The Effects of State-level Mandatory Advanced Placement Curriculum Policies on AP Participation and Performance

by

Tianyuan Zheng

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Authored by: Tianyuan Zheng
Department of Electrical Engineering and Computer Science
May 17, 2024

Certified by: Joshua D. Angrist
Ford Professor of Economics, Thesis Supervisor

Accepted by: Katrina LaCurts
Chair, Master of Engineering Thesis Committee

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ABSTRACT

AP (Advanced Placement) courses allow high school students to earn college credits. While the AP program aims to broaden educational opportunities for a diverse student body across the U.S., disparities in the availability and participation rates of AP courses may exacerbate inequality. To address this, some states require all high schools to offer at least one AP course. This study analyzes the impacts of AP mandates using difference-in-differences models. My findings indicate that school-level AP mandates are associated with a 36% increase in the number of public schools offering AP. I find little evidence, however, that these mandates significantly increase student AP participation. Furthermore, they decrease AP credit attainment rate by 11% conditioned on students taking AP exams.

Thesis supervisor: Joshua D. Angrist
Title: Ford Professor of Economics

Acknowledgments

This research topic is inspired by my high school experiences in Alabama, where I longed for universal access to STEM education within the convenience of our local schools. I dedicate this paper to all high school students who similarly hope for systematically accessible and equitable advanced educational opportunities that allow them to fully realize their academic potential.

I would like to thank my advisor, Prof. Joshua Angrist, for his insightful instructions and unwavering care. Thank you for enlightening me from the very first day I stepped into an economics class at MIT, for motivating econometrics so creatively, and for appreciating my silly re-imaginations of econometric concepts. It has been an absolute honor and pleasure to learn, teach, and research under your guidance and example.

Thank you also to my family and friends at MIT and back home who have watched through all the breakdowns and growth. Thank you to my high school teachers who allowed me to take extracurricular AP courses and learn anything I would like at my own pace. Thank you to Mrs. Betty Stone and Dr. John Stone for taking me in as a family member; I am forever indebted to your kindness and love.

Finally, I dedicate this paper to my parents, Dr. Chen Liu and Mr. Yi Zheng. I could not have been where I am or achieved anything nearly as meaningful without their constant support, immense sacrifice, and unconditional love. Thank you for believing in me more than I believe in myself, for tolerating my mistakes over and over again, and for opening my eyes to new worlds after new worlds.

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1 Introduction

Advanced Placement (AP) is a program in the United States that provides secondary school students with introductory college-level curricula (AP courses). Students can enroll in these courses as part of their high school course selection and take nationally administered AP exams for each subject in May. Successful scores on these exams may grant them college transfer credits at most accredited U.S. higher education institutions. Along with dual enrollment and International Baccalaureate (IB), it is one of the most recognized pathways for a U.S. high school student to take challenging coursework, earn college credits, and enhance their college admission prospects.

Diverse demographic characteristics and school quality across U.S. states contribute to significant disparities in AP participation and performance. Although most states do not mandate that high schools within their jurisdiction offer AP courses, some states view AP program performance as a key benchmark for improving educational quality. Consequently, a few of them have established and implemented policies requiring each high school to offer at least one AP course in the early 2000s. By requiring high schools to offer AP courses, the state policymakers hoped to provide students with easier access to challenging courses and pathways to college completion. They anticipated that this access would enhance educational outcomes and better prepare students for post-secondary studies.

This thesis aims to investigate whether these state-administered AP curriculum mandates were 1) successful in enforcing schools to offer AP courses, and 2) subsequently improving student engagement and performance in advanced coursework. Using a state-year panel data concatenated from several public sources, it uses a difference-in-differences approach to evaluate the effects of those mandates on AP participation at both the school and individual levels, as well as their influence on AP performance.

The rest of this paper proceeds as follows. Chapter 2 provides an overview of the operation of the AP program and reviews existing research on its effects on various outcomes. Chapter

3 describes the dataset and hypotheses explored in this paper. Chapter 4 focuses on the difference-in-differences methodology and results. Chapter 5 concludes with a discussion of the implications of these findings. Furthermore, Appendix A contains summary statistics tables and figures and Appendix B details supplementary analyses using synthetic control methods.

2 Background

2.1 The AP Program

The Advanced Placement (AP) program was initiated in 1956 by The College Board, a U.S. non-profit organization committed to facilitating pathways to higher education for secondary school students. AP courses, developed by a national committee of educators, adhere to a standardized syllabus to maintain consistency across the country. These courses are integrated into the regular high school curriculum, with students taking the corresponding exams simultaneously in May. Students may then submit their AP exam scores to colleges they choose to attend, where transfer credits are typically granted for scores of 3 or higher. There are currently 39 AP courses recognized by the College Board [1], spanning a range of subjects including core areas such as English, mathematics, social sciences, and natural sciences, as well as elective courses like art, music theory, languages, and research.

AP course availability in high schools varies significantly across the United States. While some schools offer all 39 AP courses in their course selection, approximately 30% of U.S. public high schools did not offer any AP courses in 2021 [2]. The availability of AP courses can vary based on several factors, including geographic region, racial demographics, and the rural or urban nature of the community. For instance, in 2015, 47.2% of rural school districts reported that no secondary students were enrolled in any AP courses, compared to only 2.6% of urban districts [3].

2.2 Related Literature

Numerous studies have examined the relationship between AP participation, AP performance, and other post-secondary educational outcomes. Many of these studies, particularly those with significant findings, rely on proprietary, individual-level data. Overall, the research presents mixed conclusions about the effectiveness of the AP program.

Reports from the College Board generally highlight positive outcomes of the AP program. Using a matching procedure that considered enrollment in five specific AP courses, Hargrove et al. (2008)[4] found that AP students had higher first and fourth-year high school GPAs than their non-AP peers, even when controlling for socioeconomic status and SAT scores. In contrast, research not affiliated with the College Board shed more skepticism regarding the AP curriculum's ability to improve educational outcomes. For example, a 2004 technical report for the University of California system [5] concluded that neither AP test scores nor AP enrollment had causal effects on students' college performance.

Studies with access to individual-level data were able to generate more precise results on students' AP outcomes. Using student-level data in public high schools in Texas, Dougherty et al. (2006)[6] regresses student college graduation rates on several attributes of their AP program and status. The report concludes that, when controlling for race, socioeconomic, and gender variables, the passing rate of AP exams is a much better indicator of students' college graduation rates than enrollment in AP courses. Similarly, Smith et al. (2015) [7] and Avery et al. (2016) [8] employ a regression discontinuity design over 4.5 million AP exam score data points and longitudinal data to yield several significant findings. The former study discovered that achieving passing scores on AP exams both increases the likelihood of students taking more AP courses and enhances college graduation rates. Meanwhile, the latter study demonstrated that scoring a 5 on an AP exam significantly increases the chances of an AP examinee majoring in that subject.

Although research on the impact of the AP program itself is extensive, few studies have examined it from the perspective of a state-controlled policy. One of the few existing research is due to Arce-Trigatti (2013), which uses a difference-in-differences approach to find Arkansas' AP mandate policy responsible for a decrease of science and technical course offerings, a 60-student decrease in enrollment, but also a 2.5% increase in high school graduation rate [9].

With closer scrutiny of each state's educational laws [10], I find that different states applied AP mandates at different intensities. For instance, Arkansas, Mississippi, and Louisiana mandated that every public high school offer at least one AP course by their respective treatment years. In contrast, Connecticut and Idaho adopted a more lenient approach, requiring only that each district offer at least one AP course.

Drawing on the work of Arce-Trigatti and my own experiences in secondary school, this thesis explores whether these stringent mandates are more effective at expanding educational opportunities than more decentralized, school-led initiatives. Additionally, it seeks to interpret any observable differences in the effects of these mandates across treatment states, thereby extending this existing literature to encompass a broader range of scenarios.

3 Data and Hypotheses

3.1 Data Collection

This thesis utilizes publicly available data aggregated at the state level from 2002 to 2023. The data is sourced from three main organizations: the AP College Board, the National Center for Education Statistics (NCES), and the Education Commission of the States (ECS). Data on key outcome variables directly associated with AP participation and performance are exclusively sourced from the College Board.

There exist several specifications for AP participation. AP student participation for a given school year in a state is defined as the number of students who took at least one AP exam in that state during that academic year, while AP school participation is the count of high schools offering at least 1 AP course in a given year and state. In this context, a high school is defined as an educational institution that offers instruction for grades 9 through 12, and may also include other grade levels.

Student-level AP program participation, public and private school participation, public high school AP passing rate (defined as the percentages of tests with a score of 3 or above), and counts of various AP honors recipients are available from 2000 to 2019 at the state level. Racially disaggregated data on AP participation and performance is available for 2012, 2013, 2017, 2018, 2022, and 2023 from the AP National and State Data section of the College Board's website [11]. This data is ultimately unusable due to its non-overlap with pre-treatment periods.

Information regarding the AP mandate is sourced from the ECS, a nonprofit organization that reports on education policy in the United States. [10] While most states do not mandate that high schools offer AP courses, several have established AP requirements at various levels. States explicitly requiring each high school to offer at least one AP course include Arkansas (2004), Mississippi (2008), and Louisiana (2012). The years in parentheses indicate the academic year during which the policy took effect. Arkansas and Mississippi require each high school to offer at least one AP course in each core subject — English, mathematics, social sciences, and natural sciences, amounting to a minimum of four AP courses. Meanwhile, Louisiana adopted a staggering approach, mandating that all public high schools increase their AP course offerings by one each year from 2012 until 2015.

Some states employ a softer variation of this AP mandate. For instance, Connecticut (2011), and Idaho (2007) do not require AP course offerings at the individual school level but instead mandate them at the district level. Additionally, Idaho also requires each high school to offer at least one option of nationally accredited advanced curriculum, including AP, IB, and dual enrollment.

Data on control variables and other types of outcomes (e.g., average freshman graduation rate, dropout rate, plans after college) are obtained from NCES. Additional supplementary data are from the Civil Rights data collection and the Current Population Survey (CPS).

3.2 Data Cleaning and Specification

The final dataset is a state-year panel with variables available - albeit not continuously for some variables - from 1990 to 2023. The difference-in-differences analysis uses outcome and control variables available continuously from 2002 to 2019. Control variables and pre-treatment outcome variables available outside this range are used to construct synthetic controls for treatment states using the synthetic control method detailed in Appendix B.

The availability of mandate policies is represented by the indicator variable D_{st}. This variable is set to 1 if a state s implements an AP curriculum mandate during the academic year t; otherwise, it is set to 0. Additionally, separate indicator variables are used to distinguish between stricter school-level mandates and more lenient district-level mandates.

Additionally, state-level data on AP participation and performance are reported in two distinct formats. Data are available concerning the AP passing rate and the number of graduates who took at least one AP exam, sorted by class year (e.g., class of 2013). In contrast, data encompassing all students and schools participating in the AP program within a state are compiled according to the school year. Due to the alignment of outcome and independent variables with the graduation class year, the mandate treatment dummies are coded as "1" starting one year before the mandate takes effect. For example, the participation data for public high school graduates in 2004 pertain to the class of 2004, indicating that these students entered their senior year in 2003.

Finally, I limit all analyses to the years 2002 to 2019. 2002 was chosen as the starting year because it was the first year where data on most covariates were publicly available. 2019 represents the last year unaffected by the COVID pandemic, which significantly reduced student participation in virtually all educational activities, including AP courses.

3.3 Empirical Hypotheses

This thesis examines several outcome variables related to AP participation and performance and gives way to several hypotheses to test. All hypotheses are tested using a difference-in-differences approach, detailed in Chapter 4.

First, I hypothesize that state AP mandates significantly increase the proportion of schools participating in the AP program, with the most noticeable effects occurring in public schools. This serves as a measure of school compliance with state policies and may significantly impact the interpretability of subsequent hypotheses. If the observed effect is negligible or negative, it may suggest noncompliance with the policy, inadequate enforcement, or the presence of omitted variable bias. After establishing a noticeable improvement in school participation, I further conjecture that the mandate also enhances student participation in AP courses, with the effect more pronounced in states that implemented a school-level mandate as opposed to a district-level mandate.

Second, I hypothesize that AP mandates significantly affect AP performance, though the direction of this impact is less straightforward to predict. On one hand, AP mandates could provide more capable students with access to AP exams, potentially increasing the number of students who pass these exams and receive AP awards. On the other hand, a more complex counterargument exists: AP mandates might lead schools to offer some AP courses, but not a sufficient variety to allow each student to take AP courses in their preferred subjects. Consequently, this could result in stagnant or even declining performance.

3.4 Summary Statistics

Raw figures render meaningless without the big picture - for this reason, I first provide referential statewide trends in AP enrollment at the student level in Figure A.1, as well as AP participation numbers considering both individual students and schools as units of analysis across all states in Tables A.1 and A.2.

Table A.1 reports the number of schools offering at least 1 AP course by state in 2003, 2008, 2013, and 2018. Table A.2 reports the number of students taking at least 1 AP exam in select years. The 4 year intervals (2004-2005, 2007-2008, 2011-2013, 2018-2019) cover treatment years for the five treatment states: Arkansas (2004), Idaho (2007), Mississippi (2008), Connecticut (2011), and Louisiana (2012). In both tables, states that have introduced any level of mandate are in bold fonts. Washington D.C. is excluded from these reports and all analyses due to data insufficiency.

At first glance, the treatment states show similar baseline AP participation at both the student and school levels, with Connecticut's figures slightly exceeding those of the other states. Additionally, the data from both tables indicate that baseline AP participation levels in California, Florida, New York, and Texas are significantly higher than in other states, by an order of magnitude. As these states are not part of any treatment group, they are excluded from the analyses to maintain the assumption of parallel trends.

4 Difference-in-Differences Analysis

This paper first follows a classical difference-in-differences analysis setup:

$$Y_{s,t} = \alpha + \delta_{DD} D_{s,t} + \beta_s + \gamma_t + \varepsilon_{s,t}, \tag{1}$$

where $Y_{s,t}$ is the outcome variable, $D_{s,t}$ is a dummy treatment variable indicating whether state s employed the mandate in year t, δ_{DD} is the diff-in-diff treatment effect estimate, β_s and γ_t represent state and year fixed effects respectively.

A valid difference-in-differences model specification requires the parallel trends assumption. To attribute any post-treatment difference to the treatment, the treatment and control group outcomes must follow similar pre-treatment trends. To test this assumption, I run the following event study model:

$$Y_{s,t} = \alpha + \sum_{j=-6}^{-2} \tau_j \Delta D_{s,t-j} + \sum_{j=0}^{5} \tau_j \Delta D_{s,t-j} + \beta_s + \gamma_t + \varepsilon_{s,t}, \tag{2}$$

where τ_j are treatment effects by event time, and $\Delta D_{s,t} = D_{s,t} - D_{s,t-1}$ is a dummy variable that evaluates to 1 if state s becomes treated in year t, and 0 otherwise. Using this definition, $\Delta D_{s,t-j}$ (leading treatment switches) is equal to 1 in year t when state s imposed the mandate j years ago, $\Delta D_{s,t+j}$ (lagged treatment switches) is equal to 1 in year t when state s imposes the mandate j years ahead. This specific model includes 5 lags and 5 leads, as the lag $\Delta D_{s,t-1}$ is omitted by construction.

To allow separate linear trends for each state, I also run the following difference-in-difference setup

$$Y_{st} = \beta_s + \gamma_t + \theta_s t + \delta_{DD} D_{s,t} + e_{st} \tag{3}$$

with the θ_s term denoting individual trend for state s, thereby relaxing the parallel trend assumption.

Finally, since there are two types of mandate intensities (one at the school level, the other at the district level), I estimate equations 1 and 2 separately for three specifications of $D_{s,t}$. In the first scenario, $D_{s,t}$ is turned on only if state s employed school-level AP mandate in year t. In the second scenario, $D_{s,t}$ is turned on if state s employed any level of AP mandate in year t. In the third scenario, $D_{s,t}$ is turned on only if state s employed district-level AP mandate in year t, with states exercising school-level AP mandate excluded from the dataset. Results on AP participation and performance are reported in the subsections below.

4.1 AP Participation

This section approaches the effects of state-imposed AP curriculum mandates on AP participation from two angles - the school level, and the student level. Note that these mandates should, first and foremost, impact AP offerings at the school level. Without a significant change in the number of schools that offered AP post-treatment, it is difficult to attribute any variation in student AP participation to the mandate effect. Therefore, I first analyze the effect of different levels of mandate enforcement on the participation of high schools in the AP program. Subsequently, I explore how these mandates influence the number of students participating in the program.

Table 1 displays the impact of AP mandates on the increase of high schools participating in the AP program at the state level. The outcome variable of interest is the logarithm of the AP participation count in high schools, aggregated at the state level and broken down separately for public and private high schools. Columns (1), (3), and (5) report diff-in-diff estimates with two-way fixed effects following Equation 1, whereas columns (2), (4), and (6) report estimates that include state trends, following Equation 3. Regression estimates for the treatment variables—school-level mandate, district-level mandate, and any level of mandate —are presented in Panels A, B, and C, respectively. States that have implemented stricter school-level mandates — specifically Arkansas, Louisiana, and Mississippi —are excluded from analyses in Panel B. This exclusion is necessary to isolate the effects of district-level mandates by comparing states with these mandates only to those that have never had any mandates.

Findings from Table 1 reveal three overarching phenomena on school-level AP participation. First, mandate effects are more positive for public schools than private schools. Second, mandate effects are more positive for school-level mandates than district-level mandates. Third, adding state trend controls generally shrinks the effect towards 0 no matter its direction.

Panel A shows that a school-level mandate is associated with a 24.8% increase in statewide school AP participation with statistical significance ($p < 0.01$). The mandate effect is more prominent at 35.9% and more significant ($p < 0.001$) when restricting data to public high schools; however, this effect becomes slightly negative and statistically insignificant for private schools. Conversely, when AP mandates are implemented at the district level, the overall impact across different school categories drops below 0.

Panel B shows that a district-level mandate decreases statewide school AP participation by 8.2%. This negative effect is more pronounced at -14.6% when the analysis focuses solely on private schools. Notably, the results for private schools are estimated much more precisely than those for public schools, implying a higher variation in the number of public schools across states than that of private schools.

Including individual state trends in the model shrinks all estimates towards 0 and statistical insignificance, except for the -5.8% district-level mandate effect on public schools reported in column (4). Similarly, as shown in Panel C, results from pooling mandates are scaled towards 0. This observation may not come as a surprise as school-level and district-level mandates appear to have contrasting effects. However, it is indeed puzzling that district-level AP mandates seem to discourage school AP participation. One reason may be that many districts had already implemented AP courses in at least one high school as the mandate was introduced, diminishing its positive effect. Alternatively, control states

Table 1: Effect of AP Mandate on Log Count of Statewide Participating High Schools

	All Schools		Public Schools		Private Schools	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: School-level Mandate						
Mandate	0.248**	0.111	0.359***	0.122	-0.0856	0.0783
	(0.0728)	(0.0554)	(0.0766)	(0.105)	(0.0642)	(0.0421)
State Trend	No	Yes	No	Yes	No	Yes
Observations	782	782	782	782	778	778
R^2	0.620	0.868	0.526	0.828	0.645	0.784
Panel B: State-level Mandate						
Mandate	-0.0822**	-0.0689	-0.0736**	-0.0581**	-0.146***	-0.128
	(0.0234)	(0.0379)	(0.0210)	(0.0167)	(0.0322)	(0.112)
State Trend	No	Yes	No	Yes	No	Yes
Observations	731	731	731	731	727	727
R^2	0.608	0.885	0.483	0.835	0.648	0.787
Panel C: Any Mandate						
Mandate	0.0825	0.0184	0.142	0.0285	-0.117*	-0.0255
	(0.100)	(0.0628)	(0.127)	(0.0759)	(0.0456)	(0.0810)
State Trend	No	Yes	No	Yes	No	Yes
Observations	782	782	782	782	778	778
R^2	0.602	0.866	0.491	0.826	0.647	0.784

Robust standard errors in parentheses, clustered at the state level.

CA, DC, FL, NY, and TX were excluded from all panel analyses due to outlier issues or missing data.

AR, MS, LA were excluded from the analysis of Panel B as they employed a stricter Mandate.

State and year fixed effects included in all columns.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

with a comparable number of high schools may have been implementing other policies that encouraged AP participation more effectively than the AP curriculum mandate.

The event study results shown in Figure 1 confirm the parallel trend assumption necessary for difference-in-differences analysis. For overall school count and school count by public/private categories, pre-treatment trends p-values are well above the threshold of 0.05, indicating little evidence for significant differences in AP participation trends between treatment and control states.

When observing the percentage point of public high school student AP participation by graduation class, the estimates become considerably smaller and less significant, though they all remained slightly positive. Table 2 reports the effect of different types of mandates on the percentage points of public high school student participation in the AP program by graduation class. As illustrated in column (5), a school-level mandate increases AP participation rate amongst public high school graduates by 4.45 percentage points, though this effect is imprecisely estimated.

Interestingly, estimates from models that included state trends for both district-level mandates and pooled mandates are more statistically significant than their simpler counterparts. This is partly due to the higher variance exhibited in columns (1), (3), and (5), where the standard errors reported are notably much larger than those in columns (2), (4), and (6). Event study results displayed in Figure 2 show no significant pre-treatment differences in trends. As seen from the event study figure, the AP mandate effect on the percentage of student participation rises above 0 after 2 years of the mandate start year. This result implies that requiring schools to offer APs generated more AP accessibility for students just entering high school as the mandate went into effect than those graduating eminently by then.

[9] Figure 1 shows event study estimates of school-level mandate on log count of high schools participating in the AP program. The outcome variables for Panel I, II, and III are log(count of all schools), log(count of public schools), and log(count of private schools) respectively. Standard errors are clustered at the state level. The effect of the mandate at event time -1 year is set as a reference and thus omitted from the regression model.

[10] Figure 2 shows event study estimates of school-level mandate on public high school student AP partic-

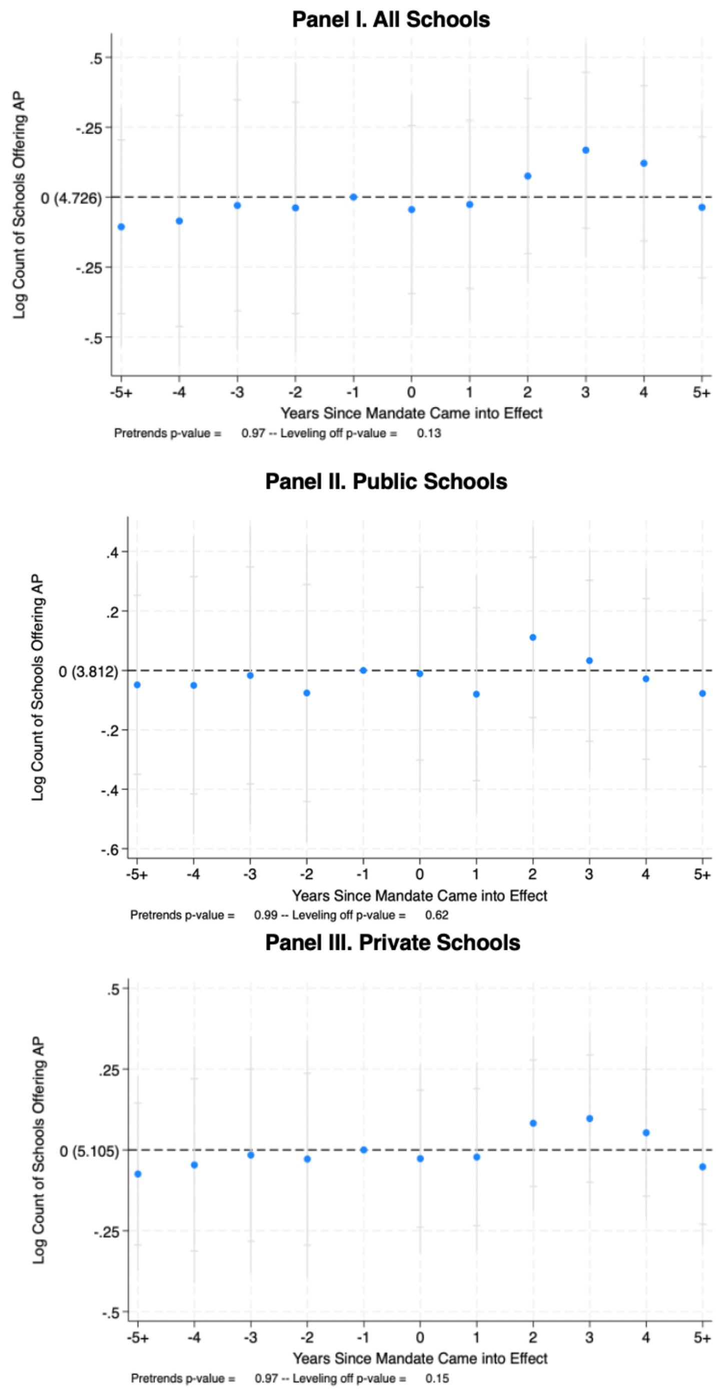

Figure 1: Event Study Estimates of AP Mandate on AP School Participation [9]

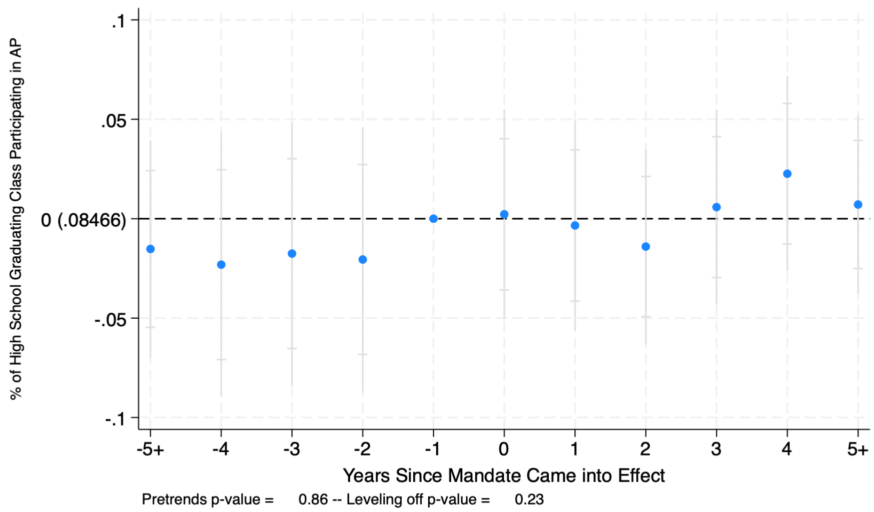

Figure 2: Event Study Estimates of AP Mandate on AP Participation Rate Across Public High Schools, by Graduation Class [10]

Table 2: Effect of AP Mandate on AP Participation Rate in Public High Schools, by Graduation Year

	(1)	(2)	(3)	(4)	(5)	(6)
School-level AP Mandate	0.0445	0.0311				
	(0.0375)	(0.0173)				
District-level AP Mandate			0.00305	0.00986**		
			(0.0327)	(0.00313)		
Any AP Mandate					0.0257	0.0229*
					(0.0255)	(0.0113)
State Trends	No	Yes	No	Yes	No	Yes
Observations	920	920	860	860	920	920
R^2	0.855	0.955	0.872	0.962	0.853	0.955

Robust standard errors in parentheses, clustered at the state level. CA, DC, FL, NY, TX were excluded from analyses. AR, LA, MS were excluded from analyses reported in Panel B.

State and year fixed effects included in all columns.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.2 AP Performance

This section reports the effect of mandates on two AP performance-related outcomes: the proportion of AP exam-passing public high school students and average AP reporting quantity by in-state colleges. The former is measured across graduating seniors in public high schools, while the latter accumulates all high school students within the state.

Table 3: Effect of AP Mandate on AP-passing Public HS Student Proportion Condition on AP Participation

	(1)	(2)	(3)	(4)	(5)	(6)
School-level AP mandate	-0.109***	-0.0730**				
	(0.0238)	(0.0217)				
District-level AP mandate			0.0169**	0.0256*		
			(0.00502)	(0.0109)		
Any AP mandate					-0.0528	-0.0344
					(0.0323)	(0.0267)
State Trends	No	Yes	No	Yes	No	Yes
Observations	920	920	860	860	920	920
R^2	0.407	0.676	0.254	0.602	0.324	0.660

Robust standard errors in parentheses, clustered at the state level. CA, DC, FL, NY, TX were excluded from analyses. AR, LA, MS excluded from analyses reported in Panel B.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3 shows the estimated effect of the AP mandate on the proportion of AP-passing students within the population of AP-participating public high school students. An "AP-passing" student is one who earned a score of at least 3 on at least one AP exam before graduating from high school. From raw data sources, the outcome variable (denoted $Y_{s,t}$ for convenience) is calculated below:

$$Y_{s,t} = \frac{\text{number of AP-passing public high school graduates in state } s\text{, year } t}{\text{number of AP-taking public high school graduates in state } s\text{, year } t}$$

ipation rate at state level. Standard errors are clustered at the state level. The effect of mandate at event time -1 year is set as a reference and thus omitted from the regression model. Baseline outcome occurring at event year -1 is 8.466%, which is represented by the horizontal dotted line.

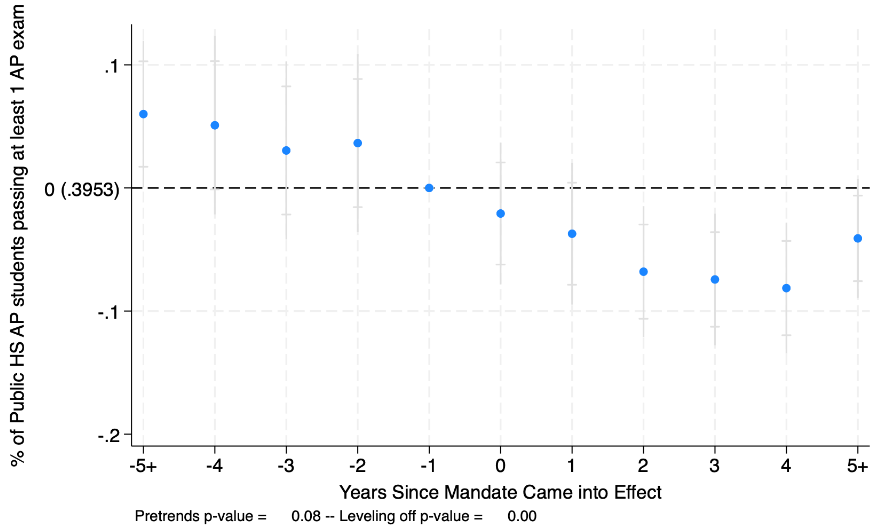

Figure 3: Event Study Estimates of AP Mandate Effects on AP-passing Rates of Public High School Students, Conditional on AP Participation [11]

In stark contrast to AP mandate effects on AP participation, which are generally significant, mandate effects on AP performance seem mostly negative. Notably, school-level mandates decreased the proportion of AP-passing public high school students by 10.9 percentage points with strong statistical significance. On the other hand, district-level mandates increase this proportion by 1.69 percentage points - albeit statistically significant, the estimate is much closer to 0. Figure 3 visualizes this mandate effect by years since mandate implementation: it indicates that effect is the largest for high school classes graduating 2-4 years afterward.

Table 4 presents mandate effects on a more implicit AP performance result: the average number of AP exam scores sent to colleges by in-state students. This metric was computed by dividing the total number of AP exams received by in-state colleges by the number of AP-participating graduates within the state. Since students may choose not to report some of their scores to colleges, the count of AP exams received by in-state colleges is most definitely less than that of AP exams taken by graduates.

[11]Figure 3 shows event study estimates of school-level mandate on the proportion of AP-taking students who passed at least 1 AP exam. Standard errors are clustered at the state level. The effect at event time -1 year is omitted for reference. The baseline proportion (39.53%), which occurs 1 year before treatment, is marked by a dotted horizontal line.

Table 4: Effect of AP Mandate on Average Number of AP Exams Sent to In-State College

	(1)	(2)	(3)	(4)	(5)	(6)
School-level Mandate	-0.119***	-0.0599***				
	(0.00759)	(0.00588)				
District-level Mandate			-0.0743***	-0.00792		
			(0.00794)	(0.00683)		
Any Mandate					-0.0999***	-0.0343
					(0.0177)	(0.0193)
State Trends	No	Yes	No	Yes	No	Yes
Observations	644	644	602	602	644	644
R^2	0.605	0.810	0.612	0.819	0.611	0.809

Robust standard errors in parentheses, clustered at the state level.
Outcome variable is the number of total AP exams received by in-state colleges divided by the total number of AP-participating high school graduates who chose to attend an in-state college.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
State and year fixed effects included in all columns.

The estimates here are small yet significantly negative across all types of mandates. When accounting for only state and year-fixed effects, the school-level AP mandate significantly decreases the average number of AP courses reported by students by 0.12 while the district-level AP mandate decreases this quantity by 0.07, as shown in columns (1) and (3) respectively. The inclusion of state trends again shrinks results towards 0; nonetheless, the effect for school-level mandates remains precisely estimated at -0.06.

Why might requiring schools to offer AP courses decrease the average number of AP exams sent to in-state colleges? There may be several possible interpretations. One explanation assumes a significant increase in the number of high school graduates who took AP courses due to the mandate. In this case, there may be a considerable student population who would not have taken any AP exams without the AP mandate. Typically, these students take fewer AP exams than those who take AP exams regardless of whether their schools are required to offer them. Adding these marginal students to the mix thus decreases the average of AP exams taken and AP exams sent to colleges. A more optimistic interpretation is that the AP mandate enables more college mobility for more AP-prolific students. As more selective colleges tend to prefer students with more AP exam scores, having taken more AP classes due to the AP mandate may encourage top students to move out of state for college.

Lastly, Table 5 focuses on a select subgroup of high-performing students: AP Scholar award recipients. The table presents models using the total number of AP awards granted in each state as the outcome variable, with results shown in columns (1) and (2). It also includes models focusing on the three most common AP awards, with results detailed in columns (3) to (8), ranked by the rigor of the awards. Specifically, the AP Scholar with Distinction Award is granted to students who average at least 3.5 across all AP exams taken over multiple years and score a minimum of 3 on at least five exams. The AP Scholar with Honor Award is awarded to students who average at least 3.25 on their AP exams and score a minimum of 3 on at least four exams. Lastly, the AP Scholar status is conferred on students achieving a score of 3 or higher on three or more AP exams [1]. Notably, students who receive the AP Scholar with Distinction Award must also meet the criterion for the AP Scholar with Honor and AP Scholar awards. Furthermore, the College Board designates these awards as mutually exclusive, meaning each student is recognized with the highest award they qualify for.

Table 5 shows that both types of mandates significantly influence the increase in the total number of AP award recipients. Specifically, school-level mandates increase the number of AP awardees by 43.5%, whereas district-level mandates increase the number of AP awardees by 7.6%.

Though most estimates in Table 5 are marred by imprecision, one can nonetheless inspect their magnitudes to inform approximate trends. For example, while the estimates on AP Honor recipients are almost negligible, effects on AP Distinction and AP Scholar awards are positive and more significant when taking state trends into account. The implications are promising—the mandate appears to expand both the highest-achieving and the marginally high-achieving student groups.

Table 5: Effect of AP Mandate on Log AP Award Student Count

	Total AP Awards		AP Distinction		AP Honor		AP Scholar	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: School-level Mandate								
Mandate	-0.0585	0.435*	-0.132	0.277*	0.0106	-0.00858	0.0385	0.472*
	(0.253)	(0.196)	(0.238)	(0.135)	(0.0882)	(0.0462)	(0.249)	(0.183)
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Trends	No	Yes	No	Yes	No	Yes	No	Yes
N	731	731	731	731	730	730	731	731
R^2	0.831	0.892	0.805	0.889	0.937	0.973	0.807	0.873
Panel B: District-level Mandate								
Mandate	-0.00608	0.0764***	-0.108	-0.0178	0.0373	0.0917	-0.0152	0.0972***
	(0.0698)	(0.0157)	(0.0875)	(0.0230)	(0.0485)	(0.0492)	(0.0871)	(0.0181)
FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Trends	No	Yes	No	Yes	No	Yes	No	Yes
N	683	683	683	683	683	683	683	683
R^2	0.944	0.983	0.887	0.960	0.937	0.975	0.933	0.977
Panel C: Any Mandate								
Mandate	-0.0308	0.275	-0.119	0.146	0.0244	0.0397	0.0149	0.305*
	(0.137)	(0.147)	(0.135)	(0.111)	(0.0572)	(0.0421)	(0.139)	(0.142)
State Trends	No	Yes	No	Yes	No	Yes	No	Yes
N	731	731	731	731	730	730	731	731
R^2	0.831	0.891	0.806	0.889	0.937	0.973	0.807	0.872

Robust standard errors in parentheses, clustered at state level. CA, DC, FL, NY, TX excluded from analyses; AR, LA, MS excluded from analyses in Panel B.

AP distinction, honor, and scholar are mutually exclusive. Total number of AP award recipients includes counts of other AP awards are not reported in this table.

State and year fixed effects included in all columns.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5 Conclusion

The difference-in-differences analyses discussed in Chapter 4 reveal one main phenomenon: while state-mandated AP curriculum guidelines for high schools generally succeed in increasing the number of schools participating in the AP program, they are less effective at encouraging student participation at the state level. Indeed, Tables 1, 2, to 3 sketch a hierarchy of decreasing effects. In other words, though AP mandates seem to increase public school participation in the AP program at the school level, they fail to make comparable improvements in student-level AP participation. Furthermore, when it comes to AP passing rate, the effects even plunge into the negatives, which makes one wonder if the mandate is worth the trouble.

There are many reasons to motivate high school students towards or against taking AP courses. The mandate may be most effective for highly motivated students whose high schools did not previously offer AP courses. To them, having a free opportunity to take AP courses at the convenience of their high schools - as opposed to having to commute to other campuses for challenging courses - may encourage them to take on additional AP courses. However, not many students fall into this category. 66.9% of U.S. public high schools already offered AP courses by 2003 [12], implying that the mandate would only possibly affect a small proportion of schools and students.

On the other hand, negative effects on passing rates do not necessarily imply that student performance worsens due to the mandate. Indeed, The decline could be due to either a true drop in performance or an increase in the number of students taking the AP program. Since the mandate effect on student-level AP participation is mostly positive, the latter scenario is probable to occur.

Additional results from synthetic control analysis may be able to explain other pieces to the puzzling result. When the difference between the treated state and its respective synthetic control is displayed at each post-treatment period, it is evident that there are substantial variations both between different treatment states and across different years within the same treatment state, even when the type of mandate they received is similar. For example, Arkansas and Louisiana saw a much more positive picture than Mississippi in student AP participation, which may be partially explained by the lack of response in Mississippi school participation, as shown in Figure A.1.

Another takeaway from these observations is that variations between large units, such as states, can significantly alter the treatment effect and may even reverse its direction. Among all treatment states, Arkansas showed the most significant positive results, while Mississippi experienced the opposite effect. Consequently, the findings of this project caution against states hastily adopting educational policies that have been successful elsewhere without considering particular contexts.

Finally, evidence from Table 5 implies that state-administered school-level AP mandates appear to expand the group of top-performing students in the measure of AP awards. Given that AP awards are determined by both scores and participation frequency, the mandates seem effective in enabling more capable and possibly previously underprivileged students to access greater opportunities.

5.1 Caveat & Suggestions for Future Work

The biggest caveat that this project suffers from is the lack of publicly available disaggregated data consistent throughout observation periods. The precision of this project would be helped significantly if data was not aggregated at the state level, but instead at the school or district level. Alas, data reporting systems and existing data across states are highly variable and unavailable especially in years earlier than 2010, making the ideal data collection effort an infeasible feat.

This project would produce much more precise and informative results with finer data. It would be particularly desirable, for instance, if data dis-aggregated by race, gender, and socioeconomic backgrounds were collected, as it would be interesting to study the effect of such state-level mandate policies on a subgroup of disadvantaged students, thereby evaluating the mandates' role in closing the inequality gap. Though some results discussed above may be attributable to omitted variable bias, preliminary abnormalities observed in simplified models can inform new directions for future work. For example, the drop in number of Mississippi schools and students participating in the AP program against the school-level AP curriculum mandate detailed in Appendix B invites investigations on potential successes of alternative advanced curriculum offerings or failed attempts to sustain the AP program that are specific to Mississippi - much to the contrast to the tones of the state's official reports [13].

Appendix A

Summary Statistics Tables and Figures

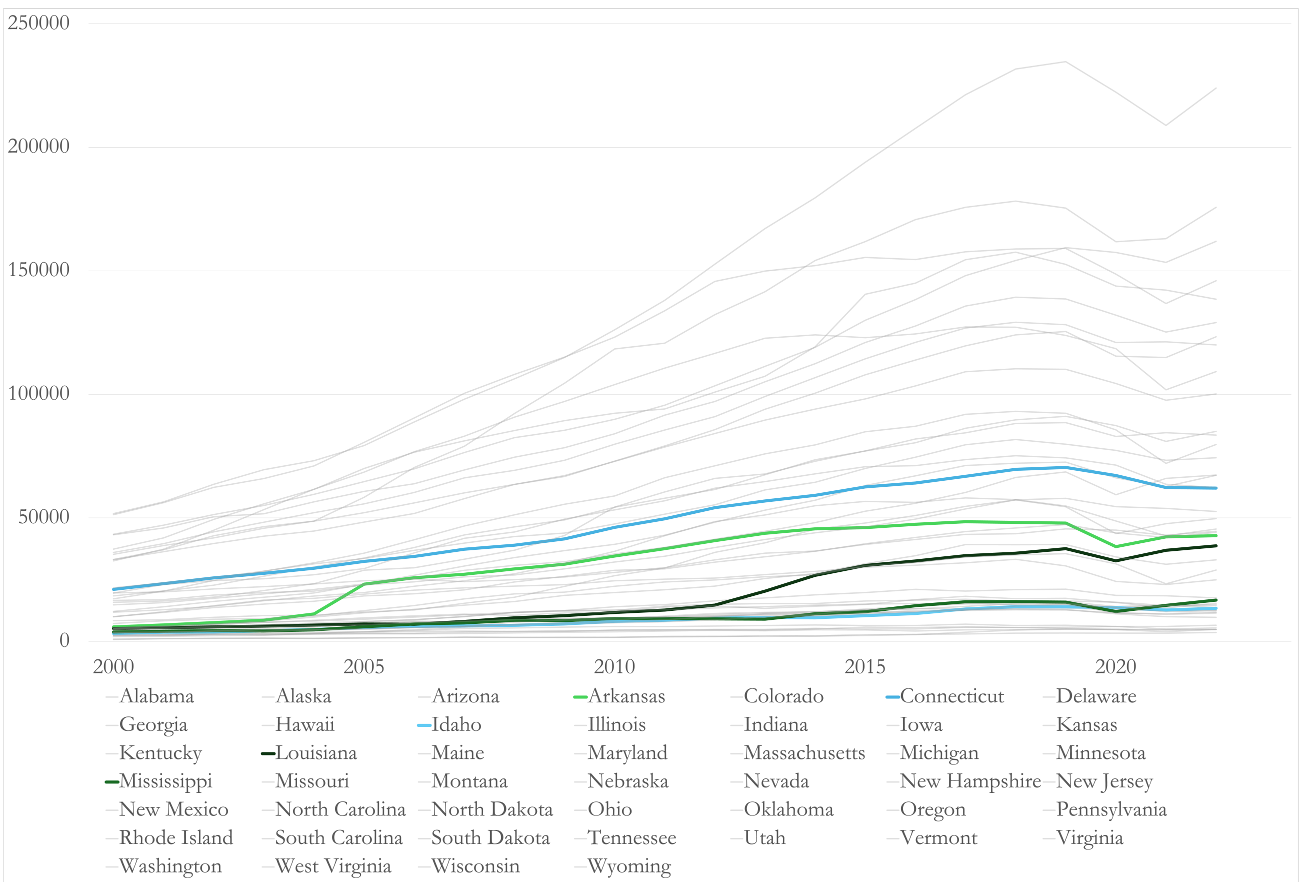

Figure A.1: AP Student Participation by State, 2000-2022[1]

[1] CA, FL, NY, TX excluded from this figure to ensure visible scale for treatment states. DC excluded due to data insufficiency. States with school-level mandates are highlighted with green. States with district-level mandates are highlighted in blue.

Table A.1: Number of Schools Participating in AP by State (Select Years)

	Total				**Public**				**Private**			
State	**2003**	**2008**	**2013**	**2018**	**2003**	**2008**	**2013**	**2018**	**2003**	**2008**	**2013**	**2018**
Alabama	170	223	282	342	126	174	217	262	44	49	65	80
Alaska	40	43	55	90	34	38	50	75	6	5	5	15
Arizona	151	213	263	338	124	178	213	276	27	35	50	62
Arkansas	**148**	**295**	**293**	**305**	**135**	**276**	**274**	**272**	**13**	**19**	**19**	**33**
California	1272	1514	1739	2411	931	1115	1299	1699	341	399	440	712
Colorado	214	258	288	366	177	210	241	303	37	48	47	63
Connecticut	**208**	**229**	**239**	**267**	**150**	**168**	**168**	**187**	**58**	**61**	**71**	**80**
Delaware	41	49	51	65	25	28	32	40	16	21	19	25
Florida	527	667	760	1120	373	457	503	625	154	210	257	495
Georgia	368	478	525	630	279	350	391	407	89	128	134	223
Hawaii	62	69	78	84	39	41	43	48	23	28	35	36
Idaho	**79**	**83**	**88**	**120**	**67**	**75**	**75**	**93**	**12**	**8**	**13**	**27**
Illinois	485	564	616	687	376	443	470	522	109	121	146	165
Indiana	331	380	403	433	292	327	345	347	39	53	58	86
Iowa	187	220	215	216	167	196	183	183	20	24	32	33
Kansas	111	110	119	138	94	93	101	112	17	17	18	26
Kentucky	241	261	258	268	199	218	210	206	42	43	48	62
Louisiana	**122**	**180**	**255**	**287**	**72**	**119**	**167**	**217**	**50**	**61**	**88**	**70**
Maine	125	134	137	138	103	120	121	104	22	14	16	34
Maryland	267	307	329	363	174	191	201	212	93	116	128	151
Massachusetts	366	400	434	458	262	287	305	330	104	113	129	128
Michigan	513	568	601	670	427	476	493	534	86	92	108	136
Minnesota	250	292	282	317	208	238	223	255	42	54	59	62
Mississippi	**118**	**189**	**150**	**200**	**85**	**152**	**115**	**161**	**33**	**37**	**35**	**39**
Missouri	214	262	284	325	161	200	215	243	53	62	69	82
Montana	91	95	100	104	81	82	86	87	10	13	14	17
Nebraska	68	82	76	91	51	57	54	65	17	25	22	26
Nevada	62	80	95	126	55	67	80	99	7	13	15	27
New Hampshire	89	99	98	119	69	76	76	85	20	23	22	34
New Jersey	433	472	505	575	320	349	365	400	113	123	140	175
New Mexico	86	100	110	129	71	78	88	109	15	22	22	20
New York	980	1149	1243	1449	738	880	931	1116	242	269	312	333
North Carolina	406	489	550	634	335	398	432	489	71	91	118	145
North Dakota	18	21	28	55	16	16	22	46	2	5	6	9
Ohio	600	644	693	739	492	518	546	578	108	126	147	161
Oklahoma	335	322	323	297	319	305	297	267	16	17	26	30
Oregon	163	187	210	229	135	156	169	175	28	31	41	54
Pennsylvania	625	704	728	798	472	537	557	583	153	167	171	215
Rhode Island	47	55	61	73	35	40	43	51	12	15	18	22
South Carolina	226	234	255	291	181	188	199	210	45	46	56	81
South Dakota	59	88	114	71	56	81	99	60	3	7	15	11
Tennessee	235	284	308	385	174	213	228	270	61	71	80	115
Texas	1124	1352	1552	1862	974	1154	1298	1511	150	198	254	351
Utah	98	119	145	197	86	95	117	152	12	24	28	45
Vermont	66	70	68	70	54	58	57	56	12	12	11	14
Virginia	356	411	427	469	269	308	318	321	87	103	109	148
Washington	272	338	379	428	221	281	311	340	51	57	68	88
West Virginia	104	114	121	127	94	103	107	111	10	11	14	16
Wisconsin	408	436	456	504	356	374	386	416	52	62	70	88
Wyoming	26	26	28	43	26	25	26	40	0	1	2	3

Table A.2: Number of Students Participating in AP by State (Select Years)

State	2004	2005	2007	2008	2011	2012	2013	2018	2019
Alabama	10625	11909	15448	17863	29715	36049	39916	57245	54462
Alaska	3252	3687	4148	4036	4636	4648	4570	5606	5260
Arizona	19590	23087	30513	33913	42982	48254	53138	72143	72533
Arkansas	**11112**	**23140**	**27170**	**29339**	**37527**	**40772**	**43760**	**48193**	**47899**
California	344089	381015	431403	453166	550988	592457	632571	794126	793695
Colorado	30144	33764	43089	46369	57937	61489	67460	89675	91101
Connecticut	**29634**	**32380**	**37314**	**38932**	**49608**	**54129**	**56838**	**69640**	**70423**
Delaware	5764	7317	7950	8117	9303	10295	11081	13307	13361
Florida	140297	160584	208825	235030	326341	333023	344996	398873	394624
Georgia	48658	58352	79017	92232	120706	132266	141528	178201	175394
Hawaii	6584	7058	8058	8857	10249	11290	11741	15829	16022
Idaho	**4821**	**5599**	**6232**	**6522**	**8584**	**9395**	**9723**	**14038**	**13984**
Illinois	73150	79257	98048	106305	138091	152709	167102	231728	234674
Indiana	23326	28821	33291	36907	60512	65970	67777	88225	88555
Iowa	8192	8986	10776	11786	14896	16413	17628	20986	21111
Kansas	6854	7959	9994	11755	14277	14988	15339	16314	16378
Kentucky	18348	19747	24534	27340	42768	48506	51174	57408	54791
Louisiana	**6644**	**7050**	**8099**	**9547**	**12680**	**14685**	**20328**	**35675**	**37544**
Maine	7408	8113	10113	11697	12781	13541	14051	15021	15056
Maryland	61620	68533	83060	90768	110641	116614	122726	127155	123872
Massachusetts	48661	52108	60117	63550	79130	85753	93959	124064	125437
Michigan	44652	48312	57806	63554	78679	84175	89598	110345	110149
Minnesota	27007	29480	41763	44281	56942	62023	64709	75185	74291
Mississippi	**4688**	**5910**	**7468**	**8520**	**9329**	**9119**	**9032**	**16087**	**15882**
Missouri	16269	18407	20842	24056	29352	32093	34248	45896	47277
Montana	3029	3250	3757	4048	4683	4844	4868	5599	5706
Nebraska	3270	3920	5842	6933	8738	9987	11117	15240	15506
Nevada	9847	11568	14664	16137	20908	22377	25479	39112	39223
New Hampshire	6344	6686	8157	8758	10061	10201	10596	12800	12697
New Jersey	59545	64682	76449	82499	95590	103483	111363	154215	159398
New Mexico	8532	9505	11040	10567	13941	14369	13365	17292	17430
New York	157568	167032	193014	200609	228147	237371	245002	309055	319337
North Carolina	61526	70026	81151	85378	94061	100945	107317	157532	152602
North Dakota	1279	1422	1716	1668	1823	1934	2295	4595	5053
Ohio	52079	55702	66232	69220	85580	91010	99156	129177	128221
Oklahoma	17461	19138	21656	22359	25188	25646	27015	33222	30559
Oregon	10311	12452	17231	19232	24045	24898	26158	34989	35521
Pennsylvania	56520	60736	69430	74538	91599	97140	105120	139358	138647
Rhode Island	4577	5113	6078	6610	7925	8733	9824	14342	14896
South Carolina	20371	22850	26117	26872	34476	37982	41246	57332	57895
South Dakota	2963	3085	3211	3418	4207	4496	4326	4771	4895
Tennessee	21017	23243	28791	30797	38068	41337	44583	66389	68620
Texas	183130	204403	246096	270466	360735	374091	398130	594643	598008
Utah	23252	24528	24183	24974	29851	33017	35721	43569	45542
Vermont	3608	3914	5219	5468	5986	6216	6433	6431	6555
Virginia	71009	80583	100435	108076	133831	145708	149918	158833	159084
Washington	31815	35704	46751	51235	66242	71070	75915	93123	92346
West Virginia	4750	4840	6162	7778	9834	10842	11486	13110	12895
Wisconsin	31404	33524	39811	42450	51486	55300	61335	81735	79817
Wyoming	1174	1365	1725	1599	2029	2113	2050	3341	3387

Appendix B

Additional Analysis: Synthetic Control Estimates

One could argue that data aggregated at the state level with few covariates makes it difficult to generate precise estimates. Furthermore, when data is aggregated at a large unit level such as state, region, or country, it is conceivably difficult to find suitable control groups with parallel trends to the treatment unit [14]. As an alternative to the difference-in-differences approach, the synthetic control method creates a synthetic control - a weighted average of select control units- with a synthesized pre-treatment-period outcome closely mimicking the treatment unit's trend.

The synthetic control method (SCM) framework similarly features T_0 pre-treatment periods, T_1 post-treatment periods, and a treatment indicator, D_{it}, for unit i at time t. However, the SCM specifications for treatment and control units differ slightly from the classic difference-in-differences model. it mandates that there exists exactly one treatment unit that is treated in the T_1 post-treatment periods and J control units, also known as "donor pool", that is never treated. One also observes the outcome variable Y_{it} for each unit i at time t and optional covariates $k \leq 0$ covariates $X_{1it}, ..., X_{kit}$.

A few more notations is needed to precisely describe the estimates of interest. Without loss of generality, assume that unit 1 is treated, whereas all other units are controls (i.e., in the “donor poll"). Let $\mathbf{W} = (w_2, ..., w_{J+1})'$ be a $J \times 1$ vector consisting of weights for each unit in the donor pool. Then

$$\hat{Y_{1t}^N} = \sum_{j=2}^{J+1} w_j Y_{jt} \tag{B.1}$$

$$\hat{\tau}_{1t} = Y_{1t} - \hat{Y_{1t}^N}, \text{ where} \tag{B.2}$$

$\hat{Y_{1t}^N}$ is a "synthetic" outcome based on linear combinations of $Y_{2t}, ..., Y_{(j+1)t}$ and $\hat{\tau}_{1t}$ is the causal difference estimate for each post-treatment period t.

To construct $\mathbf{W}$, one considers various attributes of donor pool units that may collectively match the attributes of the treated unit - notably, those attributes may include both covariates $X_{1it}, ..., X_{kit}$ that are unaffected by the treatment and Y_{it} observed in the T_0 pre-treatment periods. The root mean square error, $||X_1 - X_0\mathbf{W}||$, is minimized, where X_1 and X_0 denote covariates' values for treatment and synthetic control unit respectively, as described in Abadie & Gardeazabal (2003)[15] and Abadie, Diamond, Hainmueller (2010)[16]. Furthermore, under most contexts, all w_i in $\mathbf{W}$ are restricted to non-negative values and sum to 1.

To evaluate the significance and validity of a synthetic control estimate, one runs a “placebo test", which iteratively applies the synthetic control method to units in the donor pool. A permutation distribution is then constructed by pooling the effects estimated for each control unit together with the effect estimated for the treated unit. If the placebo test returns post-treatment gaps that are similar to the results estimated for the treated unit, then the analysis does not provide sufficient evidence for a significant effect.

Abadie, Diamond, and Hainmueller (2010) [16] define this process more formally with a test statistic that measures the ratio of post-intervention fit to pre-intervention fit between the tested unit and the synthetic control unit:

$$r_j = \frac{R_j(T_0+1, T)}{R_j(1, T_0)}, \text{ where} \tag{B.3}$$

$$R_j(t_1, t_2) = \left(\frac{1}{t_2 - t_1 + 1} \sum_{t=t_1}^{t_2} (Y_{jt} - \hat{Y_{jt}^N})^2 \right)^{1/2} \tag{B.4}$$

is the root mean squared prediction error (RMSPE) of the synthetic control estimator for unit j and time periods between t_1 and t_2, inclusive. The p-value one reports for the placebo tests is defined to be

$$p = \frac{1}{J+1} \sum_{j=1}^{J+1} I_+(r_j - r_1), \tag{B.5}$$

where I_+ is an indicator function that evaluates to 1 if $r_j - r_1 \geq 0$.

The validity of the synthetic control method hinges on a different set of assumptions. It is generally recommended that the data is aggregated at some large unit level, such as region, state, or city [14]. Concurrently, the dataset should have sufficient pre-treatment and post-treatment periods to ensure accurate fits for the synthetic control unit. Moreover, the empirical application should satisfy the following assumptions:

1. The outcome variable should not be too volatile. Otherwise, it is difficult to attribute the change in outcome variable to the treatment being tested against.

2. There exist comparable control units so that the pre-trend outcomes follow very closely with the pre-trend treatment unit outcome. Otherwise, it is difficult to construct an appropriate synthetic control unit.

3. There is no anticipation of treatment. That is, the pre-treatment outcome variable should not causally vary due to assignment to treatment.

4. One unit's outcome does not affect other units' outcomes. Otherwise, the effect observed is potentially at least partially due to substitution effects, rather than the treat-

ment itself.

I contend that this dataset is potentially well-suited for the synthetic control method as it meets all the requisite assumptions. Firstly, the data is structured as a state-year panel, which is ideal for this methodology. Moreover, since policies typically take effect 6 months to a year after their passage, schools generally lack sufficient time to make preemptive changes that might skew the data. Additionally, it is plausible to assume that the decision by one state to implement a statewide AP curriculum mandate occurs independently of similar decisions in other states. Finally, such policy implementations are unlikely to affect the outcomes of the control state as they offer a minor feature to school curricula that is improbable to cause significant student mobility across state lines.

In this section, I present synthetic control estimates on both AP participation and AP performances for states where such an analysis is sensible to construct (i.e., follows all assumptions for model validity). For each treatment state, estimates are calculated separately for each year after treatment. The donor pool consists of all control states excluding the 5 units (CA, DC, FL, NY, TX) dropped from analysis due to sheer participation volume.

Figure B.1 displays the trend of AP student participation in the treatment states compared to their respective synthetic control states. Table B.1 presents the weights assigned to each control state (referred to as the "donor pool") used in constructing the synthetic control. The vertical dotted line represents one year before the treatment (note that the treatment variable corresponds to the start of the academic year, while the outcome variables are measured at the end of the academic year.) The treatment effect, separately estimated for each year, can be observed as the vertical difference measured at each year between the treatment state outcome and the synthetic control outcome.

Under the synthetic control method, inference involves generating a point estimate of the treatment effect for each post-treatment period, including the period when the treatment

[1]Figure B.1 shows treatment states and their respective synthetic controls. The outcome variable is count of students participating in AP in each state. Covariates used to construct synthetic controls include pre-treatment AP student count, state and federal spending per student, total state student population, and various high school graduation requirements. Vertical dotted line denotes one year before treatment.

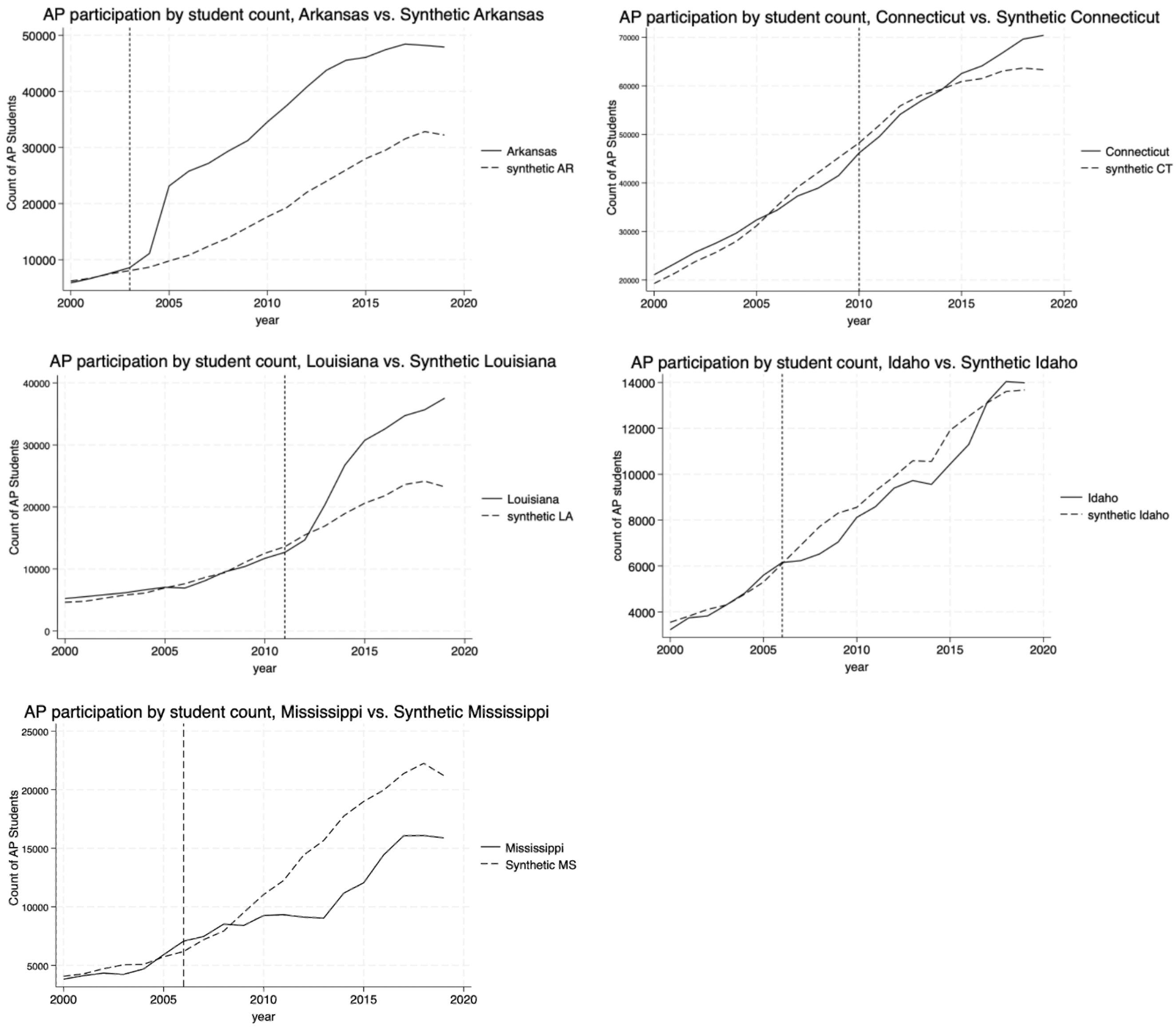

Figure B.1: AP participation by Student Count, Treatment States vs. Respective Synthetic Control States [1] begins. For each period, an associated p-value is calculated from the results of the placebo test. This p-value indicates the probability that the observed results could occur by chance. Visual inspection reveals that the synthetic control states closely replicate the trends of the treatment states during the pre-treatment periods. Additionally, the mandate effect appears positively significant for Arkansas and Louisiana, indistinguishable from zero for Connecticut and Idaho, and visibly negative for Mississippi.

Estimates of the mandate effect broken down by years since treatment are reported in Table B.2 and Table B.3, as well as plotted in Figures B.4. These estimates mostly affirm the visual inspections discussed above. Specifically, the treatment effect for Arkansas is about 15,000 and is statistically significant ($p < 0.001$) two, three, and four years after the mandate was enforced. This implies that Arkansas' school-level mandate has consistently caused Arkansas to enroll 15000 more students in the AP program than its synthetic control counterpart shortly - albeit not immediately - following the implementation of the mandate.

This result seems intuitive: the mandate may not have a significant impact in the first year because students typically decide their course selections well before the semester begins, rendering the introduction of a new AP class largely irrelevant for that academic year. On the other hand, students would have had a much higher chance to learn about and enroll in AP courses when they have been in existence for more than one year, thus marking the substantial jump in effects in years 2, 3, and 4. Lastly, this effect seems to plateau around year 10 of the mandate as schools experience significantly fewer changes in AP course offerings due to compliance with the mandate than in the earlier periods.

In contrast, the estimates for other states are not statistically significant. Nonetheless, one can still learn from the differences in trends they reveal. Though Idaho's figures are quite volatile and inconclusive, one sees that estimated effects for Louisiana and Connecticut rise steadily, while Mississippi's results drop visibly, which may indicate a case of omitted variable bias.

Further analysis of AP performance was conducted for Arkansas and Louisiana using the

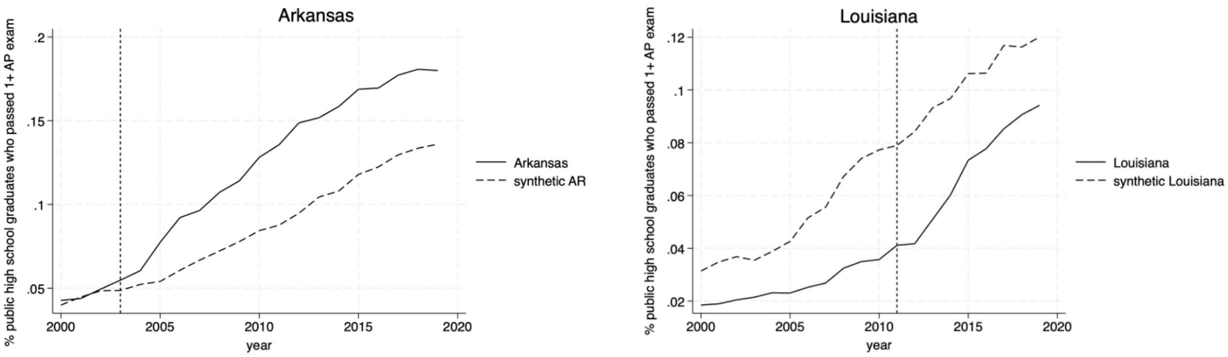

Figure B.2: Effect of AP Mandate on Count of AP Exam Passing Students by Synthetic Control [2]

percentage of AP exam-passing graduates as the outcome variable, where the effect of the mandate appears to be notably substantial. From Figures B.2 and B.3, one observes that the Arkansas mandate increases the percentage of AP-passing graduates in public high schools by around 5% percentage points consistently after around 3 years of mandate with statistical significance, which translates to approximately 25% to 40% of increase in proportions. By comparison, the same analysis on Louisiana is not only less statistically significant but also structurally less sound. On the other hand, the best-case synthetic Louisiana does not closely match the pre-treatment trends of true Louisiana's AP-passing graduate count, making the mandate effect much less interpretable.

The classical difference-in-differences approach and synthetic control methods somewhat

[2]Figure B.2 shows select treatment states (Arkansas and Louisiana) and their respective synthetic controls. The outcome variable is the proportion of AP-passing public high school students. Vertical dotted line denotes one year before treatment.

[3]Figure B.3 plots the probability (p-value) that each estimate by year after treatment is due to chance. The estimated effect here is the AP-passing rate in public high schools.

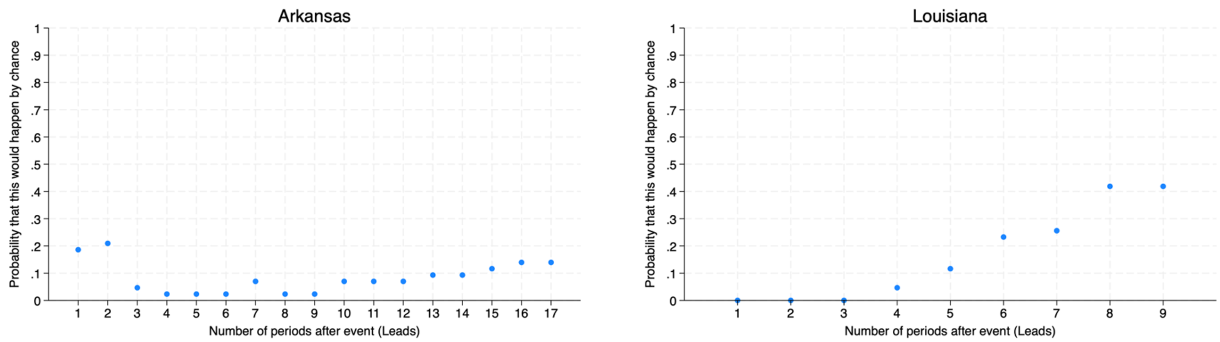

Figure B.3: Placebo Test Inference: Probability that the Mandate Effect on AP Student Passing Rate is Due to Chance [3]

complement each other in their respective advantages and shortcomings on data requirements. Synthetic control analysis is less dependent on pre-treatment parallel trends between treatment and control units. However, it requires complete data across all years and variables, as a single missing value can invalidate a unit or variable in constructing a synthetic control. On the other hand, the validity of a difference-in-differences model hinges more on the parallel trends assumption, whereas a singular missing observation does not affect much of the analysis. Although the synthetic control analyses offered insights into the trends of mandate effects for each state, they also revealed that the existing dataset lacks sufficient information to construct robust synthetic treatment units for most of the outcome variables of interest in this paper.

[4]Figure B.4 plots the probability (p-value) that each estimate by year after treatment is due to chance. The estimated effect here is count of AP-participating students.

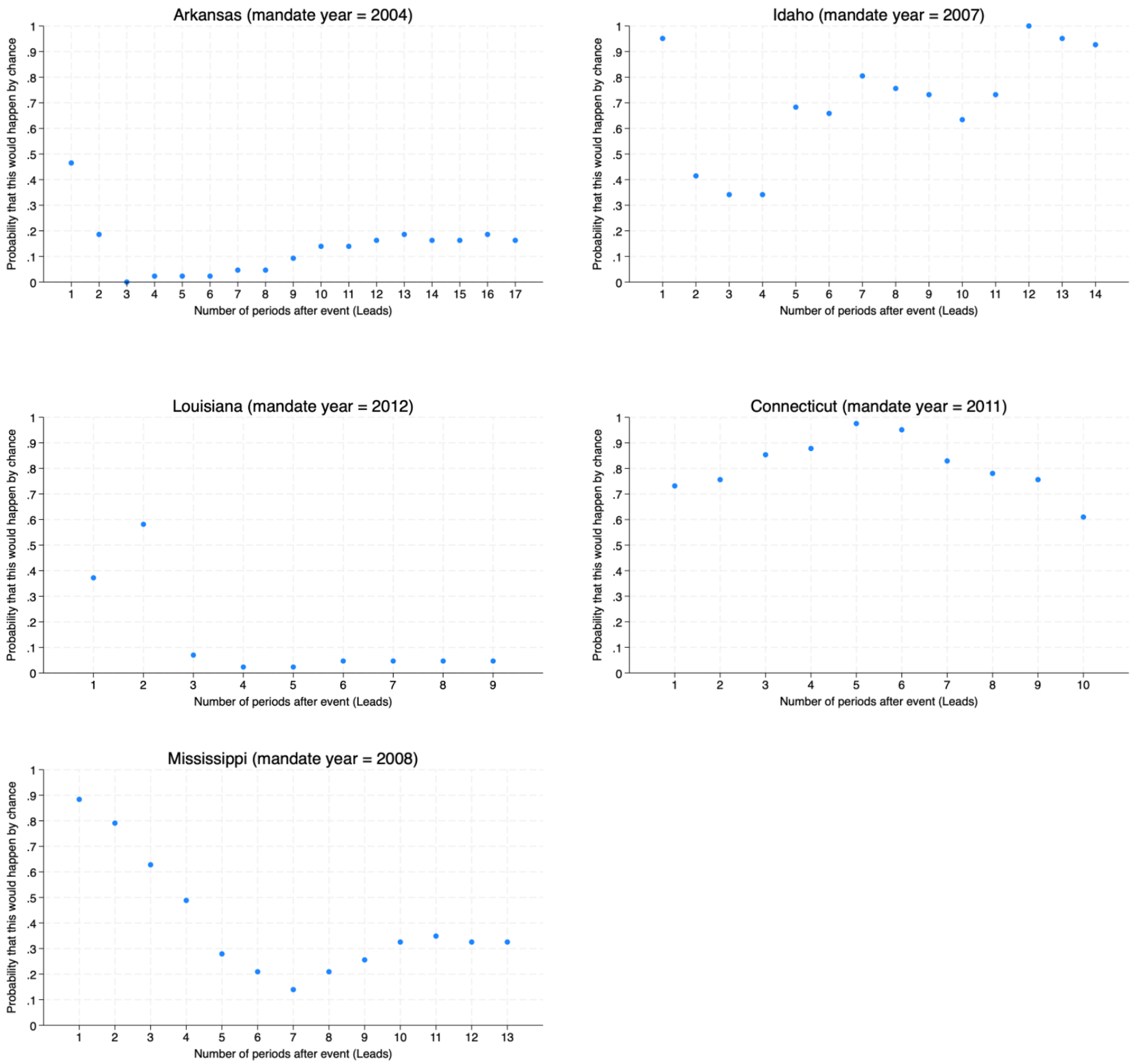

Figure B.4: Placebo Test Inference Probability that the Mandate Effect on AP Student Participation is Due to Chance [4]

Table B.1: State Weights for Each Synthetic Control State

Syn. Arkansas		**Syn. Louisiana**		**Syn. Mississippi**		**Syn. Connecticut**		**Syn. Idaho**	
State	**Weight**	**State**	**Weight**	**State**	**Weight**	**State**	**Weight**	**State**	**Weight**
AL	0.257	AL	0.262	AL	0.336	AL	0.002	KS	0.061
AK	0.006	AK	0.552	AK	0.353	AK	0.001	NE	0.384
AZ	0.008	Nevada	0.152	WY	0.311	AZ	0.001	NV	0.021
CO	0.005	WY	0.034			CO	0.006	NH	0.439
CT	0.004					DE	0.002	WY	0.095
DE	0.009					GA	0.002		
GA	0.003					HI	0.001		
HI	0.007					IL	0.002		
ID	0.022					IN	0.002		
IL	0.002					KS	0.002		
IN	0.007					KY	0.002		
IA	0.015					ME	0.001		
KS	0.027					MD	0.082		
KY	0.007					MA	0.003		
ME	0.008					MI	0.002		
MD	0.003					MN	0.122		
MA	0.003					MO	0.001		
MI	0.004					MT	0.001		
MN	0.004					NV	0.006		
MO	0.011					NH	0.409		
MT	0.013					NJ	0.002		
NE	0.242					NM	0.001		
NV	0.043					NC	0.003		
NH	0.012					OH	0.002		
NJ	0.002					OK	0.001		
NM	0.008					OR	0.002		
NC	0.003					PA	0.001		
ND	0.033					RI	0.001		
OH	0.003					SC	0.002		
OK	0.007					SD	0.001		
OR	0.013					TN	0.002		
PA	0.003					UT	0.008		
RI	0.015					VT	0.11		
SC	0.006					VA	0.209		
SD	0.029					WA	0.002		
TN	0.009					WV	0.001		
UT	0.004					WY	0.002		
VT	0.01								
VA	0.002								
WA	0.005								
WV	0.014								
WI	0.004								
WY	0.107								

Table B.2: Effect of School-level AP Mandate on AP Student Participation, SCM Estimates and p-values

	Arkansas			Louisiana			Mississippi		
t	**estimates**	**p-vals**	**std**	**estimates**	**p-vals**	**std**	**estimates**	**p-vals**	**std**
0	532.527	0.535	0.465	-911.404	0.535	0.372	276.753	0.791	0.884
1	2443.889	0.186	0.186	-798.68	0.721	0.581	596.035	0.744	0.791
2	13358.68	0.000	0.000	3404.86	0.488	0.070	-1106.547	0.651	0.628
3	14988.43	0.000	0.023	7811.408	0.233	0.023	-1785.007	0.535	0.488
4	14765.07	0.000	0.023	10139.82	0.116	0.023	-2922.767	0.465	0.279
5	15459.61	0.047	0.023	10762.91	0.116	0.047	-5291.351	0.349	0.209
6	15470.96	0.047	0.047	11094.47	0.186	0.047	-6630.536	0.372	0.140
7	16908.85	0.093	0.047	11523.68	0.209	0.047	-6569.566	0.372	0.209
8	18189.1	0.093	0.093	14294.38	0.163	0.047	-6943.969	0.326	0.256
9	18761.44	0.116	0.140				-5536.405	0.442	0.326
10	19782.83	0.093	0.140				-5312.663	0.512	0.349
11	19538.87	0.140	0.163				-6165.289	0.512	0.326
12	18036.51	0.140	0.186				-5327.369	0.512	0.326
13	17913.22	0.163	0.163						
14	16885.12	0.186	0.163						
15	15365.25	0.256	0.186						
16	15684.36	0.233	0.163						

Note: t denotes years since mandate. p-val denotes the probability that the estimates are due to chance. std denotes the standard deviation of p-values from placebo test.

Table B.3: Effect of District-level AP Mandate on AP Student Participation, SCM Estimates and p-values

	Connecticut			Idaho		
t	**estimates**	**p-vals**	**std**	**estimates**	**p-vals**	**std**
0	-2071.208	0.415	0.732	49.996	0.976	0.951
1	-2324.564	0.439	0.756	-673.704	0.707	0.415
2	-1746.119	0.610	0.854	-1192.871	0.610	0.341
3	-1203.24	0.683	0.878	-1261.878	0.659	0.341
4	-131.232	1.000	0.976	-435.247	0.902	0.683
5	1659.892	0.780	0.951	-690.891	0.780	0.659
6	2613.381	0.683	0.829	-503.167	0.878	0.805
7	3748.165	0.610	0.780	-863.06	0.878	0.756
8	5971.084	0.439	0.756	-999.105	0.829	0.732
9	7091.438	0.366	0.610	-1475.549	0.780	0.634
10				-1230.236	0.951	0.732
11				35.328	1.000	1.000
12				432.739	0.976	0.951
13				311.207	0.976	0.927

Note: t denotes years since mandate. p-val denotes the probability that the estimates are due to chance. std denotes the standard deviation of p-values from placebo test.

References

[1] *AP Courses and Exams – AP Students | College Board*. URL: https://apstudents.collegeboard.org/course-index-page (visited on 12/12/2023).

[2] L. Hamm, *AP courses falling short as a tool for narrowing equity gaps*, en-US, Sep. 2021. URL: https://feed.georgetown.edu/access-affordability/ap-courses-falling-short-as-a-tool-for-narrowing-equity-gaps/ (visited on 12/12/2023).

[3] D. Gagnon and M. Mattingly, "Limited Access to AP Courses for Students in Smaller and More Isolated Rural School Districts," *The Carsey School of Public Policy at the Scholars' Repository*, Feb. 2015. DOI: https://dx.doi.org/10.34051/p/2020.227. URL: https://scholars.unh.edu/carsey/235.

[4] L. Hargrove, D. Godin, and B. Dodd, "College Outcomes Comparisons by AP and Non-AP High School Experiences. College Board," The College Board, Tech. Rep., 2008.

[5] S. Geiser and V. Santelices, *The Role Of Advanced Placement And Honors Courses In College Admissions*, Jun. 2004. URL: https://cshe.berkeley.edu/publications/role-advanced-placement-and-honors-courses-college-admissions (visited on 12/12/2023).

[6] C. Dougherty, L. Mellor, and S. Jian, "The Relationship between Advanced Placement and College Graduation. 2005 AP Study Series, Report 1," en, National Center for Educational Accountability, Tech. Rep., Feb. 2006, Publication Title: National Center

for Educational Accountability ERIC Number: ED519365. URL: https://eric.ed.gov/?id=ED519365 (visited on 12/12/2023).

[7] J. Smith, M. Hurwitz, and C. Avery, "Giving college credit where it is due: Advanced placement exam scores and college outcomes," National Bureau of Economic Research, NBER Working Paper 21147, 2015. DOI: 10.3386/w21147. URL: https://www.nber.org/papers/w21147.

[8] C. Avery, O. Gurantz, M. Hurwitz, and J. Smith, "Shifting college majors in response to advanced placement exam scores," National Bureau of Economic Research, NBER Working Paper 22841, 2016. DOI: 10.3386/w22841. URL: https://www.nber.org/papers/w22841.

[9] P. Arce-Trigatti, "The impact of state-mandated Advanced Placement programs on student outcomes," *Economics of Education Review*, vol. 63, pp. 180–193, Apr. 2018, ISSN: 0272-7757. DOI: 10.1016/j.econedurev.2018.02.001. URL: https://www.sciencedirect.com/science/article/pii/S0272775717306234 (visited on 12/12/2023).

[10] *ECS Topic: High School–Advanced Placement*. URL: https://b5.caspio.com/dp.asp?AppKey=b7f93000695b3d0d5abb4b68bd14&id=a0y70000000Cbp5AAC (visited on 04/15/2024).

[11] *AP National and State Data Archive – AP Central | College Board*, en. URL: https://apcentral.collegeboard.org/about-ap/ap-data-research/national-state-data/archive (visited on 04/15/2024).

[12] National Center for Education Statistics, "Digest of education statistics 2010," National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, Tech. Rep., 2011. URL: https://nces.ed.gov/pubs2011/2011015.pdf.

[13] Mississippi Department of Education, *Advanced placement (ap) participation and achievement increase among mississippi students for 2022-23*, Accessed: May 4, 2024, Sep.

2023. URL: https://www.mdek12.org/news/2023/09/25/Advanced-Placement-AP-participation-and-achievement-increase-among-Mississippi-students-for-2022-23.

[14] A. Abadie, "Using Synthetic Controls: Feasibility, Data Requirements, and Methodological Aspects," en, *Journal of Economic Literature*, vol. 59, no. 2, pp. 391–425, Jun. 2021, ISSN: 0022-0515. DOI: 10.1257/jel.20191450. URL: https://www.aeaweb.org/articles?id=10.1257/jel.20191450 (visited on 12/12/2023).

[15] A. Abadie and J. Gardeazabal, "The Economic Costs of Conflict: A Case Study of the Basque Country," en, *American Economic Review*, vol. 93, no. 1, pp. 113–132, Mar. 2003, ISSN: 0002-8282. DOI: 10.1257/000282803321455188. URL: https://www.aeaweb.org/articles?id=10.1257/000282803321455188 (visited on 12/12/2023).

[16] A. Abadie, A. Diamond, and J. Hainmueller, "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program," *Journal of the American Statistical Association*, vol. 105, no. 490, pp. 493–505, Jun. 2010, Publisher: Taylor & Francis _eprint: https://doi.org/10.1198/jasa.2009.ap08746, ISSN: 0162-1459. DOI: 10.1198/jasa.2009.ap08746. URL: https://doi.org/10.1198/jasa.2009.ap08746 (visited on 12/12/2023).