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IS ONLINE EDUCATION WORKING?

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ABSTRACT

The pandemic has revived the longstanding debate about the effect of online versus face-to-face instruction on student achievement. The goal of this paper is to provide new evidence on the impact of online versus face-to-face instruction on student learning outcomes, using rich, transcript-level longitudinal data from a public university. We pay particular attention to eliminating selection bias by incorporating student and instructor fixed effects into the empirical analysis as well as to separate out the impact of online versus in-person education from COVID-19-related confounding factors. Our results indicate that students in face-to-face courses perform better than their online counterparts with respect to their grades, the propensity to withdraw from the course, and the likelihood of receiving a passing grade. However, our investigation also reveals that instructor-specific factors, such as leniency in grading or actions towards preventing violations of academic integrity, play a significant role in determining the studied relationship. Without accounting for these instructor-specific factors, the relationship is severely biased, causing one to mistakenly conclude that online instruction is better for student learning than face-to-face instruction. Our analysis further documents a rise in grades associated with COVID-19-triggered changes to student assessment policies embraced by universities as well as instructors adopting a more flexible approach to grading. While these developments led to an increase in grades for all students overall, those who began Spring 2020 in face-to-face courses appear to have benefitted more generously from them. Finally, an auxiliary analysis shows that living in neighborhoods with better broadband technology is associated with a larger increase in grades among students who had to switch from in-person to online instruction during COVID-19. This finding supports the argument that unequal access to technology might have caused learning disparities to get deepened during the pandemic.

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I. Introduction

Questions concerning the effectiveness of the online course delivery methods on student learning have been a topic of debate since universities and colleges began offering these alternatives in the early 1990s. Recently, this debate has become more urgent with the outbreak of the COVID-19 pandemic, which brought the education system to a complete halt in March 2020, causing the most severe disruption of education in history. Unable to continue with face-to-face (F2F) instruction, virtually all higher education institutions in the United States scrambled to switch to online modality. As a result, instructors, most of whom did not have any previous training or experience in teaching online courses, suddenly found themselves having to teach remotely.

As the pandemic appears to wane and universities across the country plan to resume on-campus operations in the upcoming academic year, the administrators and academic leaders will have to reflect on how experiences from the pandemic-afflicted period would affect education in the years ahead. An important question in this debate is to what extent the adoption of online education necessitated by the pandemic would persist in the future. Most experts believe that the integration of online instruction into university education will further accelerate and will eventually become an integral part of the whole university experience (Lieberman 2020; Schwartz et al. 2020; Xi et al. 2020).[1] Given this prospect, it is all the more important to have a complete understanding of the impact of online instruction on student learning in general and during the COVID-19 pandemic in particular.

[1] Note that the growth in online education has begun well before the pandemic. According to data from the National Center for Education Statistics, the proportion of undergraduate students who take online courses rose from 15% in 2003 to 34.5% in 2018 (De Brey et al. 2021). Proponents of online education argue that this type of modality leads to lower costs of instruction and improves access and affordability for students, especially those from underrepresented minority groups (e.g., Cowen and Tabarrok 2014; Deming et al. 2015; Bailey et al. 2018; Deming et al. 2020). In fact, low cost and convenience are the most important explanations behind the rapid growth in online education (McPherson and Bacow 2015).

In this study, we provide fresh evidence on the impact of online education on student performance outcomes, using transcript level panel data from the Spring 2019, Fall 2019, and Spring 2020 semesters from a medium-sized, public R1 university, referred to as the *University* hereafter. In addition to traditional F2F instruction, the *University* also has a well-established online education program, which offers a convenient and flexible learning platform for its students. Notably, online classes are taught by instructors who deliver the F2F versions of the same courses. In a typical semester, a significant share of classes (about one in four) is offered in an online modality at this institution. These online courses were not impacted (in terms of their method of delivery) when the *University* switched to remote instruction in March 2020. However, those that started in the F2F modality in Spring 2020 had to convert to online instruction with the onset of the COVID-19 outbreak. Importantly, the *University*'s transition to remote instruction took place in mid-March after students obtained a midterm grade from their instructors.[2] Therefore, the midterm grades were not impacted by the change in the course delivery method in Spring 2020.

In addition to providing an estimate of the effect of online versus F2F instruction on student learning outcomes, our analysis pays particular attention to the difference in these outcomes between two types of education modalities in the Spring 2020 semester, during which the COVID-19 pandemic caused an abrupt shift from F2F to virtual instruction. A key challenge to estimating the causal effect of online education on student performance outcomes is the likely endogeneity of selection into a particular instruction modality. Students who are enrolled in online courses are likely different from those in F2F classes in observed and unobserved ways that are correlated with their learning outcomes. Our primary approach to overcoming this problem is to estimate a student fixed effects model, which is made possible by the transcript data that allow us to track students

[2] Although midterm grades are not reflected in the transcripts, almost all students in our data have a midterm grade and final grade entry for each class in which they were enrolled.

over time, and the fact that a significant share (63 percent) of the students in the *University* takes a mix of online and F2F classes. This enables us to obtain *within-student* estimates, comparing grades of a particular student in her/his F2F courses versus online courses.

Most of the empirically credible evidence in the line of research that compares the efficacy of F2F versus online instruction comes from experimental studies conducted at a single-course level, in which students are randomly assigned to purely F2F, purely online, or blended versions of the same course. The findings from these studies seem to indicate that online education leads to more unsatisfactory academic performance, although the literature is far from a consensus due to conflicting results or statistically insignificant differences between online versus F2F formats documented in some of the studies.[3] These studies are typically small-scale experiments with samples of 300-700 students in introductory microeconomics courses. Although the research design in these studies overcomes the endogenous selection problem into online versus F2F classes, the conclusions drawn from them may not generalize beyond the experimental setting.

Recently, there has been renewed interest in the relationship between online education and student learning due to the crucial role played by distance learning technologies during COVID-19. An excellent example is Kofoed et al. (2021), who perform an evaluation of academic performance among West Point students randomized across a F2F or an online version of a course in Fall 2020. The authors find that students performed worse in both assignments and exams in the sessions offered online than those in the F2F sessions, with the most significant difference

[3] For example, Figlio et al. (2013) show that F2F instruction yields moderately higher scores, especially among Hispanic, male, and low-achieving students. Joyce et al. (2015) study the performance of students who are randomized between a traditional twice-per-week lecture format and a compressed version that meets once-per-week, with both groups having access to online material. While the students in the traditional format scored slightly better, albeit statistically insignificant, scores compared to those in the compressed format, there were no differences in attendance, withdrawal rates, or hours spent online doing assignments. Similarly, Alpert et al. (2016) find that students in the purely online section of a course received significantly lower grades than those in the F2F sections or the compressed sections with no significant differences between the latter two versions.

concentrated among the academically at-risk students. By virtue of the randomized control design used in the study, the concern about selection bias is eliminated, and thus, the results represent causal evidence on the impact of online education on student outcomes. However, the study is conducted in Fall 2020, at the height of the COVID-19 crisis. Therefore, it is not clear to what extent these results would still be informative when the pandemic is history and life returns to normalcy. In fact, we show in the present study that the relationship between online education and student learning outcomes differs significantly between the COVID-19 period and before. Relatedly, as the authors note, the West Point setting is unlikely to be representative of the education experience of a typical university in the United States.

As another notable example, Cacault et al. (forthcoming) provide evidence on the impact of distance learning technology on student learning using a randomized field experiment, in which first-year students were offered access to live-streamed lectures for their compulsory economics and management courses at a Swiss university in 2017. A particular novelty of this study is that the randomization was administered both across students and over weeks of the term, which enabled the authors to exploit variation both across and within students and time. The study found that attending lectures via live streaming had opposite effects between low-ability and high-ability students, reducing achievement for the former while increasing it for the latter. Unlike the context of the previous studies, in which students volunteered to participate in the experiment, both Kofoed et al. (2021) and Cacault et al. (forthcoming) focus on "required" courses, eliminating the possibility of self-selection bias. Like previous studies, however, both studies have a relatively narrow scope, with Kofoed et al. (2021) targeting a "principles of microeconomics" course and Cacault et al. (forthcoming) focusing on management and economics courses. Accordingly, it is questionable whether the findings from these studies would apply to other courses.

Aside from these experimental studies, a recent working paper by Bird et al. (2020) evaluates the impact of the pandemic-triggered shift to online education in Spring 2020 on the academic performance of students attending Virginia's community colleges. Using a difference-in-differences strategy and exploiting within-course variation on whether students started their Spring 2020 courses in person or online, the authors find that the shift to the online modality led to a decrease in course completion driven primarily by withdrawals and, more narrowly, by course failures.[4] One limitation of this study is that the research design only accounts for differences across courses and instructors, but not students who might select themselves into online classes. To the extent that these differences across students are correlated with learning outcomes, the estimates may be biased. The transcript level panel data in our study allow us to control for student fixed effects in the analysis, thereby overcoming this problem. Finally, the pandemic caused unprecedented and countless disruptions to the lives of students, their parents, and instructors (Jaeger et al., 2021). Therefore, the differences in student learning between online and F2F courses measured during the pandemic would likely reflect a combination of the impact of a shift in instruction modality and the effect of the pandemic.

Our article makes several contributions to the scholarship of teaching and learning. For example, unlike the experimental studies, which typically focus on a single or a small number of courses routinely offered in economics or business departments, we consider the universe of the courses provided at an entire university. Thus, the emerging picture from our analysis is more

[4] Note that Bird et. (2020) only present and discuss the estimate on the interaction coefficient between F2F instruction and the Spring 2020 semester. This estimate reveals the difference in student learning between of F2F and online instruction net of any difference in these two instruction modalities between Spring 2020 and earlier semesters. This would represent the impact of the COVID-19 induced shift to online instruction but would not provide any information about the impact of online instruction relative to F2F instruction in general. Furthermore, the shift to online instruction induced by the pandemic occurred in the middle of March 2020, well after the beginning of Spring 2020. Thus, it might have influenced the learning outcomes of those who began the semester in online and F2F modalities differently. These differences cannot be assessed without recognizing the pre-COVID differences between online and F2F instruction and the potential impact of the pandemic on both types of instruction modalities.

likely to be representative of the experience of a typical university student in the United States. Furthermore, there is no possibility of a Hawthorne effect in our research design since, unlike the experimental studies, students or instructors were not aware of their participation in the study. A particularly novel aspect of our analysis is the ability to control for student fixed effects made possible by the availability of transcript level panel data over three semesters. Furthermore, a sizeable number of students take a mix of both online and F2F courses in a given semester. Therefore, we identify the effect of the switch to the online instruction modality from the variation *within a student*. The ability to control for student fixed effects is an important advantage since students who select into online courses are likely to differ in measurable and unmeasurable ways from those taking F2F classes. Relatedly, there may be preexisting differences between students taking online versus F2F, and the disruption in students' lives caused by COVID-19 may vary by these preexisting differences. Therefore, it is not clear whether the differences in student outcomes observed when the COVID-19 outbreak began in Spring 2020 can only be driven by the transition from F2F to online education. One way to address this potentially significant problem is to rely on within-student variation by controlling for student fixed effects. The inclusion of student fixed effects in the analysis is also a key difference between our paper and Bird et al. (2020), which relies on within-course and within-instructor variation.[5] Finally, another advantage of our analysis is that we are able to observe the midterm grades obtained by students right before COVID-19 broke out in Spring 2020, which further facilitates our efforts to separate out the impact of online versus F2F education from pandemic-related confounding factors.

Our results indicate that students in F2F courses perform better than those in online courses in general. However, this pattern only emerges after controlling for instructor-specific factors, such

[5] Another noteworthy difference is that Bird et al. (2020) only relies on data from Spring semesters, while we use data from both Fall and Spring semesters.

as leniency in grading or actions towards preventing violations of academic integrity, which signifies the importance of the instructors' role in determining the relationship between instruction modality and learning outcomes. Without accounting for these instructor-specific factors, the relationship is severely biased, leading to the inaccurate conclusion that online instruction is better for student learning than F2F instruction. Furthermore, our findings reveal a rise in student grades caused by COVID-19-related changes to assessment policies adopted by universities, as well as instructors embracing a more flexible approach to grading. While these developments led to an increase in grades for all students overall, those who began Spring 2020 in F2F courses appear to have benefitted more generously from them. Finally, the results from a supplementary analysis suggest that living in a neighborhood with better broadband technology is associated with a larger increase in grades among students who had to switch from in-person to online instruction during COVID-19. This finding supports the view that learning disparities among students from various backgrounds might have been widened by unequal access to broadband technology during the pandemic.

II. Data

Our analysis draws upon administrative student records from a public research university granting bachelor's, master's, and doctoral degrees. With close to 15,000 students enrolled from all U.S. states and many countries, the *University* attracts a diverse student population. In addition to the standard F2F instruction, the *University* also has a long-established online education program, which offers a convenient, flexible learning platform for its students. In response to the pandemic and following their state Governor's declaration of a state of emergency around mid-March in 2020, the *University* had shifted all instruction to online modality and remained online

throughout the Spring semester. Like many colleges and universities, the *University* enacted a change to its grade policy by allowing the students to opt into a grade of Z (for A, B, and C), P for grade D, and NP for grade F as an alternative to standard grades. These options did not count towards the students' GPA, but grade Z satisfied the degree requirements. However, we are able to observe the actual grades of the students in our data, and we use them in our analysis instead of these options.

Our dataset includes information on students' midterm and final grades in both online and F2F courses. It also provides information on students' age, gender, ethnic background, their major, zip code of their residence, and course information, including the course name, delivery method, and course level. We restrict our sample to undergraduate students who were enrolled in their classes as of Spring 2019, who are taking courses for credit, and those with a midterm and a final grade in the 2019-2020 academic year. The number of students and instructors contributing to our analytic sample broken down by semester is shown in Table 1. We have 4,339 students enrolled in Spring 2019, 7,022 students in Fall 2019, and 6,760 students in Spring 2020, resulting in a total sample of 18,121students. We have a total of 1,086 unique instructors. Six hundred eighty-four of these instructors taught at least one course in Spring 2019. The numbers of instructors who taught in Fall 2019 and Spring 2020 are 724 and 699, respectively. An important advantage of our analysis sample from the perspective of our empirical strategy is that a non-trivial share of students and instructors participate in both online and F2F education at the same time in one of these three semesters. Specifically, between 40 to 44 percent of students are enrolled in both an online and F2F course, while between 13 to 16 percent of instructors teach both an online and F2F course in a given semester.

We consider several outcomes of student performance. The first two outcomes, *Midterm Grade* and *Final Grade,* are based on grade points assigned by the instructor at the mid-semester (about six weeks after the semester begins) and at the end of the course, respectively. These grades can be A (4), B (3), C (2), D (1), and F (0). We also create two binary outcomes to indicate whether the midterm and final grades are "A" or "B or higher." Finally, we consider binary outcomes for whether (i) the student withdrew from the course, received an incomplete, or failed due to non-attendance; and (ii) completed the course by receiving A, B, C, or D.

Figures 1A and 1B display the grade distributions in the semesters of Spring 2019, Fall 2020, and Spring 2020 for online and F2F courses separately. As shown in the figures, there is an increase in the proportion of students receiving a grade of A in both online and F2F courses in Spring 2020 over the previous two semesters. At the other tail of the distribution, the share of students receiving an F appears to have increased somewhat in online courses in Spring 2020, while it remained stable in F2F courses. Interestingly, the proportion of students who withdrew from their courses decreased slightly in Spring 2020 compared to the previous semesters.

Table 2 presents summary statistics for all the outcome variables as well as student and course characteristics for the full sample as well as separately for treatment and control groups. With respect to learning outcomes, students who participate in online classes are more likely to withdraw from their courses and less likely to receive a passing grade of A, B, C, or D. These differences are statistically significant, but they are small in magnitude. In contrast, online students appear to earn higher scores at the upper tail of grade distribution. For example, the percentage of students receiving a grade of A is six percentage points higher for online students compared to F2F students. Similarly, the fraction of students receiving either A or B is four percentage points higher for online students compared to their F2F counterparts.

There are also significant differences in student characteristics between those in the treatment and control groups. For example, students in online courses are relatively older and more likely to be White and less likely to be Black compared to students in F2F courses. Furthermore, students in F2F classes are more likely to be enrolled in the *University's* Honors Program vis-à-vis their counterparts in online courses. The Honors Program is designed to supplement the experience of particularly motivated and higher-achieving students who have demonstrated excellence in certain subjects. The students in this program have to satisfy a GPA requirement in their majors, in addition to taking a number of special honors courses. In that sense, enrollment in the Honors Program can be considered as a proxy for the high-achievement status of a student.[6]

We augmented our data with a measure of access to high-speed internet in the zip code of the student's home. We constructed this measure based on the Fixed Broadband Deployment Data from Federal Communications Commission's (FCC) Form 477, which includes information about the internet service providers (ISPs) and the quality of the internet service they offer at the Census block level.[7] We identified Census blocks as having access to high-speed internet if at least one ISP offers internet through one of the following technologies: "Cable Modem-DOCSIS 3.0," "Cable Modem-DOCSIS 3.1," or "Optical Carrier / Fiber to the end-user." On average, 85% of the population in the zip codes in our data set have access to one of the high-speed internet technologies.[8] We group students as having access to *High-speed Internet* if they are in the top

[6] Typically, students who are in this program take courses such as "Honors Colloquium," "Honors Seminar," and "Honors Thesis." We identified a student as an Honors student if she/he took one of these classes at any point during our sample period. In the Colloquium courses, students are required to take several honors courses designed to improve and teach students' writing, analytical reading, collaboration, engaging in academic discussions, ethics of research and how to conduct research. In Seminar courses, students take 300 level honors courses on a variety of topics. As part of their curriculum, honors students write a thesis under the supervision of a faculty.

[7] These data and their more detailed description are in the following link: https://www.fcc.gov/general/broadband-deployment-data-fcc-form-477.

[8] Using the population counts in each Census block and the crosswalk between the Census tracts and the zip codes provided by the Department of and Urban Development's (HUD) Office of Policy Development and Research, we computed the share of each zip code's population that has access to fast internet. It is important to underline that

three quintiles of the distribution, i.e., at least 92% of the population in their zip codes have fast internet.[9] As shown in Table 2, the proportion of the population living in neighborhoods with access to high-speed internet is slightly higher among students in online courses than those in F2F courses, though the difference is not statistically significant.

Finally, with respect to course characteristics, online courses are more likely to be classified as a Capstone/Writing class compared to F2F courses. The propensity of a course being taught online appears to be negatively correlated with the level of the course. For instance, a higher proportion of courses taught in F2F are 100-Level courses compared to those taught online. However, this pattern is reversed for 200-, 300-, and 400-Level courses.

III. Empirical Strategy

Our main approach to obtaining the impact of F2F relative to online instruction on student learning outcomes is a fully interacted model specified as follows:

$$Y_{ict} = \beta_0 + \beta_1 Spring2019_t + \beta_2 Spring2020_t + \beta_3 F2F_{ict} + \beta_4 F2F_{ict} \times Spring2019_t + \beta_5 F2F_{ict} \times Spring2020_t + X_{ict}\beta_4 + \mu_i + \varepsilon_{ict}, \quad (1)$$

where Y_{ict} stands for one of the outcome variables for student i who takes course c in semester t. $Spring2020$ and $Spring2010$ are binary indicators that take on the value of one for the Spring 2019 and 2020 semesters, respectively. The comparison category in this specification is the Fall 2019 semester.

having access to fast internet technology in a neighborhood does not necessarily mean that a household's actual internet download/upload speed is fast. For example, a household does not have a fast internet connection if the household does not purchase that service, even though their ISP supplies it. Put differently, we do not have data about the actual internet service, but only about the services offered.

[9] The quintiles are determined by the distribution of the proportion of zip codes' populations who have access to fast internet. The 20th, 40th, 60th, and 80th percentiles of this distribution are 79%, 92%, 97%, 99%, respectively.

Note that our goal is to estimate the causal effect of F2F instruction relative to online instruction from a general perspective. Because the COVID-19 crisis and the ensuing abrupt shift to online modality universally might have influenced the relationship between online instruction and F2F instruction, we formulate a flexible empirical specification that allows the estimated effect to vary over time. To understand the logic behind equation (1) more closely, it is worth spelling out what each of the parameters in the equation represents.[10] $\beta_1$and β_2 refer to the difference in student performance outcomes between online courses taken in Spring 2019 and Spring 2020 versus Fall 2019 (the reference category), respectively. Similarly, β_3 captures the difference in the outcomes between F2F versus online courses in Fall 2019. Regarding the interaction coefficients, β_4 is the impact of F2F education over the online education in Spring 2019 relative to Fall 2019, and, finally, β_5 represents the impact of F2F education over the online education in Spring 2020 relative to Fall 2019. The β_4 is analogous to an event-study parameter in the sense that it would indicate whether the difference between F2F and online instruction was stable prior to the pandemic. Similarly, the β_5 would reveal whether any difference observed in student learning outcomes between online and F2F instruction exhibited a departure from its pre-pandemic trend in Spring 2020.

In Spring 2020, when the COVID-19 epidemic broke out, the campus was shut down, and the courses that started with the F2F instruction switched to online modality. This shift occurred *after* the midterm grades were assigned. Therefore, students obtained a set of midterm grades with F2F instruction and another set (Final Grades) after the switch to online instruction. The students whose courses started with an online delivery got both grades with online instruction. On the other hand, in Spring 2019 and Fall 2019, courses that started with a particular instruction mode

[10] Note the empirical model expressed in equation allows the pandemic to differentially influence the student learning outcomes of students in both online and F2F courses.

continued with that same mode throughout the semester. Never in these semesters, a course that started with an online modality switched to F2F.

Student- and course-level control variables are included in the vector X_{ict}. For example, in the regressions, we control for student's age with a set of age dummies (the comparison category is 18). Although we have some time-invariant student characteristics, such as race/ethnicity, sex, and nativity, we do not include them in the regressions. This is because we condition on student fixed effects, denoted by μ_i in equation (1).

Other variables in X_{ict} in equation (1) are designed to isolate the course characteristics. *Capstone or Writing-Intensive Course* takes the value of one if the course has these attributes. Capstone courses require students to do a research project, prepare a portfolio, a report, or a demonstration of field-related skills in a field of their major. In writing-intensive courses, students engage in intensive writing in their field. In both courses, the students are required to write a minimum of 2,500-5,000 words per semester. Finally, we control for three binary variables indicating course level. The standard errors are clustered at the class level.[11]

IV. Results

The results obtained from the estimation of equation (1) are presented in Table 3. The estimates in the first row indicate that there is no difference between students in F2F and online courses in terms of their likelihood of withdrawing from the course or earning a passing grade (A, B, C, or D) in Fall 2019 (β_3). As shown in columns 1 and 2, the estimates are both small in magnitude and statistically insignificant. The emerging picture, however, is different if we turn to

[11] A course can be taught in multiple sections to different students by different instructors. We define a class as one section of a course. For example, a Principles of Economics course taught by a particular instructor at one time slot is referred to as one class, and the same course taught by the same instructor at a different time slot constitutes another class. The total number of clusters is 2,442.

the estimates on grades presented in columns 3 to 8. Specifically, the grades are lower in F2F courses than those in online courses in Fall 2019. For example, a student taking a F2F course in Fall 2019 is seven percentage points less likely to earn a grade of A in that course at the end of the semester compared to an online course. Similarly, the likelihood of receiving an A or B is 5.1 percentage points lower in a F2F course than an online course in Fall 2019. The difference in grades between F2F and online courses is even greater (by about 50 percent) in mid-semester, as captured by the variable Midterm Grade.

The estimates in the second row of Table 3 show no apparent differences in grades in online versus F2F courses between Fall 2019 and Spring 2019 (β_1) as all the estimates are small in magnitude and statistically insignificant. This is not surprising because, to our knowledge, there was no shock that had occurred between these two semesters that might have influenced the learning outcomes of online and F2F students differently. While the difference in learning outcomes between the two instruction modalities is stable between Spring 2019 to Fall 2019, the students enrolled in online courses experienced an increase in their final grades in Spring 2020. As shown in the third row, the grade points at the end of the semester in online courses in Spring 2020 are about 0.06 points higher in Spring 2020 compared to Fall 2019 (β_2). Furthermore, this jump is almost entirely driven by an increase in the likelihood of receiving a grade of A. While the final grades are higher in Spring 2020 compared to earlier semesters among online courses, the same pattern is not true for midterm grades. Importantly, the midterm grades in Spring 2020 are no different from those of the earlier semesters for online courses. This finding is not surprising because the midterm exams in Spring 2020 were administered before the pandemic broke out. This

is important because it further supports the notion that the increase in grades of online courses in Spring 2020 is due to the COVID-19 pandemic.

How are the differences in grades between online and F2F courses in Spring 2019 and Spring 2020 changed compared to Fall 2019? The answers to these questions are revealed in the rows [4] and [5] of Table 3 (β_4 and β_5, respectively), shown by the estimates on the interaction terms. According to these estimates, there are no differences in learning outcomes between students in F2F and online courses in Spring 2019 relative to that difference in Fall 2019. Row 6 presents the estimates of the sum of the coefficients of F2F and F2F × Spring 2019 (β_3+β_4). These estimates all show the same pattern of the coefficients of F2F. Again, this is not surprising in the sense that the relative difference between the course outcomes of F2F and online students was stable prior to COVID-19. However, the gap between F2F and online students has narrowed for final grades in Spring 2020 relative to Fall 2019, as shown in columns 7 and 8 of row 5. In fact, as displayed in row 7, where we present the estimates of the sum of F2F and F2F × Spring 2020 (β_3+β_5), the difference between the two types of instruction modalities is no longer significant for the outcomes of grade points and the likelihood of receiving an A or B.[12] With respect to the final grades, the only statistically significant difference is for the likelihood of earning a grade of A, which appears to have narrowed, but still remained in favor of students in online courses. Furthermore, the likelihood of receiving a passing grade now appears to be slightly higher for F2F students than online students by 2.1 percentage points. For midterm grades, however, the differences remained intact where online students continued to have performed better than F2F students. Again, this is not surprising given the fact that these grades were assigned prior to the abrupt shift to online instruction initiated due to the pandemic.

[12] Note that (β_3+ β_4) and (β_3+ β_5) reveal the difference in the outcomes of students in F2F and online courses in Spring 2019 and Spring 2020, respectively.

The results discussed so far suggest that students enrolled in online courses perform better than those enrolled in F2F courses in terms of their grades, as measured in various ways. Furthermore, the grades seem to have increased for students in both types of classes in Spring 2020, which was disrupted by the pandemic. However, while the pandemic caused an increase in the final grades of both types of students, it appears to have benefitted the students in F2F courses more generously than those in online courses, resulting in a narrowing of the gap between the two groups.

The important question, however, is whether the picture emerging from Table 3 reflects better learning in online courses than F2F courses, or it merely reflects some other factor that has nothing to do with learning, such as grade inflation caused by lenient grading by instructors teaching online courses or more widespread violation of academic integrity in these courses. The answer to this question is key in terms of informing the debate about the future of online education.

While the empirical model specified in equation (1) accounts for differences across students who select into particular instruction modality such as ability, income, or availability of time, it does not take into account factors that are external to the student. A potentially important factor that may explain these results is the difference in approaches to the assessment of student performance by instructors teaching F2F and online courses. To provide insights into the above question, we estimate an augmented version of equation (1) that adds instructor fixed effects as an additional set of control variables into the regressions.

The results obtained from a version of equation (1) with both student and instructor fixed effects are presented in Table 4. Strikingly, the pattern observed in the previous table is reversed once we accounted for the heterogeneity across instructors. Specifically, not only do the students in online courses no longer perform better than those in F2F courses, they actually do

comparatively more poorly. For example, students in F2F instruction are 2.4 percentage points (69% of the mean of the online classes) less likely to withdraw from a course than those in online instruction in Fall 2019 (row 1 in column 1). Moreover, students in F2F courses are 4.1 percentage points (4 percent) more likely to receive a passing grade, i.e., A, B, C, or D, than their counterparts in online courses. There are also differences in terms of grades favoring students in F2F courses though the differences are small and not precisely estimated, with the exception of final grade points shown in column 8. The second row reveals no differences in learning outcomes in online courses between Spring 2019 and Fall 2019. Again, this is an expected finding since there is no apparent reason why instructors' approaches to assessment might have changed between Spring and Fall 2019. The estimates in the third raw confirm the earlier observation that grades in online courses increased in Spring 2020 relative to Fall 2019, but only after the midterm when COVID-19 caused the *University* to shift to online instruction for all courses. For example, the probability of receiving an A increased by 6.7 percentage points in Spring 2020 relative to Fall 2019, and the probability of receiving a B or higher went up by 2.8 percentage points. The estimates in row 4 show that there are no significant differences in the gap between F2F versus online grades between Spring 2019 and Fall 2019. This is again an expected finding as long as there is no change in the instructors' approaches to grading that might have affected online and F2F courses differentially. However, students in F2F instruction continued to perform better than those in online instruction with respect to their likelihood of withdrawing from their courses (-0.024+0.004=0.020*** estimate in row 6) and passing their course (0.041-0.007=0.034*** estimate in row 7) in Spring 2019. Both estimates are statistically significant ($p<0.001$). Finally, the results in row 5 suggest that the advantage in learning outcomes experienced by students in F2F courses over those in

online courses widened in Spring 2020 following the COVID-19 outbreak relative to the difference that existed in Fall 2019.

Overall, the results shown in Table 4 indicate that a difference in student learning outcomes between students in F2F and online courses favoring the latter group observed in the model with student fixed effects only is not driven by better learning facilitated by online instruction. Rather, the results from a regression model with both instructor and student fixed effects reveal that it is the differences in the approaches to student performance assessment by instructors teaching online versus F2F courses as the likely explanation for that pattern. For example, instructors teaching online courses may be more lenient in their approach to grading than instructors teaching F2F courses. Aside from leniency, a related factor may be the difficulty of preventing academic integrity violations in online courses relative to F2F courses. Note that student fixed effects would help account for time-invariant student traits that may be correlated with propensity to cheat in an exam or assignment. However, it would not eliminate the differences in grades caused by students engaging in academic integrity violations if less strict monitoring by instructors leads to more cheating.

To further explore the role of instructor-driven factors in explaining the difference in learning outcomes between students in F2F versus online courses, we make use of information on a remote proctoring service used by the *University* instructors to ensure exam integrity.[13] This service allows instructors to proctor an exam by authenticating students as well as recording and monitoring personal computer activity during an exam. The instructors teaching online courses in the *University* have the option to administer their exams with online proctoring, and we have information on whether an instructor has requested the online proctoring service and has an

[13]To preserve anonymity of the *University*, we refrain from naming the company name for the remote proctoring service; we call it "Online Proctoring."

account in Fall 2019 and Spring 2020. Each semester, instructors who plan to use this service in their class send a request to the *University* for an account.[14] Then, their course gets linked to these services. The number of instructors who requested the service is 62 in our data.[15] Note that an instructor teaching a F2F course may request the proctoring service and administer the tests online for some or all students, although the lectures are F2F. A closer look at our data reveals that some F2F courses linked to online proctoring have a laboratory component. This may be due to greater challenges to monitoring individual student actions in laboratory sessions. It could also be that an instructor who is teaching both an online and a F2F version of the same course could offer tests online in order to save effort and time to prepare different tests for different modalities. In our data, 18 instructors teaching a F2F course appears to have requested the online proctoring service.

If the instructor style or approach to assessing students is a factor in explaining differences in grades between online and F2F courses, then this factor may manifest itself in a discrepancy in learning outcomes in students taught by instructors with an online proctoring account and those who do not. One way to test this is to estimate our models controlling for online proctoring and its interaction with F2F instruction. As displayed in Table 5, students in F2F courses perform better than those in online courses with respect to the likelihood of withdrawing from a course (by 1.9 percentage points) and receiving a passing grade (by 3.8 percentage points) if the instructor does not use the online proctoring software. Furthermore, the use of online proctoring is associated with lower grades, a higher tendency of withdrawing from a course, and a lower likelihood of receiving a passing grade of A, B, C, or D, after controlling for time-invariant differences across students

[14] The instructor has to include this information in the course syllabus, along with the cost of the online proctoring service to the students.

[15] Although we do not have information on whether instructors with an account for the online proctoring service do in fact use this tool in administering their exams, it is reasonable to assume that they do. To the extent that some instructors do not, the estimates from this analysis would represent a lower bound.

and instructors. For example, students in online courses in which the instructors use online proctoring are 3.4 percentage points more likely to withdraw from their course and 3.7 percentage points less likely to receive a passing grade. However, the gap in the likelihood of withdrawing from a course and receiving a passing grade between students in online and F2F courses becomes larger if the instructors in online courses administer exams using proctoring software, as shown by the interaction coefficients between F2F instruction and online proctoring indicators (row 4). This finding is consistent with the notion that online courses do not result in better student outcomes, at least as measured by the likelihood of withdrawing from a course and receiving a passing grade.

Heterogeneity Analyses

In this sub-section, we present results from a series of analyses that test whether the difference in learning outcomes between students receiving F2F versus online instruction varies by several measures of student characteristics. We begin by presenting results separately for female and male students in Table 6 (Panels A and B, respectively). After controlling for student and instructor fixed effects, both female and male students appear to do better in terms of their tendency of withdrawing from a course and receiving a passing grade of A, B, C, or D, if they are enrolled in a F2F course relative to an online course. Furthermore, there is an increase in grades in both online and F2F classes regardless of gender in Spring 2020, but the increase experienced by F2F students appears to be larger. The rise in grades observed in Spring 2020 above and beyond its previous trend is likely due to COVID-19 related grade inflation, as discussed earlier.

In Table 7, we show the estimates for subsamples separated by their race. Panels A and B present results pertaining to Black and White students, respectively. Both Black and White students earn higher grades in F2F courses than online courses regardless of the semester.

However, consistent with the patterns in earlier results, the gap in grades favoring students in F2F courses becomes larger in Spring 2020.

Next, we explore whether the difference in learning outcomes between students in F2F and online courses varies by a proxy of student quality. We do this by presenting estimates from our most comprehensive specification separately for students who are enrolled in the honors program and those who are not. Recall that the honors students have to satisfy a GPA requirement in their major, in addition to taking a number of special honors courses. The results obtained from this analysis are shown in Table 8, which reveals interesting patterns in the relationship between student learning and instruction modality. Strikingly, for honor students, there seems to be no difference between online and F2F instruction (Panel A of Table 8). Students in the Honors program perform equally well regardless of whether the course is offered online or in person. Furthermore, this pattern is true for all semesters, including Spring 2020. Specifically, honors students did not experience a jump in their grades in Spring 2020, and their grades were not different from those taking courses in person. All the estimates are small in size, and none are statistically significant. When we turn to students in regular courses, however, the results are very different and resembles the earlier pattern that we discussed in the previous results (Panel B of Table 8). Notably, students in F2F courses perform better than those in online courses, and this gap appeared to have widened in Spring 2020. Taken together, the results shown in Table 8 indicate that for high achieving and highly motivated students, the course modality matters little, if any. For all other students, however, those in F2F courses appear to perform better than those in online courses.

Lastly, we perform a sub-group analysis directed towards exploring the role of access to technology in explaining the disparity in learning outcomes between online and F2F instruction.

We do this by producing our estimates broken down by a measure of access to high-speed internet. The top panel of Table 9 presents estimates for the students living in zip codes with access to high-speed internet, and the bottom panel shows those living in zip codes with relatively low-speed internet. As illustrated in the table, students in F2F courses perform better than their online counterparts, especially with respect to the outcomes of withdrawing from a course and receiving a passing grade. Consistent with the previous findings, the final semester grades shown in the last three columns increased among students in online courses regardless of internet speed in Spring 2020 compared to Spring 2019. Interestingly, however, the increase appears to be slightly larger among students with access to high-speed internet than others. Furthermore, the students in F2F courses living in neighborhoods with access to high-speed internet appear to have experienced a greater jump in their grades in Spring 2020 than their counterparts living in neighborhoods with more limited access to high-speed internet. Note that these are students who began the Spring 2020 semester in F2F classes offered on the *University* campus but then had to switch to online education after the COVID-19 pandemic broke out. The last rows in Panels A and B of Table 9 indicate that, among the students who made the transition from in-person to online learning, those living in neighborhoods that are more likely to have access to high-speed internet technology experienced a greater rise in their grades.

V. Conclusions

Remote learning has been the fastest-growing segment of the higher education industry. Despite its growth, there is a longstanding controversy about the relative quality of online versus in-person approach to instruction, and a wide range of audiences and stakeholders in higher education, including instructors, academic leaders, and the public, remain skeptical about the

merits of online education, which they perceive as inferior to traditional F2F instruction (Baum, 2020).

In this paper, we try to help inform this debate by providing insights on the impact of online instruction on student learning outcomes. According to our results, students in face-to-face courses perform better than their online counterparts with respect to their grades, the propensity to withdraw from the course, and the likelihood of receiving a passing grade. Furthermore, we document a significant rise in student grades in Spring 2020. The finding is consistent with the reports about most colleges and universities adopting changes to their assessment policies and instructors taking a more flexible and compassionate approach towards students in an effort to alleviate difficulties caused by COVID-19. In many universities, academic policies were modified to ensure that students were not penalized heavily for poor performance as they have experienced countless disruptions in their lives and might encounter inadequate technology, financial emergencies, and other barriers to effective learning (Jaeger et al. 2021). Similarly, instructors were advised to lower expectations, reduce required coursework, and be more flexible with students with respect to meeting deadlines, offering make-up exams (Lederman 2020; Lin 2021). This story is further supported by our finding that the increase in grades occurred only for the final semester grades but not in midterm grades, which were registered prior to the onset of the pandemic.

Our results also reveal that living in neighborhoods with better broadband technology was associated with a larger increase in grades among students who had to transition from in-person to online instruction during the height of COVID-19 in Spring 2020. This finding supports the argument that unequal access to technology might have caused learning disparities to deepen during the pandemic.

While our paper shows that online education results in poorer student learning than F2F education in general, this finding should not be regarded as the final verdict in the debate about the merits of online versus F2F education. It is important to keep in mind that remote learning is a constantly evolving experience, driven by reliable connectivity and high-speed broadband, as well as the advancement of cloud-based technologies. Therefore, it is possible that integration of information technology in education would eventually improve student and instructor experience in ways that result in achievement gains for online over the traditional form instruction.

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Figure 1A
Distribution of Student Learning Outcomes Over Time in Online Courses

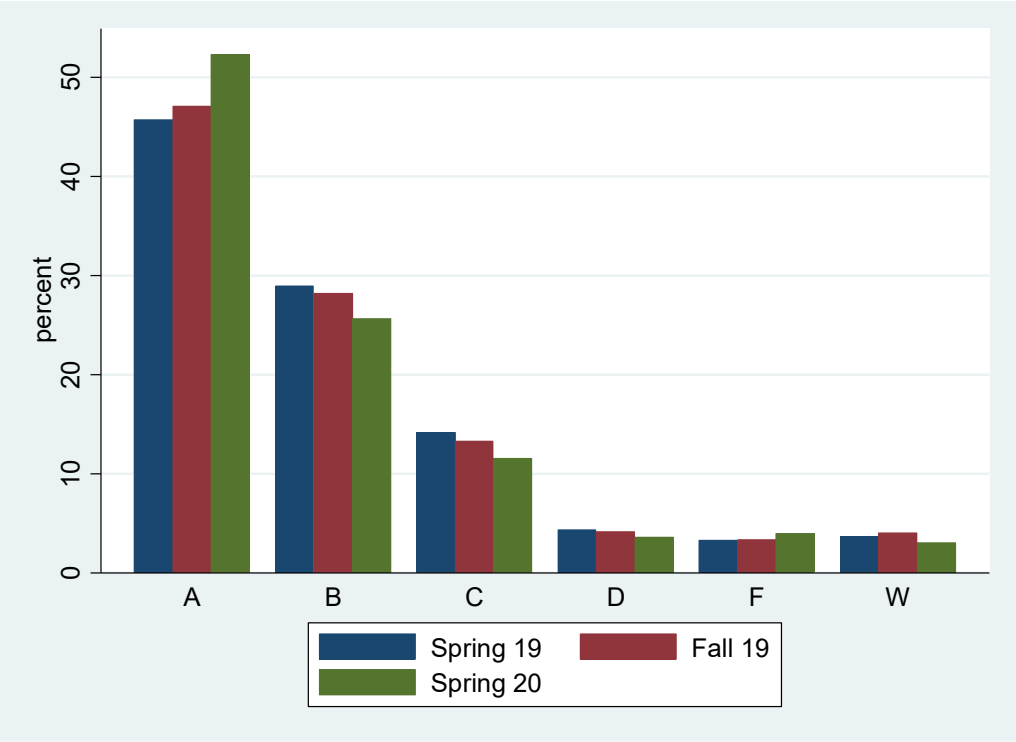

Figure 1B
Distribution of Student Learning Outcomes Over Time in F2F Courses

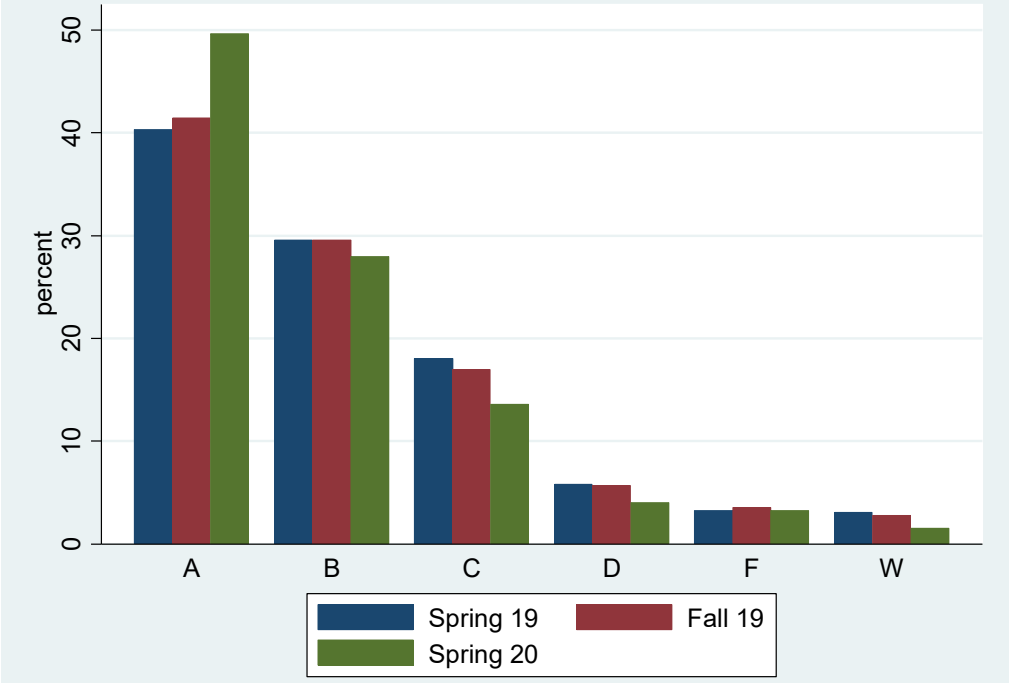

Table 1

Distribution of Students and Instructors by Semester and Whether They Take/Teach Both Online and F2F Classes

Panel A: Students

	Total Number of Students in the sample	Students who take a mix of online and F2F classes
Spring 2019	4,339	1,913 (44%)
Fall 2019	7,022	2,788 (40%)
Spring 2020	6,760	2,893 (43%)

Panel B: Instructors

	Total Number of Teachers	Teachers who teach a mix of online and F2F classes
Spring 2019	684	92 (13%)
Fall 2019	724	102 (14%)
Spring 2020	699	111 (16%)

Table 2
Summary Statistics by Instruction Modality

	Whole Sample		F2F		Online		Difference
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean	St.D.	Mean	St.D.	Mean	St.D.	(3)-(5)
Course Outcomes							
Withdraw	0.03	0.16	0.02	0.15	0.04	0.18	-0.012***
Passed	0.94	0.24	0.94	0.23	0.93	0.26	0.013***
Midterm Grade is A	0.43	0.50	0.41	0.49	0.51	0.50	-0.106***
Midterm Grade is A or B	0.70	0.46	0.68	0.47	0.76	0.43	-0.073***
Midterm Grade (0-4)	2.92	1.23	2.87	1.23	3.08	1.20	-0.217***
Final Grade is A	0.47	0.50	0.45	0.50	0.51	0.50	-0.052***
Final Grade is A or B	0.76	0.43	0.75	0.43	0.79	0.41	-0.039***
Final Grade (0-4)	3.11	1.06	3.08	1.06	3.18	1.05	-0.097***
Course Characteristics							
Capstone/Writing Class	0.04	0.19	0.03	0.18	0.05	0.22	-0.014***
100-Level	0.36	0.48	0.39	0.49	0.28	0.45	0.105***
200-Level	0.19	0.40	0.19	0.39	0.21	0.41	-0.021***
300-Level	0.28	0.45	0.27	0.45	0.31	0.46	-0.041***
400- or Higher Level	0.16	0.37	0.15	0.35	0.19	0.39	-0.043***
Student Characteristics							
Age	22.13	5.47	21.04	3.74	25.37	7.93	-4.328***
Female	0.65	0.48	0.64	0.48	0.67	0.47	-0.035***
White	0.61	0.49	0.60	0.49	0.65	0.48	-0.046***
Black	0.28	0.45	0.29	0.45	0.25	0.43	0.040***
Other Race	0.11	0.31	0.11	0.31	0.10	0.30	0.007
Honors Student	0.07	0.25	0.08	0.27	0.03	0.18	0.045***
High-speed Internet at Home	0.60	0.49	0.59	0.49	0.61	0.49	-0.014

Notes: The unit of observation is a student-class. The number of observations is 78,048. Column 7 shows the difference between columns 3 and 5. *** indicates statistical significance at the 1% level.

Table 3
Differences in Student Learning Outcomes in F2F vs. Online Courses
(Within Student Estimates)

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.008	0.009	-0.108***	-0.073***	-0.206***	-0.070***	-0.051***	-0.130**
		(0.005)	(0.007)	(0.023)	(0.017)	(0.052)	(0.027)	(0.016)	(0.051)
[2]	Spring 2019	-0.007	0.006	0.028	0.007	0.038	-0.033	-0.021	-0.061
		(0.005)	(0.007)	(0.030)	(0.025)	(0.071)	(0.025)	(0.017)	(0.050)
[3]	Spring 2020	-0.005	-0.001	0.003	-0.017	-0.035	0.050***	0.019	0.062*
		(0.004)	(0.006)	(0.021)	(0.016)	(0.048)	(0.019)	(0.012)	(0.036)
[4]	F2F × Spring 2019	0.005	-0.005	-0.012	-0.008	-0.035	0.018	0.003	0.024
		(0.005)	(0.008)	(0.033)	(0.027)	(0.079)	(0.029)	(0.020)	(0.057)
[5]	F2F × Spring 2020	-0.004	0.012*	-0.004	-0.005	-0.023	0.029	0.039***	0.096**
		(0.004)	(0.006)	(0.024)	(0.020)	(0.057)	(0.022)	(0.015)	(0.044)
	N	78,048	78,048	72,316	72,316	72,316	75,959	75,959	75,944
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	No	No	No	No	No	No	No	No
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.003	0.004	-0.121***	-0.081***	-0.242***	-0.052*	-0.048**	-0.106*
		(0.005)	(0.008)	(0.029)	(0.026)	(0.073)	(0.031)	(0.020)	(0.061)
[7]	F2F + F2F × Spring 2020	-0.011***	0.021***	-0.112***	-0.077***	-0.230***	-0.041*	-0.012	-0.034
		(0.004)	(0.006)	(0.026)	(0.019)	(0.059)	(0.023)	(0.014)	(0.043)

Notes: The unit of observation is a student-class. Observations from Spring 2019, Fall 2019, and Spring 2020 enter into the regressions. F2F takes the value of one if the class is delivered F2F. Outcomes: Column 1-An indicator that is equal to one if the student withdrew from the class without obtaining a letter grade; Column 2-An indicator that is equal to one if the student completed the course with a passing grade (A, B, C, or D); Column 3: Indicator that is equal to one if student's midterm grade is A; Column 4: Indicator that is equal to one if student's midterm grade is A or B; Column 5: Value of student's midterm grade (A=4, B=3, C=2, D=1, F=0); Column 6: Indicator that is equal to one if student's final grade is A; Column 7: Indicator that is equal to one if student's final grade is A or B; Column 8: Value of student's final grade. All regressions include the following controls: age group dummies, level of the course dummies, and an indicator for whether the course is a capstone or a writing-intensive class. All regressions also contain student fixed effects. Rows 6 and 7 present the estimates of the sum of the coefficients in rows [1] and [4] and rows [1] and [5], respectively. Standard errors are clustered at the class level. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 4

Differences in Student Learning Outcomes in F2F vs. Online Courses
(Within Student and Within Instructor Estimates)

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.024***	0.041***	-0.016	0.014	0.056	0.006	0.011	0.055*
		(0.005)	(0.006)	(0.017)	(0.016)	(0.046)	(0.014)	(0.011)	(0.030)
[2]	Spring 2019	-0.004	0.005	0.011	-0.007	0.001	-0.019	-0.017	-0.039
		(0.004)	(0.006)	(0.021)	(0.017)	(0.051)	(0.014)	(0.011)	(0.028)
[3]	Spring 2020	-0.005	0.002	0.012	-0.009	-0.011	0.067***	0.028***	0.094***
		(0.003)	(0.005)	(0.015)	(0.013)	(0.037)	(0.013)	(0.010)	(0.026)
[4]	F2F × Spring 2019	0.004	-0.007	-0.005	-0.005	-0.032	-0.004	-0.004	-0.013
		(0.005)	(0.007)	(0.025)	(0.019)	(0.059)	(0.017)	(0.013)	(0.034)
[5]	F2F × Spring 2020	-0.006	0.012**	-0.015	-0.002	-0.033	0.022	0.037***	0.087***
		(0.004)	(0.006)	(0.017)	(0.015)	(0.042)	(0.016)	(0.012)	(0.032)
	N	78,048	78,048	72,316	72,316	72,316	75,959	75,959	75,944
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.020***	0.034***	-0.022	0.008	0.024	0.002	0.007	0.042
		(0.005)	(0.006)	(0.023)	(0.019)	(0.055)	(0.017)	(0.013)	(0.035)
[7]	F2F + F2F × Spring 2020	-0.030***	0.053***	-0.031*	0.012	0.023	0.028**	0.048***	0.142***
		(0.004)	(0.006)	(0.018)	(0.014)	(0.041)	(0.014)	(0.011)	(0.028)

Notes: All the regressions include both student fixed effects and instructor fixed effects. Everything else is identical to the specifications in Table 3. See notes to that table.

Table 5

Role of Online Proctoring in Student Learning Outcomes

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.019***	0.038***	-0.020	0.007	0.032	-0.003	0.016	0.053*
		(0.004)	(0.006)	(0.018)	(0.016)	(0.045)	(0.014)	(0.010)	(0.028)
[2]	Online Proctoring	0.034***	-0.037***	-0.049	-0.055*	-0.174**	-0.099***	-0.060**	-0.200***
		(0.009)	(0.012)	(0.032)	(0.029)	(0.080)	(0.034)	(0.025)	(0.069)
[3]	Spring 2020	-0.010***	0.010***	0.005	-0.010	-0.035*	0.083***	0.053***	0.151***
		(0.002)	(0.003)	(0.008)	(0.007)	(0.019)	(0.007)	(0.006)	(0.015)
[4]	F2F × Online Proctoring	-0.019**	0.025*	0.052	-0.014	-0.039	-0.124	-0.091	-0.211
		(0.010)	(0.015)	(0.053)	(0.049)	(0.132)	(0.087)	(0.059)	(0.167)
	N	59,582	59,582	54,771	54,771	54,771	58,087	58,087	58,078
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[5]	F2F + F2F × Online Proctoring	-0.038***	0.062***	0.033	-0.007	-0.007	-0.127	-0.075	-0.158
		(0.010)	(0.015)	(0.052)	(0.047)	(0.127)	(0.086)	(0.058)	(0.165)

Notes: Observations from Fall 2019 and Spring 2020 enter into the regressions. Online Proctoring is an indicator of whether online proctoring software is used in a class. Row 5 presents the estimate of the sum of the coefficients in rows [1] and [4]. Everything else is identical to the specifications in Table 4. See notes to that table.

Table 6
Differences in Student Learning Outcomes in F2F vs. Online Courses by Student Gender

Panel A: Female Students

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.015***	0.038***	-0.030	-0.000	0.012	0.002	0.013	0.060*
		(0.004)	(0.006)	(0.019)	(0.017)	(0.047)	(0.015)	(0.012)	(0.032)
[2]	Spring 2019	-0.005	0.008	-0.000	-0.021	-0.038	-0.025*	-0.024*	-0.047
		(0.005)	(0.007)	(0.023)	(0.018)	(0.055)	(0.015)	(0.012)	(0.030)
[3]	Spring 2020	-0.003	0.002	0.007	-0.007	-0.017	0.066***	0.029***	0.101***
		(0.004)	(0.005)	(0.017)	(0.013)	(0.038)	(0.014)	(0.010)	(0.027)
[4]	F2F × Spring 2019	0.006	-0.016**	0.005	0.008	-0.003	0.003	0.003	-0.007
		(0.005)	(0.008)	(0.028)	(0.021)	(0.064)	(0.018)	(0.014)	(0.036)
[5]	F2F × Spring 2020	-0.005	0.011*	-0.013	-0.000	-0.017	0.025	0.040***	0.089***
		(0.004)	(0.006)	(0.019)	(0.016)	(0.044)	(0.016)	(0.012)	(0.032)
	N	50,474	50,474	47,167	47,167	47,167	49,416	49,416	49,408
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.008*	0.022***	-0.025	0.007	0.009	0.005	0.017	0.053
		(0.005)	(0.007)	(0.025)	(0.020)	(0.060)	(0.019)	(0.015)	(0.038)
[7]	F2F + F2F × Spring 2020	-0.020***	0.048***	-0.042**	-0.000	-0.006	0.027*	0.054***	0.149***
		(0.004)	(0.006)	(0.020)	(0.015)	(0.045)	(0.016)	(0.012)	(0.031)

Table 6 Continued
Differences in Student Learning Outcomes in F2F vs. Online Courses by Student Gender

Panel B: Male Students

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.046***	0.051***	0.014	0.042*	0.143**	0.012	0.002	0.041
		(0.010)	(0.011)	(0.021)	(0.022)	(0.060)	(0.019)	(0.017)	(0.041)
[2]	Spring 2019	-0.003	-0.002	0.040	0.022	0.084	-0.005	-0.005	-0.022
		(0.009)	(0.010)	(0.025)	(0.022)	(0.062)	(0.022)	(0.017)	(0.042)
[3]	Spring 2020	-0.011*	0.003	0.023	-0.008	0.012	0.068***	0.025*	0.080**
		(0.006)	(0.008)	(0.021)	(0.019)	(0.052)	(0.019)	(0.015)	(0.038)
[4]	F2F × Spring 2019	-0.000	0.009	-0.035	-0.040	-0.111	-0.026	-0.019	-0.035
		(0.010)	(0.012)	(0.028)	(0.024)	(0.070)	(0.024)	(0.020)	(0.048)
[5]	F2F × Spring 2020	-0.004	0.012	-0.020	-0.006	-0.071	0.021	0.037**	0.093**
		(0.007)	(0.009)	(0.023)	(0.021)	(0.059)	(0.023)	(0.018)	(0.045)
	N	27,574	27,574	25,149	25,149	25,149	26,543	26,543	26,536
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.046***	0.060***	-0.021	0.002	0.032	-0.015	-0.018	0.005
		(0.010)	(0.013)	(0.025)	(0.022)	(0.061)	(0.023)	(0.020)	(0.048)
[7]	F2F + F2F × Spring 2020	-0.050***	0.063***	-0.006	0.036*	0.073	0.032*	0.038**	0.133***
		(0.008)	(0.011)	(0.021)	(0.019)	(0.051)	(0.020)	(0.016)	(0.039)

Notes: Panel A (B) displays the results of female (male) students. Everything else is identical to the specifications in Table 4. See notes to that table.

Table 7
Differences in Student Learning Outcomes in F2F vs. Online Courses by Student Race

Panel A: Black Students

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.025***	0.043***	-0.008	-0.026	-0.001	-0.006	-0.030	-0.020
		(0.008)	(0.012)	(0.024)	(0.023)	(0.062)	(0.022)	(0.020)	(0.049)
[2]	Spring 2019	0.003	0.001	0.046	0.002	0.062	-0.021	-0.019	-0.038
		(0.010)	(0.014)	(0.033)	(0.024)	(0.075)	(0.021)	(0.022)	(0.048)
[3]	Spring 2020	-0.011	0.007	0.034*	0.006	0.039	0.065***	0.022	0.088*
		(0.007)	(0.011)	(0.020)	(0.018)	(0.049)	(0.021)	(0.018)	(0.045)
[4]	F2F × Spring 2019	0.000	-0.017	-0.044	-0.028	-0.122	-0.015	-0.015	-0.064
		(0.011)	(0.015)	(0.037)	(0.028)	(0.086)	(0.025)	(0.025)	(0.057)
[5]	F2F × Spring 2020	-0.007	0.013	-0.042*	-0.015	-0.085	0.024	0.060***	0.125**
		(0.008)	(0.012)	(0.023)	(0.022)	(0.058)	(0.025)	(0.021)	(0.053)
	N	21,744	21,744	20,350	20,350	20,350	21,025	21,025	21,022
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.025**	0.026*	-0.052	-0.054*	-0.123	-0.021	-0.045*	-0.084
		(0.011)	(0.014)	(0.034)	(0.029)	(0.085)	(0.025)	(0.025)	(0.059)
[7]	F2F + F2F × Spring 2020	-0.032***	0.056***	-0.050**	-0.041*	-0.086	0.019	0.030	0.105**
		(0.008)	(0.011)	(0.025)	(0.023)	(0.061)	(0.022)	(0.019)	(0.047)

Table 7 Continued
Differences in Student Learning Outcomes in F2F vs. Online Courses by Student Race

Panel B: White Students

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.028***	0.041***	-0.022	0.028*	0.067	0.010	0.013	0.059**
		(0.005)	(0.006)	(0.019)	(0.017)	(0.047)	(0.015)	(0.011)	(0.029)
[2]	Spring 2019	-0.010*	0.009	-0.009	-0.010	-0.028	-0.029*	-0.020*	-0.055**
		(0.005)	(0.006)	(0.021)	(0.017)	(0.049)	(0.015)	(0.011)	(0.028)
[3]	Spring 2020	-0.003	0.000	0.002	-0.009	-0.031	0.074***	0.029***	0.101***
		(0.003)	(0.005)	(0.017)	(0.014)	(0.039)	(0.013)	(0.010)	(0.024)
[4]	F2F × Spring 2019	0.011*	-0.007	0.018	0.004	0.013	0.012	0.000	0.021
		(0.006)	(0.007)	(0.025)	(0.020)	(0.057)	(0.018)	(0.013)	(0.033)
[5]	F2F × Spring 2020	-0.004	0.009*	-0.005	-0.003	-0.010	0.014	0.033***	0.067**
		(0.004)	(0.005)	(0.019)	(0.016)	(0.044)	(0.016)	(0.012)	(0.030)
	N	47,888	47,888	44,185	44,185	44,185	46,744	46,744	46,735
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.017***	0.034***	-0.004	0.032*	0.080	0.022	0.013	0.080**
		(0.005)	(0.007)	(0.023)	(0.018)	(0.051)	(0.019)	(0.013)	(0.034)
[7]	F2F + F2F × Spring 2020	-0.032***	0.050***	-0.026	0.025*	0.057	0.024	0.046***	0.126***
		(0.005)	(0.006)	(0.019)	(0.015)	(0.041)	(0.015)	(0.010)	(0.027)

Panel A (B) displays the results of black (white) students. Everything else is identical to the specifications in Table 4. See notes to that table.

Table 8
Differences in Student Learning Outcomes in F2F vs Online Courses by Academic Standards

Panel A: Honors Students

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.010	0.012	-0.006	0.019	0.015	-0.016	0.018	0.014
		(0.013)	(0.014)	(0.050)	(0.034)	(0.092)	(0.040)	(0.020)	(0.057)
[2]	Spring 2019	-0.005	0.007	-0.019	-0.058	-0.075	-0.004	-0.005	-0.012
		(0.015)	(0.016)	(0.079)	(0.049)	(0.145)	(0.056)	(0.023)	(0.077)
[3]	Spring 2020	-0.009	0.001	-0.007	-0.019	-0.028	0.021	0.015	0.030
		(0.010)	(0.012)	(0.052)	(0.035)	(0.096)	(0.037)	(0.019)	(0.054)
[4]	F2F × Spring 2019	0.005	-0.003	0.018	0.059	0.103	0.017	-0.003	0.025
		(0.016)	(0.016)	(0.080)	(0.050)	(0.146)	(0.058)	(0.024)	(0.078)
[5]	F2F × Spring 2020	0.007	-0.006	0.039	-0.000	0.012	0.030	-0.010	0.016
		(0.011)	(0.013)	(0.057)	(0.035)	(0.101)	(0.039)	(0.019)	(0.057)
	N	5,206	5,206	4,866	4,866	4,866	5,145	5,145	5,144
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.005	0.009	0.012	0.078	0.119	0.001	0.015	0.039
		(0.011)	(0.012)	(0.075)	(0.045)	(0.128)	(0.066)	(0.026)	(0.093)
[7]	F2F + F2F × Spring 2020	-0.003	0.007	0.033	0.019	0.028	0.014	0.008	0.030
		(0.011)	(0.012)	(0.058)	(0.033)	(0.097)	(0.037)	(0.017)	(0.050)

Table 8 Continued
Differences in Student Learning Outcomes in F2F vs Online Courses by Academic Standards

Panel B: Students Who Are Not in the Honors Program

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.025***	0.042***	-0.017	0.009	0.052	0.003	0.008	0.049
		(0.005)	(0.006)	(0.018)	(0.017)	(0.048)	(0.014)	(0.012)	(0.031)
[2]	Spring 2019	-0.004	0.004	0.015	-0.002	0.013	-0.017	-0.016	-0.036
		(0.005)	(0.006)	(0.020)	(0.017)	(0.050)	(0.014)	(0.012)	(0.029)
[3]	Spring 2020	-0.005	0.001	0.013	-0.009	-0.012	0.068***	0.028***	0.095***
		(0.003)	(0.005)	(0.015)	(0.013)	(0.037)	(0.013)	(0.010)	(0.027)
[4]	F2F × Spring 2019	0.004	-0.007	-0.010	-0.012	-0.050	-0.007	-0.006	-0.018
		(0.005)	(0.007)	(0.024)	(0.020)	(0.059)	(0.017)	(0.014)	(0.035)
[5]	F2F × Spring 2020	-0.007*	0.014**	-0.017	0.000	-0.032	0.025	0.042***	0.099***
		(0.004)	(0.006)	(0.017)	(0.015)	(0.043)	(0.016)	(0.012)	(0.033)
	N	72,842	72,842	67,450	67,450	67,450	70,814	70,814	70,800
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.021***	0.035***	-0.028	-0.003	0.002	-0.004	0.002	0.031
		(0.005)	(0.007)	(0.022)	(0.019)	(0.055)	(0.017)	(0.014)	(0.036)
[7]	F2F + F2F × Spring 2020	-0.032***	0.056***	-0.035**	0.009	0.020	0.027*	0.050***	0.148***
		(0.004)	(0.006)	(0.018)	(0.015)	(0.042)	(0.014)	(0.011)	(0.029)

Panel A (B) displays the results of students that are (not) in the honors program. Everything else is identical to the specifications in Table 4. See notes to that table.

Table 9

Differences in Student Learning Outcomes in F2F vs Online Courses by Internet Speed at Student's Residence

Panel A: Students with Greater Access to High-Speed Internet Technologies

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.022***	0.040***	-0.010	0.022	0.075	0.007	0.020	0.068**
		(0.006)	(0.007)	(0.019)	(0.018)	(0.050)	(0.015)	(0.013)	(0.031)
[2]	Spring 2019	-0.004	0.003	0.003	-0.007	0.005	-0.012	-0.026*	-0.043
		(0.006)	(0.007)	(0.024)	(0.020)	(0.058)	(0.016)	(0.013)	(0.032)
[3]	Spring 2020	-0.005	0.005	0.023	-0.005	0.008	0.073***	0.028***	0.104***
		(0.004)	(0.005)	(0.018)	(0.015)	(0.041)	(0.015)	(0.011)	(0.027)
[4]	F2F × Spring 2019	0.001	-0.000	-0.005	-0.015	-0.056	-0.013	0.004	-0.011
		(0.006)	(0.008)	(0.028)	(0.022)	(0.067)	(0.019)	(0.015)	(0.037)
[5]	F2F × Spring 2020	-0.007	0.010	-0.019	-0.002	-0.036	0.020	0.045***	0.088***
		(0.005)	(0.006)	(0.020)	(0.017)	(0.047)	(0.017)	(0.013)	(0.034)
	N	44,210	44,210	41,040	41,040	41,040	43,096	43,096	43,086
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.021***	0.040***	-0.015	0.007	0.019	-0.006	0.023	0.057
		(0.006)	(0.008)	(0.025)	(0.021)	(0.061)	(0.020)	(0.015)	(0.039)
[7]	F2F + F2F × Spring 2020	-0.029***	0.050***	-0.030	0.020	0.038	0.028*	0.065***	0.156***
		(0.005)	(0.007)	(0.019)	(0.016)	(0.045)	(0.015)	(0.013)	(0.031)

Table 9 Continued

Differences in Student Learning Outcomes in F2F vs Online Courses by Internet Speed at Student's Residence e

Panel B: Students with Less Access to High-Speed Internet Technologies

				Midterm			Final		
		Withdraw	Passed	A	A or B	Grade	A	A or B	Grade
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
[1]	F2F	-0.023***	0.042***	-0.024	0.009	0.049	-0.000	0.003	0.049
		(0.006)	(0.009)	(0.020)	(0.019)	(0.052)	(0.018)	(0.014)	(0.037)
[2]	Spring 2019	-0.006	0.013	0.027	-0.001	0.018	-0.034*	-0.006	-0.031
		(0.007)	(0.009)	(0.022)	(0.019)	(0.053)	(0.018)	(0.015)	(0.036)
[3]	Spring 2020	-0.001	-0.004	-0.012	-0.005	-0.022	0.058***	0.033**	0.090***
		(0.006)	(0.008)	(0.018)	(0.016)	(0.044)	(0.016)	(0.013)	(0.034)
[4]	F2F × Spring 2019	0.009	-0.019*	-0.018	0.001	-0.029	0.017	-0.007	-0.005
		(0.008)	(0.010)	(0.026)	(0.022)	(0.063)	(0.021)	(0.017)	(0.042)
[5]	F2F × Spring 2020	-0.006	0.014	-0.004	-0.008	-0.051	0.024	0.018	0.068*
		(0.007)	(0.009)	(0.021)	(0.018)	(0.050)	(0.019)	(0.015)	(0.039)
	N	29,894	29,894	27,622	27,622	27,622	29,018	29,018	29,013
	Student FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Instructor FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[6]	F2F + F2F × Spring 2019	-0.014*	0.022**	-0.041*	0.009	0.019	0.017	-0.004	0.044
		(0.008)	(0.010)	(0.025)	(0.022)	(0.059)	(0.021)	(0.017)	(0.043)
[7]	F2F + F2F × Spring 2020	-0.029***	0.056***	-0.028	0.001	-0.002	0.023	0.020	0.117***
		(0.006)	(0.009)	(0.021)	(0.017)	(0.046)	(0.018)	(0.014)	(0.036)

Panel A (B) displays the results of students that have (not) greater access to fast internet technologies. Everything else is identical to the specifications in Table 4. See notes to that table.