The Effects of Class Size on Student Achievement in Higher Education: Applying an Earnings Function

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When considering higher education, economists often view it as a business and apply the theory of the firm. They model a matching process between student and school; describe the economic characteristics of higher education and/or consider the costs of higher education and the policy implications of relative cost increases. This paper approaches one aspect of higher education that is not often addressed**;** the modeling and estimation of how the classroom environment, particularly class size, affects the delivery of education to the student and the grade, or "reward," they earn.

INTRODUCTION

In this paper we employ the theory of wages to higher education in order to consider the influence of class size on student achievement[1]. Equating grades to wages, we consider the issue from the student's perspective, focusing on the effect class size has on student performance as measured by grades. When reviewing the literature on class size, we look both at studies focusing on K-12 (where the evidence suggests class size negatively influences student outcomes at least under certain circumstances) as well as higher education (where the evidence is more mixed). We then present a fairly parsimonious model of grades employing wage theory as a framework. The logistic regression created from the model reveals that class size is a very important variable in predicting grades and that the functional form of the relationship is consistent with the theoretical model developed by Glass and associates (1982) to explain the negative effect of class grades on K-12 student performance. We then explore how the effect of class size on grades differs for advance placement, at-risk, underrepresented and female undergraduates. Potential for future studies are also addressed.

LITERATURE REVIEW

K-12 studies.

By the 1970's there was near consensus in the educational research community that class size had little effect on student achievement[2]. However, Glass and Smith, in a series of articles beginning in the late 1970s (Glass and Smith, 1979; Smith and Glass, 1980; Glass, McGraw and Smith, 1981) presented a theoretical model suggesting that the functional form of the relationship

between class size and student achievement should be negatively sloped and concave (logarithmic). This model has become a basis for further normative discussion on whether, or how, class sizes should vary (Lipman, 1990; Kennedy, 1996). They also presented the results of their own meta-analysis of studies looking at the effect of class size sustaining their model that there is a negative logarithmic relationship between class size and student performance. Heavily weighting studies that they considered more experimental in design, and discounting those they considered non- or quasi-experimental, Glass et al. (1982) argued that the positive effect of smaller class sizes results from attitudinal changes in both teachers and students in that environment.

Given this evidence that smaller class sizes are beneficial, several states designed experiments to replicate, and thereby substantiate, Glass's et al. findings. The most extensive experiment was Tennessee's STAR project. (Word et al., 1990; Ritter & Boruch, 1999) The results of the STAR Project showed that students scored better on 3rd grade standardized tests in math and reading if they had attended smaller sized kindergartens (Finn & Achilles, 1999; Krueger, 1999). Follow up studies showed that those students who continued in small classes beyond kindergarten did better than those that did not (Nye et al., 1999), and that small classes seem to be most beneficial to those coming from disadvantaged backgrounds (Krueger & Whitmore 2000; Slavin 1990). Subsequently, the findings from the STAR program and more modest experiments elsewhere (Tillitski, 1990; Molner et al., 1999;Weiss, 1990) heavily influenced California's decision to spend 6 billion dollars on class size reduction (Santa Barbara, 2001).

Even though there is now clear evidence that smaller class sizes improve student performance, at least in some circumstances, the debate continues over what to do with that evidence. In particular, economists point out the need to weigh the costs of achieving smaller classes versus the costs of improving student achievement by other means. (Nelson & Hevert, 1992; Maxwell & Lopus, 1995)). The evidence suggests that average class sizes must be reduced to 15 to achieve significant improvement in test scores, yet it has been estimated that this would cost up to eleven billion dollars a year if enacted nationwide (Brewer et al., 1999). While the STAR project does show significant improvement in students attending smaller sized kindergarten, the estimated beneficial effect of continuing in small classes is far more modest and its significance more debatable (Harder, 1990; Slavin, 1990). Further, the implementation of the STAR experiment has been question. The attempts to randomly assign students into different sized classrooms may not have been perfect, given that some parents may have tried to get their child into the treatment group of smaller classes. For similar reasons, the morale of teachers and students in control groups might have been different than those assigned to the treatment groups (Hanushek, 1999a). Indeed, in a recent sophisticated statistical analysis, Hoxby (2000) critiques numerous class size studies on the basis of how they assigned students to different sized classrooms. Using an exogenous assignment model she found only sketchy evidence that class size positively influences performance.

Class Size at the College Level

Though there is some debate about the amount of benefit small classes bring or how much it costs to achieve, there is at least some agreement in the K-12 literature that class size matters in

certain circumstances. No such agreement exists in the literature concerning the effect of class size in higher education. Indeed, in two well-respected reviews of the literatures (William et al., 1985; Pascarella & Terenzini, 1991), the authors conclude that the overall evidence suggests that class size plays no or little influence on student achievement. This however has not quelled the debate. McKeachie (1980,1990) in particular has presented arguments that class size is the primary environmental variable college faculty must contend with when developing effective teaching strategies. He argues that while class size may not be significant in courses best suited for lecture style learning, courses geared toward promoting critical thinking and advanced problem solving are best suited for smaller classroom environment

McKeachie's view is consistent with findings that suggest that students' (and professors') motivation and attitude tends to be more negatively affected by larger classes. (Feldman, 1984; Bolander, 1973; McConnell & Sosin, 1984; Spahn, 1999) Though they may have learned the material, students do not feel as satisfied with the classroom experience as they would have in smaller classes, suggesting that some learning opportunities may have been lost. Also, there is some evidence that class size may matter is some courses but not in others. Raimondo, Esposito & Gershenberg (1990) found that students in smaller sized introductory macroeconomic courses did better in subsequent intermediate macroeconomic courses even though the same was not true when conducting the same analysis for microeconomic courses. They suggest, consistent with McKeachie argument, that smaller classroom environments enhance the more wide-ranging, non-formula based knowledge necessary for understanding macroeconomic principles.

Given that there is a lack of consensus about how to measure student achievement in higher education it is not surprising that there is no definitive answer to the question of how class size relates to it. Nor do we attempt to solve the debate in this paper. We do present findings, based on data from a single institution, of how class size effects student outcomes, as measured by grades, after controlling for other relevant student and course characteristics. In doing so we rely on Economist's theory of wages as a way to think about what grades are from a student's perspective. We also explore some interesting interactive effects we found and suggest a plan of action for future studies.

THE MODEL

Human capital theory tells us that people are paid in relation to their applicable human capital. Labor theory (Mincer, 1974) suggests that earnings or wages depend upon ability, education, and experience. Applying this to the market for higher education, we postulate the following story:

Students attend institutions of higher education to gain experience and education. They pay for this education through tuition, fees, living expenses, living conditions, and foregone wages. They are rewarded with some sort of certification at the end of some period of study. During this time, they are paid by a form of script, that is, credit hours, which, when amassed, indicate the extent and quality of their performance in school. When accumulated sufficiently, the script can be used to "buy" a certificate or degree. The quality of the script, and indeed its acceptability in buying a degree, is represented by the course grade. Since there often are grade point standards, course grades have further importance. We can consider a course grade then, as a form of reward or

payment of the quality of the script for the performance the student has in a specific course. We define the relationship between script (proxied by course credit hours, *H*), and its quality (proxied by course grade, *G*) as *W*, the wage as

(1) $W = f(G, H)$.

Selecting the specific functional form becomes our next problem. We postulate

(1a) $W = \alpha G + (1 - \alpha)H, 0 < \alpha < 1$

as the maintained hypothesis and further assuming α approaches unity[3]. Thus we assume in what follows that $W = G$.

We apply earnings theory and write for the *i th* students in the *j th* class during trial period *t*:

(2) $W_{ijt} = b0 + b1 * E_{it} + b2 * E_{it}^2 + b3 * A_i + b4 * V_{jt}$

Here, W stands for the wage, or, in this case, the grade, E the student's experience (level in college, 1st semester freshmen through 2nd semester senior), E^2 the student's pre-enrollment education (dichotomous variable whether a student obtained AP credits in high school), A stands for ability (how well the student performed in other courses that semester), and *V* is a vector of environmental factors including class size (CS).

The null hypothesis (H_{01}) then is that class size does not affect student learning or performance at the university level and this would be reflected in the stability of grade distributions over various class sizes. Initially, we posit that if

(3) $W_{ijt} = f(CS_{jt})$, then $f(.) = 0, ceteris\ paribus$

A second hypothesis or corollary is that H_{01} holds even when the arguments other than *CS* in Equation (3) have non zero coefficients, and the inclusion of other environmental variables such as gender, ethnicity, department, etc. resulting in a yet more complete model, still results in non-rejection of H_{01}.

Data

This study was conducted using data from a highly selective extensive research institution (new Carnegie classification) located in a small city in the Northeast. There is one observation per student per course for each semester analyzed. The population sampled is all undergraduate students for the period Fall 1996 through Fall 2001. The undergraduate population, approximately 10,000, is in five schools, Arts & Sciences, Education & Human Development, Engineering, Nursing, and Management. The dependent variable is the letter grade a student receives in a course. Only grades that count toward a student's GPA are considered.

Results

The Base Model (No Interactive Terms)

We begin by presenting the results of a fairly parsimonious model of grades, including the four variables discussed above (experience, education, ability and class size) and four additional environmental variables, the mean grade given out by the department, gender, students whose ethnicity is underrepresented in higher education, and students from the Educational Opportunity Program (EOP), a program designed to help students who are economically and academically

disadvantaged. The departmental mean grade is included because of its importance in explaining variation in grades; the others are included because we hypothesize they may influence how class size affects grades. Specifically, we suspect the performance of underrepresented and EOP students may be more sensitive to class size. Furthermore, we propose that females also will perform better in smaller classes, since such classroom environments encourage class participation where females' verbal skills may allow them to excel. In the second run of the model they will be interacted with class size to test these hypotheses. In this first run, they are included to show their effect *san*s interaction.

Operationalization of Variables

Grade: Is the grade a student received in a credit bearing section that counts towards their cumulative GPA (Pass/Fail, Satisfactory etc. are not included). Grades are re-numbered 0=F, 1=D, 2=C-,3=C,4=C+,5=B-,6=B,7=B+,8=A-,9=A.

Experience: Is measured by **Student Level** at the start of the semester and range from 1 for first semester freshmen to 8 for second semester senior.

Education: A dummy variable equaling 1 for students admitted with **AP Credit.**

Ability: For each other course a student took in a given semester, we measure the difference between the grade they received and the average grade given in that course. The sum of these differences, **Other Grades**, measures a student's ability in that semester. This specification

controls for the relative difficulty of the other coursework and was found to fit better than a model that uses a student's average grade in other coursework in the same semester[4].

Class size: The natural log of the number of students registered for the class at the end of the third week of classes (**Ln Class Size**). The natural log was chosen since the theoretical model linking class size to learning assuming a logarithmic form (Glass et al 1982). We ran the model both ways and the logged version fit better.

Difficulty of Department: Acknowledging that different academic departments grade differently, we included a variable (**Dept Mean**) that takes on the value of the mean grade given out by the academic department over the time period covered in this analysis. (This is similar but more parsimonious than creating dummy variables for each department)

Female: A dummy variable equaling 1 for students that are **Female**.

Underrepresented in Higher Education: A dummy variable equaling 1 for students who report their ethnic background as Black-Non Hispanic, Hispanic, or American Indian/Alaskan Native (**Underrep**).

Educational Opportunity Program: A dummy variable equaling 1 for students admitted into the **EOP** program.

Table One
Descriptive Statistics
Sample size = 363,023

	Min	Max	Mean	SD	Median		Min	Max	Mean	SD	Median
Grade	1.0	9.0	6.41	2.49	7.00	Dept Mean	4.6	9.0	6.41	0.82	6.42
Student Level	1.0	8.0	4.87	2.24	5.00	Female	0.0	1.0	0.54	0.50	1.00
AP Credit	0.0	1.0	0.43	0.50	0.00	Underrep	0.0	1.0	0.11	0.31	0.00
Other Grades	-20.0	8.7	0.09	2.22	0.31	EOP	0.0	1.0	0.06	0.23	0.00
Ln Class Size	0.0	6.1	4.05	1.09	3.91						

Results *The Basic Model*

Since the dependent variable is limited and ordinal, use a multi-ordinal logistic regression to estimate the model. SAS (version 8) was used to run the regression (Cody 1997).

Table Two
Model One (No interactive terms)
Dependent variable: Student course grade
Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	-5.6284	0.0335	28261.2426	<.0001
Intercept2	1	-4.6063	0.0331	19335.3337	<.0001
Intercept3	1	-3.7801	0.0329	13226.9391	<.0001
Intercept4	1	-2.9238	0.0326	8020.6333	<.0001
Intercept5	1	-2.3019	0.0325	5004.3625	<.0001
Intercept6	1	-1.7775	0.0325	2991.7555	<.0001
Intercept7	1	-1.1004	0.0325	1143.5825	<.0001
Intercept8	1	-0.5348	0.0327	267.4315	<.0001
Intercept9	1	0.1999	0.0332	36.2441	<.0001
Student Level	1	0.0667	0.00141	2238.2489	<.0001
AP Credits	1	0.3198	0.00637	2518.6649	<.0001
Other Grades	1	0.4780	0.00161	88628.1112	<.0001
Ln Class Size	1	-0.3863	0.00312	15295.5772	<.0001
Dept Mean	1	0.8032	0.00407	38935.8576	<.0001
Female	1	0.1293	0.00610	450.3494	<.0001
Underrep	1	-0.2259	0.0108	441.5564	<.0001
EOP	1	-0.2883	0.0141	419.4747	<.0001

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	1496953.7	1314060.5
SC	1497050.9	1314244.1
-2 Log L	1496935.7	1314026.5

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	182909.256	8	<.0001
Score	140070.289	8	<.0001
Wald	152976.618	8	<.0001

Odds Ratio Estimates

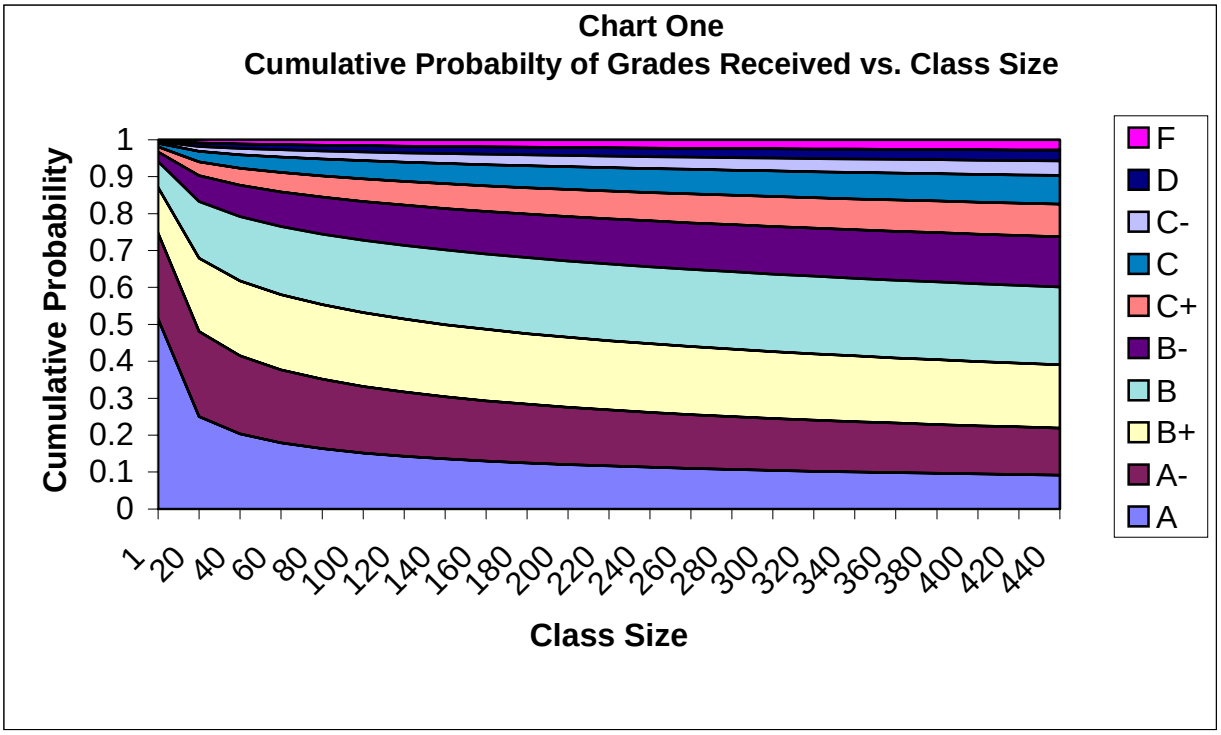
Effect	Point Estimate	95% Wald Confidence Limits	
Student Level	1.069	1.066	1.072
AP credits	1.377	1.360	1.394
Other Grades	1.613	1.608	1.618
Ln Class Size	0.680	0.675	0.684
Dept Mean	2.233	2.215	2.250
Female	1.138	1.125	1.152
Underrep	0.798	0.781	0.815
EOP	0.750	0.729	0.771

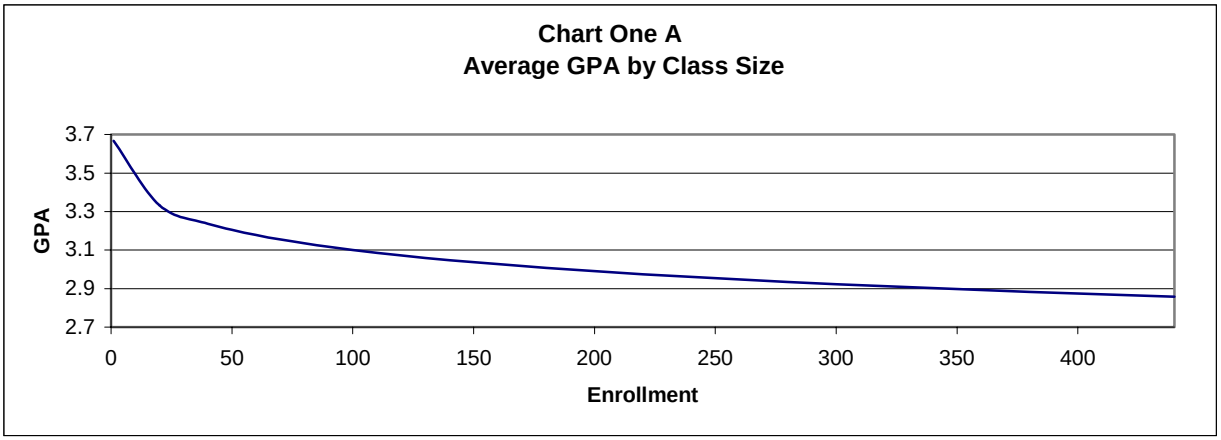
Association of Predicted Prob & Observed Responses

Percent Concordant	75.5	Somers' D	0.514
Percent Discordant	24.1	Gamma	0.516
Percent Tied	0.4	Tau-a	0.437
Pairs	55950155390	c	0.757

Score Test for the Proportional Odds Assumption

Chi-Square	DF	Pr > ChiSq
8147.3053	64	<.0001





All eight independent variables, including the log of class size[5], have a significant influence on grades. Therefore, the null hypothesis that class size does not matter can be rejected. As well, the sign of the parameter estimates are as expected. Student level (proxy for experience), advanced placement credit (proxy for education), performance in other courses (proxy for ability) are positively associated with grades, as are the average grade given out by the department and whether a student is female (consistent with the hypothesis that they do better in small classes). Class size is negative, as are variables indicating that the student is either in the Educational Opportunity Program or has an ethnic background that is underrepresented in higher education (consistent with the hypothesis that they will do worse in large classes).

Chart One[6] provides a fairly clear picture of how important enrollment is in determining grades, especially the grade of A. The probability of getting an A drops from .5 to .25 as class size moves from 1 to 20 and then continues to drop as class sizes continue to rise. Chart One A provides the same picture with less detail, showing that the mean class grade goes down as class size goes up. The graphs show a negative logarithmic relationship between class size and grades, consistent

with the model proposed by Glass and associates.

Adding interactive terms

Next we interact the log of enrollment with four dichotomous variables, AP credits, Female, Underrepresented and EOP. The expectation are that students entering with AP credit, since they come in with higher educational achievement, may be less negatively affected by large classes. Females may be expected to do better than males in smaller classes because they of their verbal and social skills. Underrepresented minorities and Educational Opportunity Program participants may be expected to do even worse in large classes, since, as cited earlier, the literature suggests that small classes should be most beneficial to at-risk students.

Table Three
Model Two (Includes interactive terms)
Analysis of Maximum Likelihood Estimates

Parameter	DF	Estimate	Standard Error	Chi-Square	Pr > ChiSq
Intercept	1	-5.7965	0.0375	23891.4556	<.0001
Intercept2	1	-4.7747	0.0372	16516.4305	<.0001
Intercept3	1	-3.9478	0.0369	11437.2693	<.0001
Intercept4	1	-3.0895	0.0367	7077.2535	<.0001
Intercept5	1	-2.4655	0.0366	4527.4677	<.0001
Intercept6	1	-1.9389	0.0366	2803.8641	<.0001
Intercept7	1	-1.2587	0.0367	1177.9823	<.0001
Intercept8	1	-0.6904	0.0368	351.3888	<.0001
Intercept9	1	0.0469	0.0373	1.5843	0.2081
Student Level	1	0.0686	0.00141	2360.4704	<.0001
AP Credits	1	0.0464	0.0249	3.4752	0.0623
AP*Class Size	1	0.0658	0.00583	127.3928	<.0001
Other Grades	1	0.4781	0.00161	88689.1026	<.0001
Ln Class Size	1	-0.3410	0.00523	4245.0898	<.0001
Dept Mean	1	0.7984	0.00407	38450.3128	<.0001
Female	1	0.5597	0.0243	530.7526	<.0001
Female*Class Size	1	-0.1037	0.00571	329.9699	<.0001
Underrep	1	0.1559	0.0424	13.5270	0.0002
Underep*Class Size	1	-0.0953	0.0101	88.8434	<.0001
EOP	1	0.2500	0.0559	19.9823	<.0001
EOP*Class Size	1	-0.1415	0.0137	105.9911	<.0001

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	1496953.7	1313186.9
SC	1497050.9	1313413.7
-2 Log L	1496935.7	1313144.9

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	183790.814	12	<.0001
Score	140715.651	12	<.0001
Wald	153681.172	12	<.0001

Odds Ratio Estimates

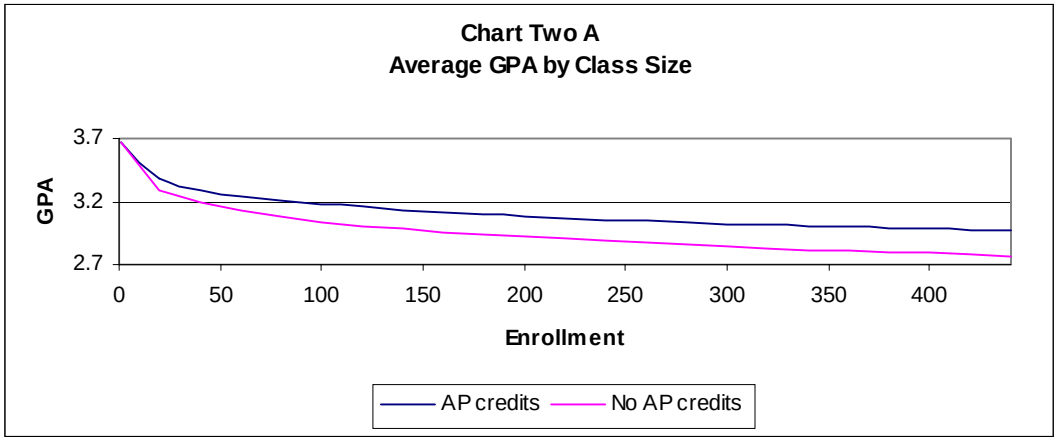
Effect	Point Estimate	95% Wald Confidence Limits	
Student Level	1.071	1.068	1.074
Other Grades	1.613	1.608	1.618
Dept Mean	2.222	2.204	2.240

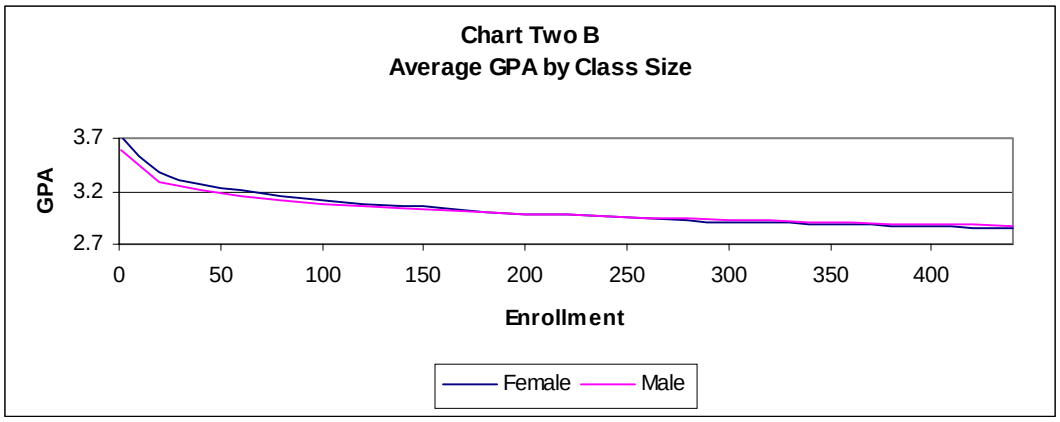
Association of Predicted Prob and Observed Responses

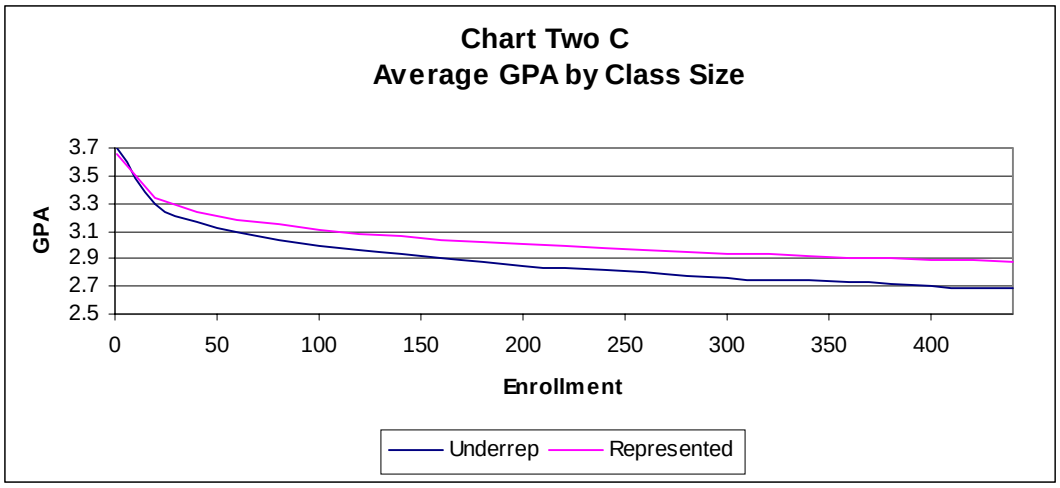
Percent Concordant	75.6	Somers' D	0.515
Percent Discordant	24.1	Gamma	0.517
Percent Tied	0.4	Tau-a	0.437
Pairs	55950155390	c	0.757

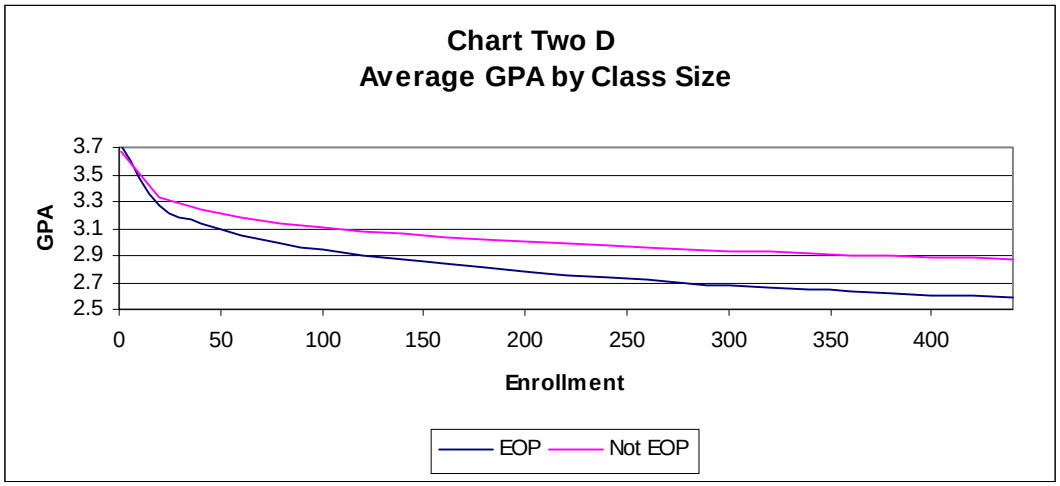
Score Test for the Proportional Odds Assumption

Chi-Square	DF	Pr > ChiSq
8663.2045	96	<.0001









The results of the model sustain the view that the effect of enrollment on grades varies across different category of students. In very small classes, where grading is less competitive (A being most popular grading option), students with AP credits do no better than students without AP credit. But as class size increases, their advantage tends to increase. For females the effect is nearly the opposite. In smaller classes they do better than males, but that difference disappears as grade size increases. Underrepresented and at-risk students, like students with AP credit, do no better or worse than their counterparts in small classes, but unlike those with AP credit, they do

worse, not better, as class size increases.

Further study

This is a first cut effort into looking at the effect of class size on student achievement. The goal here is to set up a framework by which to conduct further analyzes. The results suggest that size does matter, but that the effect might be more severe to some students then to others. Future studies will focus on the effect of class size on persistence, subsequent course work, along with a more detailed analysis into just how class size effects different students differently.

Persistence

The fact that students receive lower grades in larger classes is not itself a problem. Indeed, some faculty and administrators might suggest the results indicate the need for more large classes to offset perceived grade inflation. If however large classes negatively affect persistence as well as grades, this would suggest a heavy price could be paid for over-relying on large classes both in terms of lost revenue due to the decrease student retention and the loss of reputation caused by lower graduation rates. Indeed, if we could quantify the indirect costs associated with loss of reputation, the direct costs of losing tuition and other revenue because of lower retention rates, along with the cost saving of using larger classes to teach courses, we could estimate an optimal class size for the institution. Of course, it may be found that larger classes have no effect on retention. The evidence presented in this paper suggests class size mostly influences the likelihood of getting an A; the increase in the likelihood of failing rising only modestly as class size increases. So it is likely that if class size does greatly influence persistence, it will do so by

promoting voluntary as well as non-voluntary stop out. Consequently, future studies will look at the effect class size has on both kinds of attrition.

Subsequent Course Work

Though we have found a link between grades and class size, we cannot conclude that students learn more in smaller classes. To do so we need to compare the same course with different sized sections. If we can determine that the sections were taught and evaluated in the same manner, we could than judge, after controlling for student characteristics, whether students in smaller sections performed better. Alternatively, we could compare different sized sections in terms of how well their students performed in subsequent, more advanced, coursework in the same discipline. Comparing introductory/intermediate to intermediate/advanced coursework has the advantage that we do not need to assume the coursework and evaluation in different introductory/intermediate courses were the same. As long as students from differently sized courses take the same subsequent course, their grade in the subsequent course can be used to judge the effect of class size in preparing the students for future coursework (controlling of course, faculty, and student characteristics associated with classroom performance) As well, studying the link between previous and subsequent coursework allows us to investigate how large classes influence the likelihood that students continue in a discipline after taking different sized introductory/intermediate courses. It could be that, while grades in subsequent coursework is not influenced by the class size of the previous course, size may still play a role in the likelihood that students continue onto the next level of coursework.

Effect on different students

Our results suggest that large classes negatively affect some students more than others. But we have not really addressed why this occurs. Grouping whole classes of students, such as females, to show that class size affects them differently is OK to begin an analysis. But we need to delve deeper if we are to understand why this occurs. It may turn out that, in the case of females, we were correct to surmise it is their verbal skills that allow them as a group to do better in smaller classes. If this is true, and we are able to produce other more refined proxies for verbal skills (i.e. Verbal SAT scores) we should be able to better understand our results. Likewise, being underrepresented in higher education in our model may in fact be a proxy for financial need, and that is the need that is driving the results. If so, including financial aid indicators should provide us with a clearer picture of why class size affects some students more than others.

Conclusion

Applying an earning function to the study of grades in higher education allows us to produce a parsimonious model predicting undergraduate course grades. We use this model to show that class size has a negative logarithmic relationship to grades and that the effect on class size on grades differs across different category of student. Future work will include studying the effect of class size on persistence, subsequent coursework as well as better understanding why class size affects different students differently.

Bibliography

Akerhielm, Karen (1995) "Does Class Size Matter?" **Economics of Education Review,** 14 (3) (9): pp. 229-241.

Bolander, Steven F. (1973) "Class Size and Levels of Student Motivation", **Journal of Experimental Design**, 42(2): pp. 12-18.

Borden, Victor M. H. and Kathy L. Burton. (1999) "The Impact of Class Size on Student Performance in Introductory Courses", Paper presented at the 39th Annual Conference of the AIR in Seattle, WA..

Bracey, Gerald W. (1996) "Money Improves Test Scores - Even State-Level SATS. Participation Rates", **Phi Delta Kappan Journal**, 78(1): pp. 91-92.

Brewer, Dominic, Cathy Krop, Brian P. Gill, and Robert Reichardt (1999) "Estimating the Cost of National Class Size Reductions Under Different Policy Alternatives", **Educational Evaluation and Policy Analysis,** 21(2): pp. 179-192.

Cody, Ronald P. (1997). **Applied Statistics and the SAS Programming Language.** (New Jersey, Prentice Hall)

Correa, Hector (1993) "An Economic Analysis of Class Size and Achievement in Education", **Education Economics,** 1(2): pp. 129-135.

Cramer, J. S. (1991). **The LOGIT Model for Economists.** (London, New York, Edward Arnold)

Feldman, Kenneth A. 1984. "Class Size and College Students' Evaluations of Teachers and Courses: A closer Look." *Research in Higher Education* 21(1):45-91.

Finn, Jeremy D., and Charles M. Achilles. 1990. "Answers and Questions About Class Size: A Statewide Experiment." *American Educational Research Journal* 27(3):557-577.

Finn, Jeremy D., and Charles M. Achilles. 1999. "Tennessee's Class Size Study: Findings, Implications, Misconceptions." *Educational Evaluation and Policy Analysis* 21(2):97-110.

Glass, G. V., L. S. Cahen, M. L. Smith, and N. N. Filby. 1982. *School Class Size: Research and Policy*. Beverly Hills: Sage.

Glass, Gene V., Barry McGaw, and Mary Lee Smith. 1981. "Meta-Analysis in Social Research." Beverly Hills, California: Sage Publications.

Glass, Gene V. and Mary Lee Smith. 1979. "Meta-Analysis of Research on the Relationship of Class-Size and Achievement." *Evaluation and Policy Analysis* 1: 2-16.

Gursky, Daniel. 1998. "Class Size Does Matter." *The Education Digest* 64(2 October):15-18.

Hanushek, Eric A. (1999a) "Some Findings From an Independent Investigation of the Tennessee STAR Experiment and From Other Investigations of Class Size Effects", **Educational Evaluation and Policy Analysis,** 21(2): pp. 143-164.

Hanushek, Eric A. (1999b) The Evidence on Class Size, in Mayer, Susan E. and Paul E. Peterson (Eds), **Earning and Learning: How Schools Matter** (Washington D.C.,Brookings Institutional Press)

Hanushek, Eric A. (1996) "Outcomes, Costs, and Incentives in Schools", **Improving America's Schools: The Role of Incentives** Washington, D. C. National Academy Press.

Hanushek, Erik A. (1995) "Moving Beyond Spending Fetishes", **Educational Leadership,** 53(3) pp. 60-64.

Hanushek, Eric A., and Lori L. Taylor (1989) "Alternative Assessments of the Performance of Schools: Measurement of State Variations in Achievement", **The Journal of Human Resources**, 25(2): pp. 179-200.

Harder, Heather (1990) "A Critical Look at reduced Class Size", **Contemporary Education,** 62(1): pp. 28-30.

Hoff, David J. (1998) "Federal Class-Size Reports Do an About-face", **Education Week,** 17(9 June 10): pp. 22.

Hoxby, Caroline M. (2000) "The Effects of Class Size on Student Achievement: New Evidence From Population Variation", **The Quarterly Journal of Economics**, 11: pp. 1239-1285.

Kennedy, Peter E and John J. Siegfried (1997) "Class Size and Achievement in Introductory Economics: Evidence from the TUCE III Data", **Economics of Education Review,** 16(4October): pp. 385-394.

Kennedy, Peter E and John J. Siegfried (1996) "On the Optimality of Unequal Class Sizes", **Economics Letters**, 50: pp. 299-304.

Keil J. and Peter Partell (1998) "The effect of class size on student performance and retention at Binghamton University", paper presented at the 38th annual meeting of the AIR Forum in Minneapolis, MN.

Krueger, Alan B. and Diane M. Whitmore (2000) "The Effect of Attending a Small Class in the Early Grades on College-Test Taking and Middle School Test Results: Evidence from Project Star"

Krueger, Alan B. (1999) "Experimental Estimates of Education Production Functions", **The Quarterly Journal of Economics**, 5: pp. 497-531.

Lipman, Steven A. (1990) "On the Optimality of Unequal Class Sizes", **Economics Letters**, 33: pp. 193-196.

Maxwell Nan L.& Jane S. Lopus (1995) "A Cost Effectiveness Analysis of Large and Small Classes in the University", **Educational Evaluation and Policy Analysis**, 17(2): p. 167-178.

McConnell, Campbell R. and Kim Sosin (1984) "Some Determinants of Student Attitudes Toward Large Classes" **Journal of Economic Education** Summer 1984 pp. 181-190.

McKeachie W. J. (1980) "Class Size, Large Classes and Multiple Sections", **Academe** (2): pp. 24-28.

McKeachie W. J., Asghar Iran-Nejad, & David C. Berliner. (1990) "The Multi-source nature of learning: An Introduction", **Review of educational research**. 60(4) pp.509-516.

Mincer, J. (1974) "Schooling, Experience and Earnings" NBER. ??

Menard, Scott W. (1995) **Applied Logistic Regression Analysis**. (Thousand Oaks, CA, Sage Publications)

Molnar, Alex, Phillip Smith, John Zahorik, Amanda Palmer, Anke Halbach, and Karen Ehrle. (1999) "Evaluating the SAGE Program: A Pilot Program in Targeted Pupil-Teacher Reduction in Wisconsin", **Educational Evaluation and Policy Analysis,** 21(2): pp. 165-178.

Mosteller, Fredrick, (1999) How Does Class Size Relate to Achievement in Schools?, in Mayer, Susan E. and Paul E. Peterson (Eds), **Earning and Learning: How Schools Matter** (Washington D.C., Brookings Institutional Press)

Mosteller, Fredrick, Richard Light, and Jason Sachs (1996) "Sustained Inquiry in Education: Lessons from Skill Grouping and Class Size", **Harvard Educational Review,** 66(4 Winter): pp. 797-842.

Nelson, Randy and Kathleen T. Hevert (1992) "Effect of Class Size on Economies of Scale and Marginal Costs in Higher Education", **Applied Economics**, 24: pp. 473-482.

Nye, Barbara, Larry V. Hedges, and Spyros Konstantopoulos (1999) "The Long-Term Effects of Small Classes: A Five-Year Follow-Up of the Tennessee Class Size Experiment", **Educational Evaluation and Policy Analysis,** 21(2): pp. 127-142.

Pascarella, E.T & P. T. Terenzini (1991) **How College Affects Students**, San Francisco: Jossey-Bass.

Raimondo, H. J., L. Esposito, and I. Gershenberg (1990) "Introductory Class Size and Student Performance in Intermediate Theory Courses", **Journal of Economic Education**, 21: pp. 369-381.

Ritter Gary W. and Robert F. Boruch (1999) "The Political and Institutional Origins of a Randomized Controlled Trial on Elementary School Class Size: Tennessee Project STAR", **Educational Evaluation and Policy Analysis** 21(2): pp. 111-125.

Santa Barbara (2001): www.cc.santa barbara.ca.us/cced/budget/research / proposedbudget /document/secIB.pdf

Slavin, R. E. (1989) Achievement Effects of Substantial Reductions in Class Size, in R. E. Slavin (Eds), **School and Classroom Organization** (Hillsdale, NJ,Earlbaum)

Slavin, Robert (1990) "Class Size and Student Achievement: Is Smaller Better?", **Contemporary Education,** 62(1): pp. 6-12.

Smith, Mary Lee and Gene V. Glass (1980) "Meta-analysis of Research on Class Size and Its Relationship to Attitudes and Instruction", **American Educational Research Journal,** 17(4): pp. 419-433.

Spahn, Karen (1999) "Class Size and Faculty Effectiveness & Quality", Paper Presented at the 39th Annual Institutional Research Forum in Seattle, WA.

Tillitski, Christopher (1990) "The Longitudinal Effects Size in PRIME TIME, Indiana's State Sponsored Reduced Class Size Program", **Contemporary Education,** 62(1): pp. 31-32.

Tomlinson, Tommy (1990) "Class Size and Public Policy: The Plot Thickens", **Contemporary Education,** 62 (1): pp. 17-23.

Weiss, Trish (1990) "Indiana's PRIME TIME", **Contemporary Education,** 62(1): pp. 31-32.

Williams David D., Paul F. Cook, Bill Quinn and Randall P. Jensen (1985) "University Class Size: Is Smaller Better?", **Research in Higher Education**, 23(3): pp. 307-317.

Word, Elizabeth, Charles M. Achilles, Helen Bain, John Folger, John Johnston, and Nan Lintz (1990) "STAR Final Executive Summary: Kindergarten Through Third Grade Results", **Contemporary Education,** 62(1): pp. 13-16.

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[2] Student/pupil ratios in schools had been dropping since the 1950's without any marked increased in standardized test scores or other indicators of overall student performance, and the majority of the studies conducted at the classroom level showed either no or very modest affect of class size on student performance. The U.S. Department of Education reports that K-12 student teacher ratios fell from 26.9 in 1955 to 17.2 in 1998. Yet average class sizes remain at about 24. The increase in special education teachers is believed to be the principle reason (School Reform News, 2000)

[3] In subsequent test H was found to be statistically insignificant

[4] The inclusion of a variable that estimates a student's performance in other courses in a particular semester means that the analysis excludes those cases where a student receives only a single GPA relevant grade in a semester.

[5] To make sure that the negative effect of class size on grades was not overly influence by grades in very small classes, the model was re-run where class size needed to be over a certain size (>1,>5,>10,>25,>50). In all cases the log of enrollment continued to be negative and significant.

[6] Chart One is created by assuming that all variables beside class size take on their mean value and then varying class size to see how it influences the probability that students receive different grades