Does AP Improve Student Achievement in Economics?

Christopher Clark
Benjamin Scafidi
John R. Swinton*

Georgia College and State University
CBX 14
Milledgeville, GA 31061

Abstract

We estimate the effect of taking Advanced Placement (AP) Economics on student performance on a high-stakes, statewide End-of-Course Test (EOCT) with data on all Georgia students who took high school economics from 2006 to 2008. We use propensity score matching to control for the endogeneity of the choice to take AP economics. Our most conservative estimate suggests that students who take high school economics in an AP class score 0.376 standard deviations higher on the Economics EOCT than "matched" students who are in high schools that do not offer AP Economics. We find large differences in "AP effects" across subpopulations—in particular, African Americans and students who performed poorly in prior mathematics courses benefit the most from AP Economics. All estimates of AP effects are substantially below OLS estimates, suggesting positive selection into AP Economics. Finally, the results are robust to different matching techniques for the full sample and all large and medium sized subpopulations.

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I. Introduction

Since 1955 the Advanced Placement (AP) Program sponsored by the College Board has been offering standardized high school courses that are designed to be more rigorous than typical high school courses (Willingham and Morris 1986). The College Board offers AP courses in 34 subjects, including high school Economics. The prominent education writer Jay Mathews of the *Washington Post* and *Newsweek* uses AP (and International Baccalaureate) course or test taking as the primary basis for ranking American high schools.

In recent years states and school districts have devoted significant resources in order to increase enrollment in AP courses. One reason for this increased focus on AP may be because most colleges give increased weight to AP courses when calculating high school grade point averages used for college admission (Geiser and Santelices 2004). Furthermore, about 90 percent of four-year colleges and universities give college credit to students who successfully complete AP coursework and an appropriate score on the standardized AP exam (College Board 2009).[1] But, with additional resources flowing into AP programs, high schools face trade-offs when allocating resources (Finn and Winkler 2009). AP classes are often smaller than non-AP classes and teachers must be certified to teach an AP class. There is also some concern that poor and minority students are underrepresented in AP classes (Taliaferro and DeCuir-Gunby 2008).

Despite the almost ubiquitous use of AP in determining college admissions and advance college credit, there is not a consensus in the research literature regarding whether completing an AP course increases human capital relative to completing the corresponding standard high school course. It may be the case that more able or conscientious students enroll in AP so that any estimated AP effect may be little more than a signaling device.

While there is a large number of research studies on AP—many done by the College Board itself (see Hargrove, Godin, and Dodd 2008 for one example), only two studies (Klopfenstein and Thomas 2009; Sandler and Tai 2007) use a multivariate analysis and control for prior academic achievement outside of AP coursework to analyze whether AP increases student achievement relative to "regular" high school courses. Because students and teachers

[1] Typically, college credit is awarded only to students with an appropriate score on standardized AP exams. The College Board offers 34 AP exams that correspond with 34 AP courses. In this paper we do not use information on student performance on AP exams because all students who complete an AP class do not take the corresponding AP exam, students who do not take an AP course do not take an AP exam—so there would be no control group, and we do not have this information available to us.

select (or are selected) into AP courses, an OLS estimate of the effect of taking an AP course on a measure of human capital could be biased upwards. This is particularly true if more able students and/or teachers are enrolled in AP courses, as seems likely. Klopfenstein and Thomas (2009) and Sandler and Tai (2007) use extensive controls for students' non-AP course taking and achievement in models estimating the effect of AP course taking and achievement on AP exams on success in college. Klopfenstein and Thomas find a positive effect of taking AP Economics on college grade point averages during the first year and first year retention for African American and white students, but generally they find no effects on college success from other AP courses.[2] Sandler and Tai find that AP science courses and higher scores on AP exams are associated with modest increases in success in college science courses.

As an important motivator for this study, Klopfenstein and Thomas find that failure to control for success and course work outside of AP courses biases estimates of the effect of AP course work on student success in college upwards. They also note that it is possible that if students who took AP courses in high school take more challenging courses than other students in college, then their empirical approach could lead to underestimates of the true effects of AP on college success. The upward selection bias may be countered by the inclination to take more challenging college coursework. They cite evidence, however, that suggests to them that any downward bias is likely to be minimal. They note that a minority of students earning AP Calculus credit never take advanced math in college.

In this paper we seek to estimate whether AP course taking increases human capital in high school. It would seem logical that a precondition for AP to have beneficial effects on achievement in college that it must first have beneficial effects on student achievement in high school. We address this issue by analyzing whether AP Economics leads to higher student achievement on a statewide standardized exam of the state of Georgia's high school economics curriculum. Specifically, we use data on all Georgia students who took high school economics from 2006 to 2008 to estimate the effect of taking AP Economics on student performance on Georgia's high-stakes, statewide End of Course Test (EOCT). We use propensity score matching to control for the endogenous choice to take the AP economics course. Our matching

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[2] The exception is that Klopfenstein and Thomas find that some high school AP courses seem to increase success in college for Hispanic students.

variables include student demographic characteristics and prior achievement on Georgia's Algebra I and Geometry EOCTs.

Our most conservative estimate suggests that students in the full sample who take high school economics in an AP class score 0.376 standard deviations higher on the Economics EOCT than "matched" students who are in high schools that do not offer AP Economics. We find large differences in "AP effects" across subpopulations—in particular, African Americans and students who performed poorly in prior mathematics courses benefit the most from AP Economics. All estimates of AP effects are substantially below OLS estimates, indicating positive selection into AP Economics. Finally, the results are robust to different matching techniques for the full sample and all large and medium sized subpopulations. These results are consistent with Klopfenstein and Thomas who find that taking AP Economics leads to higher GPAs and retention rates in the first year of college for black and white students.

Georgia data offer a unique opportunity to examine whether or not students who take AP economics coursework learn more economics. All Georgia students are required to take economics in order to graduate. And, all students are required to take the same standardized test upon completion of the course.

We find that AP Economics does have a positive impact on student performance on the EOCT. While the impact of the AP economics coursework as measured by the propensity score matching model is smaller than OLS estimates or estimates generated from a model with teacher fixed effects the results remain both statistically significant and significant for policy purposes. But, the differences between the alternative approaches to estimation suggest that AP Economics course taking should be treated as endogenous, even when controlling for prior achievement in mathematics.

In the next section we describe the testing environment in Georgia. Section III contains a description of the data. We then describe our approach to estimation and discuss the importance of addressing selection issues when examining the impact of advanced coursework. Finally, we discuss our results and conclude with policy implications suggested by the results.

II. Background

In response to Georgia's A+ Educational Reform Act of 2000 (O.C.G.A. §20-2-281) and the No Child Left Behind legislation (Public Law 107-110, 115 Stat. 1425) the Georgia

Department of Education revamped its required curriculum now referred to as the Georgia Performance Standards. The new curriculum requires all Georgia students to demonstrate proficiency in eight subject areas: Mathematics I: Algebra/Geometry/Statistics; Mathematics II: Geometry/Algebra/Statistics; United States History; Economics/Business/Free Enterprise; Biology; Physical Sciences; Ninth Grade Literature and Composition; and American Literature and Composition. As part of the movement to assess student achievement, each subject area is accompanied by a high-stakes end-of-course test (EOCT). By law, the EOCT counts for 15 percent of the student's final grade. To pass the course, the student must have a final score of 70 percent or better. (GaDOEa) Our focus is on the Economics/Business/Free Enterprise (economics) required course.

School districts have broad leeway as to how they will teach the required economics course. But, all students take the same EOCT. The economics EOCT has five domain areas: Fundamental Economic Concepts, Microeconomics Concepts, Macroeconomic Concepts, International Economics, and Personal Finance Economics (GaDOEb).[3] The selection of the domain areas is intended to represent basic skills students will need when they leave high school without any assumptions as to whether or not they will continue onto college. Therefore, every economics class must cover the same domain areas no matter what other goals the teacher may have.[4]

The economics EOCT is a 90 question, multiple choice exam. Typically 15 of the 90 questions are field test questions. The Georgia Department of Education (GaDOE) ascertains the validity of the field test questions before rotating them into the exam. This process assures that the test remains current as well as valid. For a complete description of the test development and administration see GaDOEc (2009).

Georgia students have had to take the high-stakes EOCT in economics since the spring of 2004 as part of their coursework. The test is offered in the fall and the spring of each year.[5] Over 60,000 students take the course and the test each year. On average, about five percent of

[3] For an example copy of the economics EOCT see http://www.doe.k12.ga.us/DMGetDocument.aspx/Released%20Econ.pdf?p=4BE1EECF99CD364EA5554055463F1FBBF5D074D5FB1F2CAEB3B63B3ECB220CDD26C2114F3C57D8D2E064BA2E9A3A8B3E&Type=D.

[4] High school economics classes span a wide range of goals. On one end of the spectrum are classes geared to prepare students for clerical work. On the other end are AP classes and International Baccalaureate classes that aim to help prepare students for college level work.

[5] The test is offered in the summer for students who do not pass the course during the normal school year. We do not include the scores of retests in our data.

the students enrolled in an economics course take AP Economics each year. Two different AP courses are offered in Georgia: AP Macroeconomics and AP Microeconomics. While some schools offer both the Macroeconomics course and the Microeconomics course, students must be prepared for the EOCT after either course. Therefore, teachers must add sufficient material to either of the AP courses to ensure full coverage of the tested domains. The students who take the EOCT after taking AP Macroeconomics tend to do a little better, on average, than the students who take the EOCT after taking AP Microeconomics.[6]

Because all students sit for the same economics EOCT at the completion of their economics course, we can use the standardized test to compare outcomes of students who take different types of economics classes. In particular, we can test the hypothesis that the AP economics coursework better teaches economic concepts than other classes as measured by the standardized EOCT.

III. Data

The data for our research come from the Georgia Department of Education. They contain student level administrative data that matches each EOCT score to information such as gender, economic status, and ethnicity. Also contained in the data is a code for the type of course the student has taken before sitting for the EOCT. Contained in the data are scores of all EOCTs a student has completed. This is important because it allows us to model a measure of student ability before taking an economics class. Table 1 presents data summary statistics.

The decision to take an AP class represents a series of choices. When presented with the choice to take and AP course the student must decide if he or she is up to the challenge and if the potential benefit of college credit is worth the additional effort the course will require. This decision is further balanced against the fact that many schools (and college admission boards) count AP course grades higher than other course grades. These choices provide a modeling problem. Students who choose to take an AP course tend to be systematically different from those who choose not to take and AP course. The challenge is to model the impact of having had an AP Economics course in such a way as to capture the impact of the AP course in economics apart from all of the other confounding factors.

[6] Georgia students on average score lowest on the macroeconomic strand of the EOCT in economics. We do not, however, wish to speculate as to the reason that having additional macroeconomics coverage improves the overall score.

The first variable interest is the EOCT score in economics itself. Because high-stakes end-of-course testing has existed in Georgia since 2004, students and teachers have learned to adjust to the environment. We account for this adjustment and any differences in the standardized test by norming the test scores. Therefore, the reported average score as shown in Table 1 is close to zero. Note that the EOCT of those students who took an AP Economics course is significantly higher (at the one percent level using a standard t-test of difference in means) than those who did not take an AP Economics course. Likewise, the standardized EOCT scores in geometry and algebra are significantly greater for those students who took an AP economics course than those who did not.

The data include information concerning whether or not students receive free or reduced price lunch. Of the sample as a whole, 35 percent of the students receive the benefit. But, significantly fewer (again, at the one percent confidence level) of participants in AP economics coursework receive free or reduced price lunches. A little fewer than half of the student population is male. The representation of males in AP coursework is proportional to the population as whole. About five percent of the population is characterized by the Georgia Department of Education as being disabled.[7] But, less than two percent of the AP Program participants are disabled.

African Americans are disproportionately underrepresented in the AP classroom as well. Meanwhile, Asian students are slightly more likely to be in an AP economics class than their population suggests. Other ethnic groups not categorized above are also slightly (but significantly) more represented in the AP economics classroom.

Finally, although the administrative data do not provide any information concerning teachers, we do have information concerning whether or not the teacher of record attended any in-service economic workshops provided by the Georgia Council on Economic Education. For a description of how workshop data are matched to the GaDOE administrative data see Swinton et al. (forthcoming). About four percent of students have teachers who have attended a Georgia Council workshop. A much smaller percent of the AP students have a teacher who has attended a Georgia Council in-service workshop.[8]

[7] The label of “Disabled” covers a wide variety of disabilities including physical and cognitive impairments.
[8] We exclude “Teaching AP Economics” workshops because the Georgia Council is the official trainer of AP economics teachers in Georgia.

The data present many opportunities but we must make careful use of them. The full sample in Table 1 represents all of the students who have taken the economics EOCT since 2004 and had previously taken both the Geometry and Algebra (now Math I and Math II) EOCTs. This restriction eliminates more than half of the student observations since the inception of end of course testing in 2004. Many school districts taught Geometry (now Math I) well before the economics course. Therefore, for many of the early observations, an EOCT score for Geometry is not available. And, some schools teach economics before Algebra (now Math II).[9]

The "restricted" sample in Table 1 refers to our matched sample. We limit our sample to students who are in an AP economics class (treatment group) and those who are not in an AP economics class and are not in a school that offers AP economics (control group). This eliminates (mostly) the student level choice of attending the class for the control group. It is worth noting that over 40,000 students took their required economics class in a school that did not offer an AP economics class over the years covered by the data.

IV. Empirical Model

A naïve approach to discussing the impact of AP coursework on student outcomes would be to note that students who take AP classes score better on a standardized test or do better in college. Obviously, students who choose to take an Advanced Placement class are different in many ways than students who choose not to take the same class when the opportunity arises. Many of the systematic differences between participants in the AP program and non participants are important in determining how successful the students are in numerous other measures of outcomes. For this reason it is important to control for selection into AP coursework before drawing conclusions about the impact of the AP coursework. Without such controls, selection bias will taint any conclusions that one might wish to draw from the research.

Researchers utilize three general approaches to tackle the problem of measuring the efficacy of particular education programs. In the first method researchers develop an educational production function in which the measure of success is modeled as a function of various "inputs" that are thought *a priori* to influence success. Marginal effects of changes in various inputs inform the research as to the relative importance of various inputs. Bosshardt and Watts (1990,

[9] We leave it for another study to show the importance the two math courses play in properly preparing students for success in the economics classroom.

1994) and Watts and Bosshardt (1991) examine the importance of teacher effects using fixed-effects educational production functions. Similarly, Swinton, DeBerry, Scafidi, and Woodard (forthcoming) use a teacher fixed-effects model to examine the impact of in-service workshops on teacher's ability to teach economic content. The fixed-effects approach allows an otherwise linear regression model to shift based on some unobservable but otherwise systematic difference linked to specific subgroups of the study sample. In this study we also present a teacher level fixed-effects model to estimate the impact of the AP economics curriculum.

A second approach is to estimate the production of educational outcomes in two stages. In the first stage the research estimates the likelihood of a student experiencing the treatment. In the second stage the researcher estimates the impact of the treatment conditional on the probability of receiving the treatment. One recent example of this approach that utilizes the propensity scores as a first stage estimation approach is Bosshardt and Manage (2009). Their work is worth noting because they focus on the importance of student math experience as a predictor of success in economics coursework.

Propensity score matching (PSM) represents a third approach used by researchers to isolate the impact of a particular treatment on students' measured ability. PSM is not a regression technique. PSM corrects for selection bias in making estimates of the effect of a treatment on the treated subjects by matching treated and non-treated observations on observable characteristics and computing the average difference in outcomes between observations that are matched. Whereas in a laboratory a researcher might be able to eliminate extraneous factors by using genetically identical subjects, PSM requires sufficient numbers of observations to find clusters of subjects in both the treatment group and control group who are similar enough as to sufficiently reduce the probability that other factors are responsible for any observed impact of the treatment on the matched treated and untreated subjects. This approach is similar in nature to Hargorve, Godin, and Dodd's (2008) examination of students' success in college based on their AP Program experiences. In our case, our large data set allows us not only to examine the impact of AP coursework on the EOCT in economics, but also to compare the impact for several sub-groups of students. We estimate both an educational production function using a teacher fixed-effects model and a PSM model to show the importance of carefully controlling for selection bias.

Regression-based Education Production Function

Although we observe student characteristics, in our data we cannot observe all of the teacher characteristics that might affect student performance. Therefore, we use a fixed-effects model to allow the intercept term to shift for different teachers. Similarly, we know that the trend in test scores over the three year period we examine is slightly upward. Therefore, we use normal curve equivalent (NCE) transformations of EOCT scores. The transformation allows us to compare test scores across time while controlling for the influence of any underlying time trend.

For comparison purposes, we first present a linear regression (Equation 1) that models the students standardized EOCT score ($EOCTScore_i$) as a function of that student's AP enrollment (as is common in this literature, let D = 1 if an individual takes an AP Economics course and D = 0 otherwise), previous scores in the Geometry and Algebra EOCTs, whether or not the student received a free or reduced-price lunch, the student's gender, whether or not the student was disabled, and the student's ethnicity (with white being the omitted dummy variable), and whether or not a student's teacher had attended an in-service teaching workshop taught by the Georgia Council on economic Education. Students are indexed by a subscript i and teachers are indexed by a subscript t:

$$EOCTScore_i = \alpha + \delta D_i + \sum_1^{10} \beta_j \underline{Student_i} + \varepsilon_i . \qquad (1)$$

Next, in Equation 2, we specify a teacher-level fixed-effects linear regression model by including a shift parameter that represents the unobserved but systematically relevant characteristics of teachers (λ_t):

$$EOCTScore_{it} = \alpha + \delta D_i + \lambda_t + \sum_1^{10} \beta_j \underline{Student_{it}} + \varepsilon_{it} . \qquad (2)$$

Propensity Score Matching

Unfortunately, even the fixed-effects model does not allow us to completely control for the student's decision to take the AP class in the first place. We turn to PSM as a technique to isolate the impact of the AP economics course from the factors that initially led the student to take the course. We define the outcome for AP students (D = 1) on the Economics EOCT as Y_1 and the outcome for students in regular Economics (D = 0) on this same test as Y_0.

Our goal is to identify the average treatment effect on the treated (i.e., the effect of taking AP Economics on performance on the Economics EOCT for those who take an AP Economics course). Equation 3 defines the expected impact of taking the AP Economics course as:

$$\Delta = E(Y_1 - Y_0 \mid D = 1) = E(Y_1 \mid D = 1) - E(Y_0 \mid D = 1), \quad (3)$$ [10]

where Δ represents the treatment effect. We observe the first term on the right-hand side of Equation 3, the Economics EOCT scores for students who actually took AP Economics. However, we do not observe the second term on the right-hand side—what the economics EOCT scores would be for students who actually took a non-AP economics course had they instead taken an AP economics course. We use PSM to estimate $E(Y_0 \mid D=1)$. This term is estimated by matching students in a regular economics course with students in an AP economics course on the following observable characteristics: prior performance on the Algebra I and Geometry EOCTs, recipients of free and reduced price lunch, gender, disability, and ethnicity. We then calculate the average economics EOCT score for these control students (D=0) who have been matched to our treatment students (D=1) and compute Equation (3) above. This computation yields an estimate of any benefit of taking an AP Economics course for students who actually took AP Economics.[11]

However, for PSM to be a valid technique to estimate a treatment effect in the presence of selection bias, certain assumptions must hold. The fundamental assumption underlying matching estimators is *ignorable treatment assignment* (ITA) (Rosenbaum and Rubin 1983) or *selection on observables* (Heckman and Robb 1985). In other words, this assumption implies that selection into the treatment is a function of the observable right-hand side variables. Because we have a strong measure of students' prior achievement in the form of EOCT scores in Algebra and Geometry, we are fairly confident that ITA holds. When students have the choice to attend either an AP class or the standard high school class, the best indication of likely success in the class is generally prior achievement (which will encapsulate most other determining factors).

[10] See Heckman, LaLonde and Smith (1999) for a discussion of when estimating the effect of "treatment on the treated" may be more useful than estimating an average treatment effect. The seminal paper in the matching literature is Rosenbaum and Rubin (1983).

[11] See Abadie, Drukker, Herr, and Imbens (2004) for an explanation of how the procedure to estimate PSM coefficients in STATA.

V. Results

OLS

The results of estimating Equation 1 using Ordinary Least Squares are presented in the first column of Table 2. These results imply that students who choose to take an AP class in economics score significantly better on the Economics EOCT than do students who do not take an AP class in economics. AP students score 42 percent of one standard deviation higher than non-AP students. This result is significant at the one percent level. Having had a teacher who attended an in-service economic workshop had no significant impact on student performance on the economics EOCT.[12]

Our OLS results also indicate that students who score higher on the Algebra and Geometry EOCTs perform better on the Economics EOCT. A one standard deviation increase in Algebra ECOT score translates to a 19 percent of one standard deviation increase in an individual's score on the Economics EOCT. The effect of a one standard deviation increase in an individual's Geometry score results in an increase in the student’s Economics EOCT score of 40 percent of a standard deviation.

Students who receive free or reduced price lunch, students with disabilities, and non-white students score significantly lower on the economics EOCT. Male students score significantly higher than female students.

Fixed Effects

OLS estimates of the effect of AP classes on performance are likely to be biased due to omitted teacher quality. Better teachers may be more likely to teach AP classes and also have students who score better on the EOCT thus causing an upward bias in OLS estimates of the effect of AP enrollment on EOCT scores. Some of the same teachers who teach an AP section may also teach a non-AP section. The students of these teachers are likely to have an unobserved advantage. We introduce teacher-level fixed effects into our OLS model in an

[12] This result is not inconsistent with Swinton et al. (forthcoming) who found that positive impacts of in-service learning did not accrue until after teachers attended multiple workshops.

attempt to remove this omitted variable bias. The results of this fixed effect model (Equation 2) are presented in the second column of Table 2.

As expected, the introduction of teacher-level fixed effects into the model significantly decreases the magnitude of the AP effect. The magnitude decreases by roughly 10 percent, but remains statistically significant at the one percent level. The signs and significance levels of the coefficients on the other variables do not change when teacher-level fixed effects are added to the model.

Propensity Score Matching

While the linear fixed-effects model allows us to control for unobserved teacher-level effects, there are likely to be other selection issues at play. Most important among them, those factors that to the student taking the AP course in the first place. Estimates of the effect of AP enrollment on ECOT scores are likely to be biased by unobserved individual level intelligence and work ethic. In an attempt to control for these unobservable characteristics we turn to propensity score matching to obtain estimates of the AP effect. We match students based on a number of observable characteristics including race, gender, free or reduced price lunch status, and disability. We also match students based on Algebra EOCT score and Geometry EOCT score as a way of addressing the omitted variable bias, because scores on these previous tests should be reliable proxies for intelligence and work ethic. Students are also matched based on teacher in-service economics workshop experience under the assumption that attendance to such in-service educational opportunities on the part of teachers is a measure of teacher quality.

We use two samples to estimate our propensity score matching model: An unrestricted sample of students who have recorded values for all necessary variables and a restricted sample that only includes students who are either enrolled in an AP class or attend a school that does not offer AP classes. The restricted sample is used to avoid individual-level selection issues, as students are allowed to decide if they want to take AP classes when offered.

We then estimated propensity matching models for different segments of the sample to see how the AP effect varied based on observable characteristics and previous Algebra and Geometry EOCT performance.

Unrestricted Sample

The results of estimating the effect of AP enrollment on Economics EOCT score using propensity scores and the unrestricted sample are provided in the first row and column of Table

3. Comparing these results to the OLS and teacher-level fixed effects results in Table 2 indicates that the magnitude of the effect decreases significantly when using the propensity score matching approach. These results indicate that individuals who enrolled in an AP class scored 36 percent of a standard deviation higher on the Economics EOCT than other very similar students who did not take an AP class.

After estimating our propensity matching model for various segment of the sample we found that the AP effect varies considerably across races, genders, disability status, socioeconomic standing, and previous academic performance. These results are presented in the first column of Table 3. They indicate that the effect of AP enrollment on economics EOCT performance is significantly higher for nonwhites than whites. The AP effect is also larger for males than females and is larger for individuals who are eligible for free or reduced price lunch than for those who are not eligible. Disabled students appear to benefit less from AP enrollment than do those who are not disabled.

Interestingly, we also find that the effect of AP enrollment is also significantly higher for students with lower scores on the Algebra and Geometry EOCT. The AP effect for students whose average score on those tests was in the lowest quartile of the sample is roughly twice as large as the effect for students in the top quartile. This may be due to peer effects. See Clark, Scafidi, and Swinton (forthcoming) for evidence of a peer effect in high school economics classes.

Restricted Sample

The second column of Table 3 contains the results of estimating the effect of AP enrollment on Economics EOCT score using propensity scores and the restricted sample that contains only students who are either enrolled an AP classes or attend a school that doesn't offer an AP economics class. The estimated AP effect for the full sample is in the first row of column two. Once again, the magnitude drops as we refine our methodology. This result implies that AP enrollment increases performance on the economics EOCT by 32 percent of a standard deviation. While the magnitude of the effect is considerably smaller than the OLS, fixed effect, and unrestricted sample estimates, it is still a rather large effect and is highly statistically significant.

As for the unrestricted sample, we also estimated our propensity score matching model for the various segments of the restricted sample. The results for the restricted sample are very similar, but slightly smaller in magnitude than the results for the unrestricted sample for the various segments listed in Table 3. This decrease in magnitude for every category is a very strong indication that selection issues arising from students choosing whether to enroll in a more rigorous class were biasing results.

Robustness Checks

In order to test the robustness of our nearest neighbor matching with replacement findings we also estimated, using our restricted sample, our matching model via five other specifications: 1) Nearest neighbor matching without replacement with propensity score sorted ascending, 2) Nearest neighbor matching without replacement with propensity score sorted descending[13], 3) Radius matching using a 0.00001 caliper, 4) Radius matching using a 0.00005 caliper, and 5) Radius matching using a 0.0001 caliper. The results of these robustness checks are presented in Table 4.

We generally, though not universally, find that these other specifications provide larger estimates of the effect of AP course enrollment on EOCT test score than our nearest neighbor matching with replacement estimates presented in Table 3. These findings indicate that our primary result may be cautious and that the true effect may be even larger.

VI. Concluding Remarks

Our results suggest that AP Economics has a positive impact on student achievement as measured by their performance on Georgia's standardized EOCT in economics. This estimated impact is large even controlling for prior achievement in mathematics and controlling for endogenity using propensity score matching. As expected, the PSM estimates are smaller than OLS estimates, indicating positive selection into AP. But, the impact is still significant both statistically and for those in a position to allocate school funding.

The positive impact after controlling for other factors that influence student outcomes does indicate school administrators face a policy choice. All else constant, the AP coursework resulted in higher EOCT scores in economics. Every sub-sample in the data – even students with the lowest performance on the Geometry and Algebra EOCTs – demonstrated the positive

[13] Rosenbaum (1995) suggests that results can vary based on how treatment and control individuals are matched, so we match using both ascending and descending propensity score sorting.

influence of the curriculum. Therefore, given the choice between an AP curriculum and a non-AP curriculum, there is an advantage to be had by installing the AP curriculum.

Furthermore, when administrators are concerned about education gaps along economic strata or ethnic strata the results demonstrate larger gains from the AP economics courses for poor individuals than non-poor individuals (as measured by free and reduced-lunch eligibility) and black students gained more than white students. This result raises interesting questions about future opportunities in expanding the AP Program.

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Table 1: Summary Statistics for Sample with Algebra and Geometry Scores

Variable	Full Sample Mean (Std. Dev.)	Unrestricted Sample In AP Mean (Std. Dev.)	Unrestricted Sample Not AP Mean (Std. Dev.)	Unrestricted Sample Difference (Std. Error)	Restricted Sample In AP Mean (Std. Dev.)	Restricted Sample Not AP Mean (Std. Dev.)	Restricted Sample Difference (Std. Error)
In AP	0.053	1	0	--	1	0	--
	(0.224)	--	--	--	--	--	--
Standardized Economics EOCT Score	-0.013	1.008	-0.070	1.078***	1.008	-0.110	1.118***
	(0.911)	(0.930)	(0.876)	(0.012)	(0.930)	(0.875)	(0.013)
Standardized Algebra EOCT Score	0.132	1.069	0.080	0.989***	1.069	0.018	1.051***
	(1.003)	(1.099)	(0.971)	(0.014)	(1.099)	(0.964)	(0.014)
Standardized Geometry EOCT Score	-0.056	0.966	-0.113	1.079***	0.966	-0.164	1.131***
	(0.974)	(1.137)	(0.932)	(0.013)	(1.137)	(0.926)	(0.014)
Receive Free or Reduced Price Lunch	0.353	0.202	0.362	-0.159***	0.202	0.410	-0.208***
	(0.478)	(0.402)	(0.480)	(0.007)	(0.402)	(0.492)	(0.007)
Male	0.470	0.469	0.470	-0.001	0.469	0.462	0.007
	(0.499)	(0.499)	(0.499)	(0.007)	(0.499)	(0.499)	(0.007)
Disabled	0.052	0.017	0.054	-0.038***	0.017	0.048	-0.031***
	(0.223)	(0.128)	(0.227)	(0.003)	(0.128)	(0.213)	(0.003)
Black	0.393	0.213	0.403	-0.190***	0.213	0.430	-0.217***
	(0.488)	(0.409)	(0.491)	(0.007)	(0.409)	(0.495)	(0.007)
Asian	0.029	0.117	0.024	0.093***	0.117	0.013	0.104***
	(0.169)	(0.322)	(0.155)	(0.002)	(0.322)	(0.114)	(0.002)
Hispanic	0.054	0.050	0.054	-0.004	0.050	0.040	0.010***
	(0.226)	(0.219)	(0.226)	(0.003)	(0.219)	(0.196)	(0.003)
Other Race	0.018	0.023	0.018	0.005**	0.023	0.013	0.009***
	(0.134)	(0.149)	(0.133)	(0.002)	(0.149)	(0.114)	(0.002)
Workshop	0.038	0.006	0.040	-0.033***	0.006	0.038	-0.032***
	(0.191)	(0.078)	(0.195)	(0.003)	(0.078)	(0.191)	(0.003)
Size of Sample With both Algebra and Geometry Scores	99,558	5,250	94,308		5,250	43,950	

***indicates the means are statistically different at the 1% level & **indicates the means are statistically different at the 5% level

The Restricted sample contains only students who are either enrolled in an AP class or attend a school that does not offer AP classes to avoid individual-level selection issues.

Table 2: OLS Estimates of AP effects with and without Teacher Fixed Effects
Dependent Variable = Standardized Economics EOCT Score

Variable	OLS Coefficient (Std. Error)	Teacher FE Mean (Std. Error)
AP	0.422	0.378
	(0.010)	(0.012)
Standardized Algebra EOCT Score	0.204	0.204
	(0.003)	(0.003)
Standardized Geometry EOCT Score	0.371	0.371
	(0.003)	(0.003)
Receive Free or Reduced Price Lunch	-0.072	-0.072
	(0.005)	(0.005)
Male	0.152	0.152
	(0.004)	(0.004)
Disabled	-0.131	-0.131
	(0.010)	(0.010)
Black	-0.178	-0.178
	(0.006)	(0.006)
Asian	-0.208	-0.208
	(0.012)	(0.012)
Hispanic	-0.167	-0.167
	(0.010)	(0.010)
Other Race	-0.062	-0.062
	(0.015)	(0.015)
Workshop	-0.003	-0.003
	(0.013)	(0.013)
R-squared	49.6%	56.3%
SSR	41721	35489
F-stat	8889.78	71.85
Size of Sample With both Algebra and Geometry Scores	99,558	99,558

All coefficients are statistically significant at the 1% level except Workshop, which is not statistically significant in either specification.

Table 3: Estimates of the Effect of the Treatment on the Treated Dependent Variable = Standardized Economics EOCT Score and Treatment is AP enrollment		
	Nearest Neighbor Matching with Replacement	
Variable	Unrestricted Sample Avg. effect of Treatment on Treated (Std. Error) Matches	Restricted Sample Avg. effect of Treatment on Treated (Std. Error) Matches
Full Sample of students with both Algebra and Geometry Scores	0.358 (0.022) 5,250	0.316 (0.024) 5,250
Black Students	0.445 (0.037) 1,118	0.444 (0.037) 1,118
White Students	0.334 (0.028) 3,134	0.316 (0.030) 3,134
Students of Other Races	0.429 (0.051) 998	0.404 (0.061) 998
Male	0.426 (0.034) 2,464	0.390 (0.036) 2,464
Female	0.282 (0.029) 2,786	0.281 (0.030) 2,786
Poor	0.526 (0.041) 1,062	0.481 (0.044) 1,062
Nonpoor	0.322 (0.025) 4,188	0.291 (0.027) 4,188
Disabled	0.248 (0.159) 87	0.271 (0.157) 87
Not Disabled	0.356 (0.022) 5,163	0.325 (0.024) 5,163

Table 3: Estimates of the Effect of the Treatment on the Treated
Dependent Variable = Standardized Economics EOCT Score and Treatment is AP enrollment

	Nearest Neighbor Matching with Replacement	
Variable	Unrestricted Sample Avg. effect of Treatment on Treated (Std. Error) Matches	Restricted Sample Avg. effect of Treatment on Treated (Std. Error) Matches
Students in the Bottom Quartile of Average Geometry and Algebra Score	0.656	0.633
	(0.081)	(0.074)
	221	221
Students in the 2nd Quartile of Average Geometry and Algebra Score	0.495	0.438
	(0.041)	(0.042)
	542	542
Students in the 3rd Quartile of Average Geometry and Algebra Score	0.395	0.405
	(0.032)	(0.034)
	1,078	1,078
Students in the Top Quartile of Average Geometry and Algebra Score	0.309	0.296
	(0.026)	(0.028)
	3,409	3,409

All Effects are Statistically Significant at the 1% level except for the effect of AP on Econ EOCT scores for Disabled students. The Restricted sample contains only students who are either enrolled in an AP class or attend a school that does not offer AP classes to avoid individual-level selection issues.

Table 4: Estimates of the Effect of the Treatment on the Treated Using Various other Specifications
Dependent Variable = Standardized Economics EOCT Score and Treatment is AP enrollment

	No Replacement		Radius Matching		
	Ascending	Descending	Caliper = .00001	Caliper = .00005	Caliper = .0001
Variable	ATT (Std. Error) Matches	ATT (Std. Error) Matches	ATT (Std. Error) Matches	ATT (Std. Error) Matches	ATT (Std. Error) Matches
Full Sample of students with both Algebra and Geometry Scores	0.383	0.382	0.376	0.382	0.378
	(0.018)	(0.018)	(0.020)	(0.017)	(0.017)
	5,250	5,250	3,776	4,314	4,545
Black Students	0.442	0.440	0.495	0.487	0.479
	(0.034)	(0.034)	(0.033)	(0.028)	(0.027)
	1,118	1,118	747	926	977
White Students	0.354	0.356	0.329	0.340	0.356
	(0.022)	(0.022)	(0.024)	(0.022)	(0.021)
	3,134	3,134	2,450	2,725	2,793
Students of Other Races	0.646	0.641	0.346	0.433	0.392
	(0.040)	(0.040)	(0.080)	(0.063)	(0.062)
	998	998	223	349	381
Male	0.471	0.471	0.418	0.412	0.424
	(0.027)	(0.027)	(0.035)	(0.030)	(0.028)
	2,464	2,464	1,513	1,850	2,005
Female	0.305	0.306	0.309	0.331	0.340
	(0.023)	(0.023)	(0.027)	(0.022)	(0.021)
	2,786	2,786	1,798	2,175	2,331
Poor	0.510	0.512	0.528	0.546	0.523
	(0.038)	(0.038)	(0.036)	(0.034)	(0.032)
	1,062	1,062	649	717	795
Nonpoor	0.354	0.354	0.337	0.348	0.340
	(0.020)	(0.020)	(0.023)	(0.020)	(0.019)
	4,188	4,188	2,878	3,333	3,539
Disabled	0.303	0.259	0.546	0.305	0.331
	(0.148)	(0.149)	(0.280)	(0.162)	(0.140)
	87	87	21	43	53
Not Disabled	0.385	0.386	0.372	0.384	0.383
	(0.018)	(0.018)	(0.021)	(0.018)	(0.017)
	5,163	5,163	3,502	4,210	4,458

Table 4: Estimates of the Effect of the Treatment on the Treated Using Various other Specifications
Dependent Variable = Standardized Economics EOCT Score and Treatment is AP enrollment

	No Replacement		Radius Matching		
	Ascending	Descending	Caliper = .00001	Caliper = .00005	Caliper = .0001
Variable	ATT (Std. Error) Matches	ATT (Std. Error) Matches	ATT (Std. Error) Matches	ATT (Std. Error) Matches	ATT (Std. Error) Matches
Bottom Quartile of Average Geometry and Algebra Score	0.628	0.630	0.560	0.578	0.595
	(0.071)	(0.071)	(0.057)	(0.052)	(0.051)
	221	221	193	200	200
2nd Quartile of Average Geometry and Algebra Score	0.463	0.466	0.526	0.498	0.521
	(0.039)	(0.039)	(0.036)	(0.033)	(0.032)
	542	542	449	492	502
3rd Quartile of Average Geometry and Algebra Score	0.419	0.411	0.428	0.427	0.442
	(0.030)	(0.030)	(0.029)	(0.026)	(0.025)
	1,078	1,078	856	951	969
Top Quartile of Average Geometry and Algebra Score	0.358	0.353	0.298	0.314	0.336
	(0.020)	(0.020)	(0.028)	(0.023)	(0.021)
	3,409	3,409	1,887	2,459	2,702

All Effects are Statistically Significant at the 1% level except when examining only Disabled students. The Restricted sample contains only students who are either enrolled in an AP class or attend a school that does not offer AP classes to avoid individual-level selection issues. All estimates in this table use are obtained using the restricted sample.