture	6.7	1.4
Percent Never Attending Face-to-Face Lecture	11.1	81.7
Number of Days Students Logged into Online Lecture	NA	11.9
Number of Times Students Logged into Online Lecture	NA	18.9
Post-Course Questionnaire Information:		
Actual Job Hours Reported*	14.7	15.7
Study Hours for Course*	3.2	3.1
Study Hours for Other Courses*	12.1	11.1
Enjoys Online Exams (Strongly agree - 5 to Strongly Disagree - 1)	4.1	4.3
N for variables above	116-117	264-265

* Means of a variable created from categories checked by respondents.

Table 6. Probit Results, Marginal Effects

Variable	All But Attitudes	Attitudes Alone	Full	Parsimonious
Prescore	0.01		0.01	0.00
Previous Macro	0.12**		0.17***	0.15***
Major Requirement	0.13**		0.14***	0.13***
New Student	-0.09*		-0.05	-0.07
Female	0.06		0.08*	0.07*
Black	-0.01		0.02	0.01
Asian	-0.05		-0.13	-0.13
Hispanic	-0.09*		-0.08*	-0.09*
Long Distance	0.14**		0.14**	0.13**
Exp Job 1 to 20	0.12**		0.08	0.10**
Exp Job Over 20	0.04		0.00	
OnHW	0.03		-0.07	
OnQuiz	-0.04		0.07	
OnTest	0.03		-0.01	
Chat	0.06		0.00	
Prev Capture	0.20***		0.13**	0.14**
Live	-0.23***		-0.20***	-0.20***
BlackB	0.01		0.06	
Comf Online A/D		-0.05 / -0.03	-0.13** / -0.05	
Comm Online A/D		0.01 / -0.14*	0.01 / -0.13*	
Comf Writ A/D		0.01 / 0.09	0.02 / 0.14*	
Inter Diff A/D		0.07 / 0.04	0.02 / 0.02	
Class Home A/D		0.04 / -0.02	0.05 / -0.06	
List Skill A/D		0.15 / -0.22***	0.18** / -0.22***	0.16** / -0.23***
Self Disc A/D		-0.18** / -0.09	-0.23*** / -0.08	-0.17*** / -0.11**
Man Study A/D		0.08 / -0.03	0.07 / -0.01	
Enjoy Gr A/D		0.02 / 0.04	0.10 / 0.02	
Face Nec A/D		-0.16** / 0.09*	-0.15** / 0.05	-0.17*** / 0.07
Statistics				
N	403	404	388	396
Pseudo-R2	0.09	0.17	0.27	0.24
Area under ROC	0.69	0.78	0.83	0.82

Legend: * p < .10; ** p < .05; *** p < .01

Table 7. Regression with Selection Results

Output Equation: Dependent Variable is Total Exam Score (standardized)

Selection Equation (below): Probit with Capture as Dependent Variable, Marginal Effects

	Standard Production Function	Standard Production Function	Standard Production Function & Time	Standard Production Function
Prescore	0.05***	0.05***	0.05***	0.05***
Previous Macro	0.07	0.09	0.06	0.08
GPA	0.78***	0.78***	0.76***	0.78***
New Student	0.24**	0.25**	0.16	0.23**
Female	-0.37***	-0.34***	-0.34***	-0.36***
English	0.26**	0.29**	0.36***	0.26*
Black	0.13	0.13	0.13	0.13
Asian	0.07	0.08	0.16	0.07
Hispanic	0.18*	0.15	0.15	0.18
Days Attend Live F-to-F			0.01	
Days Attend Live L.C.			0.03**	
Days Logged On			0.01**	
Econ Study Hrs			0.01	
Other Study Hrs			0.00	
Job Hrs			-0.01**	
Capture	**0.08**	**-0.14**	**-0.17**	**0.03**
_cons	-2.92***	-2.81***	-2.80***	-2.89***
N	373	365	347	372
Selection Equation	**None**	**Parsimonious**	**Parsimonious**	**Parsimonious No Attitudes**
Prescore		0.01	0.01	0.01
Previous Macro		0.16***	0.16***	0.14***
Major Requirement		0.14**	0.14**	0.13**
New Student		-0.07	-0.07	-0.09
Female		0.06	0.07	0.06
Black		0.01	0.01	0.01
Asian		-0.17**	-0.11	-0.07
Hispanic		-0.07	-0.09*	-0.09*
Long Distance		0.21***	0.22***	0.17**
Exp Job 1 to 20		0.09**	0.09**	0.08
Prev Capture		0.14**	0.13**	
Live		-0.18**	-0.18**	
List Skill A/D		0.14 / -0.25***	0.14 / -0.25***	

Self Disc A/D		-0.16*** / -0.13**	-0.17*** / -0.14**	
Face Nec A/D		-0.16*** / 0.09*	-0.15** / 0.09*	

Legend: * p < .10; ** p < .05; *** p < .01

Table 8. Attitudes toward Online Learning, Pre- and Post-Course

	Face-to-Face		Lecture Capture	
Percent	Pre	Post	Pre	Post
Comm Online Agree	36.5	23.9**	40.8	37.3
Class Home Agree	12.7	11.1	27.8	45.1***
Prev Capture			35.7	41.3
No Prev Capture			25.3	46.3***
Self Disc Agree	18.3	10.3*	17.1	20.2
Man Study Agree	19.8	14.7	23.5	26.1
Face Nec Agree	25.6	20.5	5.8	6.0

*** Significantly different from pre-course at 1% level

** Significantly different from pre-course at 5% level

* Significantly different from pre-course at 10% level.