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Negative Impacts From the Shift to Online Learning During the COVID-19 Crisis: Evidence from a Statewide Community College System

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Abstract

The COVID-19 pandemic led to an abrupt shift from in-person to virtual instruction in Spring 2020. We use two complementary difference-in-differences frameworks, one that leverages within-instructor-by-course variation on whether students started their Spring 2020 courses in-person or online and another that incorporates student fixed effects. We estimate the impact of this shift on the academic performance of Virginia's community college students. With both approaches, we find modest negative impacts (three to six percent) on course completion. Our results suggest that faculty experience teaching a given course online does not mitigate the negative effects. In an exploratory analysis, we find minimal long-term impacts of the switch to online instruction.

Keywords: community colleges, virtual instruction, COVID-19, fixed-effects, difference-in-differences

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I. Introduction

The COVID-19 health crisis led to one of the largest disruptions in the history of American education. Beginning in March 2020, tens of millions of students attending school in person at all education levels abruptly shifted to online learning due to stay-at-home orders put in place to curb transmission of the virus. While some teachers and faculty had experience teaching online, many had to pivot into online teaching for the first time, often using videoconferencing technology (e.g. Zoom) to deliver instruction and engage students.

There are various reasons why the COVID-19 crisis and the ensuing abrupt shift to virtual instruction may have led to worse outcomes for community college students (United States Department of Education, 2021). Students may have been dealing with health challenges associated with COVID-19 infection or have had family members who became sick. Many community college students and their family members were among the tens of millions of Americans who lost their jobs during Spring 2020; the stress of these job losses may have reduced the cognitive bandwidth and attention students could devote to class (Shah, Shafir, and Mullainathan, 2015). Increased childcare responsibilities may have detracted from time adult students could invest in their college course work (United States Department of Education, 2021).

A growing body of research on online learning reinforces the potential negative impacts that an abrupt shift to online courses could have had on students' academic performance. Both experimental and quasi-experimental analyses show that students in online courses have lower rates of course completion and final grades, lower rates of persistence, and increased course repetition (Alpert, Couch, and Harmon 2016; Bettinger et al. 2017; Figlio, Rush, and Yin 2013; Hart, Friedman, and Hill 2016; Jaggars and Xu, 2016; Xu and Xu, 2019). This body of research moreover suggests that negative impacts of online learning are most pronounced for students from

lower socioeconomic and underrepresented backgrounds as well as for academically-weaker students -- populations which may have disproportionately been affected by COVID-19-related health, economic, and childcare challenges (United States Department of Education, 2021).

Specific to the COVID-19 context, several studies have investigated how this abrupt shift to online learning affected students. Most like our analysis is Altindag, Feliz, and Tekin (2021), which leverages data from a public university to investigate the performance of students in in-person versus online courses during the pandemic. Using a student fixed-effect model, the authors find that students fared better academically in in-person courses compared to online. In addition, a recent paper by Kofoed et al. (2021), in which West Point cadets were randomly assigned to an online or in-person introductory economics class during the Fall 2020 semester, finds that students in online courses performed worse than their peers in in-person courses. Aucejo et al (2020) surveyed undergraduates at Arizona State University about their expectations for academic performance because of the COVID-induced learning disruptions. A sizable share of students reported that they anticipated needing to delay graduation, withdraw from classes, or change majors, with lower-income students more likely to report that they anticipated delaying graduation than their higher-income peers.[1]

While research to date supports the likely negative impacts of the abrupt shift to online learning, it is also worth noting that there are several reasons why the magnitude of this effect may have been not as profound as some might expect. For instance, the combined shift to online learning, remote work, and even job loss may have substantially increased the time available to students to invest in their courses. Many colleges implemented emergency grading policies which

[1] In related analyses, Gurantz and Wielga (2020) find that, while first-year student Free Application for Federal Student Aid (FAFSA) submissions in early 2020 declined by nearly twenty percent compared to prior years, renewal rates among more advanced students increased.

could have reduced the effort required from students to pass their courses and make further progress towards their degree.

We build on this body of research by using two complementary identification strategies to estimate the impact of the abrupt shift to virtual instruction on students' academic performance across the Virginia Community College System (VCCS). VCCS enrolls approximately 250,000 students per year and is broadly representative of open access institutions across the country. Our primary identification strategy is a difference-in-differences model with instructor-by-course fixed-effects in which we compare changes in course completion rates along two dimensions: (1) in-person versus online courses; (2) Spring 2020 versus recent comparison terms. We classify students enrolled in in-person courses at the start of the Spring 2020 as "treated", i.e. they experienced the sudden shift to online instruction. In our secondary strategy, we estimate a student fixed-effects model using a similar difference-in-differences framework, which we elaborate upon in Section IV.

The advantage of the instructor-by-course FE model is that we maintain a substantially larger (and therefore more generalizable) sample of VCCS students, and for this reason we privilege results from the instructor-by-course FE model. While the parallel trends assumption generally appears to hold for the instructor-by-course FE model, we do see evidence of a diminishing gap over time in prior online experience between students who started the semester in person versus online. To the extent that students starting the semester in person in Spring 2020 had more previous online experience (relative to students starting the semester online) than in prior terms, the abrupt shift to online during COVID-19 could have had a smaller impact on students' academic performance. We discuss these and other threats to identification with both the instructor-by-course and student FE models in greater detail in Section IV. While we acknowledge

that our identification strategies separately do not warrant the strongest causal claim, given the scale of the COVID-19 disruption to higher education and the nascent literature examining its impact on student academic performance, and given the consistency of results across many alternative specifications, we believe our study still provides a meaningful contribution to both researchers and policy makers.

Both identification strategies yield similar conclusions. Using the instructor-by-course FE model, we estimate that the move from in-person to virtual instruction resulted in a 4.9 percentage point decrease in course completion. This translates to a 6.1 percent decrease when compared to the pre-COVID course completion rate for in-person students of 80.7 percent. This decrease in course completion was due to a relative increase in both course withdrawal (2.7 percentage points) and course failure (1.3 percentage points). The negative impacts are largest for students with lower GPAs or no prior credit accumulation.

In exploratory analyses of students' academic performance in the following academic year, we find that near-term reductions in academic performance do not appear to have resulted in substantial reductions in longer-term persistence or academic performance. Students impacted by the shift to virtual instruction in Spring 2020 were 1.1 percentage points (1.2 percent) less likely to re-enroll in the following year and earned 0.58 (4.7 percent) fewer credits.

While the point estimates from the student FE model are smaller than those from the instructor-by-course FE, both sets of estimates indicate a statistically significant but modest negative impact on course performance from the abrupt shift to virtual instruction.

Our results contribute further evidence on how COVID-19 -- and specifically the abrupt shift to online education that occurred during the pandemic -- affected community college student academic performance. While we do estimate negative impacts of the switch to virtual instruction

from both identification strategies, the magnitude of these impacts is relatively modest, especially relative to the 19 percent decline in Fall 2020 enrollment among first year students at community colleges (National Student Clearinghouse, 2020). Our exploratory analysis suggests that these near-term reductions in performance did not translate into substantial declines in persistence or academic performance in the next academic year. Our findings therefore suggest that the highest priority for policy intervention may be to support postsecondary planning among students whose initial college entry was disrupted by COVID-19, as well as to support students whose postsecondary trajectories were interrupted by COVID-19, regardless of instructional delivery format.

While situated in the COVID-19 context, our paper moreover contributes to the larger body of research on the efficacy of online education. One novel contribution relative to prior research is that we leverage plausibly exogenous variation in a mid-semester shift to virtual instruction, whereas previous analyses estimate the impact of online versus in-person learning from the start of a semester. While an abrupt, nation-wide shift to virtual instruction will hopefully be rare, student-specific mid-semester switches may be more generalizable; many speculate that flexible hybrid offerings will continue to be available at many institutions (Anderson, 2021), and disability advocates have used remote learning during COVID-19 as an example of accommodations that should continue to be offered in a post-pandemic world (Morris & Anthes, 2021). Interestingly, our results suggest that instructor experience teaching the same class online does not mitigate the negative effects of mid-semester shifts to online, suggesting that aspects of the student experience -- more so than pedagogical challenges instructors face teaching online -- make the transition difficult. Consistent with prior work, we find that mid-semester shifts to virtual instruction had the most pronounced negative effects on students with worse prior academic performance. Efforts to

increase student success in online education, whether from the start of or during the semester, will likely be most important for this population of students.

II. Literature review

As we describe in the introduction, a sizeable body of research has documented the generally worse learning outcomes that students experience in online versus in-person courses. One important distinction between this research and our paper is that most prior papers exploit variation in whether students enroll in online or in-person courses at the start of a term. We present a brief literature review for how the shift to virtual instruction in the middle of the semester may introduce unique challenges for students, drawing on research that has investigated factors inhibiting or promoting success in online education.

Several factors contribute to students' academic struggle in online education. Online learning requires a higher degree of autonomy among learners than in-person courses, which may be challenging for academically-weaker students or students with non-traditional enrollment trajectories (Corbeil, 2003; Dabbagh et al., 2019). The lack of in-person interaction in online courses can lead to a sense of isolation and disconnectedness from a learning community (Picciano, 2002), and can make it more difficult for students to engage with and learn from peers and instructors (Friesen and Kuskis, 2013; Xu and Jaggars, 2014).

In the face of these challenges ,researchers and educators have developed several strategies to promote a greater sense of connection and more interaction in online courses. For instance, Project Compass increased the frequency of synchronous class sessions and promoted more frequent individual interaction between instructors and students (Edmunds et al., 2019). Cung, Xu, and Eichorn (2018) investigate the impact of providing students with opportunities for in-person

office hours and more frequent digital communication with instructors, and find that these enhancements to student interaction led to stronger performance.

With the abrupt shift to virtual instruction during the COVID-19 pandemic, however, students who opted to start the semester in in-person courses were perhaps negatively selected for the autonomy required in online courses. Instructors who had to shift to online teaching meanwhile did not have sufficient advance notice to put into place strategies to increase students' sense of connectedness and interaction with instructors and peers. Both factors may have contributed to worse academic outcomes for students who started the semester in person than those who started the term online.

III. Study Setting

Virginia Community College System

The Virginia Community College System (VCCS) is comprised of 23 colleges across the Commonwealth, and in the 2019-20 academic year enrolled 218,985 students.[2] The demographic characteristics of VCCS students are similar to the broader community college landscape; at similar institutions, 49 percent of students are White or Asian and 37 percent are Black or Hispanic. VCCS serves a slightly higher percentage of White and Asian students (58 percent) with 33 percent Black or Hispanic.[3] Thirty-five percent of students at similar institutions receive Pell grants, compared to 31 percent at VCCS. The graduation rate in 150 percent of expected time to completion is 34 percent at VCCS and at similar institutions.

[2] Source: https://www.vccs.edu/about/#statistics

[3] Source: authors' calculations using College Scorecard data from 2019-20.

VCCS online course offerings

Online learning is a well-established practice at VCCS, dating back to 1996. Online instruction can take different forms, from synchronous formats in which instructors and students connect virtually in real time, to fully asynchronous instruction administered through a learning management system, to a "hybrid" approach in which the majority (50-99 percent) of coursework is completed online either synchronously or asynchronously, but is coupled with some in-person instruction or assessment.[4] In the 2008-2009 academic year, 38.5 percent of the student population was enrolled in online learning, either exclusively or coupled with in-person courses.[5] By the 2018-2019 academic year, this increased to 55.9 percent.[6]

Changes within VCCS due to COVID

In response to the COVID-19 crisis and the Governor's declaration of a state of emergency on March 12, 2020, in person VCCS courses were moved to virtual instruction. The switch to virtual instruction happened on March 18, 2020 and courses remained virtual through the end of the Spring semester on May 11, 2020. On March 24, the chancellor of VCCS announced the system would switch to a Pass/No Pass emergency grading system for Spring 2020. The emergency grading system consisted of four grading options: P+, indicating the course credit is transferable and counts towards VCCS degree requirements; P-, indicating the course credit is not transferable but still counts towards VCCS degree requirements; incomplete; and withdrawal. There were no updates to the financial aspect of the withdrawal policy, meaning students were not reimbursed for withdrawals after the January 29, 2020 deadline, well before the move to virtual instruction. While

[4] In our analysis, we treat hybrid courses as online due to differences across colleges in how they classify course modalities. As we show in Appendix Table A5, our results are very similar when we exclude hybrid courses.
[5] Source: https://www.vccs.edu/about/#statistics
[6] Source: authors' calculations using VCCS administrative data.

the emergency grading system was the default, students had the option of opting-in to receiving a traditional letter grade (A-F). In practice, 71 percent of students opted-in to the traditional grading scale for at least one of their courses.

IV. Research Design

Data

Data for this study come from systemwide administrative records for students enrolled in credit-bearing coursework at a VCCS college. For each term in which a particular student was enrolled, these records contain detailed academic information including the program of study the student was pursuing (e.g. an AA&S in Liberal Arts); which courses and course sections the students were enrolled in (e.g. ENG 111 taught by Instructor X, MWF 9-10am); the grades they earned; and any VCCS credentials awarded. The data also contain information about each course and course section, including the modality of instruction (online, in-person), an instructor-specific identifier, and basic instructor characteristics (sex, race/ethnicity, full-time versus adjunct status). We also observe basic demographic information about each student, as well as National Student Clearinghouse matches starting in 2005.

Analytic Samples

The basis for all sample specifications presented in this paper is student-by-course level observations from Spring 2020 and several recent pre-COVID comparison terms (beginning in Spring 2016).[7] For most of our analyses, we make a set of core restrictions to the sample to focus

[7] When we refer to a course, we treat the same general course taught at different colleges as separate courses; for example, we treat ENG 111 at Piedmont Virginia Community College as a distinct course from ENG 111 taught at Northern Virginia Community College.

our attention on college-level students and courses that either were impacted by the switch to virtual instruction or that serve as an appropriate comparison. The core restrictions exclude the following observations:

1. Dual enrollment students. The transition from in-person to virtual instruction may have been operationalized in a significantly different manner for dual enrollment classes, as many of these courses are taught in high schools by high school faculty.
2. Courses offered outside the full session. While the majority of VCCS courses are offered within the full session, which lasts 15 or 16 weeks and spans January through May (with exact start and end dates depending on the college), some courses are offered during shorter sessions. The shorter sessions during the first half of Spring 2020 were largely or entirely unaffected by COVID because they ended during March 2020, while the shorter sessions during the second half of Spring 2020 were fully online, and some students may have decided not to attempt these courses due to COVID.
3. Developmental courses. The vast majority of developmental courses, which are not credit-bearing, are offered during the abbreviated sessions. Additionally, many VCCS colleges have made meaningful changes to their developmental course policies in recent years, resulting in significant decreases in the share of students required to take developmental courses.
4. Courses that could not be switched to virtual instruction, such as clinical or on-site training courses.
5. Audited courses that students are not taking for credit; this is very rare.

After these core restrictions, the population of VCCS students in full-session, college-level, credit-bearing courses contains 2,159,200 student-by-course-by-semester observations, corresponding to

352,177 unique students.[8] As our samples are defined at the student-by-course level, individual students contribute multiple observations to the sample.

Instructor-by-course FE Sample

For the instructor-by-course FE specification, we further restrict the sample to students who were enrolled in courses that were taught both online and in person during Spring 2020 and were taught both online and in person during at least one of the pre-COVID comparison terms. We use the Spring terms from 2016-2019 as the pre-COVID comparison term; we focus on Spring terms because the population of VCCS students varies meaningfully between Spring and Fall terms, making observations from Fall terms less desirable counterfactuals.[9] The instructor-by-course FE sample consists of 537,115 total student-by-course observations from the 2016-2020 Spring semesters, which corresponds to 218,624 unique students.

Student FE Sample

In order to identify the sample of students for the student FE model, we make the student-level restriction that the students must have been enrolled in both online and in-person courses in the Spring 2020 semester and at least one pre-COVID comparison term.[10] We use Spring 2018, Fall 2018, Spring 2019, and Fall 2019 as the comparison terms for the student FE sample; because

[8] This sample is inclusive of enrollments during the Spring and Fall terms from Spring 2016 through Spring 2020.

[9] Appendix Figure A1 shows the share of enrolled students with prior VCCS enrollment and the average credits accumulated among students in Spring versus Fall terms. Because the majority of students begin their enrollment during a Fall term, the student population in Spring terms are more likely to have been previously enrolled at VCCS and have accumulated more credits. There are also differential trends between the online and in-person student populations, suggesting that online students are less likely to adhere to the traditional academic progression beginning in a Fall term.

[10] One limitation to this approach is that, because we require students to be enrolled in Spring 2020 and at least one comparison term, students are further along in their academic progression in Spring 2020 and therefore are likely taking different types of courses in Spring 2020 than in comparison terms (e.g. more likely to take 200-level courses). As we discuss below, we include course-level controls in the student FE regression model.

all students in the sample were enrolled in Spring 2020, there is not the same concern about the compositional differences between Spring and Fall terms describe above. We make the additional course-level restriction that the courses offered in the Spring 2020 semester must have been offered in that modality in at least one prior semester. The student FE sample consists of 101,077 total student-by-course observations from the 2018-2020 Spring and Fall semesters, which corresponds to 9,164 unique students.

Difference-in-differences models

Our first specification is a difference-in-differences model with instructor-by-course fixed effects, represented by the following regression equation:

$$\begin{aligned} Outcome_{scit} = {} & \beta_1 InPerson_{scit} + \beta_2 Spring2020_t + \beta_3 InPerson_{scit} * Spring2020_t + \\ & + StudentCovars_{st} + ClassCovars_{scit} + CourseCovars_{ct} + \\ & + InstructorCovars_{it} + Instructor\ X\ Course\ FE_{ci} + \epsilon_{scit} \end{aligned} \quad (1)$$

where $Outcome_{scit}$ is the course outcome for student *s* in course *c* taught by instructor *i* in term *t*. Our primary outcome of interest is course completion; we set this binary outcome to one if the student received a grade of A, B, C, D, P+, or P- and to zero if otherwise. We also estimate the model separately for the outcomes of whether the student withdrew from the course, failed the course, or earned a grade of A, B, C, or P+. $InPerson_{scit}$ is an indicator equal to one if the student was enrolled in an in-person section of course *c*, and zero for online; $Spring2020_t$ is an indicator equal to one for Spring 2020 and zero for the comparison terms. The coefficient on the interaction $InPerson_{scit} * Spring2020_t$, β_3, is the difference-in-difference estimate which

measures the impact of the move from in-person to virtual instruction on the outcome of interest. $StudentCovars_{st}$ is a set of student-level covariates including basic demographics, program of study, academic experiences at VCCS prior to term *t* (number of credits accumulated, cumulative GPA, prior experience in online coursework, etc.) and academic experiences at non-VCCS colleges prior to term *t*. $ClassCovars_{scit}$ contains the enrollment count of the section of course *c* in which the student was enrolled. $CourseCovars_{ct}$ is a set of time-variant course-level covariates that describe the performance of all students at VCCS who took course *c* prior to term *t*, including: the percent of students who received an A or B; the percent who withdrew from the course; the percent who failed the course; and the percent who received an incomplete in the course. $InstructorCovars_{it}$ is a set of time-variant instructor-level covariates that includes tenure at VCCS (measured in number of terms as a VCCS instructor since Spring 2008, which is the first term during which we reliably observe the instructor-specific identifier), and full-time versus adjunct status. $Instructor\ X\ Course\ FE_{ic}$ is the set of instructor-by-course fixed effects. Finally, we cluster the standard errors at the course by modality level. With the inclusion of instructor-by-course fixed effects, the identifying variation for the difference-in-differences estimator comes from instructors teaching the same course in both modalities (online and in-person) during both Spring 2020 and at least one comparison term, holding constant any differences across courses or instructors in grading practices, modality offering, etc.

One concern about the instructor-by-course FE approach is that students who started the Spring 2020 semester in person versus online may have been differentially affected by COVID-19 in ways unrelated to the shift to virtual instruction. For instance, because in-person students are, on average, younger than online students (see description of Table 1 below), in-person students may have been less likely to have experienced childcare challenges or may have been more likely to

experience job loss due to the types of jobs they held. Our complementary estimation strategy in which we use student fixed-effects does not suffer from this limitation.

Our empirical specification for the student FE model is the same as equation (1), except for removing the student covariates and replacing the instructor-by-course fixed effects with student fixed-effects. Our identifying variation for the difference-in-differences estimator comes from students who take courses in both modalities (online and in-person) during both Spring 2020 and at least one of the comparison terms, with an individual student serving as their own comparison for both the in-person versus online and COVID versus pre-COVID dimensions.

Testing Model Assumptions

The key identifying assumption for our difference-in-differences models is parallel trends in the pre-COVID outcomes for the in-person and online observations.[11] In this context, the parallel trends assumption is that the trend in outcomes for students enrolled online serve as an appropriate counterfactual for students who began in person.[12] We provide evidence to support this underlying assumption by testing if the differences in outcomes between online and in-person students were stable in all the pre-COVID periods using event studies.[13] Figure 1, Panel A supports the parallel trends assumption for the instructor-by-course FE model by showing that the pre-COVID estimates are generally statistically indistinguishable from zero for the four outcomes.

[11] A separate identifying assumption of the difference-in-difference approach is that there was no differential sorting of students due to the onset of "treatment". However, given the sudden and unanticipated nature of the COVID crisis during March 2020, when the full session courses were well past the date when students could unregister for courses without receiving a withdrawal, differential sorting would be very unlikely.

[12] Appendix Figure A2 shows the raw trends of the outcome variables for the instructor-by-course FE and student FE analytic samples.

[13] Specifically, we estimate equation (1) with indicators and interactions for each term, forcing the coefficients for the most recent pre-COVID term to be zero.

One exception is that the coefficient on $InPerson_{scit} * Spring2017_t$ is statistically significantly different from zero for the course completion outcome, although still small in magnitude.

Figure 1, Panel B shows the corresponding event study plots for the student FE model. We observe that students had better outcomes in in-person versus online courses during Spring 2018. Note that 23 percent of students in the student FE sample have observations for Spring 2018, and these would correspond to courses taken considerably earlier in their academic progression. The Fall 2018, Spring 2019, and Fall 2019 terms are more comparable to Spring 2020.[14]

We suggest two hypotheses for the differential trends in the event studies, which also highlight the complementarity of our two approaches. First, online course offerings increased over the sample period, and it is possible that more difficult courses were offered online during more recent terms that were not offered earlier in the sample. The instructor-by-course FE model accounts for this potential source of bias, while the student FE model does not. Second, student preferences for online versus in-person courses may have changed over the course of the sample period. For example, students may be more willing to take more difficult courses online during more recent terms compared to earlier in the sample. The student FE model accounts for this potential source of bias (assuming time-invariant preferences within student), while the instructor-by-course FE model does not. We explore these hypotheses in two ways. First, we estimate event studies using student demographic and academic characteristics as the outcome variable to observe how the student composition in online versus in-person courses may have changed over the study period. In Appendix Figure A3, we do see some differential trends -- in particular, a growing age gap (approximately 0.2 years) between in-person and online students and a differential trend in

[14] We also "false treatment term" robustness check where we estimate our main model with two modifications: (1) specifying a different false term; and (2) excluding Spring 2020 observations. Appendix Table A1 displays the results, which are highly consistent with the event studies presented in Figure 1.

any prior online experience and the share of previous credits attempted. The fact that in-person students are more likely to have online experience in Spring 2020 calls into question whether earlier comparison terms are an appropriate counterfactual. For example, suppose that a student was deciding whether to take a certain course online or in person in Spring 2020. Based on the trend in online course-taking, the Spring 2020 student would be more likely to take that course online while an otherwise similar student in Spring 2016 would be more likely to have taken that course in person.

Second, we present event studies using course attributes as the outcome variable; specifically, an indicator for the course being 200-level, an indicator for the course being in the Math department, and the historic average and completion rates of the course.[15] Appendix Figure A4, Panel A shows that students in the instructor-by-course sample are over time increasingly more likely to take 200-level courses and math courses in person (relative to online), and over time increasingly less likely to take courses with higher historic average grades in person. In Panel B, we observe similar increases in math courses and courses with lower historic completion rates to be taken in person. While these trends do not necessarily represent overall trends in course taking among VCCS students due to the selected nature of the samples and because of the full set of covariates included in the event study models, they do suggest a relative shift in student preferences for taking less difficult courses online instead of in person. While the student FE model accounts for any time-invariant unobservable student preferences, the instructor-by-course FE model does not. Therefore, the negative impact of the abrupt shift to online that we estimate may be inflated due to this potential source of bias.

[15] The historic grade and completion rates are based on the outcomes from that course for the three years prior to the beginning of the sample (2013-2015) for in-person sections of the course.

Exploring Next-Year Impacts

As we describe above, the identifying variation from our models is defined at the student-by-course level. Since the longer-term outcomes researchers and policy makers are interested in (e.g. re-enrollment in subsequent terms) are defined at the student-level, they are therefore not conducive with the identification strategies described above that rely on within instructor-by-course or within-student variation in modality of instruction.

Given the value of additional evidence on the longer-term impact of the switch to virtual instruction, we estimate the following student-level difference-in-differences model:

$$Outcome_{s(t+1)} = \beta_1 InPerson_{st} + \beta_2 Spring2020_t + \beta_3 InPerson_{st} * Spring2020_t + \\ + StudentCovar_{st} + \epsilon_{st} \quad (2)$$

where we limit the sample to students who were enrolled either fully in person or fully online during term *t.* The outcomes we consider are for the following academic year -- e.g. for observations from Spring 2020, we construct the outcomes using records from Summer 2020, Fall 2020, and Spring 2021. These outcomes include: re-enrollment, credits earned, whether the student earned a degree, and GPA (conditional on re-enrollment). We interpret these results with caution given the event studies seen in Appendix Figure A5, which shows a downward trend in differential re-enrollment for in-person versus online students.

Exploring Grading Leniency

One major constraint in the interpretation of our results is that the switch to virtual instruction was coupled with a formal emergency grading policy, and could in parallel have been coupled with more lenient grading practices by instructors. We explore the extent to which grading leniency took place during Spring 2020 by comparing the grades assigned within courses taught

by the same instructor online during Spring 2019 and Spring 2020. Specifically, we estimate the following version of equation (1):

$$Outcome_{scit} = \beta_1 Spring2020_t + StudentCovars_{st} + ClassCovars_{scit} + CourseCovars_{ct} + InstructorCovars_{it} + Instructor\ X\ CourseFE_{ci} + \epsilon_{scit} \quad (3)$$

Assuming that instructors extended the same degree of grading leniency to students who were already online as those who switched to virtual instruction, the coefficient estimate for $Spring2020_t$ is the combination of two "effects": changes in student performance due to non-academic COVID shocks (e.g. loss of childcare, increased stress due to job loss) and changes to grading practices. As it is not possible to disentangle these two effects, we interpret the results on changes in grading leniency with caution.

V. Results

Summary statistics

In Table 1, we present summary statistics for select student-level characteristics from Spring 2020 for: the full VCCS population (column 1); after making the core restrictions described above (column 2); separating the core restrictions sample to students enrolled in person or online (columns 3 and 4); and the analytic samples for the instructor-by-course and student FE models (columns 5 and 6). The data in this table is collapsed to the student level; if students show up in these samples multiple times, we only include one of those observations when presenting student-level characteristics, as these demographic and academic characteristics are stable for each student in a given semester. We present an alternative version in Appendix Table A2 which summarizes the data at the student-by-course level. Comparing the columns of Table 1, we see that students in both the instructor-by-course and student FE samples are slightly younger compared to the overall

samples; the instructor-by-course sample is slightly more Black and Hispanic while the student FE model is significantly more White. Instructor-by-course FE students have similar academic histories as students in the overall sample, with slightly lower cumulative GPAs and fewer accumulated credits, and slightly more likely to have previous experience taking online courses at VCCS. Due to the sample construction requiring prior enrollment, students in the student FE sample have significantly different academic histories than both the overall and instructor-by-course samples: students in the student FE sample have higher average GPAs, nearly double the number of credits accumulated, and attempted a larger share of past credits online. Considering programs of study, students in both the instructor-by-course and student FE samples are more likely to be pursuing a Liberal Arts and transfer-oriented degree programs, and less likely to be pursuing applied or vocational/technical programs of study. This pattern is indicative of differences across programs of study in course requirements and availability of online programming.

Columns (3) and (4) of Table 1 compare the characteristics of students who were enrolled in in-person versus online courses. Note that if a student was enrolled in both modalities in Spring 2020, they are represented in both columns. Online students are older, are more likely to be female, White, and have higher GPAs, and more credits accumulated. Not surprisingly, online students are 53 percent more likely to have previously taken an online course at VCCS, and have attempted a higher share of previous credits online. Finally, online students are slightly more likely to be pursuing applied degree and certificate programs.

Table 2 compares the characteristics of the courses, including the characteristics of the instructors who taught those courses, represented in the overall samples with the instructor-by-course and student FE samples. As with Table 1, we only present these statistics for the unique

course observations in each sample, but include the student-by-course level summary in Appendix Table A2. The instructor-by-course FE sample contains a larger share of 100-level courses (versus 200-level), a larger share of "general education" courses (Math, English, History, and Biology), and courses with larger class sizes. Instructors in the instructor-by-course and student FE samples have slightly longer tenures than the overall samples, but are otherwise similar.

Changes in grading during COVID-19

An important contextual factor in interpreting the impact of the mid-semester shift to online learning is how grading changed overall at VCCS institutions during COVID-19 relative to prior terms. Figure 2 shows the distribution of grades for student-by-course observations in the instructor-by-course and student FE samples across two dimensions: (1) online versus in-person courses; and (2) Spring 2019 and Spring 2020. The pre-COVID distribution of grades for online students is more concentrated at the tails than for in-person students, with a larger share of online students earning either As, Fs, or Ws. For both samples, there is a significant reduction in failing grades and a significant increase in withdrawals for both online and in-person students in Spring 2020. The decrease in failing grades is likely due to a combination of positive selection into the A-F scale, as well as more lenient grading practices by VCCS instructors. The grades P+ and P- are only populated during Spring 2020 as part of VCCS's emergency grading policy.

Appendix Table A3 shows the results from our exploratory grade leniency model in equation (3) comparing student outcomes in online courses that were taught by the same instructor in Spring 2019 and Spring 2020. Compared to students enrolled in the same courses in Spring 2019, we see that online Spring 2020 students were: similarly likely to complete the course or earn at least a C (columns 1 and 4); 2 percentage points (23%) more likely to withdraw, although this

estimate is not statistically significant (column 2); and significantly less likely to fail the course (3.2 percentage points, or 27%). Overall, this analysis suggests that the most likely margin of grading leniency occurred at the fail / do not fail mark, while the most likely margin of non-academic COVID related impacts occurred at the withdrawal margin. These results suggest that significantly more students who started the term in person would have failed if not for the more lenient grading policies.

Impact estimates of the shift to online learning

We present our main results from equation (1) in Panel A of Table 3, focusing our discussion on the difference-in-differences estimator $\hat{\beta}_3$. Column (1) shows an estimated 4.9 percentage point decrease in course completion due to the shift from in-person to online instruction. Relative to the course completion rate among in-person observations in the pre-COVID comparison terms of 80.7 percent, this point estimate translates to a 6.1 percent decrease. Columns (2) and (3) show that this reduction in course completion is primarily driven by a large increase in course withdrawals (2.7 pp, 37 percent increase relative to pre-COVID mean), but also by an increase in course failure (1.3 pp / 10.8 percent increase). Particularly given that students had to opt-in to the traditional grading scale in order to receive an "F", this impact on course failure suggests that the shift to virtual instruction had a negative impact even on those students who were confident enough in their ability to navigate online coursework that they actively opted out of the emergency grading policy. Finally, in column (4) we see a similar negative impact estimate (5.2pp, 7 percent), when the outcome is defined as earning a grade of C or higher (including P+).

In Panel B, we present results from the student FE model. Here, we see a smaller negative impact on course completion (2.5pp, 2.8 percent). We see no effect on the outcome of course

withdrawal. Instead, the effect on course completion is driven entirely by an increase in course failure (34 percent increase relative to pre-COVID mean). One possible explanation for this pattern of results is that students in the student FE sample, who were enrolled in both online and in-person courses at the beginning of Spring 2020, were more likely to opt out of the emergency grading policy and "stick it out" until the end of the term because they felt more confident with their ability to navigate online coursework. However, the transition to online did still have a negative impact on these students' ability to earn credit for the course.

While the instructor-by-course FE estimates differ from those in the student FE model, this is expected as these two samples are quite different, as shown above in Table 1. Students in the student FE sample have longer enrollment histories, which means they are positively selected for higher performance because they have achieved some level of persistence in college. These students also have current and prior experience in online coursework, which likely made their transition to virtual instruction for their in-person coursework smoother.

Subgroup Impacts

We test for differential impacts across student subgroups according to prior academic history. Table 4 shows the impact estimates on course completion for the academic subgroups, with each column showing the results from a separate regression with the sample limited to students in the particular subgroup listed in the column heading. For both the instructor-by-course FE (Panel A) and student FE (Panel B) models, we observe the largest impacts for students with a baseline GPA in the bottom third of the distribution; the DiD estimates across GPA terciles are statistically distinguishable from each other. Similarly, we observe significantly larger impacts for students with fewer credits accumulated compared to students who had previously earned at least

30 credits. These first two comparisons show that higher performing and more experienced students were less impacted by the switch to virtual instruction, compared to lower performing and less experienced students. This result is in line with prior research that found random assignment to a hybrid course with an online component led to worse outcomes for lower-performing students but had no negative impact among higher-performing students (Joyce et al, 2015). One explanation is that higher performing students typically have better self-regulatory behaviors, which are thought to be particularly important for success in an online learning environment (see Li et al, 2020 for a thorough review).

We also estimate impacts based on prior experience with online learning (for the instructor-by-course FE model only, as all students in the student FE have prior online experience); we observe larger impacts for students who had no prior online learning experience at VCCS before the Spring 2020 semester as compared to those who had experience with online learning. This is intuitive, as students who had prior experience with online learning may have found the abrupt transition to online learning during the Spring 2020 semester slightly easier than those who had never experienced an online learning environment.

Appendix Table A4 presents additional results for the demographic subgroups. We observe more negative impacts for male students and for students currently receiving Pell grants (both statistically distinguishable in the instructor-by-course model) though do not find meaningful differential effects by age, race/ethnicity, or enrollment intensity.

Next-year Impacts

Appendix Table A5 shows the results from our exploratory next-year difference-in-differences model represented in equation (2), comparing next year outcomes for students enrolled

fully in person versus fully online. We find statistically significant but meaningfully small effects on persistence in the next year, with students impacted by the virtual shift being 1.1 percentage points (1.2 percent) less likely to re-enroll in the following year and earning 0.58 (4.7 percent) fewer credits. We see no impact on degree completion in the following year, nor GPA (the latter conditional on enrollment). While we caution against too strong interpretation of these results due to the patterns we see in Appendix Figure A5, they do suggest that the virtual switch to online had minimal next-year impacts on VCCS students. However, it is worth reiterating that this is not a statement about the pandemic's overall impacts on college students' outcomes, and instead focused on the change in instructional modality.

Alternative Specifications

Given the selected nature of our analytic samples and the large set of covariates and fixed effects in our regression models, we test the robustness of our estimates to different specifications. We present the robustness estimates of the difference-in-difference coefficient for the instructor-by-course FE and student FE models in Panels A and B, respectively, of Appendix Table A6.[16] We begin in Panel A, column (1) with the full sample of all VCCS students from Spring 2016 through Spring 2020 (Fall terms included) with no controls, other than $InPerson_{scit}$, $Spring2020_t$, and $InPerson_{scit} * Spring2020_t$. In column (2), we make the core restrictions described above (e.g. no dually enrolled students). Starting in column (3), we begin to add in sets of fixed effects and covariates until we have the fully specified model in column (9). In column (10), we restrict the sample to Spring only terms; in column (11) we restrict the sample to courses offered in both modalities in Spring 2020 and at least one comparison term (including Fall terms);

[16] The corresponding event studies for the outcome of course completion are shown in Appendix Figure A6.

and column (12) represents our primary specification. Across these twelve columns, the difference-in-difference estimate remains quite similar, ranging from 3.2 percentage points in column (1) to 4.9 percentage points in column (12). In column (13), we present estimates from a comparative interrupted time series version of our main specification. Specifically, we include a linear term variable, stand alone and interacted with the in-person indicator. The point estimate (4.9 percentage points) is the same as the main model. In column (14), we show estimates from a model using the main analytic sample, but excluding all other covariates besides the instructor-by-course fixed effects; the point estimate increases slightly to 5.1 percentage points.

We test four additional sample definitions in the remaining columns of Appendix Table A6. First, we restrict the sample to instructors who taught the same course in both modalities in both Spring 2020 and at least one comparison term. The DID estimate in column (15) is slightly larger at 6.5 percentage points. The fact that this sample includes only instructors who had prior experience teaching the course online implies that the persistent negative impact is driven by students', as opposed to instructors', struggles with the shift to virtual learning.[17] Next, the estimate in column (16) is the result of excluding hybrid courses from the sample. The DID estimate is slightly larger at 6.2 pp / 7.8 percent suggesting that students in hybrid courses experienced some degree of negative impact of the shift to virtual instruction, although we caution against strong interpretation of this result due to differences across colleges and over time in classification of hybrid versus online courses in our sample.[18] When we restrict the main instructor-by-course analytic sample to students who were either enrolled fully online or fully in person (column 17), we find a similar result (5.6 pp, 7 percent). Finally, when we estimate the fully specified model on

[17] When we estimate the same model represented in column (13) but with course fixed effects instead of instructor-by-course fixed effects, we find the same DiD estimate.

[18] The most important example of this is that Northern Virginia Community College, which is by far the largest VCCS college, classified virtually all online courses as hybrid until the 2019-20 academic year.

the sample of all VCCS students (column 18), we estimate a similar coefficient as in column (1). The patterns are quite similar in Panel B, which follows the same pattern although some columns are not applicable for the student FE model.[19]

VI. Discussion

Using two complementary estimation strategies, we demonstrate that the abrupt shift to online learning as a result of the COVID-19 crisis led to a modest decrease in course completion among community college students in Virginia. This decrease in completion rates occurred despite suggestive evidence of more lenient grading in the context of the pandemic. This negative effect was particularly pronounced for lower-performing and less experienced students. The subgroup-specific patterns suggest that, consistent with prior research on the efficacy of online learning, institutions and instructors likely need to target outreach and support efforts after mid-semester shifts to online learning to students who are most likely to struggle with virtual learning.

Our results moreover indicate that instructor familiarity with online teaching was not able to mitigate the negative impact for in-person students. Instead, the impacts appear to be driven by student struggles with the shift to online learning. Faced with a similar need to abruptly shift students to online in the middle of future semesters, colleges and instructors may want to prioritize strategies that ease the transition from in-person environments and that foster a stronger sense of community and connection. These efforts could include some of the approaches that researchers have tested for improving online student success and that we describe in our literature review, such

[19] To show that the impacts are not driven by differences in across terms in sample composition, the last two columns show the results when the sample is restricted to students who are continuously enrolled in Spring 2018 through Spring 2020 (column 12) or Fall 2018 through Spring 2020 (column 13).

as increasing the frequency of synchronous class sessions and promoting more frequent individual interaction between instructors and students.

The declines in Spring 2020 performance resulting from the abrupt mid-semester shift to online are modest in comparison to the large year-over-year declines in initial college enrollment, particularly among lower-income student populations. Our exploratory analysis moreover suggests that these near-term reductions in performance were not accompanied by substantial reductions in students' longer-term persistence or academic performance. A higher priority for policy intervention coming out of the COVID-19 context may therefore be to encourage initial postsecondary participation among students whose initial college entry was disrupted by COVID-19, and to provide re-enrollment supports to students whose postsecondary progress was interrupted by COVID-19-related factors independent of the abrupt shift to online learning.

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Table 1: Summary statistics of students, Spring 2020

		Core restrictions				
	All VCCS (1)	All (2)	In-person (3)	Online (4)	Instructor-by-Course FE (5)	Student FE (6)
Demographic characteristics						
Age	23.5	24.9	24.0	25.8	23.6	23.0
Female	57.5%	57.0%	53.2%	63.6%	56.9%	57.1%
White	53.7%	52.6%	50.3%	60.7%	50.4%	65.7%
Black	17.4%	18.6%	17.8%	18.9%	19.6%	14.2%
Hispanic	13.6%	14.2%	16.0%	9.4%	15.0%	9.5%
Asian	7.8%	7.5%	8.6%	4.2%	7.4%	4.0%
Other Race	7.5%	7.1%	7.3%	6.9%	7.6%	6.6%
Academic history						
Prior cumulative GPA	2.64	2.82	2.80	2.88	2.74	2.95
Prior accumulated credits	22.8	29.2	28.4	31.5	25.0	37.2
Previously enrolled at VCCS?	90.4%	92.6%	93.0%	93.0%	91.8%	100.0%
Previously earned VCCS degree?	9.1%	12.2%	10.6%	14.7%	7.4%	12.9%
Previously earned bachelors degree?	4.0%	4.5%	3.7%	4.9%	2.4%	1.6%
Previously enrolled at non-VCCS?	23.5%	28.4%	25.1%	32.6%	25.7%	21.8%
Previous online enrollment at VCCS?	44.4%	56.8%	49.6%	76.0%	52.6%	90.7%
Share of previously attempted credits online	19.7%	24.3%	17.6%	37.2%	22.7%	34.3%
Current credits attempted						
Total	8.3	9.8	10.3	10.1	10.5	12.4
Online	2.2	2.8	1.6	5.6	3.0	4.9
In-person	5.7	6.5	8.3	3.6	7.0	6.4

		Core restrictions				
	All VCCS (1)	All (2)	In-person (3)	Online (4)	Instructor-by-Course FE (5)	Student FE (6)
Broad program of study category						
Liberal Arts	30.2%	38.9%	39.1%	42.5%	46.4%	51.0%
Health Sciences	8.9%	11.8%	10.8%	12.8%	7.8%	8.8%
Applied Sciences	2.6%	3.3%	4.1%	1.5%	1.2%	2.2%
Vocational / Technical	58.4%	46.0%	46.0%	43.2%	44.5%	38.0%
Degree level pursuing						
Transfer-oriented associate	45.4%	60.2%	64.1%	55.7%	71.3%	66.5%
Applied associate	16.4%	22.0%	20.6%	25.4%	14.9%	25.1%
Certificate	1.8%	2.3%	2.3%	2.4%	1.4%	1.8%
Career Studies Certificate (short-term)	4.7%	5.0%	4.2%	5.6%	3.2%	2.6%
Other	1.0%	1.1%	1.0%	1.2%	0.8%	1.5%
N	143,563	86,187	66,342	37,586	57,017	9,164

Notes: The "Core restrictions" sample excludes all observations corresponding to dual enrollment students, developmental courses, audited courses, courses that could not be switched to virtual instruction, and courses offered outside of the full-session. The instructor-by-course FE sample includes all observations corresponding to courses that are offered both online and in-person during Spring 2020, and also offered both online and in-person during at least one of the comparison terms. The student FE sample includes observations for students who were enrolled in both online and in-person courses during Spring 2020 and one of the comparison terms. All information presented is for students enrolled during the Spring 2020 term. In calculating these metrics, we use only one observation per student, as these characteristics are stable at the student level for a given semester. The "Other Race" category includes students who identify as American Indian or Alaskan, Hawaiian or Pacific Islander, two or more races, or whose race is missing. If a student has no prior VCCS enrollment history, their value for previous online enrollment and share of previously attempted credits online are both set to zero, but their value for prior cumulative GPA is left as missing.

Table 2: Summary statistics of courses and instructors, Spring 2020

Panel A: Course-level characteristics

		Core restrictions				
	All VCCS	All	In-person	Online	Instructor-by-Course FE	Student FE
	(1)	(2)	(3)	(4)	(5)	(6)
100-level	56.3%	53.4%	56.5%	51.9%	62.9%	54.0%
Course enrollment	57.9	76.2	111.8	100	255.4	97.5
Section (class) enrollment, overall	12.7	14.7	14.9	16.4	19.7	16.2
Course Subject						
Math	4.6%	5.3%	6.7%	6.8%	12.5%	6.8%
English	4.9%	4.2%	4.2%	5.9%	9.3%	5.1%
History	2.1%	2.5%	2.6%	4.0%	7.9%	3.3%
Biology	2.3%	3.3%	3.8%	3.7%	8.4%	4.0%
Foreign Language	3.2%	2.3%	2.4%	2.7%	2.7%	2.6%
Historic course outcomes						
Withdrew	5.9%	6.3%	6.0%	7.7%	8.2%	7.1%
Failed	5.4%	6.1%	5.5%	8.0%	8.9%	6.8%
Grade A or B	62.2%	62.6%	61.8%	62.3%	57.9%	61.5%
N	7,512	4,768	3,178	2,373	735	3,409

Panel B: Instructor-level characteristics

		Core restrictions				
	All VCCS	All	In-person	Online	Instructor-by-Course FE	Student FE
	(1)	(2)	(3)	(4)	(5)	(6)
Female	56.3%	52.6%	50.0%	58.2%	54.7%	51.6%
White	77.8%	78.8%	77.8%	83.1%	77.7%	80.1%
Black	12.4%	12.4%	12.6%	11.1%	13.8%	12.1%
Hispanic	2.6%	2.5%	2.6%	2.3%	2.6%	2.4%
Asian	4.8%	5.6%	6.4%	2.8%	5.2%	4.7%
Other Race	2.5%	0.7%	0.7%	0.7%	0.7%	0.7%
Tenure (terms)	18.0	20.2	19.9	23.9	22.3	21.3
Full-time	30.7%	39.5%	43.9%	46.0%	43.5%	40.6%
N	7,651	4,669	3,662	1,759	2,336	3,546

Notes: The "Core restrictions" sample excludes all observations corresponding to dual enrollment students, developmental courses, courses that could not be switched to virtual instruction, audited courses, and courses offered outside of the full-session. The instructor-by-course FE sample includes all observations corresponding to courses that are offered both online and in-person during Spring 2020, and also offered both online and in-person during at least one of the comparison terms. The student FE sample includes observations for students who were enrolled in both online and in-person courses during Spring 2020 and one previous comparison term. All information presented is for unique courses offered during and unique instructors teaching during the Spring 2020 term. Courses are either 100-level or 200-level. Total course enrollment and average enrollment are based on the overall enrollment in the Spring 2020 semester for each unique course, not restricted to students in either sample. Historic course outcomes are measured using all prior terms of data back to Spring 2000. Tenure is measured in number of terms the instructor taught at least one course between Spring 2008 and Spring 2020, inclusive, with a maximum of three terms within an academic year.

Table 3: Difference-in-differences estimates of the impact switching to virtual instruction

	Course Completion (1)	Withdrew (2)	Failed (3)	Grade A/B/C/P+ (4)
Panel A: Instructor-by-course FE model				
In-Person	0.046***	-0.018***	-0.026***	0.044***
	(0.004)	(0.003)	(0.002)	(0.004)
Spring 2020	0.033***	0.081***	-0.113***	0.047***
	(0.004)	(0.004)	(0.003)	(0.004)
In-Person * Spring 2020	-0.049***	0.027***	0.013***	-0.052***
	(0.004)	(0.006)	(0.004)	(0.006)
Pre-COVID in-person outcome mean	0.807	0.0729	0.120	0.741
R-squared	0.195	0.122	0.136	0.228
N	537,115	537,115	537,115	537,115
Panel B: Student FE model				
In-Person	0.007*	0.002	-0.009***	-0.008
	(0.004)	(0.003)	(0.002)	(0.005)
Spring 2020	-0.019***	0.090***	-0.070***	-0.018***
	(0.004)	(0.004)	(0.003)	(0.005)
In-Person * Spring 2020	-0.025***	0.006	0.019***	-0.021***
	(0.005)	(0.005)	(0.003)	(0.006)
Pre-COVID in-person outcome mean	0.905	0.0392	0.0552	0.850
R-squared	0.342	0.290	0.261	0.359
N	101,223	101,223	101,223	101,223

Notes: Within each panel, each column represents a separate regression using the model specified in the text, with the outcome variable as noted in the column header. The course completion outcome is equal to one if the student earned a grade of A-D, P+, or P-, and is equal to zero if the student earned a grade of F, I, or W. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

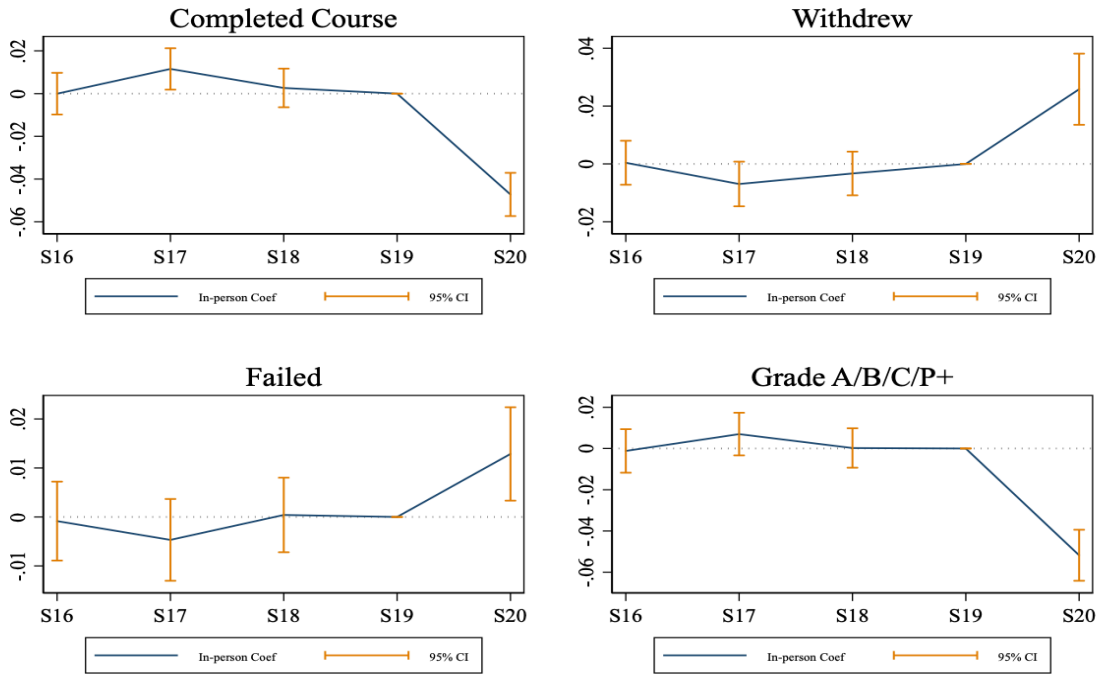
Table 4: Academic subgroup-specific impacts on course completion

	Tercile of prior cumulative GPA			Prior credits accumulated				Prior online experience	
	Bottom	Middle	Third	0	1 to 14	15 to 29	30+	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Instructor-by-course FE Model									
In Person * Spring 2020	-0.068***	-0.051***	-0.027***	-0.063***	-0.047***	-0.057***	-0.047***	-0.049***	-0.052***
	(0.010)	(0.007)	(0.004)	(0.014)	(0.008)	(0.009)	(0.006)	(0.005)	(0.009)
Comparison mean	0.656	0.855	0.936	0.702	0.764	0.836	0.882	0.823	0.789
R-squared	0.129	0.114	0.091	0.156	0.111	0.120	0.116	0.094	0.101
N	160,703	163,101	161,909	57,031	188,945	120,099	171,040	323,757	213,358
Panel B: Student FE Model									
In Person * Spring 2020	-0.062***	0.001	-0.006		-0.039***	-0.029***	-0.022***		
	(0.010)	(0.007)	(0.004)		(0.015)	(0.011)	(0.005)		
Comparison mean	0.802	0.943	0.977		0.812	0.871	0.921		
R-squared	0.322	0.264	0.269		0.473	0.368	0.285		
N	34,501	34,400	32,303		10,857	17,608	72,633		

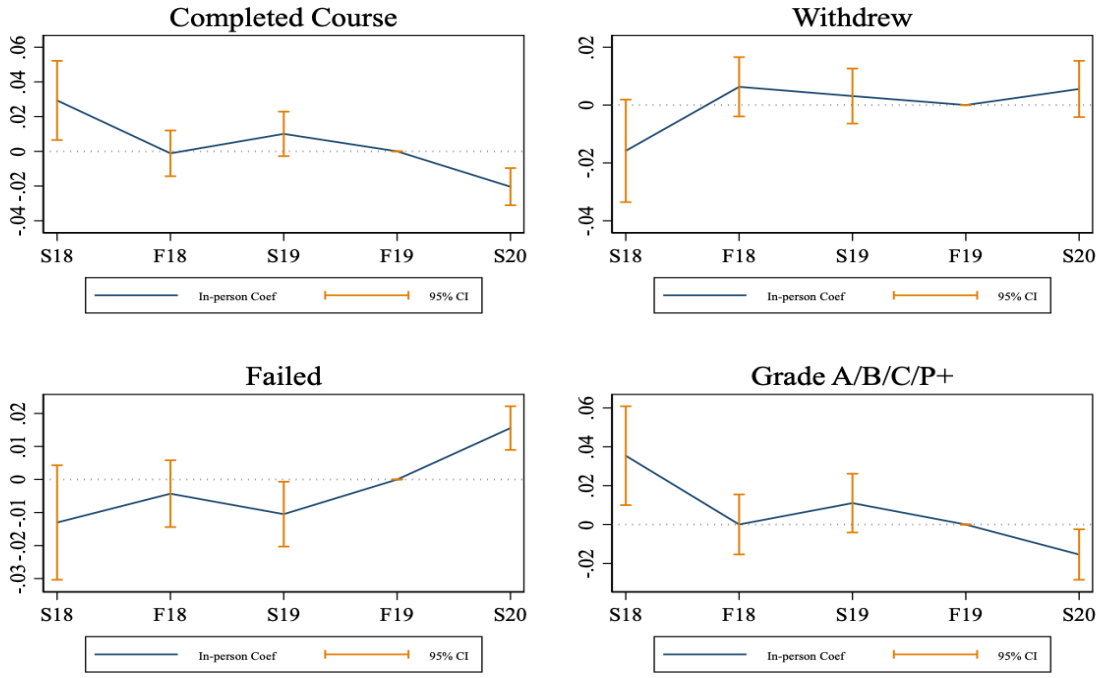
Notes: Each column within each panel represents a separate regression using the models specified in the text, using the outcome of course completion, restricted to the subgroup denoted by the column headers. Note that students with no prior cumulative GPA are not included in the first three columns. By construction of the sample, there are insufficient observations in the student FE sample with zero prior credits accumulated, and all observations have prior online experience.
*** $p < 0.01$; ** $p < 0.05$;* $p < 0.1$

Figure 1: Event study outcome plots, instructor-by-course FE and student FE models

Panel A: Instructor-by-course FE model



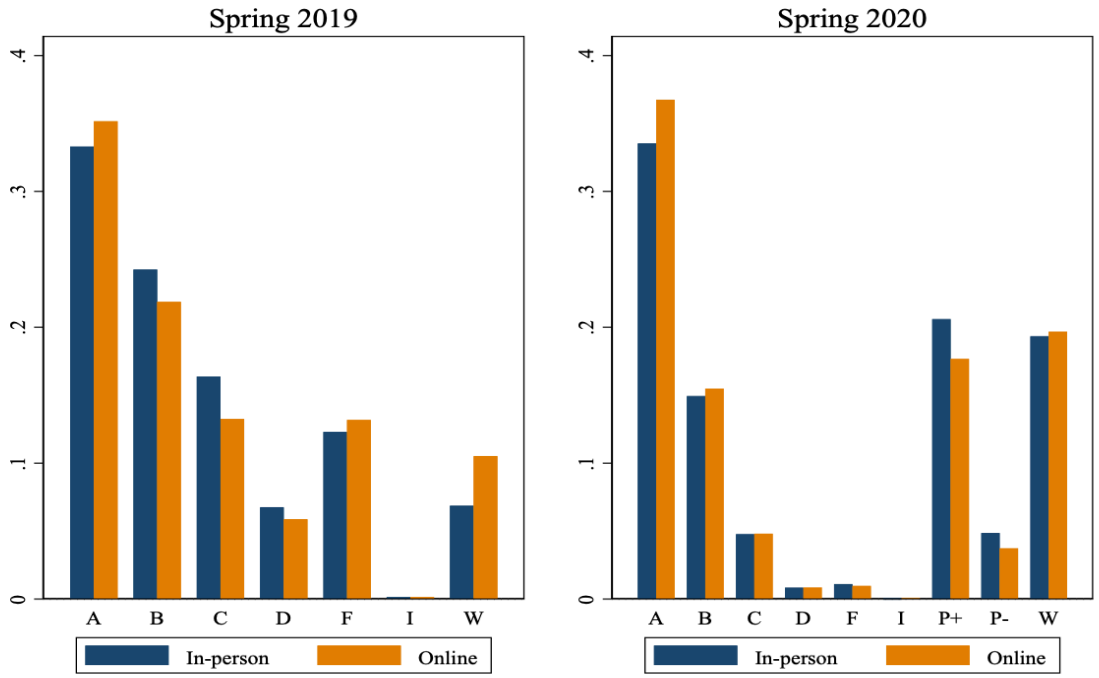
Panel B: Student FE model



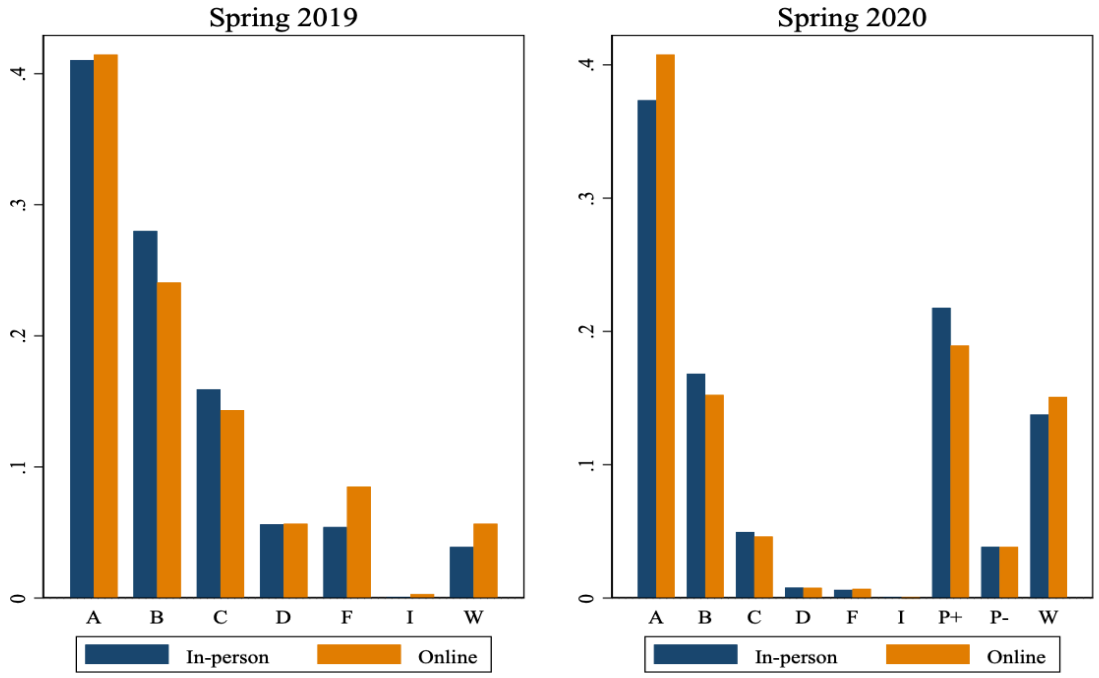
Notes: Results from event studies of the instructor-by-course FE (Panel A) and student FE (Panel B) models. The reference term with coefficient forced to zero is Spring 2019 for the instructor-by-course model and Fall 2019 for the student FE model.

Figure 2: Distribution of grades in Spring 2019 and Spring 2020, by instructional modality

Panel A: Main sample for instructor-by-course FE model



Panel B: Main sample for student FE model



Notes: The grades P+ and P- were only given during the Spring 2020 semester as part of the emergency grading policy. Students in Spring 2020 needed to opt in to the traditional A-F grading scale.

Table A1: False treatment term robustness check (course completion outcome)

Panel A: Instructor-by-course FE model

	Spring 2017	Spring 2018	Spring 2019
	(1)	(2)	(3)
In-Person * False treatment term	0.006*	-0.003	-0.003
	(0.004)	(0.004)	(0.004)
Pre-treatment in-person mean	0.793	0.802	0.807
R-squared	0.199	0.199	0.199
N	433,188	433,188	433,188

Panel B: Student FE model

	Fall 2018	Spring 2019	Fall 2019
	(1)	(2)	(3)
In-Person * False treatment term	-0.032***	-0.007	-0.009*
	(0.011)	(0.006)	(0.005)
Pre-treatment in-person mean	0.862	0.896	0.900
R-squared	0.354	0.354	0.354
N	69,415	69,415	69,415

Notes: Within each panel, each column represents a separate regression using the model specified in the text with the following modifications: (1) specifying a false treatment term, as indicated by the column headers; and (2) excluding data from Spring 2020, the true treatment term. Note that all subsequent terms to the false treatment term are also treated as false treatment terms. The course completion outcome is equal to one if the student earned a grade of A-D, P+, or P-, and is equal to zero if the student earned a grade of F, I, or W. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Appendix Table A2: Summary statistics at student-by-course level, Spring 2020

Panel A: Student characteristics

		Core restrictions				
	All VCCS (1)	All (2)	In-person (3)	Online (4)	Instructor-by-Course FE (5)	Student FE (6)
Demographic characteristics						
Age	23.1	23.8	23.0	25.6	22.8	22.7
Female	56.5%	54.8%	50.1%	64.4%	56.1%	55.6%
White	53.2%	54.0%	50.4%	61.7%	51.1%	66.9%
Black	17.8%	17.2%	16.5%	19.0%	19.2%	13.4%
Hispanic	13.9%	14.1%	16.5%	8.8%	14.9%	9.3%
Asian	7.8%	7.4%	9.1%	3.7%	7.1%	3.9%
Other Race	7.4%	7.3%	7.5%	6.8%	7.7%	6.5%
Academic history						
Prior cumulative GPA	2.76	2.85	2.84	2.88	2.75	2.96
Prior accumulated credits	24.7	29.1	27.7	31.8	23.6	36.9
Previously enrolled at VCCS?	91.0%	93.5%	93.5%	93.3%	91.8%	100.0%
Previously earned VCCS degree?	8.9%	11.0%	9.1%	14.6%	5.8%	12.5%
Previously earned bachelor's degree?	2.9%	3.3%	2.7%	4.1%	1.7%	1.4%
Previously enrolled at non-VCCS?	22.6%	25.6%	22.7%	31.4%	24.1%	20.6%
Previous online enrollment at VCCS?	48.3%	55.8%	45.1%	78.9%	50.4%	90.3%
Share of previously attempted credits online	20.8%	23.1%	15.1%	40.6%	21.4%	33.8%
Current credits attempted						
Total	10.5	11.3	11.5	10.9	11.4	13.1
Online	2.8	3.0	1.3	6.9	3.1	5.1
In-person	7.2	7.7	9.9	2.9	7.9	6.9

Broad program of study category						
Liberal Arts	35.5%	40.7%	39.1%	44.7%	49.3%	52.0%
Health Sciences	9.6%	10.8%	9.7%	11.7%	7.3%	7.5%
Applied Sciences	2.9%	3.7%	4.7%	1.2%	0.8%	2.6%
Vocational / Technical	52.0%	44.9%	46.5%	42.3%	42.5%	37.9%
Degree level pursuing						
Transfer-oriented associate	53.9%	63.0%	66.8%	55.4%	75.2%	67.0%
Applied associate	18.8%	22.5%	19.8%	28.0%	13.1%	25.4%
Certificate	1.9%	2.2%	2.1%	2.3%	1.2%	1.7%
Career Studies Certificate (short-term)	4.4%	4.1%	3.4%	5.3%	2.7%	2.2%
Other	1.2%	1.3%	1.3%	1.2%	0.7%	1.5%

Panel B: Course-level characteristics

		Core restrictions				
	All VCCS (1)	All (2)	In-person (3)	Online (4)	Instructor-by-Course FE (5)	Student FE (6)
100-level	66.9%	63.4%	65.9%	56.9%	68.9%	58.3%
Course enrollment	33.1%	36.6%	34.1%	43.1%	31.1%	41.7%
Section (class) enrollment, overall	19.7	20.5	20.4	20.5	21.8	20.0
Course Subject						
Math	9.7%	10.7%	12.4%	7.4%	12.1%	10.9%
English	14.5%	10.3%	11.1%	9.0%	17.6%	9.5%
History	6.5%	5.4%	5.5%	5.7%	9.0%	5.7%
Biology	6.6%	9.0%	9.9%	4.8%	9.6%	8.5%
Foreign Language	1.5%	1.3%	1.1%	1.8%	1.2%	1.5%
Historic course outcomes						
Withdrew	6.9%	7.6%	7.5%	8.1%	8.3%	7.7%
Failed	7.4%	8.2%	8.0%	8.7%	9.6%	7.7%
Grade A or B	56.6%	56.8%	55.5%	61.0%	56.9%	58.4%

Panel C: Instructor-level characteristics

	All VCCS (1)	Core restrictions: All (2)	Core restrictions: In-person (3)	Core restrictions: Online (4)	Instructor-by-Course FE (5)	Student FE (6)
Female	55.9%	52.1%	49.1%	58.0%	54.1%	50.7%
White	78.8%	80.5%	78.6%	85.0%	80.6%	87.0%
Black	11.7%	11.1%	11.4%	10.5%	11.6%	7.7%
Hispanic	2.5%	2.3%	2.6%	1.8%	2.6%	1.8%
Asian	5.0%	5.4%	6.8%	2.2%	4.5%	2.6%
Other Race	1.9%	0.6%	0.7%	0.5%	0.7%	0.8%
Tenure (terms)	21.5	23.4	22.1	26.4	24.5	24.7
Full-time	48.6%	59.2%	60.2%	56.7%	58.7%	58.0%
N	388,049	206,803	141,484	61,876	103,927	31,662

Notes: The "Core restrictions" sample excludes all observations corresponding to dual enrollment students, developmental courses, audited courses, courses that could not be switched to virtual instruction, and courses offered outside of the full-session The instructor-by-course FE sample includes all observations corresponding to courses that are offered both online and in-person during Spring 2020, and also offered both online and in-person during at least one of the comparison terms. The student FE sample includes observations for students who were enrolled in both online and in-person courses during Spring 2020 and one of the comparison terms. All information presented is for student-by-course observations from Spring 2020 term. Note that unlike in Tables 1 and 2, the data is summarized at the student-by-course level for all three panels. See additional notes in Tables 1 and 2 for variable definition.

Appendix Table A3: Investigating grading leniency in online courses

	Course Completion (1)	Withdrew (2)	Failed (3)	Grade A/B/C/P+ (4)
Spring 2020	0.013	0.022	-0.032***	0.020
	(0.016)	(0.014)	(0.011)	(0.018)
Pre-COVID in-person outcome mean	0.789	0.0886	0.120	0.736
R-squared	0.208	0.160	0.141	0.236
N	87,861	87,861	87,861	87,861

Notes: Within each panel, each column represents a separate regression using the model specified in equation (3) in the text, with the outcome variable as noted in the column header. The received credit outcome is equal to one if the student earned a grade of A-D, P+, or P-, and is equal to zero if the student earned a grade of F, I, or W. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Appendix Table A4: Demographic subgroup-specific impacts on course completion

	Age		Gender		Race/Ethnicity		Pell Status		Enrollment intensity	
	< 25	25+	Female	Male	Underrep Minority	White/ Asian	Receiving Pell	Not Receiving Pell	Part-time	Full-time
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Instructor-by-course FE Model										
In Person * Spring 2020	-0.055***	-0.048***	-0.040***	-0.062***	-0.057***	-0.049***	-0.061***	-0.041***	-0.045***	-0.055***
	(0.006)	(0.007)	(0.005)	(0.007)	(0.007)	(0.005)	(0.006)	(0.006)	(0.007)	(0.006)
Comparison mean	0.800	0.833	0.827	0.785	0.771	0.832	0.786	0.821	0.759	0.836
R-squared	0.095	0.111	0.094	0.103	0.118	0.084	0.109	0.087	0.104	0.096
N	402,652	134,463	298,562	237,608	218,517	318,598	232,626	304,489	218,138	318,977
Panel B: Student FE Model										
In Person * Spring 2020	-0.027***	-0.021**	-0.024***	-0.025***	-0.031***	-0.022***	-0.027***	-0.024***	-0.026***	-0.025***
	(0.005)	(0.009)	(0.006)	(0.007)	(0.009)	(0.005)	(0.007)	(0.006)	(0.009)	(0.005)
Comparison mean	0.902	0.917	0.913	0.895	0.883	0.914	0.906	0.903	0.881	0.914
R-squared	0.339	0.364	0.342	0.344	0.345	0.342	0.352	0.338	0.359	0.335
N	79,743	21,480	55,708	45,395	29,641	71,582	46,881	54,342	28,218	73,005

Notes: Each column within each panel represents a separate regression using the models specified in the text, using the outcome of course completion, restricted to the subgroup denoted by the column headers. The underrepresented minority category includes Black, Hispanic, and Other Race. Part-time status is attempting fewer than 12 credits. *** $p < 0.01$; ** $p < 0.05$;* $p < 0.1$

Appendix Table A5: Longer-term impacts of switch to virtual instruction

	Enrolled in next year (1)	Credits completed in next year (2)	Earned VCCS degree in next year (3)	Next year GPA (4)
In-Person	0.021***	1.081***	0.032***	0.041***
	(0.002)	(0.062)	(0.002)	(0.007)
Spring 2020	0.014***	1.059***	0.036***	0.095***
	(0.003)	(0.096)	(0.004)	(0.011)
In-Person * Spring 2020	-0.011***	-0.581***	-0.007	-0.020
	(0.004)	(0.110)	(0.004)	(0.013)
Pre-COVID in-person outcome mean	0.881	12.35	0.221	2.738
R-squared	0.127	0.163	0.165	0.204
N	276,906	276,906	276,906	234,580

Notes: Within each panel, each column represents a separate regression using the model specified in equation (2) in the text, with the outcome variable as noted in the column header. Next year is defined as the three consecutive terms (including Spring, Summer and Fall) that occur after term t. Next year GPA is only populated for students who had any enrollment in the next year. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Appendix Table A6: Difference-in-Differences Estimates on Course Completion, Varying Model Specification and Sample Construction

Panel A: Instructor-by-course FE model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
In Person * Spring 2020	-0.032***	-0.035***	-0.040***	-0.046***	-0.042***	-0.041***	-0.041***	-0.041***	-0.041***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Comparison mean	0.783	0.821	0.821	0.821	0.821	0.821	0.821	0.821	0.821
R-squared	0.002	0.002	0.053	0.094	0.175	0.177	0.177	0.178	0.178
N	3,969,704	2,159,200	2,159,200	2,159,200	2,159,200	2,159,200	2,159,200	2,159,200	2,159,200
Sample	All VCCS	Core restrictions	Core restrictions	Core restrictions	Core restrictions	Core restrictions	Core restrictions	Core restrictions	Core restrictions
Controls	None	None	Course FE	Instructor x Course FE	+ Student covariates	+ Course covariates	+ Instructor covariates	+ Program of study FE	+ Clustered SEs (Full set of controls)

Appendix Table A6 (cont'd): Difference-in-Differences Estimates on Course Completion, Varying Model Specification and Sample Construction

Panel A: Instructor-by-course FE model

	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
In Person * Spring 2020	-0.039***	-0.047***	-0.049***	-0.048***	-0.051***	-0.065***	-0.062***	-0.056***	-0.031***
	(0.003)	(0.004)	(0.004)	(0.006)	(0.005)	(0.009)	(0.005)	(0.006)	(0.003)
Comparison mean	0.825	0.804	0.807	0.807	0.807	0.814	0.795	0.800	0.783
R-squared	0.205	0.167	0.195	0.195	0.084	0.199	0.199	0.201	0.389
N	1,157,540	1,120,610	537,115	537,115	537,115	64,653	393,856	371,086	3,969,704
Sample	Spring terms only	Courses offered in both modalities pre and post COVID	Courses offered in both modalities pre and post COVID, Spring only	Courses offered in both modalities pre and post COVID, Spring only	Courses offered in both modalities pre and post COVID, Spring only	Instructors teaching same course in both modalities pre and post COVID	Excluding hybrid courses from online definition	Students enrolled fully online or fully in-person	All VCCS
Controls	Full set of controls	Full set of controls	Full set of controls	CITS model	Instructor x Course FE only	Full set of controls	Full set of controls	Full set of controls	Full set of controls

Appendix Table A6 (cont'd): Difference-in-Differences Estimates on Course Completion, Varying Model Specification and Sample Construction

Panel B: Student FE model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
In Person * Spring 2020	-0.026***	-0.022***	-0.021***	-0.021***	-0.017***	-0.027***	-0.025***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.005)	(0.005)
Comparison mean	0.821	0.821	0.821	0.821	0.826	0.891	0.905
R-squared	0.467	0.501	0.501	0.502	0.543	0.322	0.341
N	2,159,200	2,159,200	2,159,200	2,159,200	1,113,189	123,335	101,077
Sample	Core restrictions	Core restrictions	Core restrictions	Core restrictions	Spring 2018 - Spring 2020	Students enrolled in both modalities, pre and post COVID	Students enrolled in both modalities, pre and post COVID, beginning Spring 2018
Controls	Student FE	+ Course covariates	+ Instructor covariates	+ Clustered SEs (Full set of controls)	Full set of controls	Full set of controls	Full set of controls

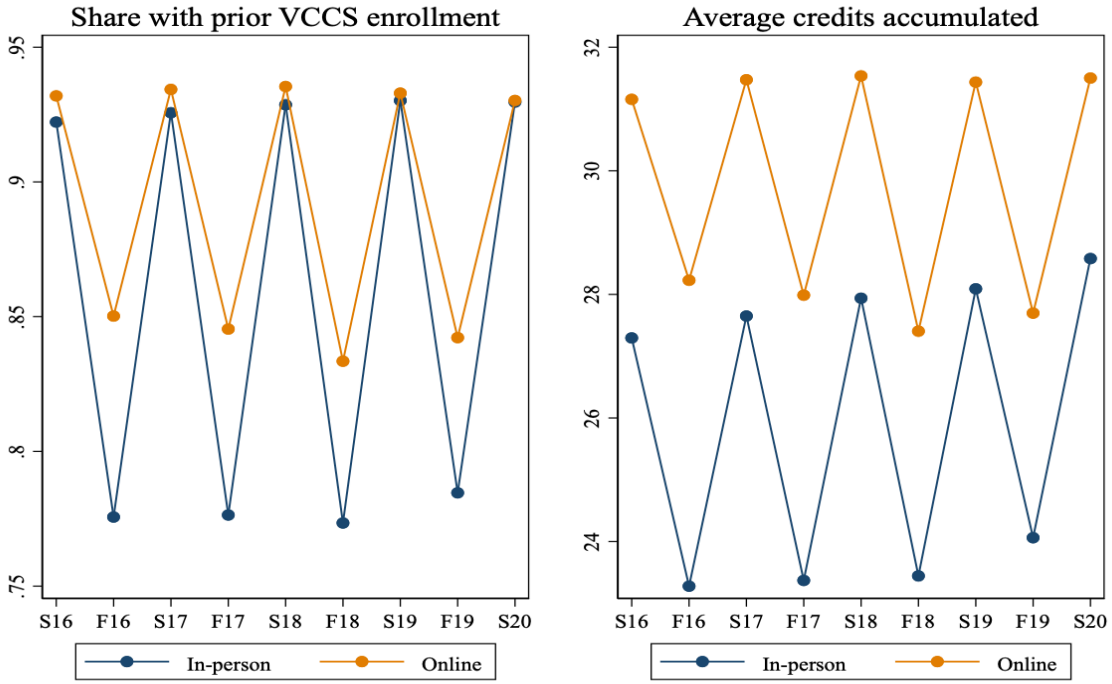
Appendix Table A6 (cont'd): Difference-in-Differences Estimates on Course Completion, Varying Model Specification and Sample Construction

Panel B: Student FE model

	(8)	(9)	(10)	(11)	(12)	(13)
In Person * Spring 2020	-0.027***	-0.027***	-0.028***	-0.018***	-0.035***	-0.018***
	(0.009)	(0.005)	(0.006)	(0.005)	(0.011)	(0.007)
Comparison mean	0.905	0.905	0.905	0.783	0.880	0.929
R-squared	0.342	0.301	0.344	0.497	0.287	0.277
N	101,077	101,077	74,258	3,969,704	21,316	39,853
Sample	Students enrolled in both modalities, pre and post COVID, beginning Spring 2018	Students enrolled in both modalities, pre and post COVID, beginning Spring 2018	Excluding hybrid courses from online definition	All VCCS	Students continuously enrolled Spring 2018 - Spring 2020	Students continuously enrolled Fall 2018 - Spring 2020
Controls	CITS model	Student FE only	Full set of controls	Full set of controls	Full set of controls	Full set of controls

Notes: Within each panel, each column represents a separate regression using a variant of the model specified in the text, with the outcome variable as noted in the column header. The course completion outcome is equal to one if the student earned a grade of A-D, P+, or P-, and is equal to zero if the student earned a grade of F, I, or W. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. The main results shown in Table 3 are represented in column (12) of Panel A, and column (7) of Panel B.

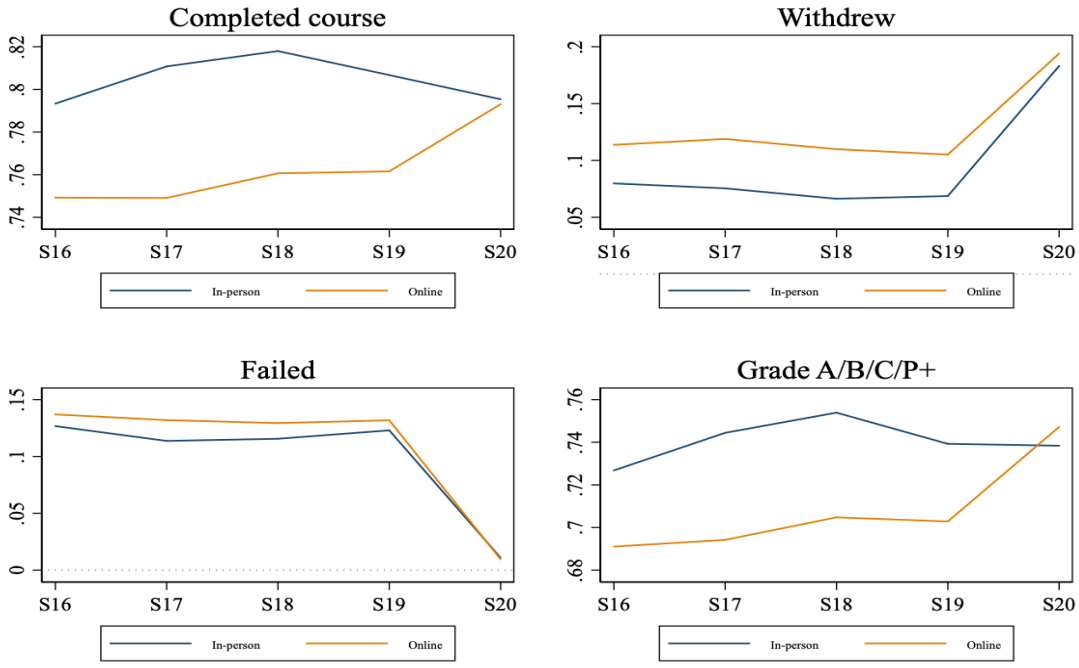
Appendix Figure A1: Differences in student composition in Fall and Spring terms



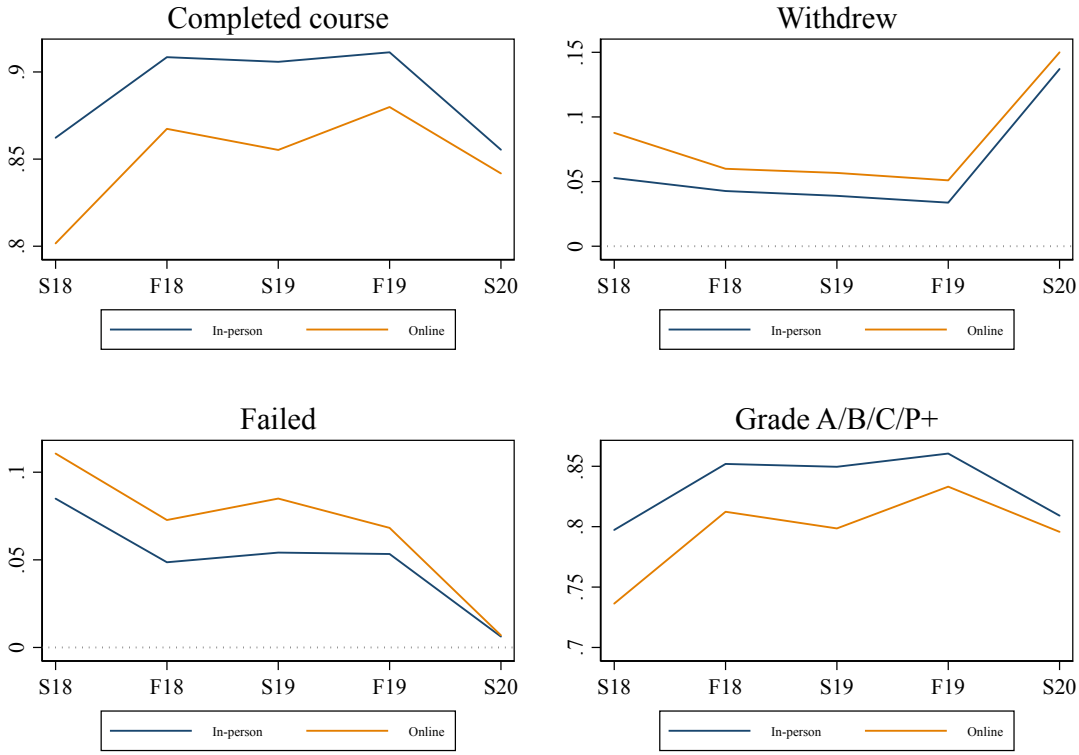
Notes: constructed using the Core restrictions sample.

Appendix Figure A2: Raw trends in outcomes

Panel A: Instructor-by-course FE sample

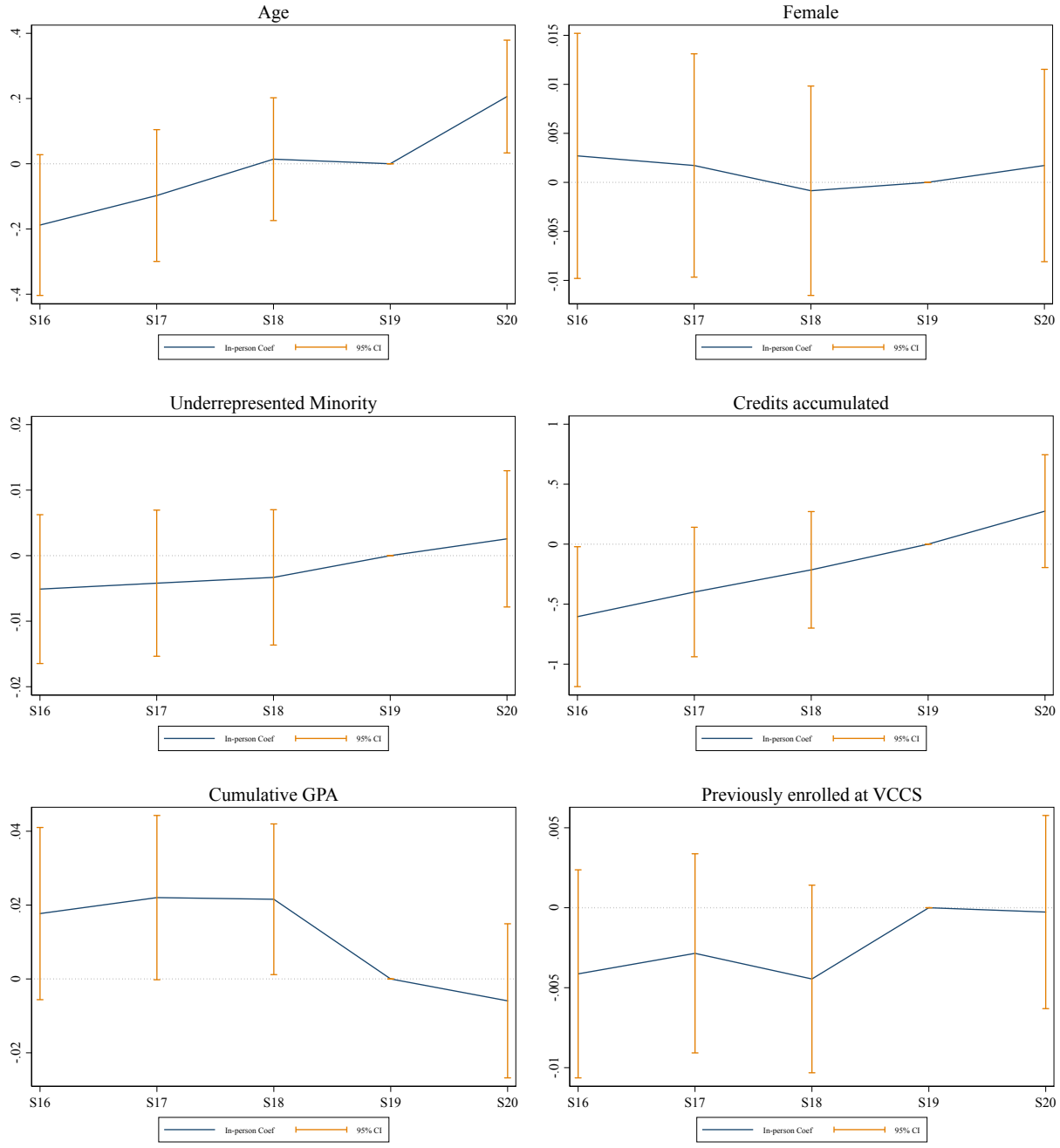


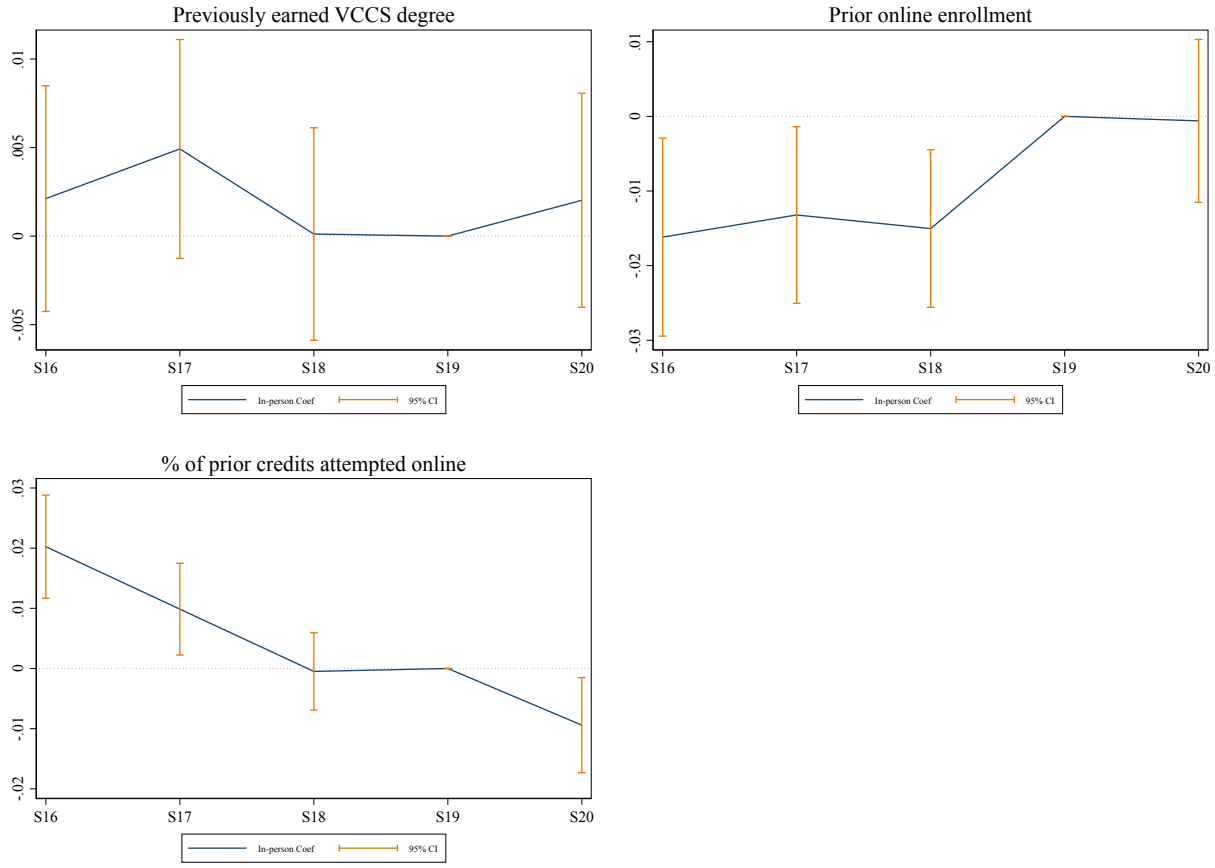
Panel B: Student FE sample



Notes: raw trends in the outcomes of interest.

Appendix Figure A3: Event studies of student characteristics, instructor-by-course model

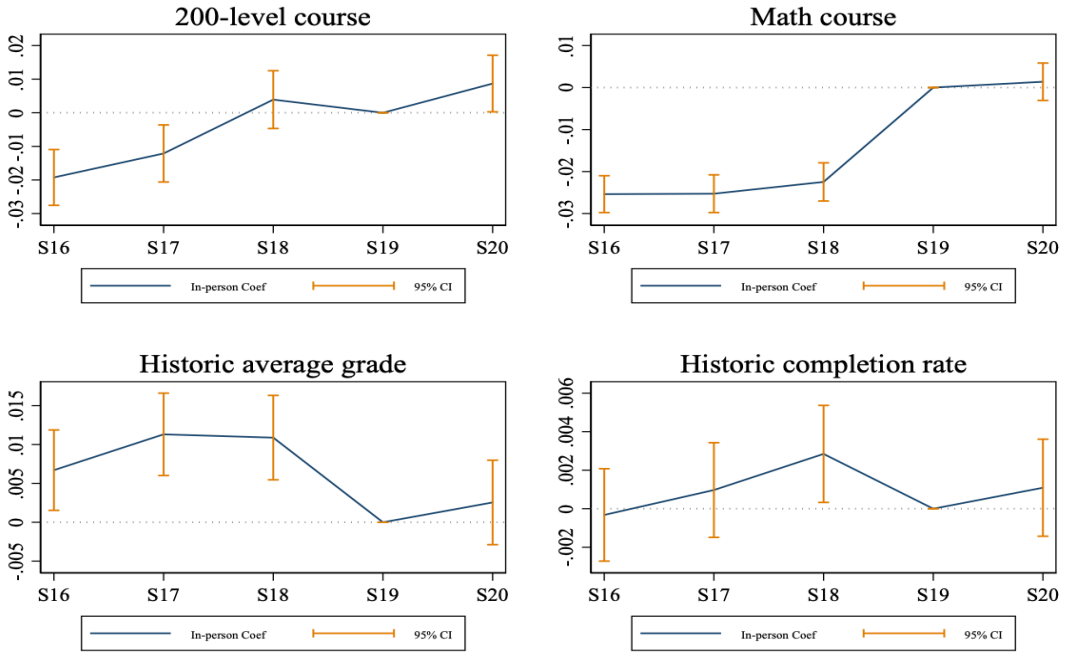




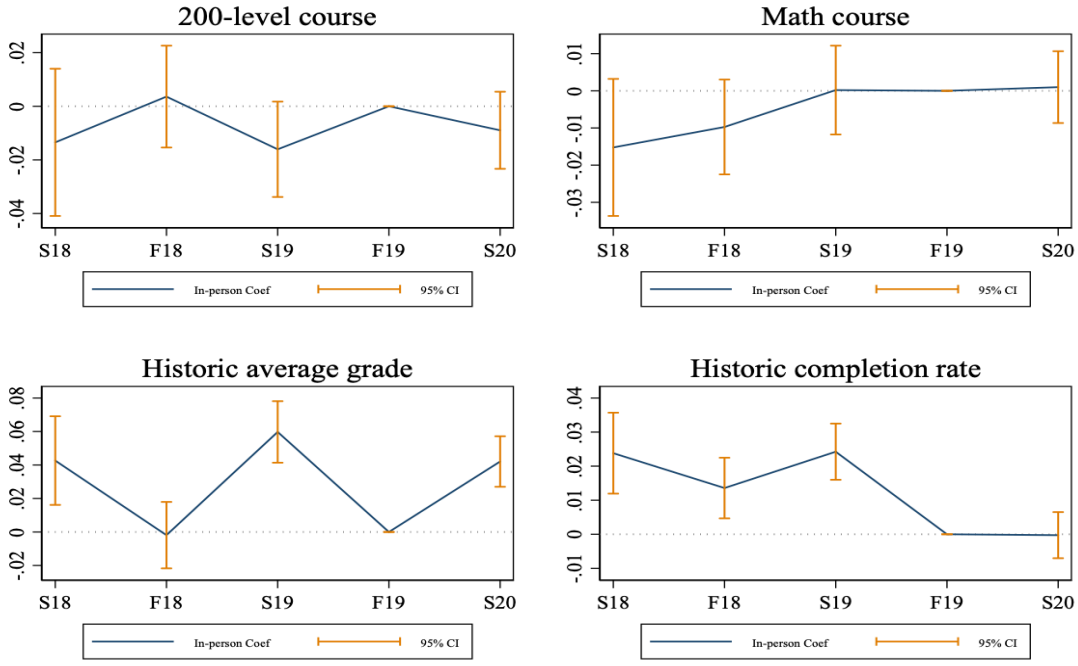
Notes: Event studies of the instructor-by-course FE model with the outcome of the specified student characteristic.

Appendix Figure A4: Event studies of course characteristics

Panel A: Instructor-by-course FE sample

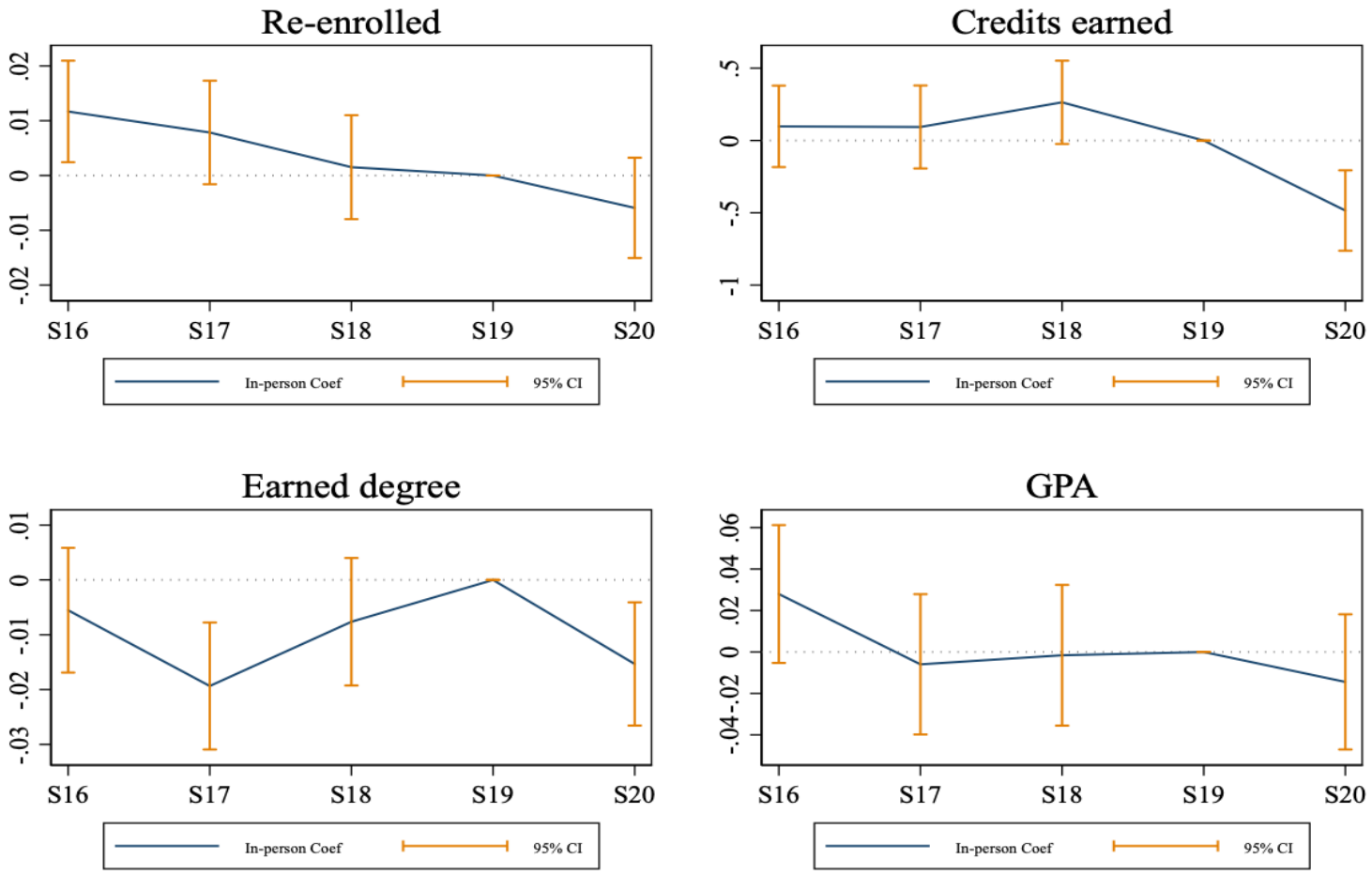


Panel B: Student FE sample



Notes: Event studies of the instructor-by-course FE model with the outcome of the specified course characteristics.

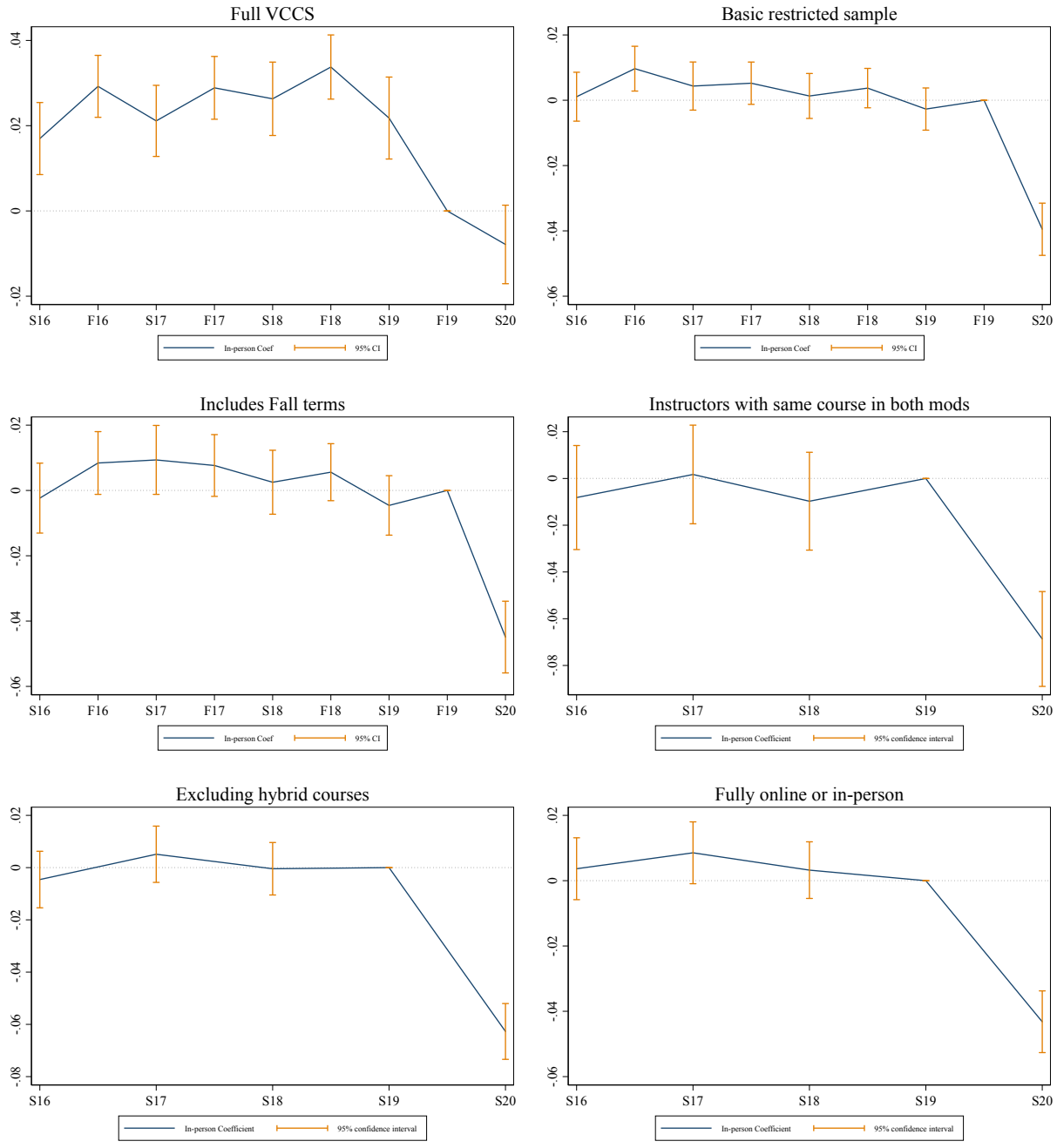
Appendix Figure A5: Event study of long-term outcomes



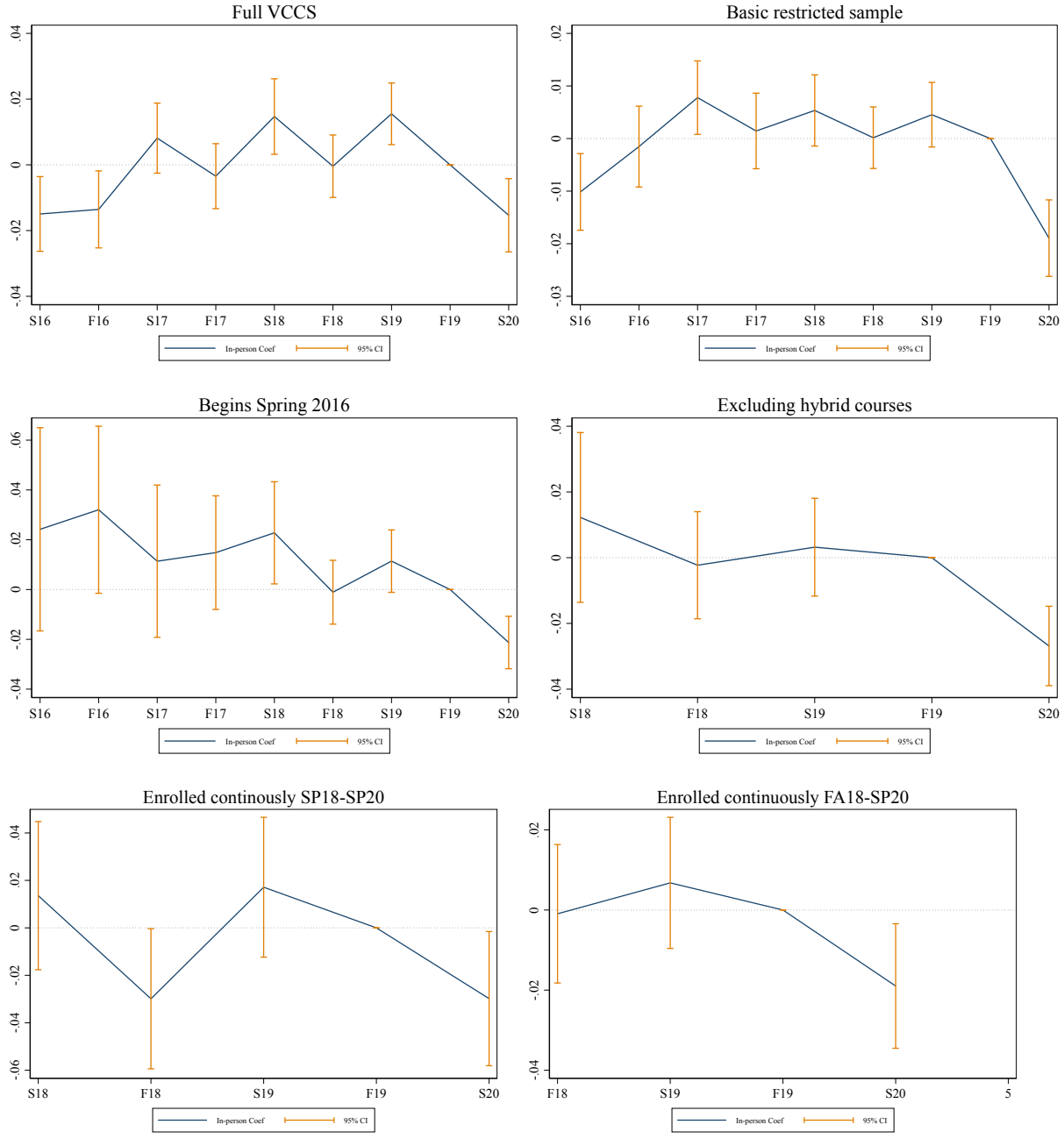
Notes: Event studies using equation (2) in the text with the next year outcomes as shown in Table A4.

Figure A6: Event studies for alternative samples

Panel A: Instructor-by-course FE model



Panel B: Student FE model



Notes: Results from event studies of the instructor-by-course FE and student FE models are presented in Plots A and B, respectively, for the outcome of course completion and for the alternative sample specified. In Panel A, the samples correspond to the following columns in Table A2, Panel A: Full VCCS (17); Basic restricted (9); Includes Fall terms (11); Instructors with same course in both mods (14); Excluding hybrid courses (15); Fully online or in-person, column (16). In Panel B, the samples correspond to the following columns in Table A2, Panel B: Full VCCS (10); Basic restricted (4); Begins Spring 2016 (6); Excluding hybrid courses (9); Enrolled continuously SP18-SP20 (12); and Enrolled continuously FA18-SP20 (13).