Student Demand for Streaming Lecture Video: Empirical Evidence from Undergraduate Economics Classes*

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Abstract

Real-time lectures recorded on video and streamed over the Internet are a useful supplement to non-classroom learning. However, because recording confines the instructor to the podium, the classroom experience is diminished when there is less social interaction. This study uses choice experiment data to estimate economics students' willingness to pay for streaming lecture video and instructor movement away from the podium. Results show a divide between students who like the flexibility of catching up on missed classes with video and students who do not. For this former group, video enhances the learning experience and students are willing to pay an additional $90 per course for video. An important source of streaming lecture video's value to students is its impact on performance. Knowledge equation estimates show a positive correlation between students' use of video and their cumulative final grade.

Introduction

Becker and Watts (2001) suggest the reward structure for academic economists moved more toward teaching in the latter half of the 1990s, and faculty spent more time on teaching. At the same time, with university budgets coming under increasing pressure, we would expect to see faculty employ new teaching innovations that increase productivity. Despite these trends, and the development of information technology (IT) that supplements instruction, the choice of teaching method for economics instructors is predominantly chalk-and-talk. This is not surprising. Chalk-and-talk easily accommodates physical and verbal expression, and provides a social experience common to most social science courses. Teachers and students may be concerned that the learning experience will degrade with the adoption of new technology.

Nevertheless, the Internet and lecture video offer several potential benefits to students. As a direct input into the learning process, and by augmenting the marginal product of other inputs, such as student aptitude and effort, streaming lecture video can increase the production of learning for a given input level. These productivity improvements can directly increase students' learning and retention, improve students' enjoyment of, and attitude towards, economics and improve their understanding of how economist's think and solve problems.[1] At the same time, use of the Internet implies learning costs for some students because they are exposed to the technology for the first time.[2] Some of the potential benefits could be cancelled out by a fixed investment cost and the time allocated to learning the new technology. Any increase in student effort caused by Internet requirements and resistance to learning and using the technology could result in lower evaluation scores for instructors and a less-positive student attitude towards economics (Agarawal and Day, 1996). The overall net benefit of IT, and its effect on each of the three individual outcomes above could be positive or negative.

There is very little empirical research that investigates how the Internet and streaming lecture video benefit students in economics courses. Recent exceptions include Agarawal and Day (1998) and Brown and Liedholm (2002) who focus on the effect of technology on student performance. Agarawal and Day find that Internet use in economic pedagogy has a positive impact on student learning and retention, as reflected in standardised test scores, but no effect on student attitudes towards economics. Brown and Liedholm find that economics students instructed solely by lecture video streamed through the Internet perform worse in exams than students receiving real-time lectures. However, to this point, the question of how much enjoyment, or satisfaction, students obtain from instructor's use of Internet technology in the classroom has been largely ignored.[3] This question is important because satisfaction, quantified by willingness-to-pay, provides a more general measure of the observed and unobserved benefits of the technology that are important to students. Administrators, economists and educators should be interested in this measure when assessing the relative merits of alternative teaching and learning technologies.[4]

This study presents some results from an ongoing study of how students use and value economics lessons produced with electronic whiteboard, recorded and delivered by Internet streaming (hereafter, streaming lecture video), and how streaming lecture video affects student performance. Data from a choice experiment are used to provide some of the first publicly available estimates of students' willingness to pay for streaming video and instructor movement away from the podium, respectively. Empirical results show a divide between students who like the flexibility of catching-up on missed classes with streaming video and students who do not. For the former group, Internet technology enhances the learning experience and students are willing to pay about an additional $90 per course for streaming video. For students who do not substitute videos for real-time class lectures, some of the value placed on streaming video is eroded by confining the instructor to the podium. An important source of streaming lecture video's overall value to students is its impact on performance. Knowledge equation estimates show that streaming lecture video has a positive effect on their cumulative final grade but this effect diminishes with intensity of use.

The paper is organised as follows. The first section provides some background on technology in the classroom at the University of Colorado at Boulder. The next describes the econometric methods used to estimate the willingness to pay for streaming video, and the effect of streaming lecture video on student performance. We then describe the survey questionnaire and sample data. Estimation results are discussed next and the final section provides conclusions.

Background: technology in the classroom

At the University of Colorado at Boulder, the Center for Advanced Engineering and Technology Education (CAETE) delivers engineering and applied science courses through the classroom, videotape, DVD and Internet streaming. Production takes place in a recording studio with a live audience, producers, big-screen televisions, fixed and mobile cameras, microphones and wireless network access.[5] Tegrity recording software permits the instructor to create material from scratch on an electronic whiteboard, simulating a real-time chalkboard presentation, and/or add to pre-existing PowerPoint slides. When the lecture ends, the presentation is augmented with full audio and video of the instructor and students, and uploaded immediately to the instructor's web site for streaming.

CAETE also provides instructors with a mobile Tegrity streaming multimedia podium (hereafter, Tegrity Cart) that can be used in a typical Arts and Sciences classroom with Internet access and an overhead projection unit. The Tegrity Cart is portable and comprises a tablet monitor, PC, keyboard, mouse, electronic pen, wireless microphone and web camera (see Figure 1). Teaching and production follow the general description outlined above but without the technical sophistication provided in a classroom studio with professional assistance. The most substantial difference from studio production is that the Tegrity Cart has only one fixed web camera and one wireless microphone. This may restrict physical and verbal interaction between the instructor and classroom students, for example, preventing the instructor from moving about the classroom. An obvious advantage is the ability to record lecture videos and make them available immediately for streaming from the instructor's web site.

Real-time lectures recorded on video and streamed over the Internet are a useful supplement to non-classroom learning. Videos can be stored on a personal computer, allowing the student to review lectures anywhere and anytime in an integrated format. Stored files provide relatively easy-to-read instructor notes viewable on a monitor or television, and printable in PowerPoint and/or JPG formats. Chapter indexing allows students to easily scroll back and forward to relevant audio and lecture material. Video also permits students to see the step-by-step development of lecture material, and the augmentation of material through instructor–student interaction, which does not always follow in PowerPoint. Just like a chalkboard lecture, the instructor can include additional detail to the electronic whiteboard if the students ask. In this context, the final product is dynamic in that it is influenced by students.

These features may affect the classroom learning experience with respect to interactivity, note taking and student effort. For instance, at any point during the lecture, a student can ask the instructor to scroll back through the electronic whiteboard to clarify a point. Other students would typically benefit from this enhanced interactivity. Because students know they can easily access the audio, instructor's notes and video after the class is finished, there may be less note taking in the classroom, greater attention toward the instructor and other students, and more questions. However, when they know they have perfect access to recorded lecture material, students may feel less need to engage with others in the classroom (or, not attend classes at all). Disengagement may be accentuated by the Tegrity Cart technology which confines the instructor to the podium and leads to less physical and social interaction.

Econometric method

We are interested in three questions. Do students use streaming lecture video outside of the classroom? Do students value the instructor's use of IT that permits them to download and watch videos outside of the classroom? Do students who are enrolled in the IT-enhanced class, with access to streaming lecture video, learn more than students in a chalk-and-talk class? The first question is addressed with summary statistics presented later. The second question is addressed by estimating a willingness-to-pay equation. The final question is addressed by estimating a knowledge equation.

Willingness-to-pay equation

The value of IT in the classroom is measured by students' willingness to pay for streaming video and instructor movement away from the podium. The random utility model and choice experiment data provide the framework for estimating willingness to pay. Students were first given brief descriptions of the teaching methods used by economics instructors at the University of Colorado: *chalk-and-talk* which is simply traditional teaching with chalk, blackboard and very little IT; *PowerPoint Presentation* that utilises teaching with prepared PowerPoint slides; and *Tegrity Cart* that utilises teaching with an electronic whiteboard and lecture videos. Respondents then answered three hypothetical choice questions. Each question presented a pair of A vs. B teaching alternatives, chalk-and-talk vs. PowerPoint, chalk-and-talk vs. Tegrity Cart and PowerPoint vs. Tegrity Cart, that differed in the two attributes described in Table 1. Respondents indicated their preferred choice and willingness to pay for that choice over the choice they did not select (see Figure 2 for choice questions). The preference parameters of the utility function were then estimated from data on the attributes of the students' observed choices and stated willingness-to-pay values.

Students are assumed to behave in a manner consistent with the maximisation of their utility of teaching alternative A or B conditional on all other consumption and time allocation decisions. Let the conditional utility (u) of student $i = 1, 2, \ldots, n$ for teaching alternative $j = A, B$ in choice question $t = 1, 2, 3$ depend upon observed attributes of the alternative and unobserved student characteristics. A linear approximation to the students' conditional utility function is:[6]

$$u_{ijt} = \alpha(y_i - wtp_{ijt}) + \beta_v video_{jt} + \beta_p podium_{jt} + \varepsilon_{ijt} \quad (1)$$

where y_i is income for student *i* which is unobserved by the econometrician but does not vary across teaching alternatives and choice questions, wtp_{ijt} is student *i*'s observed willingness to pay for teaching alternative *j* in choice question *t*, $video_{jt}$ and $podium_{jt}$ are the observed attributes of alternative *j* in choice question *t*, $video_{jt}$ equals 1 when the student is able to download and playback lecture videos and 2 when the student is unable to do so, $podium_{jt}$ equals 1 when the instructor is not confined to the teaching podium, 2 when the instructor is partially confined to the teaching podium and 3 when the instructor is completely confined to the teaching podium, and ε_{ijt} is the unobserved disturbance in the students' evaluation of utility for the posed scenario.

The disturbance ε_{ijt} in (1) is assumed to be an independent and identically distributed mean zero normal random variable, uncorrelated with the independent variables, and with constant unknown variance. The preference parameters of interest are α, the marginal utility of income, β_v, the marginal utility of video, and β_p, the marginal utility of podium. The expected sign for α is positive, however; the attribute values for video and podium have been coded in Table 1 so that the expected signs for β_v and β_p are negative. For example, utility is expected to be less when video increases from 1 (i.e. able to download and play back lecture videos) to 2 (i.e. not able to download and play back lecture videos).

The hypothetical utility of each teaching alternative is not observed. Instead, the econometrician knows that when faced with two teaching alternatives, the utility-maximising student will have willingness-to-pay values that solve $u_{iBt} = u_{iAt}$. Given (1) and $u_{iBt} = u_{iAt}$, student *i*'s willingness-to-pay equation is:

$$\alpha(y_i - wtp_{iBt}) + \beta_v video_{Bt} + \beta_p podium_{Bt} + \varepsilon_{iBt} = \alpha(y_i - wtp_{iAt}) + \beta_v video_{At} + \beta_p podium_{At} + \varepsilon_{iAt}$$

$$-\alpha(y_i - wtp_{iBt}) = -\alpha(y_i - wtp_{iAt}) + \beta_v(video_{Bt} - video_{At}) + \beta_p(podium_{Bt} - podium_{At}) + (\varepsilon_{iBt} - \varepsilon_{iAt})$$

$$\alpha wtp_{iBt} = \alpha wtp_{iAt} + \beta_v(video_{Bt} - video_{At}) + \beta_p(podium_{Bt} - podium_{At}) + (\varepsilon_{iBt} - \varepsilon_{iAt})$$

$$\Delta wtp_{it} = \delta_v \Delta video_t + \delta_p \Delta podium_t + \Delta\varepsilon_{it} \qquad (2)$$

where $\Delta wtp_{it} = wtp_{iBt} - wtp_{iAt}$, $\Delta video_t = video_{Bt} - video_{At}$, $\Delta podium_t = podium_{Bt} - podium_{At}$, $\Delta\varepsilon_{it} = \frac{\varepsilon_{iBt} - \varepsilon_{iAt}}{\alpha}$, $\delta_v = \frac{\hat{a}_v}{\alpha}$ and $\delta_p = \frac{\hat{a}_p}{\alpha}$. From the distributional assumption about ε, Δwtp_{it} is normally distributed with mean $\delta_v \Delta video_t + \delta_p \Delta podium_t$ and variance $\frac{\gamma^2}{\alpha^2}$, where γ_2 is the variance of $\varepsilon_{iBt} - \varepsilon_{iAt}$. Given non-zero continuous values for Δwtp_{ij}, ordinary least squares (OLS) estimation of (2) provides $\delta_v = \frac{\hat{a}_v}{\alpha}$ and $\delta_p = \frac{\hat{a}_p}{\alpha}$, which are the willingness to pay for streaming lecture video and instructor movement away from the podium, respectively.

Knowledge equation

Suppose there has been some IT modification or, treatment, to an economics course and data on the learning process are observed for students with and without this modification. The knowledge equation for student $i = 1, \ldots, n$ is:

$$\log GRADE_i = \tilde{a}_{0i} + \tilde{a}_t T_i + \tilde{a}_v V_i + \tilde{a}_g \log GPA_i + \tilde{\boldsymbol{a}}_x{}' \boldsymbol{X}_i + u_i \qquad (3)$$

where $GRADE_i$ is cumulative final grade, T_i equals one when the student is in the treatment class and zero otherwise, V_i is time spent downloading and watching lecture videos outside the classroom, GPA_i is cumulative grade-point average prior to the course, X_i is a vector of student characteristics, the γ's are knowledge parameters and u_i is an error. The estimated parameter of interest is γ_v. An estimate of $\gamma_v > 0$ indicates that, all other things being equal, time spent downloading and watching lecture videos outside the classroom increases student performance, as measured by their final grade in the course.

Survey and sample characteristics

In summer 2005, ECON 3070 Intermediate Microeconomic Theory was offered to students in an Arts and Sciences classroom that seats 47, has wireless Internet access and overhead projection facilities. Classes of one and three-quarter hour duration were provided each weekday from May 31 to July 1. Students were informed during the first class that the Tegrity Cart and video streaming would be used for teaching instruction, and they would be surveyed at the end of the course to evaluate the technology. Tegrity Cart instruction was used in 19 of the 23 classes. Two classes were set aside for the mid-term and final examination, respectively, and two classes employed chalk-and-talk following technical problems.

Survey questionnaire

A focus group with six students was conducted on 22 June 2005 to solicit information for the survey questionnaire. The choice experiment was administered by survey questionnaire on June 30. For an incentive, students who completed the survey had a chance to win one of three prizes of $20. The questionnaire begins with *background* questions about the respondent's previous college experience, major and expectations for ECON 3070. Next, students are asked questions about their past and present *learning experiences*, and must compare their general learning experience under alternative instruction methods. Here, respondents are provided with information to form preferences about the attributes described in Table I. This is followed by the *choice task* where each respondent must answer three hypothetical choice questions (see Figure 2), and describe the best and worse features of alternative instruction methods. Finally, students provide demographic information.

Sample demographics

39 of the 42 enrolled students completed questionnaires. About 80 per cent were male, 72 per cent where white, and the average age was 23.6 years. Most students (32 out of 39) reside in Boulder County, so are physically close to CU Boulder. All bar one student has a personal computer or laptop at home, and over 90 per cent of this group have high-speed Internet access. Student grade point average, prior to

commencing the summer 2005 class, varies from 1.15 to 4 with mean 2.751 and standard deviation 0.771.

Economics background

Table 2 summarises student responses to background questions. Almost half the class has taken courses at another college, and just over 20 per cent has taken a distance-learning course. Almost 70 per cent of students are economics majors, which is not surprising given ECON 3070 is a required for the major, and provides a gateway to higher-level economics courses. The most frequently cited reason for an economics major is 'Its good for my career path' (44.4 per cent of students), followed by 'I find it interesting' (37 per cent of students). Over 80 per cent of students said the course met their expectations, they found the topics intellectually stimulating, they now have a better understanding of how economists think and solve problems, and they now are more confident about solving real-world economics problems.

Learning experience

The questionnaire asks students about their use of streaming lecture video, to compare different instruction methods, to choose between hypothetical teaching alternatives, and to express what they perceive to be the best and worse features of Tegrity Cart instruction. As a precursor to analysis of the choice experiment data later, we briefly summarise students' responses to various survey questions.[7]

Of the 39 students surveyed, 30 (or, 76.9 per cent) downloaded and watched lecture videos of ECON 3070 during summer, 2005. This result is encouraging and reasonably consistent with Internet use for the broader population.[8] The primary viewing location was home. 66.7 per cent of students viewed less than five hours of video, 20 per cent viewed five to ten hours, 10 per cent viewed ten to 15, and the rest over 15 hours.

Tegrity Cart instruction compares reasonably well with chalk-and-talk. About 44 per cent of students indicated the Tegrity Cart and streaming lecture video provided them with a better learning experience than instruction via chalk-and-talk, and 41 per cent indicated the experience was the same as chalk-and-talk. Consistent with anecdotal and received empirical evidence, PowerPoint instruction is not viewed favorably by economics students.[9] Over two-thirds of surveyed students indicated the Tegrity Cart and streaming lecture video provided a better learning experience than PowerPoint presentation. These findings are supported by responses to questions that compare teaching alternatives. When asked to choose between chalk-and-talk or PowerPoint for the same course (ECON 3070), 76.9 per cent selected chalk-and-talk. When asked to choose between chalk-and-talk or Tegrity Cart, 74.4 per cent selected the Tegrity Cart. When asked to choose between PowerPoint or the Tegrity Cart, 92.3 per cent selected the Tegrity Cart.

In several open-ended questions, students described the best and worst features of Tegrity Cart instruction. Students consistently cited many of the streaming lecture video features described above as best features. Accurate presentation of models in class, and the in-class ability to review previously covered material were also cited (albeit much less than streaming lecture video). Students clearly disliked the instructor being confined to the podium and thought there was less interaction and student participation. Several students said the Tegrity software was cumbersome when changing pen colour, erasing and saving slides. Some students were put off by technical problems with the Tegrity Cart in the classroom, and streaming lecture video from their home computer.

These data suggest that students enjoy the convenience and many of the specific features streaming lecture video provides away from the classroom. However, because the Tegrity cart confines the instructor to the podium, classroom satisfaction is diminished when there is less physical and social interaction with students. Below we take some exploratory steps toward quantifying this trade off by conducting a simple choice experiment which permits estimation of students' willingness to pay for streaming video and instructor movement away from the podium, respectively. Because the sample is summer school students, and of relatively small size, these results should be treated somewhat cautiously when generalising to the general population of students. Nevertheless, estimates are plausible, and provide useful information for designing more ambitious future experiments with more choice occasions, attributes and potential interactions.

Estimation results

Willingness-to-pay equation estimates

There are 38 observations with complete information on the three choice questions. The initial sample size for econometric estimation is $n \times T = 114$.[10] OLS estimates of the basic WTP equation (2) are presented in Table IV under the model (i) column. Standard errors are heteroskedasticity consistent and permit intra-respondent clustering among the three choice questions. The data fit the model reasonably well, as judged by the sign and statistical significance of parameter estimates. As expected, the ratio of the marginal utility of each attribute to the marginal utility of income are negative. Students are willing to pay $73.84 to download and playback lectures, and $32.46 for a discrete improvement in the ability of the instructor to move away from the teaching podium. These estimates seem sensible when compared to supplementary education materials such as, a textbook, study guide, online access to textbook problems, etc. Students pay $115.95 for the textbook for *ECON 3070 Intermediate Microeconomic Theory* and up to $52.90 for the study guide and an ancillary to the textbook.

Individuals may not have identical preferences. Sixteen of the 39 students surveyed indicated that at least once they chose not to come to class and substituted an online lecture for the actual real-time class lecture. We would expect those students that substitute streaming videos for real-time class lectures to behave differently than those who do not. We allow for heterogeneous preferences in model (ii) by interacting *VIDEO* with *ATTENDANCE* (equals one when the student chose not to come to class and substitute a lecture video for the actual class lecture, and zero otherwise). A concern, however, is that the attendance variable may be correlated with unobserved factors that also affect willingness-to-pay such as motivation, family history, etc. We deal with this endogeneity by using the variables, *HIGH-SPEED* (equals one when the student has high-speed Internet access at home, and zero otherwise), *DISTANCE* (equals one when the student resides out of Boulder County, and zero otherwise) and *RACE* (equals one when the student is white, and zero otherwise) as instruments for *ATTENDANCE*. Summary statistics and probit estimates, reported in Table's V and VI, respectively, show these variables to be important determinants of a students' decision not to come to class and substitute a lecture video for the actual class lecture. We use *VIDEO*× *HIGH-SPEED*, *VIDEO*×*DISTANCE* and *VIDEO*×*RACE* as excluded instruments for the *VIDEO*×*ATTENDANCE* interaction.

Model (ii), with the *VIDEO*×*ATTENDANCE* interaction, is estimated by Generalised Method of Moments (GMM). The model is reasonably well specified. The Anderson LR statistic is significant which indicates the excluded instruments have good explanatory power in first-stage regressions. The Hansen J statistic is not significant and does not reject the null of zero correlation between instruments and errors. Results are qualitatively similar, with respect to coefficient signs, to those obtained for model (i). Results indicate that *ATTENDANCE* is important variable in the empirical model. Students that substitute streaming videos for real-time class lectures are willing to pay an additional $104.36 to stream lecture video than those who do not. The willingness-to-pay for a discrete improvement in the ability of the instructor to move away from the teaching podium has declined from $32.47 in model (i) to $25.91 in model (ii).

For robustness, we now consider how ability affects student preferences for the VIDEO teaching attribute. We estimate model (iv) with both a *VIDEO*×*ATTENDENCE* and *VIDEO*×*GPA* interaction, where *GPA* (equals one when the students' grade point average is above the class average and zero otherwise) is a proxy for ability. Because of missing *GPA* information we lose data for three respondents when estimating the model with both interactions. For purpose of comparison with (ii), model (iii) first re-estimates equation (2) with the *VIDEO*×*ATTENDANCE* interaction by GMM on data for $n \times j = 105$ respondents.

Model (iv), with the *VIDEO*×*ATTENDENCE* and *VIDEO*×*GPA* interactions, is estimated by GMM on data for $n \times j = 105$ respondents. Results are qualitatively similar to those obtained for model (ii), although estimated coefficients now indicate that students that substitute streaming videos for real-time class lectures are willing to pay an additional $89.57. The willingness-to-pay for a discrete improvement in the ability of the instructor to move away from the teaching podium has increased slightly to $28.31. The estimated coefficient for the *VIDEO*×*GPA* interaction is negative but is not precisely estimated at conventional levels of significance.

Some discussion of the *VIDEO vs. PODIUM* trade off is warranted in the context of teaching undergraduate economics with streaming lecture video. Discussion centers around the results from the preferred model (iv). Note that the signs on *VIDEO*, *PODIUM* and *VIDEO*×*ATTENDENCE* are all negative and although the coefficient on *VIDEO* is not significant, a Wald test ($\chi^2 = 13.81$) rejects the null that the coefficients on *VIDEO* and *VIDEO*×*ATTENDENCE* are jointly equal to zero. These estimates suggest that students value the non-classroom streaming video attribute of Tegrity Cart instruction. However, for students who *do not* substitute streamed videos for real-time class lectures, some of this value is eroded by confining the instructor to the podium. Students who *do* substitute streamed videos for real-time class lectures reduce their valuation by about 24 per cent (i.e. $28.31/$117.64 = 24.06 per cent).

These results are interesting in that they show a divide between students who like the flexibility of catching up on missed classes with streaming video and students who do not. For the former group of students, the Internet and streaming lecture video enhance the learning experience and students are willing to pay for this enhancement. However, economics instruction and learning has traditionally been a social experience and the latter group of students may feel that classroom interactivity and learning are diminished when technology restricts the mobility of the instructor. In this respect, results confirm what most economics instructors and students already know; chalk-and-talk (and social interaction with cooperative learning) continues to provide a powerful and valuable learning experience. If an electronic whiteboard, coupled with video and Internet streaming, is to make broad inroads into undergraduate economics classes, the technology needs to be developed to better mimic the physical and social attributes of chalk-and-talk.

Developers need to think about 'smarter' classrooms with many fixed and mobile cameras (and audio) that track the interaction between teacher and students.

Knowledge equation estimates

The results above suggest that streaming lecture video enhances the learning experience and students value this enhancement. We now investigate one source of this value, namely, the effect of streaming lecture video on student performance.

The knowledge equation (3) is estimated on data from two sections of ECON 3070 Intermediate Microeconomic Theory. The IT-enhanced treatment section was taught with the Tegrity Cart during summer 2005. The comparison section was taught with chalk-and-talk during summer 2006. Both sections were taught by the same instructor at the same times, in the same classroom, with the same syllabus, textbook and work requirements. Table 7 presents summary statistics that show that student characteristics for the comparison and treatment sections are similar.

Column two of Table 8, i.e. model (v), reports OLS estimates of the most parsimonious specification of (3). The estimated coefficient on *logV*, $\gamma_V = 0.024$, is not significantly different from zero ($t = 0.43$; $P > |t| = 0.56$). It is possible that streaming lecture video has a non-linear impact on student performance. In model (vi) we include *logV* and $(logV)^2$ in the knowledge equation and observe that the estimated coefficient on *logV* is positive and significantly different from zero ($t = 1.84$; $P > |t| = 0.07$), while the estimated coefficient on $(logV)^2$ is negative but less precisely estimated ($t = 1.51$; $P > |t| = 0.14$). However, after controlling for various sets of student characteristics in model's (vii) through (ix), the estimated coefficient's on *logV* and $(logV)^2$, respectively, are more precisely estimated. In model (ix), which contains the full set of control variables, the estimate coefficient on *logV* is 0.197 and significant at the 10 per cent level ($t = 1.65$; $P > |t| = 0.10$). The estimated coefficient on $(logV)^2$ is –0.145 and significant at the 5 per cent level ($t = 2.02$; $P > |t| = 0.05$).

We now use estimates from the preferred specification of knowledge, model (ix), to examine the effect of streaming lecture video on predicted final grade. Table 9 shows how students' predicted final grade ($\hat{GRADE}$) changes with their intensity of use of streaming lecture video, holding all other variables constant at their sample means. $\Delta\hat{GRADE}$ is positive but declining over all values of *V* and turns negative for *V* equals 6. These estimates show that streaming lecture video has a beneficial effect on student performance but that the benefits diminish with intensity of use. Nevertheless, the overall effect of streaming lecture video on student performance is generally positive and, as such, appears to be an important source of students' satisfaction with, and valuation of, streaming lecture video.[11]

Conclusions

This study presents some initial results from an ongoing study of how students value economics lessons produced with streaming lecture video, and how this technology affects student performance. Data from a choice experiment are used to provide some of the first publicly available estimates of students' willingness-to-pay for streaming video and instructor movement away from the podium.

Results show that economics students like many of the features streaming lecture video provides outside the classroom. By providing students with flexibility to review material they have already seen in a real-time lecture, video complements the classroom experience in much the same way as a textbook or study guide, but with a dynamic emphasis. Moreover, streaming lecture video has a positive impact on student performance, as measured by their cumulative final grade. A downside, however, is that the technology used to record lecture video restricts the instructor to the teaching podium, and students feel that their classroom experience is diminished when there is less physical and social interaction. This finding suggests that chalk and talk will continue to be a popular method of economics instruction until developers better replicate the social experience a fully interactive classroom provides.

Note that results reported here are from one experiment only and more research is needed on larger and, perhaps, more representative, samples. Future work intends to estimate willingness to pay from a sample of fall 2006 students, and examines how willingness to pay varies by who pays for the education (for instance, scholarship, student or parents). We will also employ a control-treatment approach to analyse the effect of streaming video on the academic performance of undergraduate economics students. Here, it may be important to obtain variables that provide exogenous variation in streaming lecture video in the event of a simultaneity problem that arises when unobserved productivity shocks are correlated with the students' streaming lecture video decision.

Appendix A. Estimates of ATTENDANCE model

This section estimates the ATTENDANCE model. Summary statistics of all variables in the model are reported in Table 4. Table 5 reports probit model estimates of *ATTENDANCE* (equals 1 when the student chose not to come to class and substitute a lecture video for the actual class lecture, and 0 otherwise) on selected student characteristics. The characteristics are *HIGH-SPEED* (equals 1 when the student has high-speed Internet access at home, and 0 otherwise), *DISTANCE* (equals 1 when the student resides out of Boulder County, and 0 otherwise), *RACE* (equals 1 when the student is white, and 0 otherwise), *EXPERIENCE* (equals 1 when the student had previous instructors who used the Tegrity Cart, and 0 otherwise), *DIST LEARNING* (equals 1 when the student had taken any distance-learning college classes, and 0 otherwise). Students with high-speed Internet access at home are more likely to substitute an actual class with a video lecture. White students, and students residing outside of Boulder County, are less likely to substitute actual classes.

Figure 1: The Tegrity cart

Table 1. Attribute values for teaching alternatives

TEACHING ALTERNATIVE	VIDEO	PODIUM
Chalk-and-talk: traditional teaching with chalk, blackboard and very little information technology.	2. *not able* to down download and playback lecture videos.	1. instructor is *not confined* to the teaching podium.
PowerPoint: teaching with prepared PowerPoint slides.	2. *not able* to download and playback lecture videos.	2. instructor is *partially confined* to the teaching podium.
Tegrity Cart: teaching with an electronic whiteboard and lecture videos.	1. *able* to download and playback lecture videos.	3. instructor is *completely confined* to the teaching podium.

Figure 2. Choice questions

32. Suppose you were offered the same course *(ECON 3070)* with the same Instructor, but could choose between instruction via *chalk-and-talk* or *PowerPoint Presentation*. What would you choose? (mark one answer)

❍-1 Chalk-and-talk ❍-2 PowerPoint

33. Think of your choice in Q32 the same way you think about purchasing other materials that supplement your education such as, a study guide, online access to textbook problems, tutoring, etc. How much would you be willing to pay for the choice you selected in Q32 over the choice you *did not* select? (write in a dollar amount)

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34. Suppose you were offered the same course *(ECON 3070)* with the same Instructor, but could choose between instruction via *chalk-and-talk* or *Tegrity Cart*. What would you choose? (mark one answer)

❍-1 Chalk-and-talk ❍-2 Tegrity Cart

35. How much would you be willing to pay for the choice you selected in Q34 over the choice you *did not* select? (write in a dollar amount)

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36. Suppose you were offered the same course *(ECON 3070)* with the same Instructor, but could choose between instruction via *PowerPoint Presentation* or *Tegrity Cart*. What would you choose? (mark one answer)

❍-1 Power Point ❍-2 Tegrity Cart

37. How much would you be willing to pay for the choice you selected in Q36 over the choice you did not select? (write in a dollar amount)

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Table 2. Summary of responses to background questions

Question	%
Have you taken any classes at another university, junior college, etc.?	
Yes	46.2
No	53.8
Have you taken any distance-learning college classes?	
Yes	20.5
No	79.5
Are you an economics major?	
Yes	69.2
No	30.8
Why did you choose economics?	
I find it interesting	37.0
It will complement my graduate degree	3.7
Its good for my career path	44.4
It helps me understand the economy	11.1
Other	3.7
Has *ECON 3070* met your expectations?	
Yes	82.1
No	17.9
Why (has *ECON 3070*) not (*met your expectations*)?	
It is more theoretical than I expected	42.9
It is more mathematical than I expected	42.9
It does not have enough real-world examples	–
It was just like *Principles of Microeconomics*	14.3
Other	–
Did you find the topics in *ECON 3070* intellectually stimulating?	
Yes	82.1
No	17.9
Now that you have completed *ECON 3070*, do you have a better understanding of how economists think and solve problems?	
Yes	97.4
No	2.6
Are you now more confident about solving real-world economics problems?	
Yes	84.6
No	15.4

Table 3. Summary Statistics for WTP equation (2)

	n	Mean	s.d.	Minimum	Maximum
Δ*WTP*	114	5.167	85.04	–300	250
ΔVIDEO	114	–0.667	0.473	–1	0
ΔPODIUM	114	1.333	0.473	1	2
ATTENDANCE	38	0.395	0.491	0	1
GPA	38	0.921	0.271	0	1

Note. s.d. denotes standard deviation.

Table 4. Estimates of WTP equation (2)

	Model (i) OLS	Model (ii) GMM	Model (iii) GMM	Model (iv) GMM
VIDEO	–73.842[a]	–28.370	–30.949	–28.068
	(4.67)	(1.60)	(1.55)	(1.23)
VIDEO×ATTENDANCE	–	–104.361a	–87.287[a]	–89.571[a]
	–	(2.82)	(2.06)	(2.11)
VIDEO×GPA	–	–	–	–3.189
				(0.19)
PODIUM	–32.465[a]	–25.910[a]	–27.757[a]	–28.308[a]
	(3.35)	(2.99)	(3.10)	(3.17)
R-squared	0.132	n.a.	n.a.	n.a.
Anderson LR statistic	n.a.	15.66[a]	14.27[a]	15.23[a]
Hansen J statistic	n.a.	2.804	2.366	2.419
$\chi^2(2)$	n.a.	24.14[a]	19.37[a]	13.81[a]
n×T	114	114	105	105

Note. Dependent variable is $WTP_{iBt}–WTP_{iAT}$. Absolute value of t-statistic (z-statistic) in parentheses in OLS (GMM) models. Standard errors used to calculate t-statistic (z-statistic) are robust to heteroskedasticity and intra-respondent clustering among the three choice questions. [a]denotes significance at the 5 per cent level. n.a denotes not applicable. Anderson LR statistic tests the null that the excluded instruments have zero explanatory power in first-stage regressions. Hansen J statistic tests the null of zero correlation between instruments and errors. $\chi^2(2)$ is a Wald test of the null that the coefficients on *VIDEO* and *VIDEO×ATTENDENCE* are jointly equal to zero.

Table 5. Summary statistics for variables in ATTENDANCE model

	Mean	s.d.	Minimum	Maximum
ATTENDANCE	0.395	0.491	0	1
HIGH-SPEED	0.868	0.343	0	1
DISTANCE	0.237	0.431	0	1
RACE	0.737	0.446	0	1
EXPERIENCE	0.237	0.431	0	1
DIST LEARNING	0.211	0.413	0	1

Note. s.d. denotes standard deviation. n = 38.

Table 6. Probit estimates of ATTENDANCE model

	Parameter	z-statistic
HIGH-SPEED	1.2465a	2.0844
DISTANCE	–1.1332b	1.6736
RACE	–1.4175a	2.3410
EXPERIENCE	–0.0006	0.0018
DIST LEARNING	0.2235	0.4399
Log likelihood	–21.733	
n	38	

Note. Dependent variable is *ATTENDANCE*. [a]denotes significance at the 5 per cent level. [b]denotes significance at the 10 per cent level.

Table 7. Summary statistics for knowledge equation (3)

Variable	Description	Comparison mean (s.d.)	Treatment mean (s.d.)	Difference (s.e.)
GPA LEVEL	Cumulative grade point average prior to course.	2.655 (0.691)	2.754 (0.637)	0.099 (0.077)
MAJOR	1 if economics major.	0.634 (0.482)	0.576 (0.494)	–0.058 (0.114)
NON DEGREE	1 if non-degree student.	0.049 (0.215)	0.121 (0.326)	0.072 (0.064)
MATH	1 if engineering or mathematics major.	0.024 (0.154)	0.030 (0.171)	0.006 (0.038)
FEMALE	1 if female.	0.366 (0.482)	0.212 (0.409)	–0.154 (0.107)
RACE	1 if race is white.	0.683 (0.465)	0.667 (0.471)	–0.016 (0.109)
T	1 if student is in treatment section.	0 (0)	1 (0)	n.a.
V	1 if did not download videos; 2 if download < 5 hours; 3 if download 5 to 10 hours; 4 if download 10 to 15 hours; 5 if download 15 to 20 hours; 6 if download > 20 hours.	n.a.	2.303 (1.132)	n.a.
GRADE	Cumulative final grade (100 %).	76.68 (15.63)	78.44 (10.36)	1.765 (3.167)
Sample size		41	33	n.a.

Note. s.d. is standard deviation; s.e. is standard error.

Table 8. Estimates of knowledge equation (3)

	Model (v)	Model (vi)	Model (vii)	Model (viii)	Model (ix)
T	0.007	–0.035	–0.030	–0.029	–0.031
	(0.13)	(0.64)	(0.53)	(0.51)	(0.51)
logV	0.024	0.195[b]	0.217[a]	0.217[a]	0.197[b]
	(0.43)	(1.84)	(1.99)	(2.00)	(1.65)
(logV)2		–0.113	–0.151[a]	–0.152[a]	–0.145[a]
		(1.51)	(2.10)	(2.12)	(2.02)
logGPA LEVEL	0.494[a]	0.494[a]	0.484[a]	0.487[a]	0.508[a]
	(3.98)	(3.96)	(3.89)	(3.60)	(3.21)
MAJOR			–0.037	–0.038	–0.034
			(1.03)	(0.96)	(0.91)
NON DEGREE			0.047	0.045	0.061
			(0.94)	(0.81)	(1.21)
MATH			0.264[a]	0.263[a]	0.284[a]
			(5.36)	(5.39)	(4.48)
RACE				–0.007	–0.016
				(0.13)	(0.24)
FEMALE					–0.061
					(0.72)
CONSTANT	3.842[a]	3.841[a]	3.865[a]	3.869[a]	3.873[a]
	(25.3)	(25.1)	(27.1)	(28.6)	(28.5)
R^2	0.273	0.281	0.322	0.322	0.334
F	6.92[a]	5.56[a]	6.89[a]	6.47[a]	7.96[a]

Note. Dependent variable is *logGRADE*. Absolute value of t-statistic in parentheses. Standard errors used to calculate t-statistics are robust to heteroskedasticity. [a]denotes significance at the 5 per cent level. [b]denotes significance at the 10 per cent level. n = 74.

Table 9. The effect of video on predicted final grade

V	Description	*GRÂDE*	*∆GRÂDE*	*%∆GRÂDE*
1	Download no video.	74.17		
2	Download < 5 hours.	77.67	3.504	4.725
3	Download 5 to 10 hours.	78.83	1.160	1.493
4	Download 10 to 15 hours.	79.23	0.400	0.508
5	Download 15 to 20 hours.	79.29	0.064	0.081
6	Download > 20 hours.	79.19	–0.108	–0.136

Note. *GRÂDE* is predicted final grade given sample means for all independent variables other than V.

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Notes

1 Indirect benefits also arise from time savings that can be allocated to other learning, work and leisure activities.

2 See Agarawal and Day (1996) for a discussion of the costs to instructors and students that result from incorporating the Internet into a course.

3 Chan *et al*. (2005) are an exception. They find a positive relationship between economics students' satisfaction and the university's level of resources and environment. Resources and environment includes access to computers, books and academic help, interactive multi-media packages designed for certain disciplines and units, online discussions among students, virtual tutoring and obtaining lecture and tutorial. They do not focus on the specific relationship between satisfaction and Internet technology.

4 Because it measures net utility, willingness to pay provides a measure of the benefit from new instructional technologies to students. This benefit can be compared to the learning and investment costs incurred by instructors and students to provide a measure of the economic efficiency of new technologies.

5 The studio resembles what is seen on television talk shows hosted by Oprah Winfrey, Dr. Phil, etc.

6 Equation (1) provides the indirect utility function which is derived from the utility-maximisation problem where utility is maximised subject to the income constraint. The indirect utility function is the utility function evaluated at the optimal choices, which depend on prices, income and attributes. See Varian (1992) for a derivation.

7 See Flores and Savage (2005) for more detailed discussion of the descriptive statistics for the learning experience.

8 Madden (2006) suggests that at April 2006 about 73 per cent of US adults are Internet users.

9 Sosin *et al.* (2004) find that the difference between post- and pre-course test scores for introductory economics students is lower in classes where the instructor used PowerPoint regularly. As noted by an anonymous referee, these adverse findings with respect to PowerPoint presentations suggest as much about the way PowerPoint is used in a given situation rather than about the merits of the technology itself.

10 See Table 3 for summary statistics for all variables in the willingness-to-pay equation.

11 Savage (2007) notes that the error in (3) can be decomposed into a productivity shock ω_i and a white noise component η_i. The student observes ω_i but not η_i when making input decisions, while both ω_i and η_i are unobserved by the econometrician. Simultaneity arises when the productivity shock is observed by the student early enough to affect his or her input decision about V_i. For example, when students download more videos in response to a positive productivity shock, the estimated effect of streaming lecture video on student performance will be overstated. As such, we view the results reported in Table 9 as upper-bound estimates but note that the general pattern of effects should be unaffected by any simultaneity problem.

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