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Who Engages and How They Fare

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Online offerings at traditional brick-and-mortar universities have become common, though some question if online courses can adequately substitute for the in-person college experience. We explore changes in undergraduate online course enrollment at a large, public 4-year system and the impacts of online courses on student outcomes. Online enrollment in courses nearly doubled from 2012 to 2019 when almost 40 percent took at least one class online. Female students and older students were especially likely to take online classes. Using an instrumental variables approach, we find that GPAs are higher in the terms when students take at least one class online. However, we do not find evidence that online course taking results in increased degree completion. While online course offerings offer students flexibility, those who take online courses may need additional advising for online learning to translate into higher rates of graduation. (JEL I21, I23)

Keywords: higher education, education quality, online education, educational attainment, student achievement

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I. Introduction

Having access to online education or virtual instructional options has become the norm in higher education. Due to the pandemic, colleges were forced to change the way they deliver instruction overnight. Now, most colleges are continuing to offer a mix of online, in-person, and hybrid options for students, trying to be flexible in response to student needs and demands (Anderson 2021; Kirk 2021; Lederman 2021). While we do not yet know what the new "normal" looks like in terms of online course offerings, the number of online courses and programs being offered were increasing prior to the pandemic. Initially, for-profit post-secondary institutions like the University of Phoenix dominated the online education scene, but traditional brick-and-mortar universities have been capitalizing on the movement as well. For example, in Fall 2019, 36 percent of undergraduates at public 4-year institutions took at least one "distance education" course up from 22 percent in fall 2012 (U.S. Department of Education, 2020; U.S. Department of Education, 2013).[1]

The changing landscape of instructional delivery in post-secondary settings raises questions about both the prevalence and effectiveness of online courses which we address in this paper. First, we document the extent to which online course offerings and enrollment have been expanding in a large public university system over the nearly 10 years leading up to the COVID-19 pandemic, including characterizing the student populations most likely to enroll in online courses. Further, whether or not online courses improve student outcomes is an empirical question, and we estimate the impact of online education on course grades, credit accumulation, and ultimately degree attainment. To our knowledge, this paper is the first to look at the patterns in and effects of online course taking across a large, public four-year university setting,

[1] The Integrated Postsecondary Education Data System (IPEDS) defines distance education as any course for which all instructional content can be completed remotely although other elements such as exams or orientation may require in-person attendance.

suggesting that our findings can be generalized to broader contexts and point to areas where universities need to provide more robust supports to students in order for them to succeed.

On the one hand, it is easy to see how taking college courses online can be appealing to students who may face greater barriers to enrolling and/or persisting in higher education. Online options may make college more accessible for students who are relatively isolated, due to their geographic location or health concerns. Another population that might benefit from increased online course offerings (particularly asynchronous course content) is students who require more flexibility in their schedules, such as non-traditional college goers who have childcare responsibilities or who must work to support themselves or their families. Individuals who have left college before completion may also see online offerings as a way to reduce some of the barriers to re-enrolling in order to get the credits they need to attain their degree. Further, some research suggests that offering courses online can reduce the cost of higher education (Bowen, 2015; Deming, Goldin, Katz, & Yuchtman, 2015), which could result in lower tuition and fees in the long run making college more accessible to some students.

On the other hand, it is also possible that student outcomes are worse in an online environment if, for example, students have fewer connections with faculty and peers or if the instruction is of lower quality than it would be in the classroom. One common criticism students and families voiced during periods of pandemic-induced remote college instruction was that, without the typical day-to-day interactions of on-campus residential and academic life, the cost of college wasn't worth it. In fact, total college enrollment declined 6.6 percent between fall 2019 and fall 2021 at a time when the population of 16 to 24-year-olds was declining by only half a percent per year (National Student Clearinghouse Research Center, 2021). While some of the decline in enrollment may be due to a desire for a "real" college experience, some is also

likely due to personal hardships and/or labor market strength that has led to low unemployment rates and higher wage growth.

To understand better trends in online course taking, the types of students who engage in online education, and the impact on student outcomes, we use data from the University of North Carolina System (UNC System), which includes all four-year public institutions of higher education in the state. North Carolina provides an excellent case study for answering these questions given its rich longitudinal data and the diverse rural and urban settings across 16 campuses, including 5 historically Black colleges and universities (HBCUs). We find that the share of students taking any courses online and taking all courses online has increased considerably from 2012 to 2020. In the Fall of 2012, about 20 percent of students in the UNC System took at least one class online compared with nearly 40 percent in Fall 2019, with online courses being more popular than in-person courses in the summer terms. Student groups who are more likely to engage in online course taking include female students, Pell recipients, first-generation students, and students who are older on average.

We find that students are more likely to earn As in their online courses than their in-person courses (with mixed evidence about the effect on course failures), and overall GPA is higher in terms when students take at least one course online. Further, after accounting for selection, results on educational attainment are mixed - taking more courses online reduces the likelihood of graduating in four years but increases the likelihood of graduating in six years - though we note that the estimates are imprecise and not statistically different from zero. These findings suggest that there is room for improvement in terms of the support and academic advising offered to students who rely on online learning in order to ensure that they complete

graduation requirements, but ultimately the flexibility of online course taking has the potential to benefit the students who need itin the long run.

Our paper makes significant contributions to the literature. It is the first to look at the effects of online courses across a large public university system over a nearly 10-year period. The system itself is diverse on a number of dimensions, including rural and urban campuses, as well as campuses traditionally serving marginalized student populations. While existing research on the impact of taking a course online on performance is well identified, it is narrowly focused on specific individual courses. In contrast, we are able to look at student enrollment and performance in online coursework across their entire academic career. The longitudinal nature of the data allows us to look at student success in terms of degree completion, as well as performance in their courses, which is an important addition to the available research in this area. Findings from our paper, when taken with previous research, have implications for policy and practice as institutions of higher education, academic advisors, and faculty who teach courses online continue to navigate a new era in postsecondary education where students have come to expect high-quality online options.

II. Background

A. The Evolution of the Online Education Experience

Distance education is defined by IPEDS as education using technology to deliver instruction to students who are separated from the instructor. Historically, this meant correspondence courses that were largely self-paced and provided little direct interaction between teachers and students.[2] The development of and improvements in high-speed Internet

[2] Sleator (2010) notes that the origins of distance learning can be traced to a 1728 advertisement in the Boston Gazette for training in a "new method of short hand." Technological improvements to distance education over the years included the establishment of the postal service, live radio broadcasting, television broadcasting, and satellite transmission.

access mean that distance education today can instead provide synchronous learning experiences with real-time interaction between faculty and students in addition to hybrid, asynchronous, and self-paced options. At the beginning of our study period (Fall 2012), massive open online classes, or MOOCs, were rapidly gaining in popularity, and Time Magazine called 2012 the year of the MOOCs (Webley, 2012). These courses are available online for free and designed by faculty at well-known public and private 4-year institutions. During this era, some enthusiasts claimed that MOOCs could put traditional colleges and universities out of business (Shirky, 2013). However, these courses are not part of a degree program, making it difficult if not impossible to receive credit for these courses, and they have notoriously low completion rates (Jordan, 2015). During the same period, enrollment in for-profit colleges featuring online programs was already high; for example, the University of Phoenix Online enrolled over half a million students in 2009 (Deming, Goldin, & Katz, 2013).

Regardless of the context of online education, there was much public and academic discourse about how online education could transform the world of higher education in the early 2010s, and that is true for traditional public universities as well. Various survey reports of the importance of online learning as an institutional strategy provide evidence of the increased interest in online offerings at traditional institutions of higher education. In 2011, nearly 80 percent of high-level administrators at public universities reported that online education was "critical" to their long-term viability (compared to just over 50 percent at private universities) (Allen & Seaman, 2011). Over 60 percent of university CIOs reported online learning as a top priority in 2013 in the annual Campus Computing survey (Green, 2013). Demand for online courses offered at traditional colleges and universities was increasing as well, and it was becoming more typical for students to take at least one course online. In 2012, 21 percent of

undergraduates at public 4-year universities were enrolled in at least one distance education course, and that number gradually increased to 31.5 percent in 2019 with a spike up to 81.3 percent in 2020 due to the pandemic (U.S. Department of Education, 2020). Taken together, this evidence strongly suggests that everybody from high-level university administrators to students increasingly consider online education a typical part of the postsecondary education experience.

In this paper, we use UNC System administrative data from Fall 2012 through Spring 2020, the semester of the initial pandemic disruption. Even over this relatively short period, the online education experience at UNC campuses was evolving as technology changed and improved. We describe our understanding of how online learning changed based on our conversations with technology staff who have historical knowledge about online education offerings in the UNC System (R. Lucas, personal communication, August 16, 2022). In the early period of the data, students enrolled in online courses likely had one of two experiences. First, some online courses were structured such that they were akin to "correspondence courses" but with content available online rather than through mail. These courses were self-paced with students able to work through material based on their own schedules over the term. The content would have been static, consisting of a reading list and links to various websites, with assignments outlined in advance. Interaction with instructors was likely limited, and peer interaction was virtually nonexistent. The other type of online course available at that time was more similar to asynchronous courses offered today. Instructors shared content via recorded lectures, as well as readings and links to other sites or videos. Students typically engaged in online discussion boards and forums, and instructors set expectations regarding regular participation throughout the semester. Unlike the self-paced courses, assignments had due dates throughout the semester as in typical in-person classes. Over time, the asynchronous format

became more typical with the UNC System phasing out the self-paced courses entirely. More recently, online courses were increasingly offered in a synchronous format with students attending lectures and discussion "live" in a virtual format. In the post-pandemic years, online courses in the UNC System are a mix of asynchronous and synchronous formats, primarily determined by the course instructor. Unfortunately, the administrative data do not allow us to distinguish between these different types of online experiences.

B. Institutional Context

The context for this study is the UNC System, which includes all 16 four-year public higher-education institutions in the state of North Carolina, enrolling nearly 200,000 undergraduate students in Fall 2019 (UNC System, 2022). The UNC System also houses rich longitudinal administrative data from each of the campuses, which allow us to follow students over time during this period of expansion of online educational opportunities. In this section, we characterize the UNC System and its student population within the national landscape of public 4-year higher education institutions. Then, we describe the variability across institutions within the UNC System in terms of student characteristics, educational outcomes, and online course-taking patterns.

First, UNC System undergraduate enrollees generally have similar observable characteristics to undergraduate students enrolled in 4-year public institutions nationwide. Table 1 compares these two groups of undergraduate students. Over half, 57 percent, of undergraduate students at all public 4-year institutions and in the UNC System identify as female, and just over half of students in both groups identify as white. While 22 percent of UNC System undergraduates identify as Black, and another 8 percent as Hispanic, the national numbers are the reverse with 11 percent Black and 19 percent Hispanic. There is evidence that UNC System

students are slightly positively selected in that the 25th and 75th percentiles of SAT scores are about 20 points higher in math and reading. Ultimately, UNC System students also have better graduation outcomes than at all public 4-year institutions (50 percent of the 2014 cohort of first-time undergraduates graduated within four years compared to 42 percent nationally).

When compared to other public 4-year state institutions, UNC System undergraduates take online courses at a similar rate: just over one-third of undergraduates enrolled in at least one online course in 2019 nationally and in the UNC System. We also compare online enrollment with other large public state systems (California, Florida, and Texas) and a neighboring state with a highly-rated flagship public university (Virginia). Figure 1 Panel A shows the percentage of students who took no classes online, some classes online, and all classes online in Fall 2012 and Fall 2019 for these states. A few things are noteworthy. First, across all of these state systems, online enrollment increased over this period. For example, at state institutions in California, 26 percent of students enrolled in at least one online course in Fall 2019 compared with 15 percent of students in Fall 2012. Further, there is variation in the levels of student enrollment in online courses across states with nearly half (49 percent) of students at state universities in Florida taking at least one class online in Fall 2019. Relative to these public institutions in other states, student enrollment in North Carolina is typical.

The UNC System is also a useful context for examining trends in higher education because it is made up of a diverse set of colleges, including 5 HBCUs, as well as 1 historically American Indian university. (See Appendix Table 1 for institution-level characteristics.) There is considerable variability across institutions in North Carolina in terms of admission selectivity, student diversity, and completion rates. For example, UNC-Chapel Hill, the flagship campus, admits about 1 in 5 applicants and has a 4-year graduation rate of around 90 percent whereas

UNC-Charlotte admits two-thirds of its applicants and has roughly a 55 percent 4-year graduation rate. Further, the State of North Carolina is heterogeneous in terms of urbanicity with large metropolitan areas like Charlotte and the Research Triangle (Raleigh, Durham, and Chapel Hill) as well as much more rural and isolated regions.

Another important way that the UNC System institutions vary is in the prominence of online learning opportunities available to students. For UNC-Chapel Hill, online course offerings and programs are less commonly available. As of the 2022-23 academic year, there were no undergraduate programs offered fully online with the typical department only offering a handful of undergraduate courses online (if any). These limited offerings are consistent with what we calculate from the administrative data, making UNC-Chapel Hill one of the UNC System campuses with the lowest levels of enrollment in online education. At the other end of the spectrum, Fayetteville State University (FSU), a HBCU located about 60 miles south of Raleigh and Chapel Hill, offers 15 undergraduate degree programs that enrolled juniors and seniors can complete solely online. These programs are wide ranging, including computer science, history, and nursing. In addition, FSU offers many individual undergraduate courses online beyond those offered in these online programs, stating the need to increase access and affordability to its students. In fact, FSU was named by Best Value Schools as the Best Online College in North Carolina for its commitment to quality online education opportunities (FSU, 2018). In the administrative data, FSU has the highest levels of undergraduate enrollment in online courses across all UNC System institutions.[3]

C. Research on the Effects of Online Education

[3] We find a negative correlation between the 75th percentile of an institution's SAT score and the share of students enrolling in online courses (corr = -0.760), though there is no relationship between the undergraduate admission rate and the share of students enrolling in online courses (corr = 0.022).

Online courses offer more flexibility for students, as some or all of the content may be delivered asynchronously, and, at a minimum, students do not have to commute to and from campus to attend class. There may also be financial implications for students to the extent that hours attended online are less expensive in tuition and/or fees than hours attended in person. We are just learning about how online programs can increase access to education. A recent paper about an online masters degree in computer science at a highly regarded institution suggests that offering the program online extended the opportunity to students who otherwise would not have enrolled (Goodman, Melkers, & Pallais, 2019). But whether taking courses online results in similar levels of course performance as in face-to-face courses and, ultimately, increases a student's likelihood of completing college are empirical questions that we explore in this paper.

Prior research about the effectiveness of online courses tends to fall into two areas: 1) two-year and community college settings and 2) individual courses at specific institutions. In 2-year settings, researchers using data from the community college system in Washington State document that all students had lower grades in online courses, but the largest declines were among male students, younger students, Black students, and students with lower grade point averages (Xu & Jaggars, 2014). Causal evidence from the same setting attributes these lower grades to the online course modality with additional evidence that students who take courses online are less likely to complete those courses than peers taking courses in person (Xu & Jaggars, 2013). Evidence from the California community college system supports these claims, showing that students who take a course online have worse grades than students who take the same courses in person (Hart, Friedmann, & Hill, 2018). Because many students at two-year institutions do not complete their degrees or transfer to 4-year institutions, the fact that students who take courses online are less likely to complete those courses and, if they do complete,

perform more poorly than students taking courses in person is concerning. The evidence suggests that community college students who take courses online may need more support and outreach from faculty in order to be successful.

Other papers estimating the effects of online education compare the performance of students who, typically, were randomly assigned to take a single course online or in person (or hybrid in some cases). Most of these experiments indicate that students who are assigned to online courses fare slightly worse in terms of end-of-course exam grades than students assigned to take the course in person (Figlio, Rush, & Yin, 2013; Coates, Humphreys, Kane, & Vachris, 2004; Brown & Liedholm, 2002; Alpert, Couch, & Harmon, 2016). In one case, students were randomly assigned to a hybrid section or in-person section of the course, and their outcomes were similar, though no students were completely online (Bowen, Chingos, Lack, & Nygren, 2014). These papers also point to some students who likely need more support in online courses: students who have low GPAs upon entering online courses (Figlio et al., 2013) and students who are in their first two years of college (Coates et al., 2004). We note that in many of these cases the online instruction component may feel a lot different to students who are taking online classes today, as the settings in some of these papers would have featured less-modern technology at a time when Internet usage was first expanding. For example, the "treatment" often consisted of watching recorded or live-streamed lectures, so the experiences were likely more akin to asynchronous instruction without the instructional design elements targeted to online learners. Further, many of these courses were in statistics or economics departments, which may be less interactive than other college courses. We do not know if these findings generalize more broadly to other types of courses.

Finally, the closest paper to ours in terms of methodology but very different in setting looks at a university in the for-profit sector that has approximately 100 campuses and offers a mix of online and in-person programming (Bettinger et al., 2017). The authors apply an instrumental variables approach, instrumenting for online course taking with the interaction of the distance between a student's home and nearest campus and whether a course is offered online in a given term. Using this approach, they find that online course taking negatively affects student performance in the current course and in subsequent courses and the student's likelihood of completing their program.

III. Data and Sample Description

Through a data sharing agreement with the UNC System, we have access to longitudinal administrative data for applicants and enrollees from Fall 2012 to Summer 2020. Each student has a unique identifier that allows us to link records over time and across datasets. For this paper, we merge data across four types of records–application data, career data, transcript data, and completion data.[4]

- *Application data* contain background information about students prior to entering college, such as high school performance (SAT scores and GPA) and permanent residence.
- *Career data* contain background information including student gender, age, race, citizenship, original enrollment status (new student, new transfer student, etc.), declared major, and matriculation term.

[4] See Appendix A for a more detailed description of our data construction.

- *Transcript data* include all courses students enroll in during a given term, the modality of the course (online, face-to-face, or hybrid), the institution, and the grade and credits earned. For each course, we also have the department, number, and section.
- *Completion data* include any degrees or certificates the student earns at what institution and in what term. For this study we focus only on Bachelor's degree completion.

Table 2 shows descriptive statistics for the samples of students analyzed in this paper. Column (1) is based on cross sections of undergraduate students enrolled from Fall 2012 through Summer 2020. We use course-level and term-level data for these students in analyzing grade outcomes.[5] Columns (2) and (3) are samples used for analyzing Bachelor's degree completion within four years (column 2) or within six years (column 3). In both cases, we limit the completion samples to cohorts of new students who first enroll in Fall 2012 or later. We further limit the four-year completion sample to students who first enroll prior to Fall 2017 in order to have observed the students for at least four years since first-time enrollment. Similarly, the six-year completion sample needs to have enrolled prior to Fall 2015.

Consistent with postsecondary enrollment nationwide, UNC System undergraduate students are disproportionately female (57 percent). The majority of students are white (59 percent), 22 percent of students are Black, and fewer than 10 percent of students are Latinx. The average age of enrolled students is around 22 years old. Based on the application data which are only available for 56 percent of the column (1) sample, the average student scored 1114 on the SAT and earned a 3.77 grade point average (GPA) in high school. While the completion cohorts of first-time undergraduate enrolles are quite similar to the cross-section sample in terms of sex and race, they tend to be younger on average (19 versus 22 years of age). We believe these

[5] The only difference between the grades sample and all enrolled undergraduate students in the UNC System is that 892 students enroll at some point in the period but never have course grades.

differences are likely due to the construction of the samples. For example, students who transfer into the UNC system from a community college would not be included in our completion samples.

IV. The Landscape of Online Coursetaking

A. Online Course Enrollment by Department

Next we examine the extent to which online course taking varies across departments. We group courses by classification of instructional programs (CIP) into STEM subjects (physical sciences, biological and biomedical sciences, mathematics and statistics, engineering, and computer and information sciences and support services); fine arts and humanities; social science; business and marketing; education; health professions; and other. In Table 4 we report the percentage of course enrollments that are online for each subject area for academic years 2012-13 and 2018-19 (Fall and Spring semesters), summer 2013, and summer 2019.

Across all of the major subject categories, education and the health professions rank among the top in terms of online course enrollment during the academic year. In 2018-19, 27 percent of course enrollments in the health professions were online, up from 15 percent in 2012-13. Similarly, the percentage of education course enrollment online increased from 16 to 24 percent over this same period. In contrast, online enrollment is less common in most of the STEM fields with the percentage of enrollment in online courses ranging from 3 percent in the physical sciences to 15 percent in computer sciences and IT during the 2018-19 academic year. Across all subject categories, online enrollment is much more common during the summer terms. Upper division undergraduate courses made up a disproportionate share of online enrollment in business, education, and health in 2018-19 whereas online enrollment in other subject areas was primarily in lower division courses.

B. Online Course Enrollment by Students

Because online courses offer students more flexibility, we hypothesize that students who are most likely to enroll in online courses are those who perceive that they will benefit from taking courses in that modality. Perhaps these students have more responsibilities outside of the classroom, such as non-traditional college goers who may be older and have family obligations, or students who are employed or must support themselves financially. Therefore, we begin by conducting descriptive analyses for cross sections of UNC System undergraduate students, showing changes in online course taking over time, as well as differences in engagement with online courses for student groups (e.g., female and male students). These descriptive analyses and patterns set the stage for understanding the impact of the expansion of online course offerings on student outcomes (presented in Section V).

We begin our analysis with figures showing the extent to which students enrolled in online courses for each term over our sample period. Figure 2 shows the percentage of students who took all, some, or no courses online during academic year terms (Panel A) from Fall 2012 to Spring 2020 (the initial modality of the course at the beginning of the semester before the pandemic) and summer terms (Panel B) from Summer 2012 through Summer 2020 (when the whole System was online due to the pandemic). Overall, engagement with online courses has increased pretty steadily over the period with online courses consistently more popular in the summer than during the academic year. The blue portion of the figures represents students who took all of their courses online, and the orange portion students who took some but not all courses online. In Fall 2012, 5 percent of students took all of their courses online and 17 percent took some of their courses online. By Fall 2019, those numbers were 9 and 28 percent, respectively. Online course taking also increased over the summer terms from 29 percent of

students taking all classes online in Summer 2012 to 53 percent in Summer 2019. Figure 3 also shows the distribution of the share of hours a student takes online over the course of their career in the UNC System (conditional on taking some but not all hours online). The bulk of students (53 percent) are taking an average of less than one course per term online (20 percent of a full-time credit load) while 12 percent are taking an average of more than one course online every term.

Over the course of their undergraduate career, roughly two-thirds of students take at least some credit hours online and the timing of when a student takes their first course online is fairly uniform. Figure 4 presents a histogram of the semester number in which a student enrolls in their first online course (restricted to semesters during the academic year). Most are enrolling in their first online course within the first 10 semesters of enrollment, but the distribution is fairly flat across semesters one through nine.

We now turn to describing the students who engage in online courses to different degrees. Table 3 shows descriptive statistics for students based on the cumulative share of credits taken online during their entire enrollment at UNC. Column (1) includes the 31 percent of students who take no credits online; column (2) includes the 54 percent students who take some credits but less than 20 percent of their credits online; column (3) includes the 13 percent of students who take at least 20 percent but not all of their credits online; and column (4) includes the 3 percent of students who take all of their credits online.

Female students are more likely than male students to take any (or all) credits online, while male students are overrepresented among students who take no courses online. The patterns across student race/ethnicity are less clear. We note that students taking all courses online are quite different from the other groups on several dimensions. This relatively small

group of students shown in column (4) are older, an average age of 28 years compared to under 20 years old for the other groups. Most notably, however, students taking all of their courses online have very low four-year and six-year completion rates of around 12 percent.

Focusing on students who take some but not all courses online (comparing the column (2) and column (3) samples), students who take a higher share of credits online are more likely to be female and more likely to be Black. These students taking a higher share of credits online also have lower completion rates than their peers taking some but not all of their credits online–a six-year graduation rate of 48 percent compared with 63 percent for the column (2) sample. However, the students who take no classes online have an even lower six-year completion rate of 32 percent.

V. Effects of Online Education on Student Outcomes

A. Estimation Strategy

As previously discussed, much of the existing literature on the effects of online courses relies on the random assignment of students to take a section of (typically) a single course online or in person. That research provides unbiased estimators of the effect of taking that single course online relative to in person. However, that experimental design is very different from how students approach taking a mix of online and in-person courses that they perceive will optimize their likelihood of graduating from college or attaining other future outcomes. Further, it is difficult to generalize from the course-specific experiment findings to the effects of online education across a wide range of courses or on educational attainment outcomes in the long run.

In order to estimate the impact of increases in availability of courses online to undergraduate students on the likelihood of completing college, we imagine a different experiment. During this period of rapid technological change and growth in the online sector at

traditional colleges and universities, students were exposed to different online options based on factors like their institution of enrollment, online course availability in their particular major or department, and their initial term of entry. For example, students in earlier cohorts had fewer options for mixing online and in-person course offerings. An ideal experiment, then, might rely on randomization of students within an institution to take a lower or higher share of courses online and then compare the performance and attainment outcomes of students with different levels of exposure to online course options. This comparison of outcomes would result in an unbiased estimation of the impact of the exposure to different levels of online courses on student outcomes. While such an experiment is impossible to implement, we propose a quasi-experimental instrumental variables strategy to use changes in the availability of online courses across different departments and over time within the same university to estimate the impact of online learning on outcomes. In other words, we compare the outcomes of observably similar students at the same institution who - because of their initial major choice or term of entry - experience different levels of online learning options.

In this section, we describe our estimation strategy for estimating the effects of online education on a variety of outcomes in more detail, as well as the corresponding results. The student outcomes we observe in the data vary at different levels. For example, a student's course grades vary within student and term across their classes, but educational attainment outcomes are only observed one time per student. For this reason, we take slightly different approaches to estimating the effect of online education on these various outcomes. (These outcomes, how the treatment of online education is measured, and estimation approaches are summarized in Appendix Table 2.)

1. *Effects on Course Performance.*

We begin by estimating a number of linear probability models with different fixed effect controls. Specifically, we estimate models of the form:

$$(1)\ Grade_{icput} = \alpha + \delta Online_{cput} + \phi_u + \phi_t + \varepsilon_{icput},$$

where *Grade* is an indicator for whether student *i* withdrew or received a particular grade (i.e., A, F) in course *c* with professor *p* at university *u* in term *t*, and $Online_{cput}$ is an indicator that the course mode was online. The ϕ_u and ϕ_t represent university and term fixed effects, and ε_{icput} is the error term. The coefficient of interest is δ, which reflects the associated change in the probability of withdrawing or receiving an A (or F) in an online course relative to a face-to-face course. To this baseline estimate, we can add student fixed effects, ϕ_i, course fixed effects, ϕ_c, or professor fixed effects, ϕ_p. Student fixed effects use within-student variation to compare performance in online and in-person courses taken by the same student. Course fixed effects use within-course variation, comparing performance of students who take the course online to students who take the course in person. Finally, professor fixed effects compare the performance of students who had online instruction versus in-person instruction with the same professor.

We also consider students' overall GPA in a given term as an outcome, which varies by student across terms but no longer within a term. To account for this change, we estimate models with student fixed effects but not course or professor fixed effects. Specifically, the base model is shown in equation (2):

$$(2)\ GPA_{iut} = \alpha + \delta AnyOnline_{iut} + \phi_u + \phi_t + \varepsilon_{iut},$$

Where we model term GPA for student *i* at university *u* in term *t* as a function of whether that student took any online classes in that term, university fixed effects, term fixed effects, and an error term. Additionally, we specify the base model including student fixed effects, ϕ_i,

comparing term performance in terms where a student takes any of their classes online to terms where the same student takes no classes online.

These various fixed effects approaches have different benefits in terms of estimation, but there are still concerns about selection. For example, while student fixed effects account for time-invariant unobserved attributes of the student, a student likely applies some strategy when choosing which classes to take online versus in person, introducing selection. To supplement the fixed effects estimates, we also pursue an instrumental variables strategy to estimate the causal relationship between online course taking and student outcomes. To instrument for students' engagement in online courses, we use variations of the share of courses available online at their institution during a specific term. Across all institutions over this period, online course offerings increased so that students in earlier cohorts had fewer opportunities to take online courses than students in more recent cohorts. Arguably, changes in online course offerings within each institution and over time generate exogenous variation that induces some students to enroll in online courses who might otherwise not due to the sheer availability of the course online. Our assumption is that a student who is enrolled at a campus during a term with more classes offered online will be more likely to enroll in an online class than at an institution or a term when there are fewer online courses available.

To interpret the IV estimates as causal, we have to make some assumptions. First, the share of courses offered online must induce students to take classes online. While we cannot test that directly, we provide evidence of the strong relationship between these two things. Figure 5 is a scatterplot of the share of courses offered online at an institution in a student's first term of enrollment and the share of courses that student takes online, showing the strong and positive correlation between the instrument and the treatment. For each IV regression, we also show the

first-stage F-statistic, which is always quite large. Second, the IV must satisfy the exclusion restriction, such that the availability of online courses only influences student course outcomes via their decision to take courses online or not, but the availability of online courses should not directly affect a students course outcome. Finally, decisions to offer specific courses online are typically made independently by each department and then approved by each campus's provost, so the process is not transparent or known to students.

We implement the following two-stage least squares (2SLS) approach with the first- and second-stage equations, (3) and (4), shown below:

$$(3)\ TakeOnline_{icdut} = \alpha + \gamma ShareOnline_{dut} + X_i'\beta + \phi_u + \varepsilon_{icdut}$$

$$(4)\ Performance_{icdut} = \alpha + \delta \widehat{TakeOnline}_{icdut} + X_i'\beta + \phi_u + \varepsilon_{icdut}$$

In the first stage, we predict $TakeOnline$, whether student *i* took course *c* online in department *d* at university *u* in term *t* as a function of student characteristics (sex, race, SAT scores, high school GPA), institution FEs, and the instrumental variable $ShareOnline_{dut}$, the share of courses offered online in that department at the university in the same term. The instrument varies within individuals in a given term due to variation in the share of courses offered online in different departments and over time. The second stage outcomes are about student course performance: whether student *i* withdrew from the class, whether student *i* received an A in the class, or whether student *i* failed the class. Course performance is a function of the instrumented $TakeOnline$ variable, as well as the control variables used in the first stage.

To identify the effects of online education on overall GPA in the term, we implement the following two-stage least squares (2SLS) approach with the first- and second-stage equations, (5) and (6), shown below:

$$(5)\ AnyOnline_{iut} = \alpha + \gamma ShareOnline_{ut} + X_i'\beta + \phi_u + \varepsilon_{iut}$$

$$(6)\ GPA_{iut} = \alpha + \delta \widehat{AnyOnline}_{iut} + X_i'\beta + \phi_u + \varepsilon_{iut}$$

In the first stage, we predict $AnyOnline$, whether student *i* took at least one course online at university *u* in term *t* as a function of student characteristics, university FEs, and the instrumental variable $ShareOnline_{ut}$, the share of courses offered online in the university in the term. The instrument varies within individuals across terms due to variation in the share of courses offered online at different institutions over time. The second stage outcome is the term GPA for student *i* in term *t*.

2. *Effects on Educational Attainment.*

Because we only observe educational attainment outcomes once for each student, we no longer have repeated observations within student. The treatment is now the share of credit hours a student attempts online. The descriptive OLS regression is shown in equation (7):

$$(7)\ Attainment_i = \alpha + \delta ShareOnline_i + X_i'\beta + \phi_u + \phi_f + \varepsilon_{iuf},$$

where *Attainment* for student *i* who first enrolled at university *u* in year of first entry f represents total terms enrolled, total hours attempted, or degree attainment (in 4 or 6 years). We model these outcomes as a function of the share of the student's hours that they took online over the course of their enrollment in the UNC System, and we control for a vector of student characteristics, X_i, including academic performance in high school (GPA and SAT scores) and student demographics. The model also includes university and year-of-entry fixed effects, ϕ_u and ϕ_f; ε_{iuf} represents the error term.

The 2SLS models for completion are the following:

$$(8)\ TakenOnline_i = \alpha + \gamma OfferedOnline_{muy} + X_i'\beta + \phi_y + \phi_u + \varepsilon_{imuy}$$

$$(9)\ Attainment_i = \alpha + \delta \widehat{TakenOnline}_i + X_i'\beta + \phi_y + \phi_u + \varepsilon_{iu}$$

The first stage predicts $TakenOnline$, the share of hours student *i* took online in their entire UNC System enrollment with $OfferedOnline_{muy}$, which is now the share of courses offered online at university *u* in the term of the student's matriculation, *y*, in their major, *m*, at first enrollment. Also included in the model are a vector of student characteristics, cohort fixed effects, *y*, and university fixed effects *u*. The attainment outcomes and covariates are described above.

B. Student Performance

We begin by examining the relationship between course modality and student performance in the course. Figure 6 Panel A shows the distribution of course-level grades by course modality. The distribution of grades in online and in-person courses are generally similar with students relatively unlikely to withdraw (around 5 percent) and more likely to do well in classes than poorly. However, about 55 percent of grades in online courses are As relative to 48 percent of grades in in-person courses. This could be because instructors of online courses are more likely to give As than in in-person classes, or that expectations vary across these modalities. The difference could also be because students in online courses benefit from the added flexibility and are better able to meet deadlines or allocate time more effectively. At the same time, though, online course grades are more likely to be Fs than in-person course grades. Course failures, while somewhat rare, are about 50 percent higher in online courses than in-person courses, suggesting students may need additional support with these classes to succeed academically. The difference in withdrawal rates between online and in-person courses is only 1 percentage point. Figure 6 Panel B shows the distributions of term GPA separately for students who do not take any courses online and for students who take at least one course online in the

term. Term GPAs are similar for students who are taking at least one course online and students who are not taking any courses online; however, students taking at least one course online are somewhat more likely to have an A-average for the term

These unadjusted grade distributions are informative, but they do not account for any selection into which courses a student chooses to take online or which students are taking online courses at all. The fixed effects and IV estimates are shown in Table 5 with outcome variable means for in-person courses in Column (1). Column (2) shows the difference in grades in online and in-person courses after adjusting for university and term fixed effects, indicating that students are 1 percentage point more likely to withdraw from an online than in-person course, nearly a 50 percent increase in the likelihood of withdrawing. Conditional on completing the course, we estimate that students are 4 percentage points more likely to receive an A in online courses but also 2 percentage points more likely to fail an online course. Column (3) adds student fixed effects as well, so the comparison variation used in these models is outcomes for online and in-person courses within a student, accounting for time-invariant characteristics like ability and intrinsic motivation. Here, we find that individual students remain about 1 percentage point more likely to withdraw from their online courses relative to their in-person courses. Conditional on completing, they are 2 percentage points more likely to earn As in their online courses than in-person courses but also 2 percentage points more likely to fail their online courses relative to their in-person courses. In columns (3) and (4), we control for course fixed effects or instructor fixed effects, respectively. The course fixed effects estimates compare the performance of students who take the same course online or in person, while instructor fixed effects compare grades given by the same instructor across modalities. Once again, we find a 1.5 to 2 percentage point increase in the likelihood that a student withdraws from an online course

relative to an in-person course and a 3-percentage point increase in the likelihood of failure in online courses, but these models also suggest grades are less likely to be As in online than in-person courses. Finally, column (5) shows the IV estimates which rely on the variation in the share of courses offered online in a department to induce students to take online courses. Here, we find that students are about 1.5 percentage points less likely to withdraw from online courses and the effects on earning an A or an F are large in magnitude. The effect of taking a class online on the probability that a student earns an A is 0.244, while the IV results suggest that students taking a course online are 3 percentage points less likely to fail.

The estimated effects on students' term GPAs essentially aggregate up the effects of online course taking into a net effect of online course taking on grades. Both the baseline and student fixed effects estimates in columns (2) and (3) indicate that students earn higher term-level GPAs in semesters in which they take at least one course online, by 0.02 grade points from the student fixed effects estimate. The estimated effect of online course taking on term GPA is much larger in the IV model: taking at least one course online in a semester raises a students term GPA in that semester by nearly 0.4 grade points.

C. Educational Attainment

We now consider how online education relates to educational attainment outcomes, a new contribution to the literature. For these analyses, we follow cohorts of first-time enrollees in the UNC System. The number of cohorts included in our analysis depends on the time horizon of the outcomes: total academic year terms enrolled, total hours attempted, and attains a degree in 4 (or 6) years. For graduation within six years, we are limited to the three earliest cohorts that have at least six years of data after their term of first enrollment. For the other outcomes, we use data from five cohorts of first-time enrollees.

Figure 7 shows the relationship between our educational attainment outcomes and the share of credit hours attempted online for students who take a mix of in-person and online courses over their career. As shown in Figure 2, most students who take courses online tend to take 40 percent or fewer of their hours online. Notably, regardless of the outcome, there is a strong and negative relationship between the share of hours a student takes online and their likelihood of completing college in four or six years, total academic-year terms enrolled, and cumulative credit hours attempted.

For all models, we note that the estimated treatment effect has a different interpretation than for the course- and term-level outcomes. Because the treatment is measured as the share of hours a student takes online, the estimated coefficient represents the effect of going from taking no classes online to taking all classes online. However, we do not believe that is realistically how many students approach enrolling in online courses. The standard deviation for percent of hours taken online is roughly 0.2 which would be similar to a student taking one (or one more) online course per academic year. We describe the results in terms of a one standard deviation increase in the share of courses taken online.

Table 6 shows the results for the impact of online course taking on educational attainment outcomes. Looking at terms enrolled and credits attempted, students who took a mix of in-person and online courses enroll for 7.7 terms and attempt nearly 118 credit hours over the course of their enrollment (column 1). For context, undergraduate students typically need at least 120 credit hours for a Bachelor's degree. When we include controls for student characteristics in column (3), we estimate that a one standard deviation increase in the share of hours taken online increases the number of terms enrolled by 0.22 and the number of credits attempted by 4.4, roughly one course. Looking at degree attainment, 65 percent of students who took any classes

online during their period of enrollment graduated in four years, and 80 percent of students who took any classes online graduated within six years. The column (3) estimates indicate that students who increase their online course enrollment by one standard deviation are about 2 percentage points less likely to graduate within four or six years.

The IV results shown in column (4) are imprecisely estimated and, therefore, not statistically significant. They do suggest that increases in online enrollment decrease the likelihood of attaining a college degree within four years and increase the likelihood of completing within six years. A 0.2 increase in the share of courses taken online decreases the likelihood of graduating within four years by 8 percentage points and increases the probability of graduating within six years by 11 percentage points. These results suggest that online course taking may slow down students' educational careers even though course outcomes indicate that online course taking reduces the likelihood of withdrawing from a course and improves grades.

VI. Discussion and Implications

Online education at public institutions, and the increased flexibility that goes along with it, has the potential to address equity issues around who can participate in higher education. Students who may benefit most from the expansion of online options are likely college students who have responsibilities in terms of employment or caretaking demands. However, there may be tradeoffs to the extent that online courses do not provide the same rigor or quality of instruction as in-person courses, especially if it is easier to disconnect from or go unnoticed or unsupported in online courses than in-person courses. This paper is the first that we know of to investigate the patterns in and impacts of online education across a large public 4-year university system. The findings provide insights and suggest areas for further exploration, in terms of the tradeoffs of increasing online education offerings in the higher education space.

First and foremost, there is high demand for online courses as evidenced by the nearly 40 and 60 percent of UNC System students who took at least one course online in Fall and Summer 2019, respectively, rates very similar to national numbers at 4-year public institutions. We suspect that online enrollment in higher education will be even more prevalent in the post-pandemic era, as students have become accustomed to the availability of online courses and what learning looks like in that environment. Online courses cannot work in all cases, or are certainly less than ideal, so it does not make sense for all classes to be available online. But it is clear that online courses are here to stay. Our findings suggest that students are actually more likely to do better overall in terms when they take at least one of their classes online. This finding suggests that online classes allow students to reoptimize their efforts across all of their courses during the term, resulting in better grades.

College faculty members across the country were unexpectedly and abruptly thrown into the online environment in Spring 2020. At that time, the easiest thing for faculty to do was likely to conduct class online as if it was still in person. However, teaching online in an effective manner looks very different from in-person instruction. And prior to the pandemic, faculty generally resisted teaching online, citing weakened relationships with their students when compared to traditional in-person courses (Bacow, Bowen, Guthrie, Lack, and Long 2012). Faculty can certainly use support around how to maximize the use of technology to facilitate instruction and interactions with and between students. For instance, UNC Chapel Hill provided faculty members with training in Summer 2020 to transition their in-person course materials to the online environment. The training focused on developing course websites and communicating with students, but it did not address the large pedagogical differences in teaching across the two modalities. There is certainly room for improvement to make sure that courses offered online are

explicitly designed for that modality with careful thought about how to create opportunities for genuine interaction between the instructor and students and among students.

Student experiences and performance in their online courses are a stepping stone to the ultimate goal of degree attainment. We know that students who take online courses at higher rates are the types of students who may face more challenges to completing college due to the need for employment or other barriers students may face. The evidence presented in this paper suggests that students who take higher shares of courses online are similarly likely to graduate from college in six years relative to students who take fewer online courses. Though we are limited in that our estimates are imprecise, and this is an area that could benefit from more research to get a more complete understanding of how online learning impacts educational attainment.

We also need more research to understand the role of online learning in helping non-traditional students complete college. This paper is based on more traditional undergraduate students. It is easy to imagine that online options would lower some of the barriers for students with non-continuous enrollment to reengage and complete the courses they need to attain their diploma. Non-traditional students may have additional needs such as access to technology, quiet spaces appropriate for engaging in online coursework, and high-speed Internet access that need to be addressed and given policy consideration. Even with the ability to participate in coursework online, these students may continue to benefit from wraparound services like access to childcare and counseling supports. This is an area of research we plan to pursue in the near future.

Finally, we want to address the fact that our paper uses pre-pandemic data and acknowledge that our world is forever changed. Certainly, research should investigate the

impacts of the transition to online education and the disruption to the academic lives of students. During the two to three academic years that were severely affected by the pandemic, students were facing heightened stress and trauma in their personal lives, and instructors generally implemented more flexible and lenient grading policies to account for widespread hardships in students' personal lives. As we approach a new normal, we hope that many of these stressors are largely eliminated. We think that the findings in this paper may be more generalizable as we enter the post-pandemic era of higher education. We can apply lessons from this research to target students who both need access to online education but also need support to thrive in that environment.

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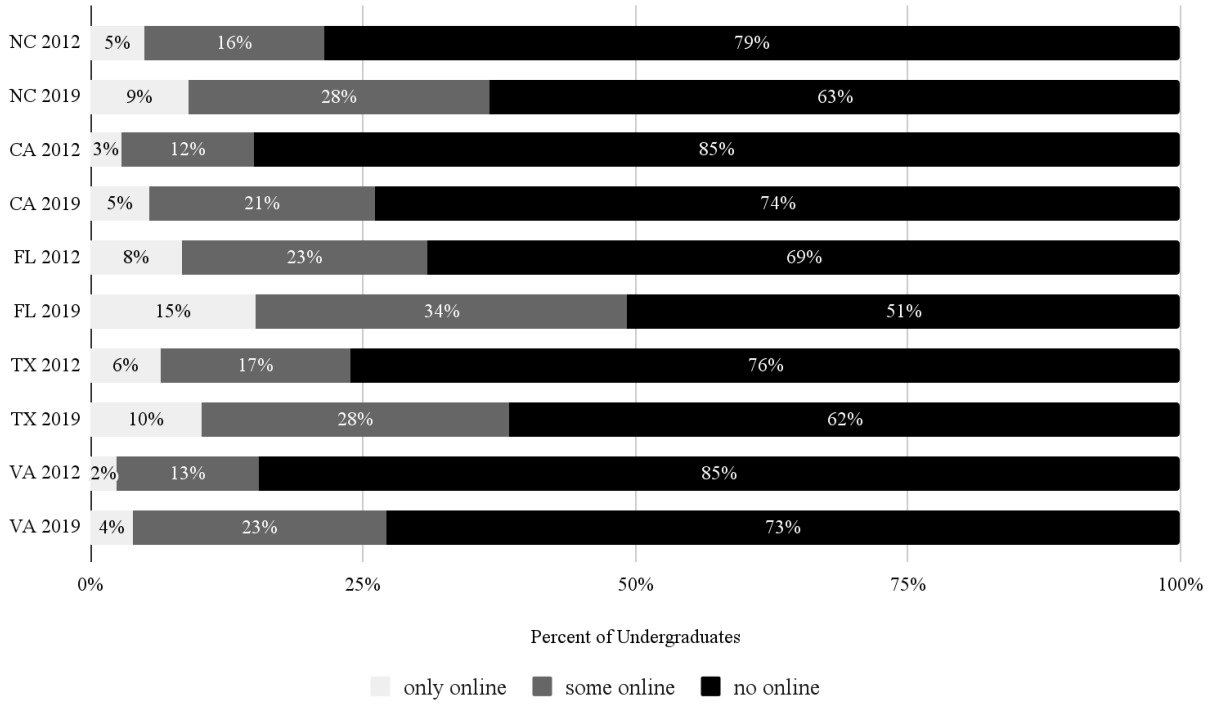
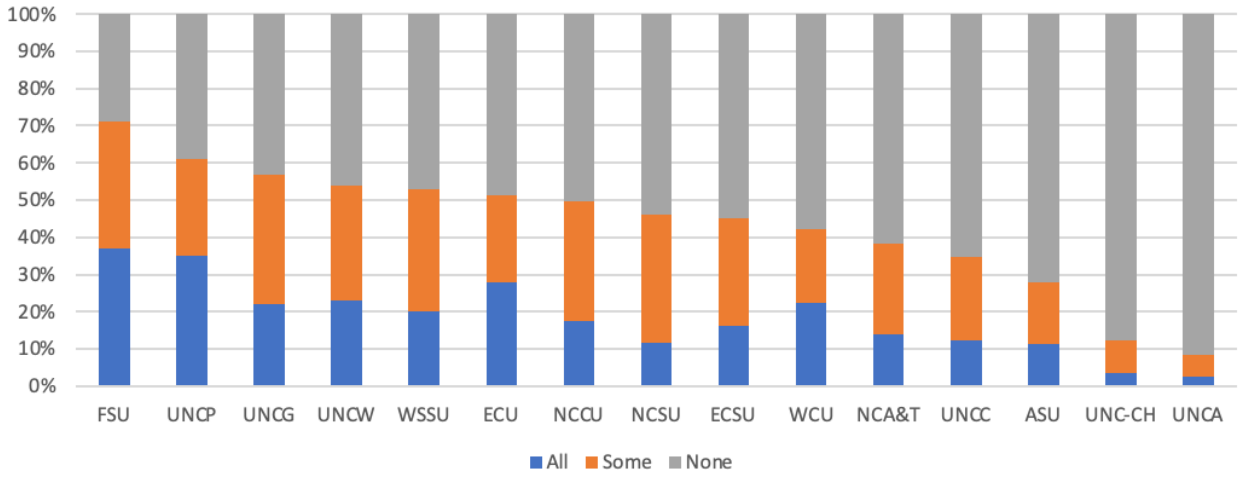
Figures and Tables

Figure 1. Variability in undergraduate online enrollment

Panel A. Percent of students by online enrollment across states and over time



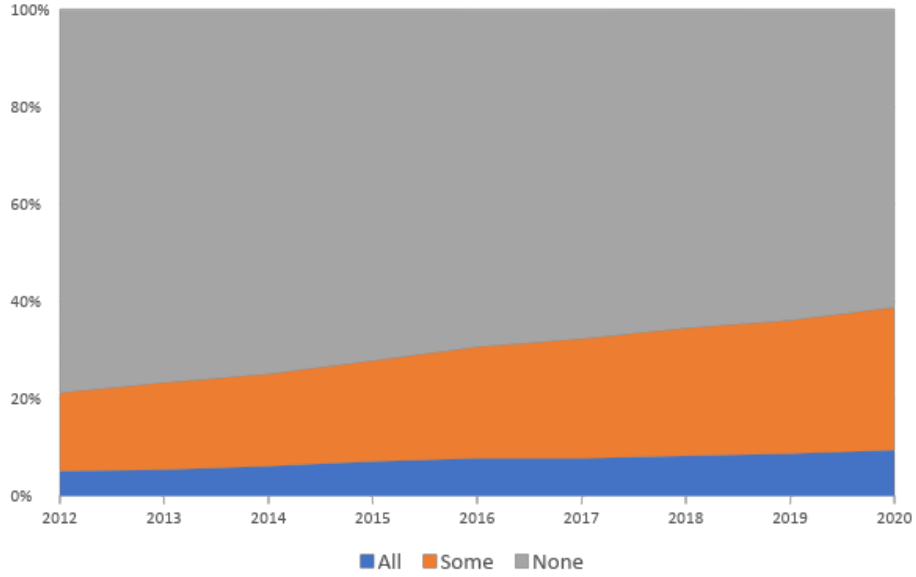
Panel B. Percent of students by online enrollment across UNC System institutions (2019)



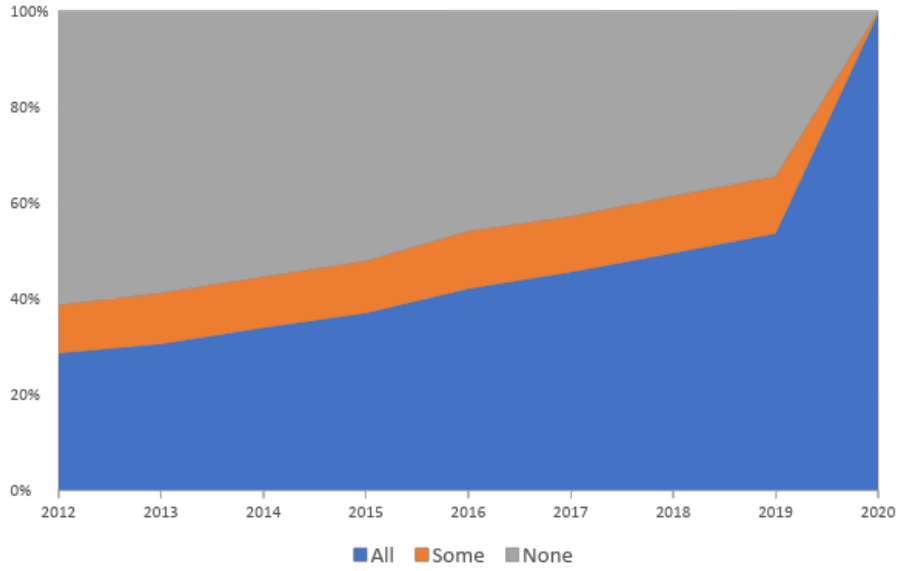
Notes. Panel A is based on authors' calculations of IPEDS data. Institutions included for each state are 4-year, degree-granting public universities. Panel B is constructed from the UNC System administrative data for the Fall 2019 semester.

Figure 2. Percent of UNC System undergraduate students taking online courses over time

Panel A. Academic year terms

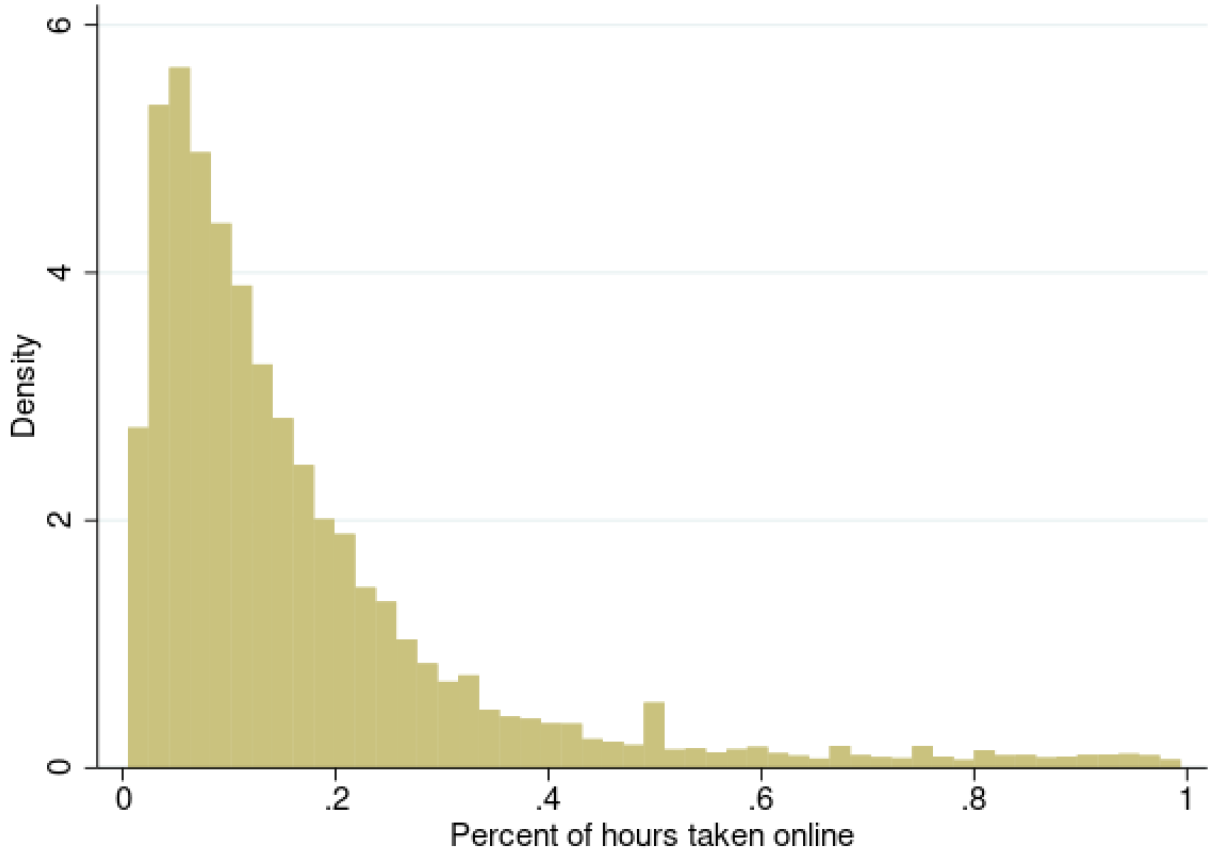


Panel B. Summer terms



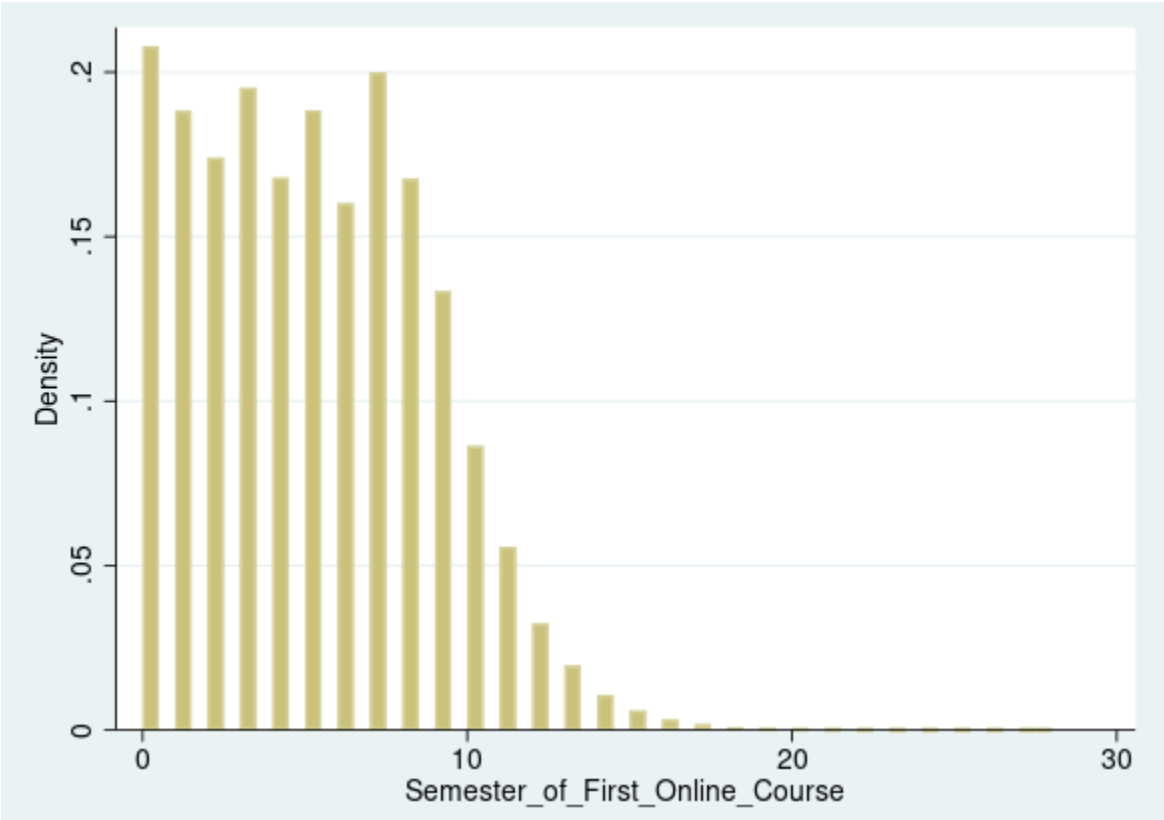
Notes. Authors' calculations based on UNC System administrative data. The percentage of students enrolled in any online courses during academic year terms increased from 21.2 percent in 2012 to 38.7 percent in 2020 (prior to the pandemic disruption) and during the summer terms from 38.7 percent in 2012 to 65.6 in 2019 (and 99.9 percent during summer 2020).

Figure 3. The distribution of the share of hours taken online over a UNC System undergraduate student's career



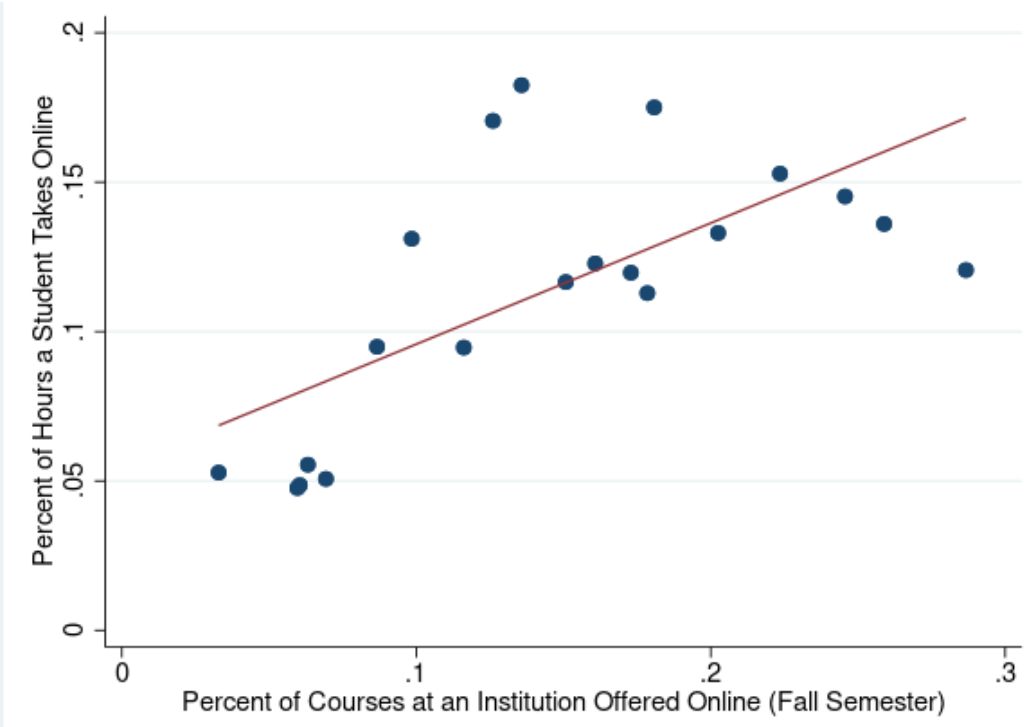
Notes. This figure is constructed conditional on students taking a mix of online and face-to-face courses. Not included are the 31 percent of students who took no courses online and the 10 percent of students who took all of their courses online. Data shown are for students in the 4-year completion sample.

Figure 4. Distribution of the semester of a UNC System undergraduate student's first online course



Notes. The data shown are restricted to academic year terms for students in the 4-year completion analytic sample.

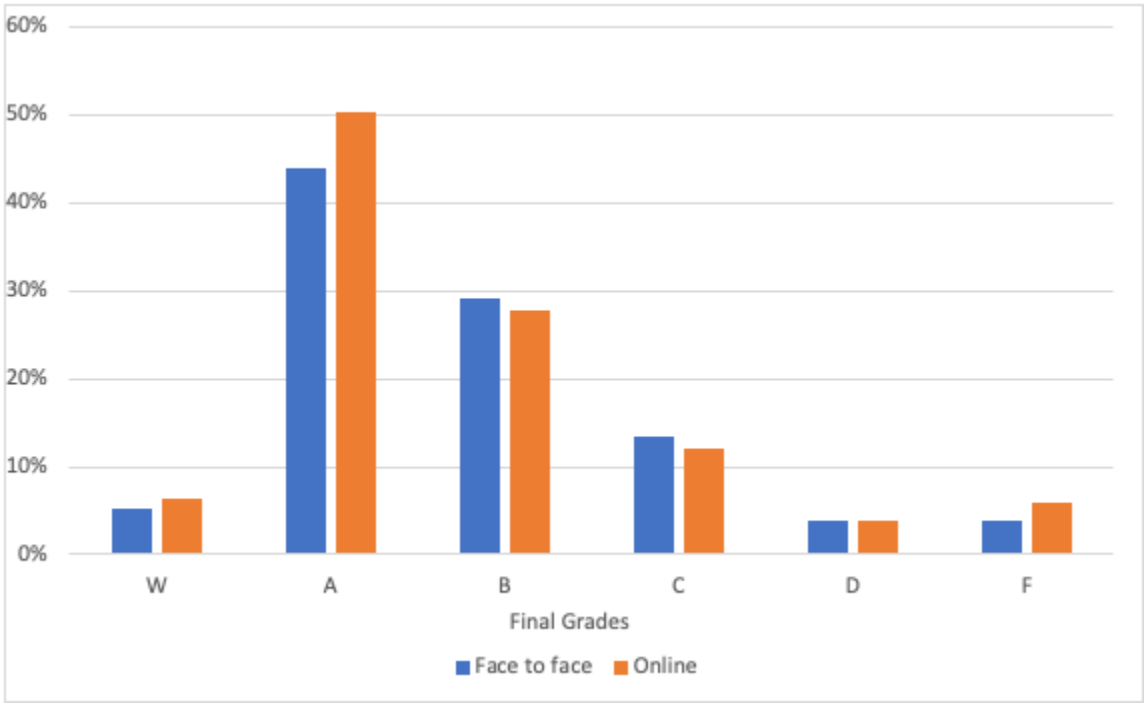
Figure 5. Scatterplot of share of courses offered online in first term and share of courses the student takes online



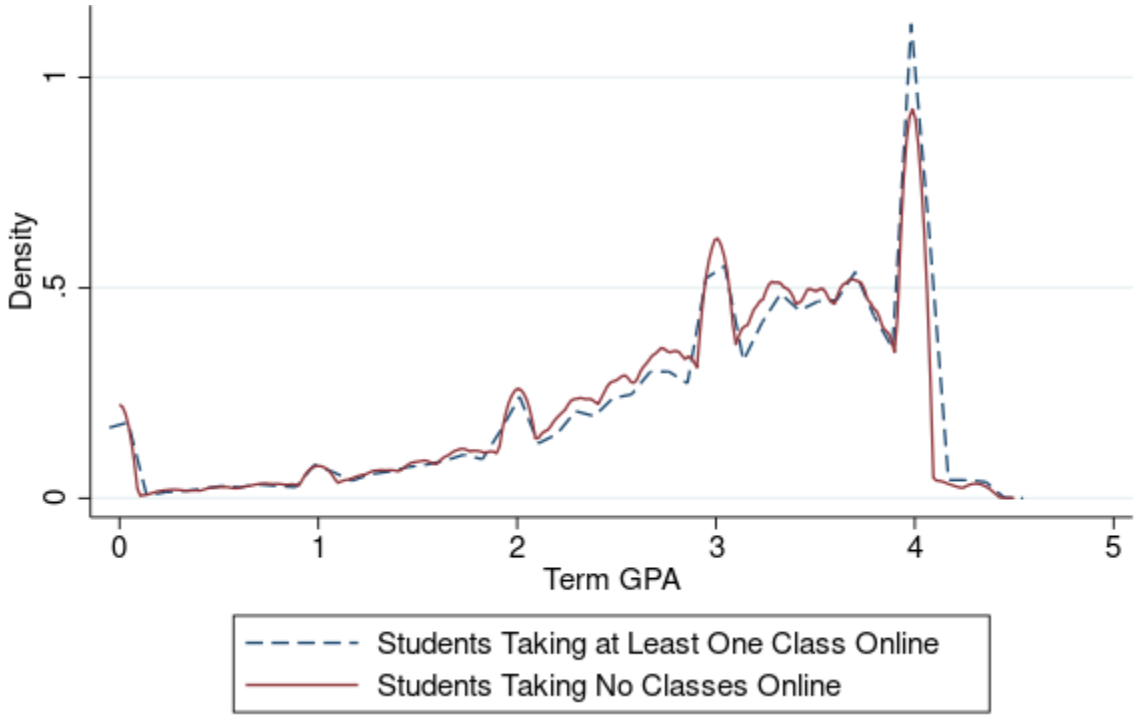
Notes. The figure uses data from the 4-year completion sample.

Figure 6. Distribution of course performance by course modality

Panel A. Individual course grades



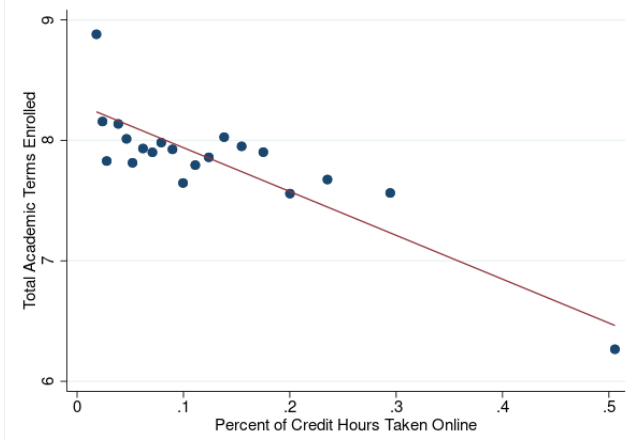
Panel B. Term GPA



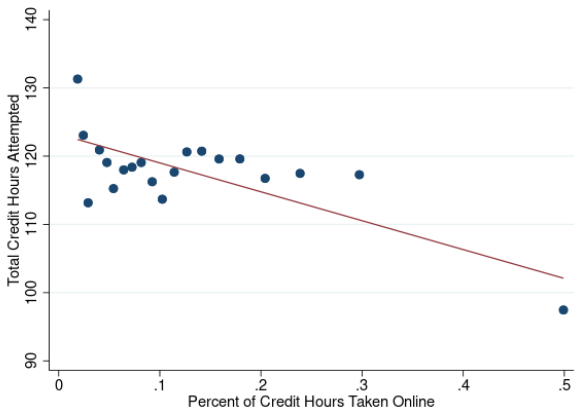
Notes. The data shown are grades earned by students in the grades analytic sample.

Figure 7. Probability of degree attainment by online course taking

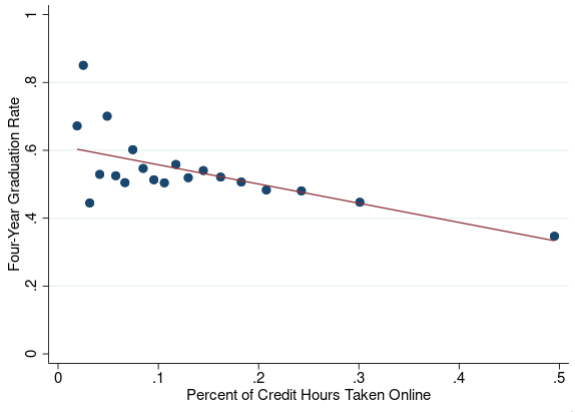
Panel A. Academic terms enrolled



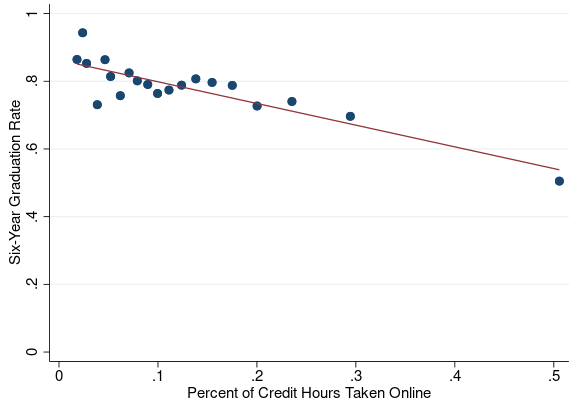
Panel B. Credit hours attempted



Panel C. Four-year completion



Panel D. Six-year completion



Notes. The figures include students in the 4-year completion analytic sample, except for Panel D that uses the 6-year completion analytic sample.

Table 1. Characteristics of undergraduate enrollees for all public 4-year institutions and UNC System institutions

Undergraduate Characteristics	Public 4-Year Institutions	UNC System Institutions
Female	0.569	0.572
Asian	0.079	0.046
Black	0.113	0.215
Hispanic	0.191	0.079
White	0.565	0.559
Other Race/Ethnicity	0.050	0.073
Missing Race	-	0.028
Pell recipient (2017-18 school year)	0.45	0.37
Reading SAT 25th/75th percentile	511/609	548/624
Math SAT 25th/75th percentile	505/607	524/626
4-year grad rate (2014 entry cohort)	0.424	0.504
Students taking online courses (select states)	0.364	0.366

Notes. Statistics for undergraduates enrolled at all public four-year institutions compiled using the U.S. Department of Education Digest of Education Statistics reported for Fall 2019 unless otherwise noted. For the share of undergraduates taking online courses, we include only data from other large (California, Florida, and Texas) public 4-year institutions, as well as from the neighboring state of Virginia, which come from IPEDS. UNC System data compiled from the UNC System's data dashboard for Fall 2019 except SAT scores, which come from IPEDS.

Table 2. Student characteristics by analytic sample

	Grades sample	4-year grad. sample	6-year grad. sample
Female	0.572	0.567	0.566
Asian	0.039	0.042	0.040
Black	0.222	0.221	0.223
Hispanic	0.065	0.058	0.055
White	0.594	0.595	0.602
Age	21.65 (7.13)	18.70 (3.91)	18.87 (4.09)
Distance (miles)	127.9 (386.8)	130.9 (311.0)	124.8 (273.1)
Average SAT score	1114.1 (183.5)	1107.2 (177.6)	1103.1 (176.5)
HS GPA	3.77 (0.74)	3.86 (0.65)	3.84 (0.63)
At least 1 online course during enrollment	0.652	0.69 (0.46)	0.67 (0.47)
Average share of hours online during enrollment	0.196 (0.303)	0.11 (0.19)	0.11 (0.19)
Sample size (unique students)	643,458	186,113	147,734

Notes. The grades analytic sample is restricted to enrolled undergraduate students who are not missing grades (N=892 students). Approximately 25 percent of the grade sample initially enrolled before Fall 2012. Completion samples exclude students we first observe as transfer or continuing students and those who complete a graduate degree. The four-year (six-year) completion sample is restricted to cohorts who matriculate for the first time in Fall 2012 through Fall 2016 (Fall 2012 through Fall 2014).

Table 3. Student characteristics by online course-taking patterns

	Takes no courses online	Takes > 0 and <20 percent of courses online	Takes ≥20 and <100 percent of courses online	Takes all courses online
Female	0.505	0.569	0.698	0.651
Asian	0.045	0.043	0.034	0.026
Black	0.201	0.215	0.302	0.194
Hispanic	0.061	0.059	0.053	0.034
White	0.583	0.614	0.528	0.656
Age	18.95 (4.51)	18.05 (1.44)	18.97 (4.32)	27.13 (10.99)
Distance (miles)	136.8 (309.8)	133.0 (311.8)	114.2 (325.6)	97.8 (228.9)
Average SAT score	1130.6 (191.7)	1110.2 (170.0)	1038.9 (154.0)	1066.0 (188.7)
HS GPA	3.82 (0.69)	3.91 (0.62)	3.71 (0.60)	3.63 (0.80)
Four-year grad	0.353	0.675	0.533	0.123
Six-year grad	0.371	0.751	0.596	0.125
Unique students	*58,156*	*100,068*	*22,619*	*5,181*

Notes. See Table 2 notes. Statistics reported for the 4-year completion analytic sample. Across all students in this sample, 31 percent take no classes online, 66 percent take some classes online, and 3 percent take all classes online. Numbers may not add to 100 percent due to rounding.

Table 4. Online course enrollment by department

	Percent of Course Enrollments That Are Online				
	AY 12-13	AY 18-19	Summer 13	Summer 19	Online Enrollments that are Upper Division AY 18-19
STEM	4%	6%	15%	35%	30%
Physical Sciences	1%	3%	7%	23%	3%
Biological Sciences	4%	6%	13%	30%	35%
Mathematics	3%	6%	12%	41%	9%
Engineering	3%	5%	7%	13%	19%
Computer Sciences and IT	12%	15%	61%	75%	41%
Fine Arts and Humanities	6%	11%	36%	65%	26%
Social Sciences	8%	14%	47%	74%	43%
Business and Marketing	10%	18%	42%	70%	63%
Education	16%	24%	57%	82%	70%
Health Professions	15%	27%	40%	71%	79%
All Other Courses	8%	14%	33%	54%	43%

Notes. We used course CIP codes to categorize the courses in the UNC System transcript data and place them into departments.

Table 5. Estimates of the relationship between online enrollment and student performance

Outcome	Mean outcome for in-person courses (1)	Baseline (2)	Student f.e. (3)	Course f.e. (4)	Professor f.e. (5)	IV: Share of courses offered online (6)
Withdraws from the course	0.031	0.014 (0.001)	0.013 (0.001)	0.018 (0.001)	0.017 (0.001)	-0.029 (0.004)
Earns an A in the course	0.431	0.041 (0.005)	0.015 (0.004)	-0.017 (0.002)	-0.027 (0.004)	0.244 (0.025)
Earns an F in the course	0.050	0.019 (0.001)	0.023 (0.001)	0.033 (0.001)	0.031 (0.002)	-0.029 (0.004)
Term GPA	2.82 (no online classes)	0.082 (0.007)	0.024 (0.006)	-	-	0.357 (0.038)
Student*courses enrolled		13,842,928	13,842,928	13,842,928	6,330,366	13,842,928
Student*courses completed		12,829,011	12,829,011	12,829,011	5,950,304	12,829,011
Student*terms		3,237,009	3,237,009	-	-	3,237,009
F.e. with online variation			52%	19%	22%	

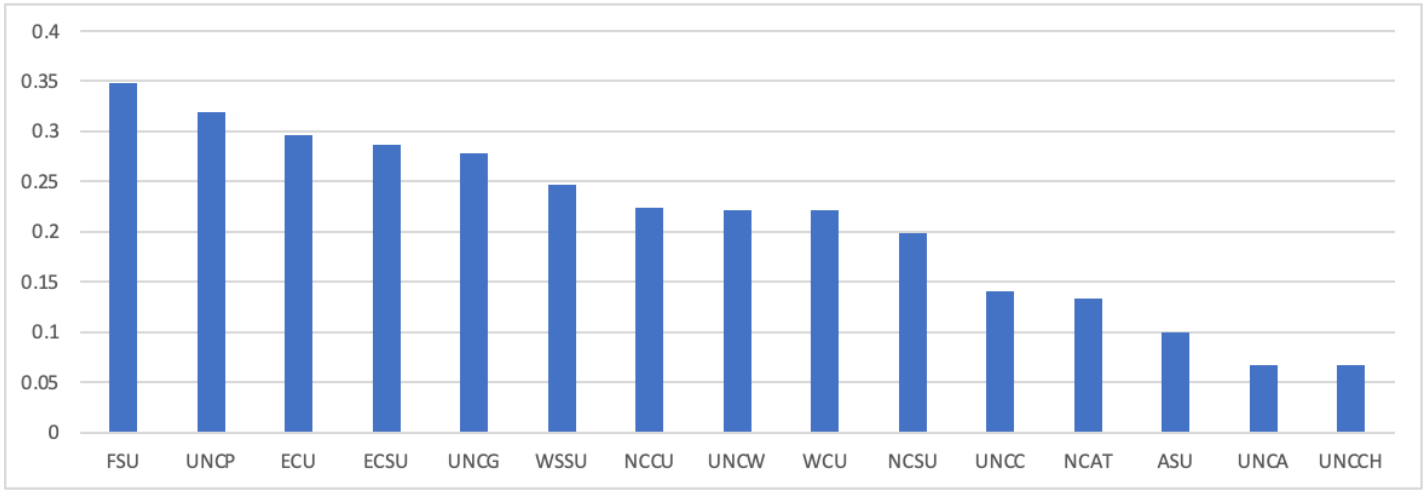
Notes. Outcomes are student grades in individual courses. Statistics reported for the grades analytic sample. Estimates reported in columns (1) through (4) all include institution and term fixed effects. The instrument used is the share of courses offered online in a department at an institution in that term. Overall, the percent of departments-by-institution-by term that offer a mix of classes online is 37.5 (35.6 percent in Fall 2012 and up to 46.9 percent in Fall 2019). The first-stage F-statistic for the 2SLS approach is 820.80. We note that the sample size is smaller for the professor fixed effects models because the course instructor is not available in the early years of the administrative data.

Table 6. Estimates of the relationship between online enrollment and educational attainment

Outcome	Mean outcome for students who take >0% and <100% of hours online (1)	Baseline (2)	Student controls (3)	IV: Share of courses offered online in initial major (4)
Total terms enrolled	7.672	-1.597 (0.313)	1.117 (0.219)	-0.650 (2.475)
Total credit hours attempted	117.770	-14.509 (5.473)	22.197 (4.069)	11.310 (58.858)
Attains a degree in 4 years	0.649	-0.107 (0.033)	0.093 (0.021)	-0.407 (0.373)
Attains a degree in 6 years	0.796	-0.161 (0.044)	0.122 (0.030)	0.573 (0.344)
Sample size (4-year)		186,024	186,024	186,024
Sample size (6-year)		111,034	111,034	111,034

Notes. There are fewer students in the analysis of 6-year completion because we have to use fewer cohorts to look six years post initial term of entry. Column (1) estimates control for institution and cohort fixed effects. Column (2) estimates include controls for student sex, race, age, SAT score, and high school GPA in addition to cohort and institution fixed effects. The instrumental variable estimates include the student characteristics. The instrument is the share of courses offered online in the student's initial major at an institution in the term a student matriculates. We use the overall share for the institution for students without a major at matriculation. The first-stage F-statistics for the 2SLS approach are: 14.08 for the 4-year sample; 20.72 for the 6-year sample; and for the cumulative hours attempted sample.

Appendix Figure 1. Share of hours taken online by the median student in their career across institutions



Appendix Table 1. UNC System institution characteristics

UNC System Institution	Total Enroll.	Enrolled in online courses	Received any financial aid	Female	Black	Asian	Latino/a	White	Admission rate	SAT math 25th/75th	SAT reading 25th/75th	4-year grad. rate (2014 entry cohort)
UNC CH	19154	0.09	0.65	0.60	0.08	0.11	0.09	0.59	0.23	640/760	630/720	0.90
UNC Asheville	3587	0.11	0.94	0.58	0.05	0.02	0.08	0.74	0.94	520/610	540/640	0.64
App. State	17518	0.22	0.70	0.56	0.04	0.02	0.07	0.82	0.69	540/630	560/640	0.70
UNC Charlotte	24070	0.28	0.74	0.47	0.16	0.08	0.11	0.56	0.67	560/640	560/630	0.55
NC A&T	11039	0.32	0.96	0.58	0.81	0.01	0.04	0.05	0.61	470/550	480/560	0.48
Western Carolina	10469	0.39	0.85	0.55	0.05	0.01	0.07	0.79	0.40	510/600	520/610	0.58
Elizabeth City	1692	0.40	0.97	0.59	0.69	0.01	0.04	0.18	0.59	440/520	450/520	0.39
East Carolina	23081	0.43	0.79	0.57	0.16	0.02	0.07	0.65	0.82	520/590	520/600	0.59
North Carolina State	25973	0.44	0.68	0.48	0.06	0.08	0.06	0.67	0.47	630/710	620/680	0.75
NC Central	6101	0.45	0.93	0.68	0.78	0.01	0.07	0.06	0.47	450/520	450/530	0.47
UNC Wilmington	14785	0.46	0.72	0.63	0.04	0.02	0.07	0.78	0.61	590/660	600/660	0.71
Winston-Salem	4656	0.47	0.97	0.73	0.78	0.01	0.04	0.11	0.65	440/510	420/520	0.46
UNC	16581	0.52	0.88	0.67	0.29	0.05	0.11	0.45	0.84	490/570	500/590	0.56

Greensboro												
UNC Pembroke	6353	0.54	0.90	0.61	0.31	0.01	0.08	0.37	0.81	455/530	470/550	0.34
Fayetteville State	5644	0.69	0.95	0.69	0.57	0.02	0.09	0.19	0.68	440/510	450/520	0.35

Notes. Compiled using IPEDS data. All statistics are from Fall 2019 unless otherwise noted. Table is sorted from the lowest to the highest share of students taking any classes online.

Appendix Table 2. Summary of Outcomes, Treatment, and Analytic Approaches

Outcome	**Variation**	**How Online Education is Measured**	**Fixed Effects Approach**	**IV Approach**	**Analytic Sample Used**
Course grade	Varies within student and term	=1 if the student took the course online =0 otherwise	-Student f.e or Course f.e. (separate models) -Institution -Term	Share of courses offered online in course department in institution in term	Grades
Term GPA	Varies within student	=1 if the student took at least one course online in the term =0 otherwise	-Student f.e. -Institution -Term	Share of courses offered online in institution in term	Grades
Educational Attainment	Does not vary within student	Percent of hours attempted the student took online in their career at UNC	-Student Xs -Institution -Term	Share of courses offered online in declared major in institution in term of enrollment	4-year, 6-year completion