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The Expanding Landscape of Online Education: Who Engages and How They Fare

By Lisa Barrow, Wesley Morris, and Lauren Sartain*

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Online course offerings at traditional universities have become common, though some question if the modality can adequately substitute for an in-person experience. We explore undergraduate online course enrollment at a large public four-year system and the relationships between taking online courses and student outcomes. Online enrollment 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. Overall students were both more likely to earn As and more likely to fail in online courses relative to in-person courses, but semester GPAs were higher in terms when students took at least one class online than when they took all in-person classes. Importantly, taking higher shares of courses online is associated with increased degree completion with the largest benefits for younger students and male students.

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I. Introduction

Having access to online 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 course options, 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 education at colleges and universities, the number of courses and programs being offered online were already increasing prior to the pandemic. Initially, for-profit post-secondary institutions like the University of Phoenix dominated the online education sector. However, traditional brick-and-mortar universities have been capitalizing on the movement as well, and in all 2019, 36 percent of undergraduates at public 4-year institutions took at least one distance education[1] course up from 22 percent in fall 2012 (U.S. Department of Education, 2020; U.S. Department of Education, 2013).

The changing landscape of instructional delivery in post-secondary settings raises questions about the prevalence and effectiveness of online courses, and we address those questions in this paper. We first document the extent to which online course enrollment expanded in a large public university system over the nearly 10 years leading up to the pandemic, including characterizing the student populations most likely to enroll in online courses. We then estimate the relationship between online course taking and students' grades, persistence, and likelihood of degree attainment. To our knowledge, this paper is the first to look at the patterns in and effects of online course taking across an entire state university system, suggesting that our findings can

[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.

be generalized to broader contexts and point to areas where universities may need to provide more robust support and guidance to students in order for them to succeed.

When considering the role for online courses in higher education, on the one hand, it is easy to see how taking college courses online may appeal to students who 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 an approachable way to re-enroll in order to get the credits needed to attain their degree. This idea is supported by a recent paper showing that an online computer science masters program resulted in increased access to students who otherwise would not have enrolled (Goodman, Melkers, & Pallais, 2019). In addition, other 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, student outcomes may be worse in an online environment if, for example, students have fewer connections with faculty and peers or if the learning environment is of lower quality than it would be in an in-person classroom. One common criticism students and families voiced during the period 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 was likely due to personal hardships and/or labor market strength that has led to low unemployment rates and higher wage growth, part of the decline may also be due to student desire for a “real” college experience.

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 have documented that students were less likely to complete online courses than in-person courses and that grades were lower in online courses than in-person courses (Hart, Friedmann, & Hill, 2018; Xu & Jaggars, 2013), but the largest declines were among male students, younger students, Black students, and students with lower grade point averages (Xu & Jaggars, 2014). 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.

The second research area typically compares the performance of students who were randomly assigned to take a single course online or in person (or hybrid in some cases). Results from these experiments indicate that students who are assigned to online courses have slightly worse 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).[2] These papers also show that 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) do disproportionately worse in online courses. In the paper most similar to ours in terms of breadth, Bettinger et al. (2017) identify the impact of taking courses online across all courses offered at a for-profit university with approximately 100 campuses that has a mix of online and in-person programming. They find that online course taking negatively affects student performance in their current and subsequent courses as well as the student's likelihood of persisting in college. We note that, in this body of research, the online instruction component would have been different from today's online courses. For example, the online courses in these papers often consisted of watching recorded or live-streamed lectures, more akin to asynchronous instruction without the instructional design elements targeted to current online learners.

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. We use rich longitudinal data from the University of North Carolina (UNC) System, which include all four-year public institutions of higher education in the state. North Carolina provides an excellent case study for answering these questions given the diversity of its campuses, including urban and rural settings and its five historically Black colleges and universities (HBCUs). We find that the share of students taking any courses online has increased considerably from 20 percent in Fall 2012 to nearly 40 percent in Fall 2019, with online courses being more popular than in-person courses during summer terms. Female students and older students tend to take more of their courses online relative to

[2] 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).

male students and younger students. Students are both more likely to earn As and more likely to earn Fs in their online courses than their in-person courses, though overall GPA is higher in terms when students take at least one course online than when they take all courses in person. Results for educational attainment are positive, showing that students who take more hours online are more likely to graduate from college than otherwise comparable students who take fewer hours online. That said, we find that younger students and male students are more likely to benefit from online enrollment than their older and female student counterparts; this is in direct contrast to some of the community college literature that found worse outcomes in online course for male students and younger students (Xu & Jaggars, 2014). On net, older students taking more online courses are no more likely to complete their degree than their peers taking fewer online courses, and we estimate that the benefit to female students of taking online courses is roughly half the size of the benefit to male students. These heterogeneity results warrant further exploration into what features of online courses generate these benefits. Online course are typically thought to be beneficial because they provide more flexibility, but younger students and male students are not the individuals we most expected to benefit from additional flexibility.

Our paper is the first to look at the effects of online courses across a large public university system over a nearly 10-year period. While much of the existing research on the impact of taking a course online on performance is well identified because of random assignment of students to an online or in-person section of the same course, 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. While we also look at performance in specific courses, the longitudinal nature of the data allows us to look at student success as defined by degree completion, which is an important addition to the literature.

In the following we describe the evolution of online courses in higher education more generally in section II followed by a description of the UNC system setting and the data analyzed in section III. We present descriptive statistics in Section IV, our analytic approach and results in Section V, and end with a discussion of the findings and implications of our research.

II. The Evolution of the Online Course Experience in Higher Education

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.[3] The development of and improvements in high-speed Internet 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 were 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 were typically not part of a degree program, making it difficult if not impossible to receive credit for these courses, and they had 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).

[3] 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.

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 Chief Information Officers 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 was increasingly thinking about online education as a typical part of the postsecondary education experience.

In this paper, we look at online course enrollments in the UNC System from fall 2012 through fall 2019, the semester just prior to the initial pandemic disruption. Over this period, the online education experience in higher education was evolving as technology changed and improved.[4] 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

[4] 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).

"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 was 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 are increasingly offered in a synchronous format with students attending lectures and discussion "live" in a virtual format. In the post-pandemic years, online courses are a mix of asynchronous and synchronous formats, primarily determined by the course instructor.

III. The UNC System Context and Data

A. Institutional Context

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 from IPEDS.) There is considerable variability across institutions in North Carolina on dimensions like 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 has universities located in large metropolitan areas like Charlotte and the Research Triangle (Raleigh, Durham, and Chapel Hill) and 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 (see Appendix Figure 1 Panel A). For UNC-Chapel Hill, online course offerings and programs are less common. 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), 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 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.[5]

Importantly for generalizability, UNC System undergraduate enrollees have similar observable characteristics to undergraduate students enrolled in 4-year public institutions nationwide (shown in Appendix Table 2). Over half (57 percent) of undergraduate students at all

[5] 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 = -0.596), though there is small positive relationship between the undergraduate admission rate and the share of students enrolling in online courses (corr = 0.200).

public 4-year institutions and in the UNC System identify as female, and just over half of students in both groups identify as white. However, UNC System students score about 20 points higher in math and reading, on average, relative to students at all other public institutions. 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 (Appendix Figure 1 Panel B provides a comparison of North Carolina with other states) Across all of these state systems, online enrollment increased over this period.

B. Data and Analytic Sample

Through a data sharing agreement with the UNC System, we have access to longitudinal administrative data for all undergraduate enrollees from fall 2012 through 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 these types of records:

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

Table 1 shows descriptive statistics for the samples of students analyzed in this paper. Column (1) is based on cross sections of students enrolled in undergraduate courses from fall 2012 through fall 2019.[6] Columns (2) and (3) are samples used for analyzing Bachelor's degree completion within four years or within six years.[7] The students enrolled in UNC undergraduate course are disproportionately female (58 percent). The majority of students are white (57 percent), 21 percent of students are Black or African American, and fewer than 10 percent of students are Latino or Hispanic. The average age of enrolled students is 21 years old. Based on the application data, which are only available for 57 percent of the column (1) sample,[8] the average student scored 1111 on the SAT and earned a 3.32 grade point average (GPA) in high school. Relative to the undergraduate course sample, students in the completion cohorts are younger on average (19 versus 21 years of age) but otherwise quite similar.[9]

IV. The Landscape of Online Coursetaking

Overall, we find that the likelihood of a student enrolling in at least one class online nearly doubled between 2012 and 2019 with online courses consistently more popular in the summer than during the academic year. Figure 1 shows the percentage of students who took all, some, or no courses online during academic year terms (Panel A) from Fall 2012 through Fall

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[6] We drop all zero credit courses (about 6 percent of all course observations) and courses for which we have no final grade, pass/fail, or withdrawal indicator (about 7 percent of all course observations). Grade outcomes are more likely to be missing prior to Fall 2015.

[7] 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, students in the six-year completion sample need to have enrolled prior to Fall 2015.

[8] High school performance indicators are only available for first-time enrollees in the UNC System. Test scores are missing at such a large rate in the grades sample because it includes transfer students and students who first enrolled before 2012 when our data begin.

[9] This difference is due to the construction of the samples. For example, students who transfer from a community college would not be included in the completion samples but would show up in the grades sample.

2019 and during summer terms[10] (Panel B) from Summer 2012 through Summer 2019. In the 2012-13 academic year, 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 27 percent, respectively. Online course taking also increased over the summer terms from 29 percent of students taking all classes online in Summer 2012 to 54 percent in Summer 2019.

The median student who takes at least one class online enrolls in 9.7 percent of their hours online across their career in the UNC System, or approximately one course an academic year if a student is taking a full load (i.e., 30 hours for the year). Figure 2 Panel A 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). About half of students (55 percent) take less than one course per term online on average, while only 13 percent take more than one course online every term on average. In addition, conditional on taking at least one class (but not all classes) online, 75 percent of students enroll in their first online course within the first two years of enrollment (shown in Figure 2 Panel B). In other words, most online course enrollees do so relatively early in their academic careers.

Table 2 shows descriptive statistics for students based on the cumulative share of credits taken online during their entire undergraduate career at UNC. While female students make up 57 percent of the overall population, we find that female students are overrepresented among students who take 20-99 percent of their hours online (71 percent female) and who take all of their hours online (67 percent female). Male students are overrepresented among students who take no courses online (50 percent male). There is not a strong relationship between the intensity of online course enrollment and student race/ethnicity, though Black students are overrepresented

[10] The UNC System has two terms during the summer (Summer I and Summer II). Summer terms are associated with the subsequent academic year (e.g., courses taken in Summer 2014 are considered part of the 2014-15 academic year). We follow this convention.

among students who take 20-99 percent of their hours online. 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 27 years compared to under 20 years old for the other groups. Educational attainment outcomes also vary across groups with different levels of online course taking. Most notably, students taking all of their courses online are enrolled for fewer terms on average (1.62 academic year terms and 0.84 summer terms) and consequently have very low four-year completion rates of around 8 percent. About one-third of the students who take no classes online complete their degree in four years (33 percent), while students who take some but not all courses online (columns (2) and (3) enroll in more terms on average and have higher completion rates than their peers who take none of or all of their classes online.

V. The Relationship between Online Education and Student Outcomes

A. Analytic Approaches

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 a single course either online or in person. That research provides unbiased estimates of the effect of taking that single course online relative to in person. However, the experimental design is very different from how students approach taking a mix of online and in-person courses across their undergraduate careers in order to optimize their likelihood of graduating from college or attaining other desired outcomes. It is also difficult to generalize from the random assignment findings about performance in a single specific course to the effects of online education across a wide range of courses or on educational attainment outcomes in the long run.

At the same time, one may be concerned that observational relationships between online course-taking and student outcomes are affected by unobservable characteristics that lead some students to take a particular course online or a higher share of the courses online than other students. In the case of the UNC System, we have already established that many students take some courses online and others in person. Most students are admitted to a specific school at an institution but not admitted to a major. After enrolling, students choose their major based on their interests and career goals. Each of those majors vary in how many online courses are available. Further, 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 their initial term of entry. For example, students in earlier cohorts had fewer options for mixing online and in-person course offerings. (See Appendix Figure 3 for the distribution of share of courses offered online by major-by-institution-by term.)

Since randomly assigning students to majors and a portfolio of online and in-person courses is not feasible, we propose using quasi-experimental strategies–described in more detail below–to understand the relationship between online course taking and two sets of outcomes:

1. Student course performance: Withdrawals, course grade earned (A or F), and term grade point average (GPA) for all courses; and
2. Educational attainment: terms enrolled, credit hours attempted, and degree completion (in 4 or 6 years).

We note that the student outcomes we observe in the data vary at different levels. That is, a student's course grades vary within student and term across their classes, term GPA varies within student across terms, and 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 course grade, GPA, and attainment outcomes. (These outcomes, how we measure online education for each, and our estimation approaches are summarized in Appendix Table 3.)

1. Fixed effects strategy.

We begin by estimating models, including different fixed effects, 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*. $Online_{cput}$ is an indicator that equals 1 if the course mode was online and 0 if in person. The ϕ_u and ϕ_t represent university and term fixed effects, and ε_{icput} is a random error term. The coefficient of interest, δ, reflects the associated change in the probability of withdrawing or receiving an A (F) in an online course relative to a face-to-face course. To this baseline estimate, we add a vector of student-level characteristics (high school GPA, SAT scores, age at first enrollment, total credits attempted in the term, race/ethnicity category, sex, and in-state residency status). We also add various fixed effects: student, ϕ_i, course, ϕ_c, or professor, ϕ_p, and we provide results for each of these specifications. 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 same 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. For this outcome, the treatment variable is an indicator that equals 1 if a student took any online classes in that term and 0 if all their classes were in person. Term GPA varies by student across terms but no longer within a term. Therefore, we estimate models with student fixed effects but not course or professor fixed effects.

2. *Group-level mean control function strategy.*

These various fixed effects approaches have benefits in terms of estimation, but there are some limitations. For example, while student fixed effects account for time-invariant unobserved attributes of the student, a student likely applies some strategy when choosing what classes to take online versus in person and if that strategy varies over time, there would be selection concerns. In addition, educational attainment outcomes are observed only once for each student, so we cannot apply the fixed effects strategy and instead rely on controlling for as many observable student characteristics as available. However, we can also control for the average characteristics of students who select into the same major or department (depending on the outcome)[11]. Altonji & Mansfield (2018) show that controlling for group averages of observable individual characteristics can potentially absorb across-group variation in unobservable characteristics. In our case, we construct a vector of average student characteristics at the major-by-institution-by-term level as well as other covariates that characterize the major. The Altonji & Mansfield paper provides a complete proof of how this group-level control function approach addresses selection into a group on unobservables and an application of the method. Recently, Card et al. (2022) applied this technique to estimate the impact of exposure to female teachers on the life outcomes of female students.

[11] Courses are associated with departments, which have 2-digit Classification of Instructional Program (CIP) codes. Majors are situated within departments and have 4-digit CIP codes. Individual courses in the administrative data are linked to their department's 2-digit CIP codes, while declared majors in the administrative data are linked to 4-digit CIP codes. An example is a department of Mathematics and Science (CIP code of 27) with associated majors of mathematics (27.01), applied mathematics (27.03), and statistics (27.05). We can link students to their declared majors and the department of their courses, and we can link each course to its department but not a specific major. Appendix Table 3 and the table notes provide more detail.

Specifically, we estimate the following equation for the course performance outcomes:

$$(2)\ Grade_{icdut} = \alpha + \delta_1 Online_{cdut(i)} + \delta_2 X_i + \delta_3 Z_{1i} + \delta_4 Z_{2dut(i)} + \phi_u + \phi_t + \varepsilon_{icdut},$$

where $Grade_{icdut}$ is a course-level outcome for student *i* in course *c* in department *d* at university *u* in term *t*. (For term-level GPA outcomes, the online indicator equals 1 if the student took any courses online in the given term and 0 if the student took all courses in person that term.) In all cases we control for institution and term fixed effects (ϕ_u and ϕ_t). X_i is a vector of observable student characteristics, Z_{1i} is a vector of group averages of these same observable characteristics at the two-digit course CIP code by institution by term corresponding to the course and when it was taken, and Z_2 is a vector of means of other two-digit CIP code characteristics: share of courses that are low-division undergraduate, share of courses offered online, share of grades awarded that are As or Fs, and four-year graduation rate in that broad department group. (See Appendix Table 4 for a complete list of group-level control variables in X, Z_1, and Z_2.) Our primary variable of interest is $Online_{cdut(i)}$, which is an indicator that the course was taken online, and we report estimates of δ_1 in Table 3. ε_{icdut} represents the error term.

We estimate the relationship between online course-taking and student attainment measures following the specification in equation (3):

$$(3)\ Attainment_{imuf} = \alpha + \delta_1 TakenOnline_i + \delta_2 X_i + \delta_3 Z_{1i} + \delta_4 Z_{2muf(i)} + \phi_u + \phi_f + \varepsilon_{imuf},$$

where *Attainment* for student *i*, majoring in major *m*, who enrolled at university *u* in cohort *f* represents total terms enrolled, total hours attempted, or degree attainment (in 4 or 6 years). The treatment, $TakenOnline_i$, is defined as the share of all hours that a student took online throughout their total period of enrollment in the UNC System; we report estimates of δ_1 in Table 4. We also control for student characteristics, X_i, and a vector of group-level averages of these same characteristics at the final major-by-institution-by-cohort entry level (Z_{1i}), as well as some other characteristics of the major at the time of matriculation such as share of students in that major ($Z_{2muf(i)}$). The model also includes university and cohort fixed effects, ϕ_u and ϕ_f; ε_{iuf} represents the error term.

B. Results: Course Performance

We begin by examining the relationship between course modality and student performance in the course. Figure 3 Panel A shows the unadjusted distribution of course-level withdrawals and grades for online versus in-person courses. About 45 percent of grades in online courses are As relative to 42 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 (8 percent of grades) than in-person course grades (6 percent of grades). Withdrawals are rare, and the difference in withdrawal rates between online and in-person courses is only about 1 percentage point. Figure 3 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 generally similar for students who are taking at least one course online in the term and students who are not taking any courses online; however, students taking at least one course online are 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 how many and what courses to take online. Table 3 shows estimates of the relationship between taking a course online and course performance outcomes (Panel A) and term GPA (Panel B). Column (1) provides outcome means for in-person courses weighted by course credit hours.[12] Column (2) shows the difference in grades in online and in-person courses weighted by course credit hours after adjusting for university and term fixed effects. These estimates are similar to the unadjusted distributions shown in Figure 3–students taking an online course are more likely to earn an A and more likely to earn an F than in in-person courses. Once we condition on student characteristics, the coefficient estimates of interest shrink substantially for the earns and A and term GPA outcomes. In contrast, estimates for course withdrawal and earns and F are relatively similar to the unadjusted outcomes. Compared to similar students, grades in online courses are 4-percentage points more likely to be As and 1-percentage point more likely to be Fs with GPAs 0.04 grade points higher, on average, in semesters when students take at least one course online relative to all in-person courses.[13]

Columns (4)-(6) show the fixed effects regression estimates (student, course, and professor, respectively). The student fixed effects models in Column (4) account 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. Students are 3 percentage points more likely to earn As in their online courses than in-person courses but also nearly 2 percentage points more likely to fail their online courses. On average, GPA is 0.01 higher in terms when a student takes at least one course online relative to terms when the same student takes all courses in person. While this

[12] Estimation samples for the grades A and F outcomes exclude courses from which students withdraw.
[13] Estimates for term GPA effects are very similar if we look only at the effect of taking at least one online course on term GPA in face-to-face courses. Results are available from the authors on request.

estimate is statistically significant, it is small in magnitude. The course fixed effects estimates in column (5) compare the performance of students who take the same course online or in person (within the same institution), while instructor fixed effects (column 6) compare grades given by the same instructor across modalities. Here, we estimate a small decrease in the likelihood that a student receives an A online relative to in-person courses, somewhat higher estimates of the probability of receiving an F, and increases in the likelihood of withdrawing.

Finally, columns (7) and (8) show the major control function results with column (7) including group-level averages of the observable student characteristics and column (8) adding the other major characteristics. Similar to the models with student controls and fixed effects, we find a roughly 1-percentage point increase in the likelihood of withdrawing from an online course relative to in-person courses. While we still find that students are more likely to received grades of A and F in online courses, the estimated relationship between taking an online course and receiving an A is less than one-half the size of the student fixed-effects estimate, while the estimated relationship between taking a course online and receiving an F is about the same. On net, however, students' GPA is about 0.025 GPA points higher in terms when they take at least one class online relative to no classes online.

We have explored heterogeneity in the estimates by age and sex (See Appendix Table 4a and 4b, respectively.) Generally speaking, younger students (age < 20) perform relatively better in online courses compared with older students. On net, term GPAs for younger students who take at least one online course are 0.022 to 0.028 grade points higher than their peers who take no courses online (corresponding to the column (7) and (8) estimates in Table 3). In contrast, for older students we estimate roughly no difference in term GPAs between students taking at least one course online and their peers who take no courses online.

The contrasts are somewhat less striking between male and female students, but the benefits of taking an online course are larger for male than female students. In particular, we estimate that male students are 0.022 to 0.029 percentage points more likely to receive an A in an online course than in an in-person course, while female students are only 0.007 to 0.009 percentage points more likely to receive an A. Female students are also relatively more likely to fail an online course. On net, male students who take at least one online course have a term GPA that is 0.04 to 0.05 grade points higher than their peers who take no online courses, while the corresponding estimates for female students are 0.008 to 0.013 grade points.

C. Results: Educational Attainment

We now consider how online education relates to educational attainment outcomes, a new contribution to the literature. Figure 4 shows the unadjusted relationship between the 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 previously in Figure 2, most students who take courses online tend to take 40 percent or fewer of their hours online. Regardless of the outcome, there is a negative relationship between the share of hours a student takes online and total academic-year terms enrolled (Panel A), cumulative credit hours attempted (Panel B), and their likelihood of completing college in four or six years (Panels C and D, respectively).[14]

For the models with educational attainment outcomes, online education is measured as the share of hours a student takes online, so 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 median UNC System student who takes at least some courses online enrolls in approximately 10 percent of their credit hours online, which equates to about one course per academic year. Therefore, we

[14] We divide credit hours by 30 to correspond to a year's worth of credit hours in a typical academic program.

describe the results in terms of a 10-percentage point increase in the share of courses taken online, which is equivalent to taking one additional course online per academic year.

Looking at terms enrolled and credits attempted, students who took no classes online enrolled for 5.22 terms and attempted 2.22 credit-years on average (shown in Column (1)). When we include controls for student characteristics in column (3), we estimate that a one-course increase per academic year in the share of hours taken online increases the number of terms enrolled by 0.29 and the number of credit-years attempted by 0.061. Looking at degree attainment, 33 percent of students who took no classes online during their period of enrollment graduated in four years, and 43 percent of those students graduated within six years. The column (3) estimates indicate that students who increase their online course enrollment by one course per academic year are about 0.8 (1.7) percentage points more likely to graduate within four (six) years.

Because we only observe educational attainment outcomes one time for each student, we can no longer implement student fixed effects, but we show the results from the major control function approach in columns (4) and (5), where column (4) includes student characteristics aggregated to the major-by-institution-by-cohort level and column (5) adds other major characteristics. These results are very similar to the column (3) estimates that include only student-level covariates. These results suggest that increases in online enrollment are associated with a higher likelihood of attaining a college degree. A one course per academic year increase in online course taking is associated with about a 1- (2-)percentage point increase in the likelihood of graduating within four (six) years.

Similar to the estimates by age and by sex for the course-level and term GPA outcomes, however, we find that younger students and male students seem to benefit more from the online course option than older students and female students (See appendix tables 5a and 5b, respectively). Focusing on the degree attainment outcomes, we find that a one course per academic year increase in online course taking for younger students is associated with a 1.7-percentage point (3.6-percentage point) increase in the likelihood of graduating within four (six) years. In contrast, we estimate no increase in degree attainment for older students who take more courses online. For male students, we estimate that an additional online course per term increases degree attainment likelihood by 1.3 percentage points (2.5 percentage points) within four (six) years. The estimates for female students are roughly one-half the size of the estimates for male students.

While the educational attainment estimates are modest in magnitude, taken together with higher GPAs, the evidence suggests that offering online course options is beneficial for students who want that option, particularly younger students and male students.

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 in online courses than in in-person courses to disconnect from or go unnoticed or unsupported. 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.

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. In fact, online enrollment at public institutions of higher education in the post-pandemic era is more prevalent than before, as students (and faculty) have become accustomed to the availability of online courses and what learning looks like in that environment. In Fall 2021, about two of every three college students enrolled in a public university took at least one course online compared to one of every three in Fall 2019 (U.S. Department of Education, 2021). 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. We find that students are actually more likely to do better overall in terms when they take at least one of their classes online, suggesting that online classes may allow students to re-optimize their efforts across all of their courses during the term and perform better. And, while student performance in their online courses is a stepping stone to the ultimate goal of degree attainment, the evidence presented in this paper shows that, in general, students who take higher shares of courses online are slightly more likely to graduate from college relative to students who take fewer online courses. The exception to this finding is that older students taking more courses online are no more likely to graduate within four or six years than their peers who take fewer courses online. This is in contrast to our hypothesis that these are some of the students who may most need and benefit from the flexibility of online courses.

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 likely 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 both between the instructor and students and among the students.

We also need more research to understand the role of online learning in helping non-traditional students complete college. Our paper is based on more traditional undergraduate students, whereas other research conducted by Bettinger et al. (2017) looks at students enrolled in a large for-profit institution who tend to be older on average and likely less-traditional college goers. Their results show that students do worse in their online courses than in-person courses. These two papers use very different samples in different settings. In the UNC setting, the typical student takes only about one course per academic year online, while about two-thirds of the course enrollments in the for-profit study setting were taken online. Another important difference between the two papers is the time period of study. The for-profit institution data is from 2009-2013, and we use data from 2012–2019 with courses, especially in the later years, that are probably more typical of the current online course-taking experience given how much technological change occurred over the 2010s (as described in Section II of the paper).

Despite the Bettinger et al. results, it is easy to imagine that online options would lower some of the barriers for students with non-continuous enrollment to re-engage and complete the courses they need to attain their diploma. The UNC System's Project Kitty Hawk is a program designed to support their institutions in developing online programming to target "adult learners" and help them attain degrees (McClellan, 2022). However, 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 where future research is needed to help reconcile conflicting results across different settings.

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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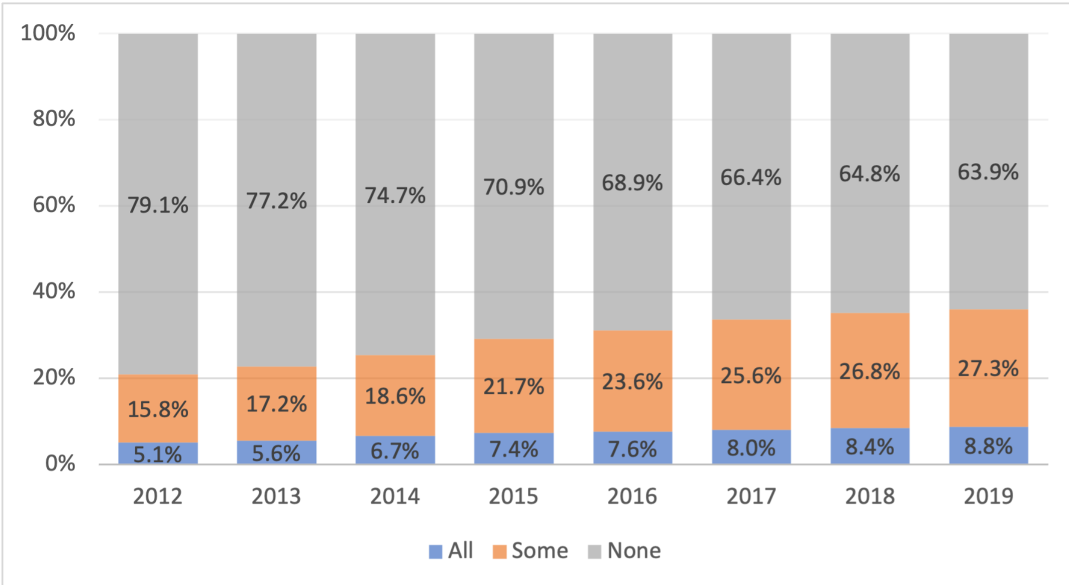
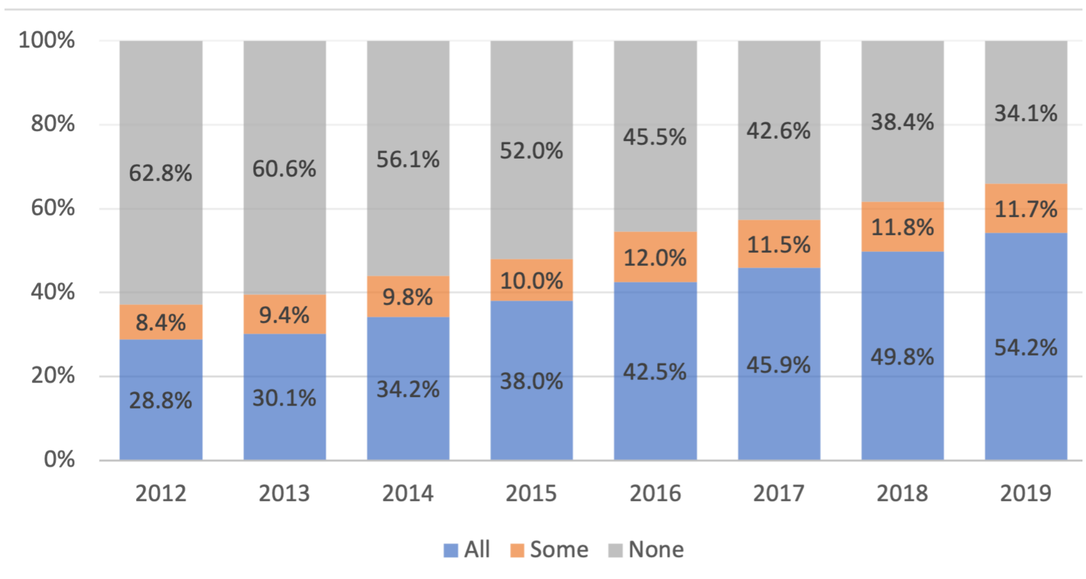
Figures and Tables

Figure 1. Percent of UNC System undergraduate students taking online courses, by term

Panel A. Academic year terms



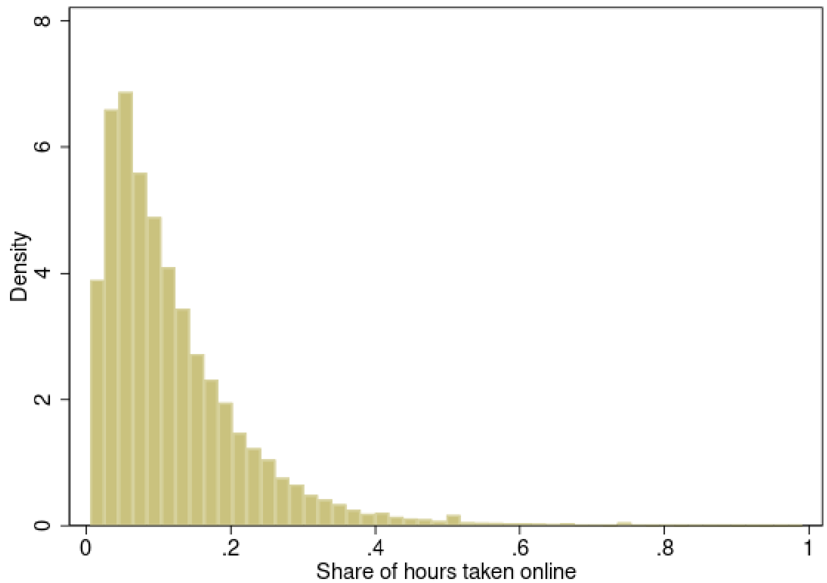
Panel B. Summer terms



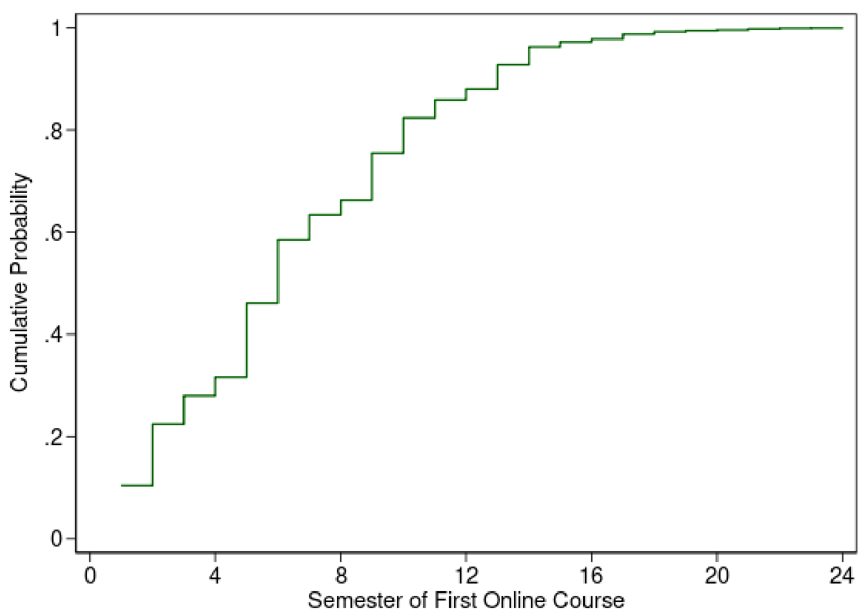
Notes. Authors' calculations based on UNC System administrative data. The percentage of students enrolled in any online courses during academic year terms increased from 20.9 percent in 2012 to 36.1 percent in 2019 (prior to the pandemic disruption) and during the summer terms from 37.2 percent in 2012 to 65.9 percent in 2019 (and 99.9 percent during summer 2020).

Figure 2. Characterizing students' online course enrollment

Panel A. Distribution of the share of hours taken online over a UNC System undergraduate student's career



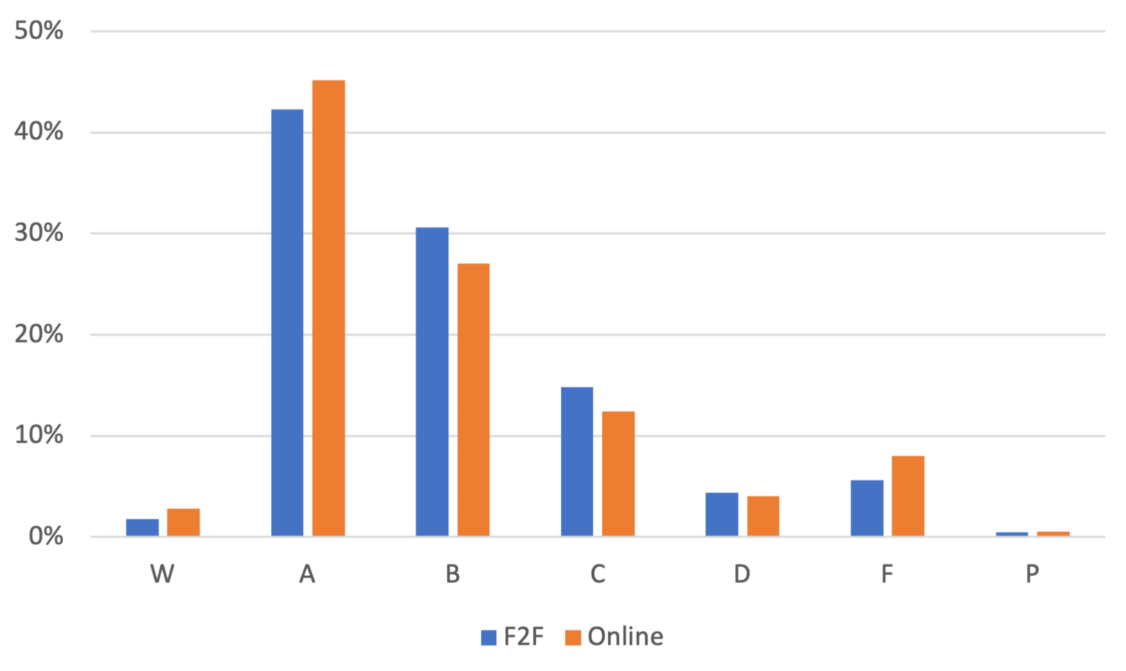
Panel B. Distribution of the term of a UNC System undergraduate student's first online course



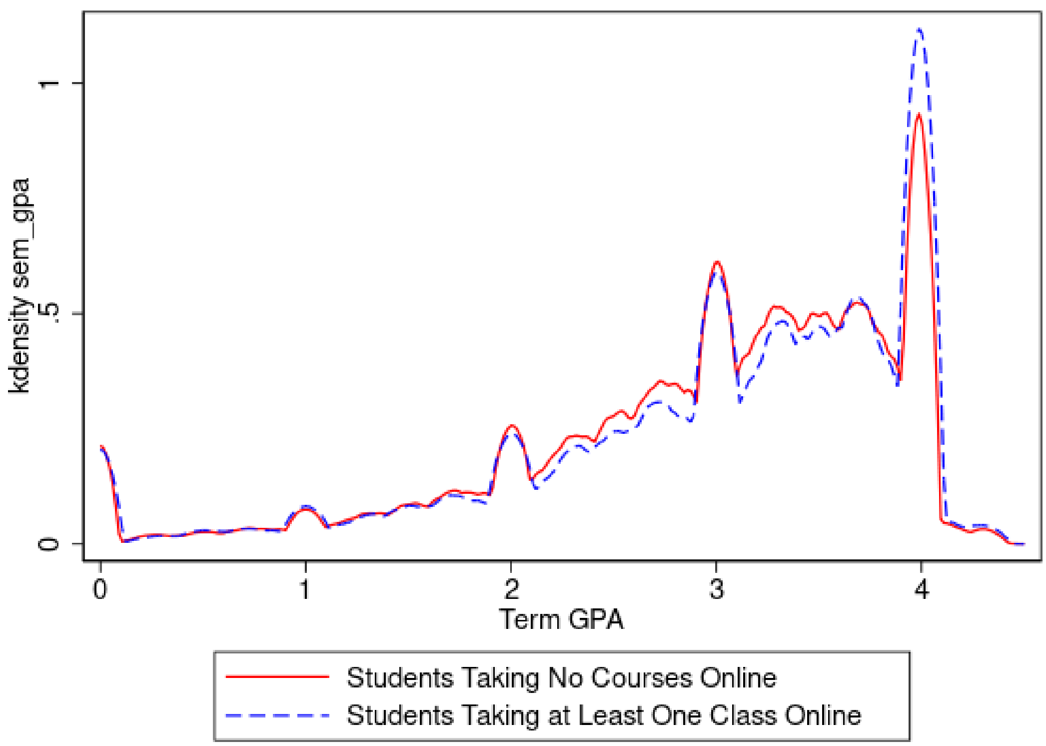
Notes. Panel A: Data shown are for students in the 4-year completion sample. This figure is constructed conditional on students taking a mix of online and face-to-face courses. Not included are the 32 percent of students who took no courses online and the 2 percent of students who took all of their courses online. Panel B: The data shown are restricted to students in the 4-year completion sample who take at least one course online, counting all semesters starting with initial enrollment. One year has four semesters–Summer I, Summer II, Fall, and Spring.

Figure 3. Distribution of course performance by course modality

Panel A. Course grades



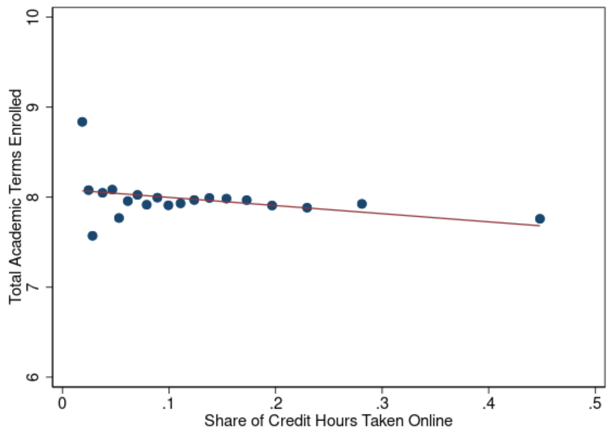
Panel B. Term GPA



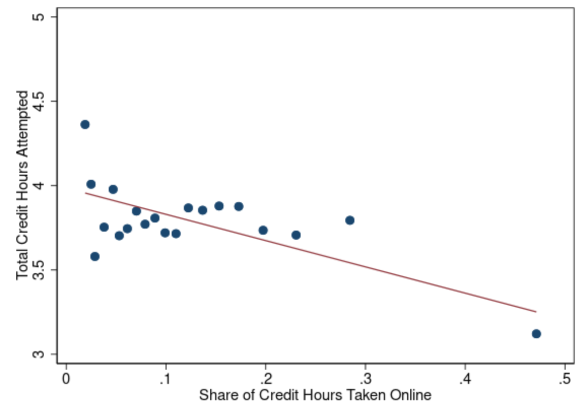
Notes. The data shown are unadjusted grades earned by students in the grades sample. F2F indicates the distribution of grades in face-to-face/in-person courses.

Figure 4. Persistence and attainment outcomes by share of courses taken online

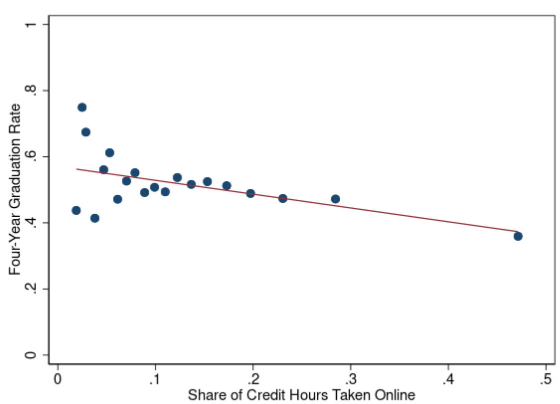
Panel A. Academic terms enrolled



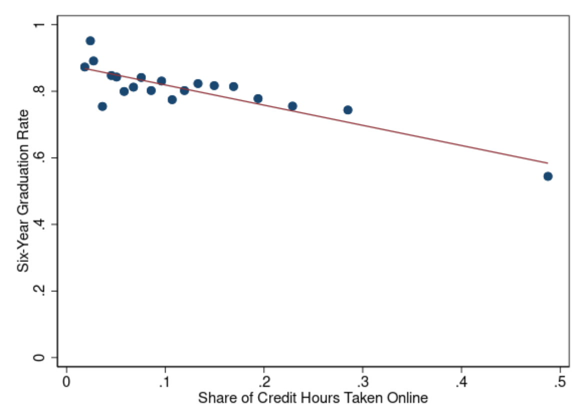
Panel B. Credit hours attempted



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. Student characteristics by analytic sample

	(1) Undergraduate grades sample	(2) 4-year completion sample	(3) 6-year completion sample
Female	0.576	0.567	0.567
Asian	0.037	0.040	0.039
Black or African American	0.214	0.218	0.220
Hispanic or Latino	0.062	0.057	0.054
White	0.572	0.581	0.589
Age	21.48 (6.94)	18.50 (3.46)	18.69 (4.03)
Average SAT score	1111.4 (137.5)	1107.0 (169.9)	1103.2 (167.1)
HS GPA	3.32 (0.59)	3.38 (0.67)	3.36 (0.66)
Undergraduate student	0.98	1.00	1.00
Transfer student	0.29	0.00	0.00
Took at least 1 online course during UNC enrollment	0.603 (0.489)	0.680 (0.466)	0.673 (0.469)
Share of credits taken online during UNC enrollment	0.175 (0.290)	0.103 (0.170)	0.104 (0.178)
Attains BA degree in four years	-	0.447	0.432
Attains BA degree in six years	-	-	0.665
Sample size (unique students)	623,667	178,913	106,575

Notes. The statistics in the table are reported for unique students in each sample. The undergraduate grades sample includes all students enrolled in a course for a grade from Fall 2012 through Fall 2019. Roughly 25 percent of the students in the undergraduate course sample initially enrolled before Fall 2012. The four-year (six-year) completion sample is restricted to cohorts that matriculate for the first time in Fall 2012 through Fall 2016 (Fall 2012 through Fall 2014). Graduate students are not included in any analyses, and transfer and continuing students are not included in cohort analyses.

Table 2. Student characteristics by online course-taking patterns

		(1)	(2)	(3)	(4)
		Percent of All Credits Taken Online			
	4-year completion sample	None	>0% and <20%	≥20% and <100%	All
Female	0.567	0.500	0.574	0.705	0.671
Asian	0.040	0.042	0.041	0.032	0.019
Black	0.218	0.200	0.214	0.297	0.203
Hispanic	0.057	0.060	0.057	0.054	0.033
White	0.581	0.569	0.601	0.516	0.612
Age	18.50 (3.46)	18.66 (3.97)	18.04 (1.33)	18.78 (3.89)	26.85 (11.14)
Average SAT score	1107.0 (169.9)	1128.2 (180.4)	1108.1 (167.4)	1044.2 (146.9)	1097.8 (79.8)
HS GPA	3.38 (0.67)	3.34 (0.69)	3.43 (0.66)	3.26 (0.64)	3.31 (0.35)
Terms enrolled (academic year)	6.43 (2.79)	4.67 (3.07)	7.56 (1.80)	6.91 (2.51)	1.62 (1.77)
Terms enrolled (summer)	1.23 (1.44)	0.55 (0.99)	1.48 (1.46)	1.98 (1.69)	0.84 (1.08)
Four-year grad	0.447	0.325	0.535	0.438	0.084
Unique students (% of sample)	*178,913*	*57,258* *(32%)*	*97,618* *(55%)*	*20,255* *(11%)*	*3,782* *(2%)*

Notes. See Table 1 notes. Table 2 statistics are based on the 4-year completion analytic sample. Numbers may not add to 100 percent due to rounding. High school GPA and SAT scores are missing for 8 and 9 percent of the four- and six-year completion samples, respectively, and race is missing for 2.6 percent of the sample.

Table 3. Estimates of the relationship between online enrollment and course performance outcomes

Outcome	(1) Mean (s.d.) in-person outcome	(2) Baseline	(3) Student Xs	(4) Student f.e.	(5) Student Xs + Course f.e.	(6) Student Xs + Professor f.e.	(7) Student Xs and major control function (Z_1)	(8) Student Xs and major control function (Z_1 and Z_2)
Panel A. Course-level outcomes								
Independent variable: Took the course online (mean [s.d] = 0.134 [0.341])								
Withdraws from the course	0.017	0.009	0.007	0.009	0.012	0.018	0.009	0.010
		(<0.001)	(<0.001)	(<0.001)	(<0.001)	(0.001)	(<0.001)	(<0.001)
Earns an A in the course	0.411	0.061	0.037	0.031	-0.006	-0.013	0.012	0.012
		(0.003)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(<0.001)
Earns an F in the course	0.059	0.014	0.011	0.017	0.028	0.018	0.016	0.017
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
F.e. with online variation		-	-	52%	16%	23%	-	-
Panel B. Term-level outcomes								
Independent variable: Took at least one course online in the term (mean [s.d] = 0.298 [0.458])								
Term GPA	2.96	0.067	0.036	0.014	-	-	0.025	0.025
	(0.89)	(0.003)	(0.003)	(0.003)			(0.003)	(0.002)
F.e. w/ online variation	-	-	-	47%	-	-	-	-

Notes. Each cell of columns (2)-(7) shows coefficient estimates and standard errors from a separate regression model. All models include institution and term fixed effects except for column (5) where the institution indicators get subsumed by the course fixed effects. Estimates are weighted by course credit hours (Panel A) or the number of credit hours attempted in the semester (Panel B). Student controls include total credits attempted in the semester, student sex, race/ethnicity, age, SAT score, and high school GPA in columns (3) and (5)-(7). Sample sizes: course withdrawals N=13,150,699 student-by-courses enrolled; course grades N=12,902,407 student-by-courses completed; and term GPA N=3,216,259 student-by-terms. Column (6) estimates have roughly half the number of observations as the other columns because the course instructor is not available in the early years of the administrative data. Standard errors are clustered at the declared major-by institution-by-term level.

Table 4. Estimates of the relationship between online enrollment and educational attainment outcomes

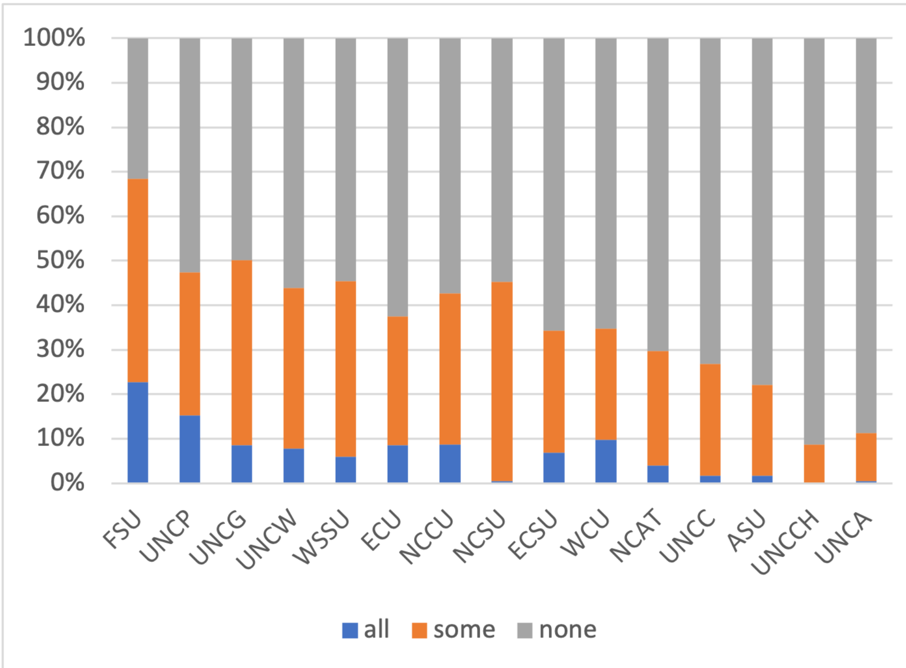
Outcome	(1) Mean (s.d.) outcome for students who took no hours online	(2) Baseline	(3) Student Xs	(4) Student Xs and major control function (Z_1)	(5) Student Xs and major control function (Z_1 and Z_2)
Independent variable: Share of courses taken online during UNC career (mean = 0.10 hours online)					
Total terms enrolled	5.22	0.296	2.935	3.014	3.088
	(3.54)	(0.531)	(0.465)	(0.441)	(0.370)
Total credit hour-years attempted	2.22	-0.697	0.610	0.652	0.690
	(1.54)	(0.193)	(0.162)	(0.153)	(0.121)
Attains a degree in 4 years	0.325	-0.050	0.076	0.077	0.094
		(0.032)	(0.023)	(0.022)	(0.015)
Attains a degree in 6 years	0.431	-0.102	0.172	0.161	0.174
		(0.048)	(0.038)	(0.030)	(0.025)

Notes. Credit hour-years are total credits attempted divided by 30 to approximate the equivalent of one full-time year. Student controls include student sex, race/ethnicity, age, SAT score, and high school GPA in columns (3)-(5). All models include institution and cohort fixed effects. Sample sizes: N=178,913 for the four-year completion sample and N=106,575 for the six-year completion sample. Standard errors are clustered at the declared major-by-institution-by-cohort level.

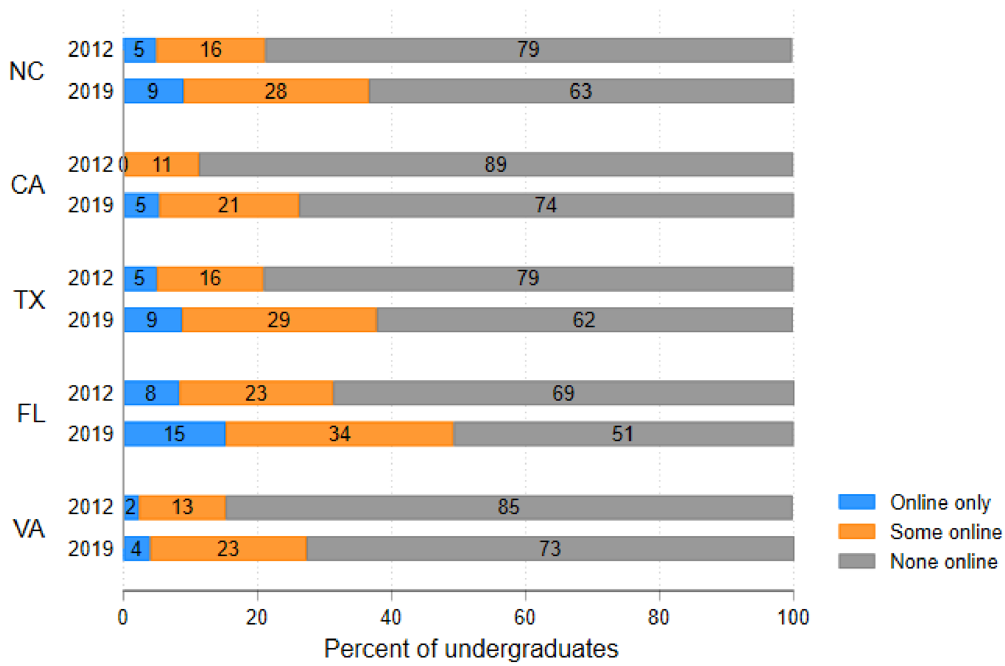
APPENDIX

Appendix Figure 1. Variability in undergraduate online enrollment

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

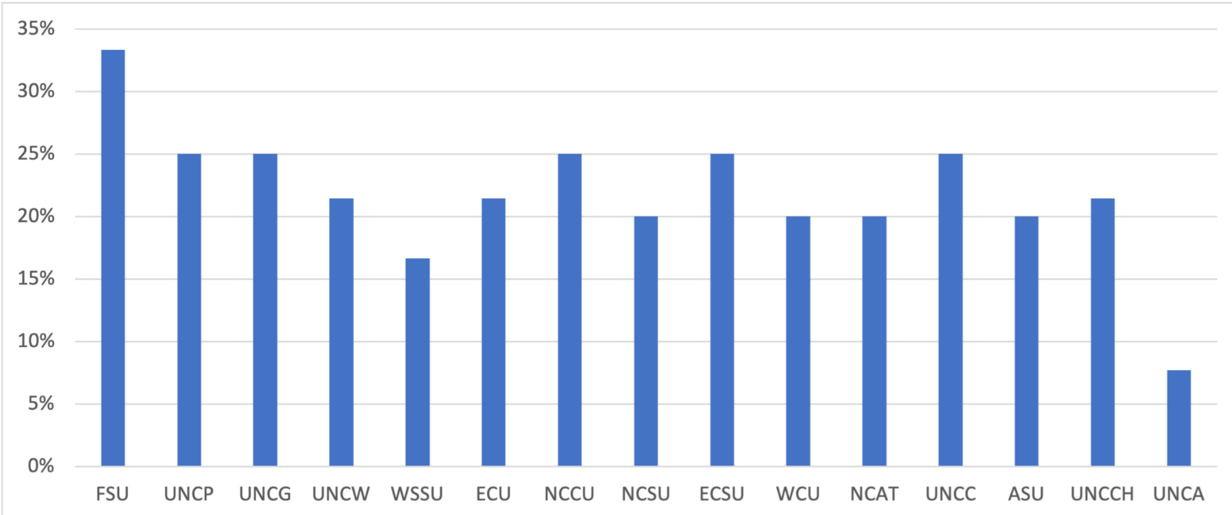


Panel B. Percent of students by online enrollment across states and over time



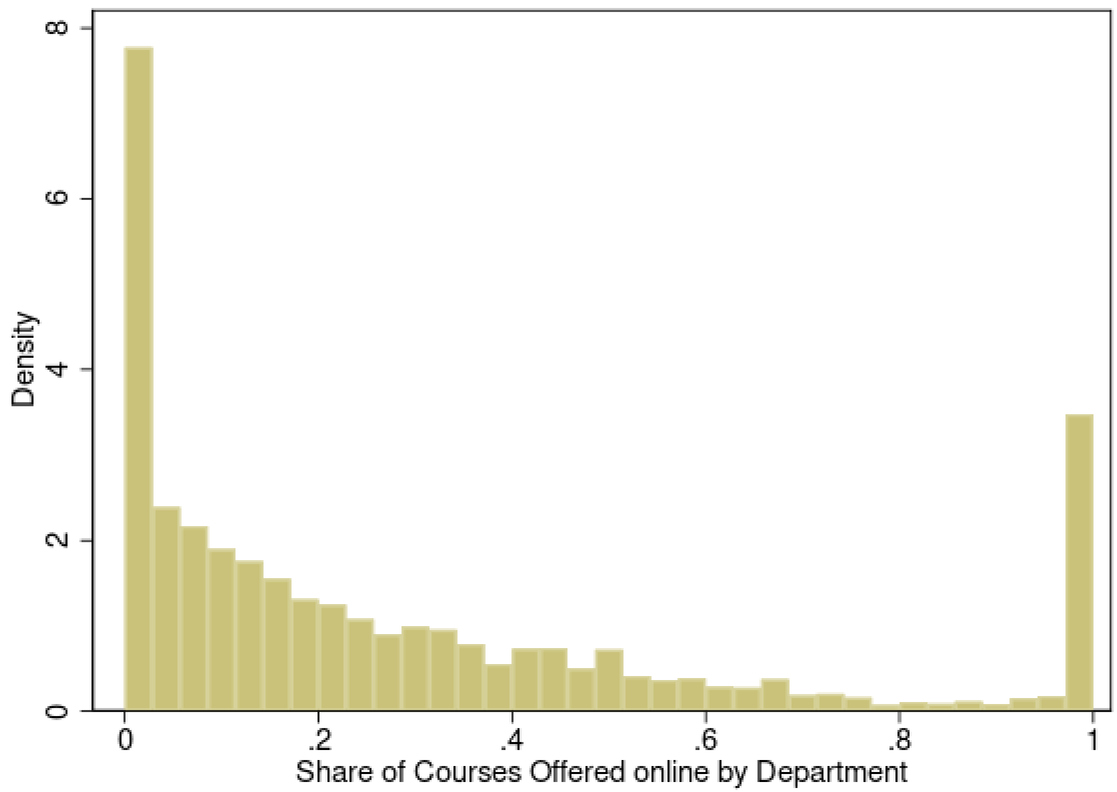
Notes. Panel A is constructed from the UNC System administrative data for the Fall 2019 semester. Bars are sorted left to right by the institution's admission rate (highest to lowest). Panel B is based on authors' calculations of IPEDS data. Institutions included for each state are 4-year, degree-granting public universities.

Appendix Figure 2. Share of hours taken online by the median student in their career across institutions



Notes. The figure is constructed from the UNC System administrative data for students enrolled in the Fall 2019 semester. It excludes students who took none or all of their classes online. Bars are sorted left to right by the institution's admission rate (highest to lowest).

Appendix Figure 3. Distribution of the share of courses offered online in a each major by institution by term



Notes. Data shown are for the grades sample. Each major-by-institution-by term share is represented once in the figure.

Appendix Table 1. UNC System institution characteristics

UNC System Institution	Total Enroll.	Enrolled in online courses	Financial aid recipients (any)	Female	Black	Asian	Latino/a	White	Admission rate	SAT math 25th/75th	SAT reading 25th/75th	4-year grad. rate (2014 entry cohort)
UNC Chapel Hill	19,154	0.09	0.65	0.60	0.08	0.11	0.09	0.59	0.23	640/760	630/720	0.90
NC State	25,973	0.44	0.68	0.48	0.06	0.08	0.06	0.67	0.47	630/710	620/680	0.75
NC Central	6,101	0.45	0.93	0.68	0.78	0.01	0.07	0.06	0.47	450/520	450/530	0.47
Elizabeth City	1,692	0.40	0.97	0.59	0.69	0.01	0.04	0.18	0.59	440/520	450/520	0.39
NC A&T	11,039	0.32	0.96	0.58	0.81	0.01	0.04	0.05	0.61	470/550	480/560	0.48
UNC Wilmington	14,785	0.46	0.72	0.63	0.04	0.02	0.07	0.78	0.61	590/660	600/660	0.71
Winston-Salem	4,656	0.47	0.97	0.73	0.78	0.01	0.04	0.11	0.65	440/510	420/520	0.46
UNC Charlotte	24,070	0.28	0.74	0.47	0.16	0.08	0.11	0.56	0.67	560/640	560/630	0.55
Fayetteville State	5,644	0.69	0.95	0.69	0.57	0.02	0.09	0.19	0.68	440/510	450/520	0.35
App. State	17,518	0.22	0.70	0.56	0.04	0.02	0.07	0.82	0.69	540/630	560/640	0.70
Western Carolina	10,469	0.39	0.85	0.55	0.05	0.01	0.07	0.79	0.79	510/600	520/610	0.58
UNC Pembroke	6,353	0.54	0.90	0.61	0.31	0.01	0.08	0.37	0.81	455/530	470/550	0.34
East Carolina	23,081	0.43	0.79	0.57	0.16	0.02	0.07	0.65	0.82	520/590	520/600	0.59
UNC Greensboro	16,581	0.52	0.88	0.67	0.29	0.05	0.11	0.45	0.84	490/570	500/590	0.56
UNC Asheville	3,587	0.11	0.94	0.58	0.05	0.02	0.08	0.74	0.94	520/610	540/640	0.64

Notes. Compiled using IPEDS data. All statistics are from Fall 2019, and the four-year graduation rate is for the 2014 entry cohort. Rows are sorted by the institution's admission rate (lowest to highest).

Appendix Table 2. Characteristics of undergraduate enrollees, by sector

Undergraduate Characteristics	Public 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. UNC System data compiled from the UNC System's data dashboard for Fall 2019 except SAT scores, which come from IPEDS. 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.

Appendix Table 3. Summary of outcomes, treatment, and analysis

Outcome	Variation	How Online Education is Measured	Fixed Effects Used	Group Control Function Aggregation	Analytic Sample
Course level: Grades Withdrawals	Multiple observations per student in a given term	=1 if the student took the course online =0 otherwise	-Student, course, or professor (separate models) -Institution -Term	Department of the course in that institution in that term	Grades
Term level: GPA	Multiple observations per student over their UNC career	=1 if the student took at least one course online in the term =0 otherwise	-Student -Institution -Term	Student's declared major at their university in that term	Grades
Educational attainment: Terms enrolled Credit hours Completion	Do not vary within student	Percent of all hours attempted that the student took online in their UNC career	-Institution -Term	Student's declared major at their university in their final term of enrollment during the fall term of their matriculation	4-year and 6-year completion

Notes. When constructing the group-level control variables, department is the 2-digit Classification of Instructional Programs (CIP) code associated with the course, and declared major is the 4-digit CIP code associated with the major.

CIP codes + UNC data:

- We are calling 2-digit CIPs "departments" and 4-digit CIPs "majors"
  - Example: department = mathematics and statistics (CIP 27); majors = (a) mathematics (27.01), (b) applied mathematics (27.03), and (c) statistics (27.05)
- We cannot associate a major with a course. Courses have 2-digit CIPs, but majors have 6-digit CIPs (we use the first four digits).
- We treat undeclared majors as their own group within an institutionXterm

Group definitions:

1. Course-level outcomes (Ws, As, Fs)

- Z1 = leave-one-out means of student Xs aggregated across all students with the same 2-digit CIP code at the same university during the term of the course
- Z2 = department-level characteristics associated with the course's 2-digit CIP (e.g., % of As given in "math and statistics" (CIP = 27) classes at a university in a given term)

2. Term-level outcomes (GPA)

- Z1 = leave-one-out means of student Xs aggregated across all students whose declared major has the same 4-digit CIP code at the same university during the term of the GPA
- Z2 = major by institution by term level characteristics associated with courses and grades that student's within a declared major at an institution enroll in each term. So, for example, % As awarded would be across all grades within a major at a institution in that term. For multiple enrollments within the same course, at the same institution, in the same term, these course enrollments were included multiple times within the group averages..

3. Student level (attainment)

- Z1 = major by institution by fall term averages at the 4-digit major CIP code. We match to students based on their final major and year of matriculation
- Z2 ("major quality" that a student "inherits") = % As given across all courses within the department associated with the students final major but for the year the student enters the UNC System; graduation rate for students with the declared major the year the student enters the UNC System; etc. Some of these variables are about the major and some are about the department depending on whether we need to create the variables from the transcript file (those are about the department) or not (those are about the major)

Appendix Table 4. Variables used as student and group controls

Variable	Included as a student-level control	Major-level control mean (s.d.)
Panel A: Student Xs aggregated to the major-by-institution-by term/cohort level		
Male	X	0.454
Student race/ethnicity		
Non-resident alien	X	0.017
Hispanic/Latino	X	0.062
American Indian/Alaska Native	X	0.013
Asian	X	0.031
Black/African American	X	0.279
Native Hawaiian/Other Pac. Islander	X	0.001
White	X	0.563
Two or more	X	0.035
SAT/ACT score	X	1078.1 (131.6)
High school GPA	X	3.19 (0.44)
Age	X	21.11 (3.68)
In-state student	X	0.877
Panel B: Information about courses in the department		
Courses offered online during the student's first year of enrollment		0.278
Share of course enrollments in lower-division classes		0.660
Share of undergraduates at the institution with the major		0.023
Panel C: Information about student performance in the major		
Average grade earned in the department's courses		2.94 (0.45)

Share of grades awarded in the major that are A	0.44
Share of grades awarded in the major that are F	0.07
Four-year graduation rate in the major	0.45
Six-year graduation rate in the major	0.47

Appendix Table 4a. Estimates of the relationship between online enrollment and course performance outcomes by student age

Outcome	Age	(1) Mean (s.d.) in-person outcome	(2) Baseline	(3) Student Xs	(4) Student f.e.	(5) Student Xs + Course f.e.	(6) Student Xs + Professor f.e.	(7) Student Xs and major control function (Z_1)	(8) Student Xs and major control function (Z_1 and Z_2)
Panel A. Course-level outcomes									
Independent variable: Took the course online (overall mean = 0.134)									
Withdraws from the course	age<20	0.017	0.010 (<0.001)	0.010 (<0.001)	0.010 (<0.001)	0.014 (<0.001)	0.020 (0.001)	0.011 (<0.001)	0.012 (<0.001)
	age>=20	0.014	0.004 (<0.001))	0.003 (<0.001))	0.006 (<0.001)	0.008 (<0.001))	0.016 (0.001)	0.004 (<0.001)	0.005 (<0.001)
Earns an A in the course:	age<20	0.413	0.036 (0.002)	0.040 (0.002)	0.042 (0.002)	-0.007 (0.001)	-0.017 (0.002)	0.020 (0.003)	0.015 (0.003)
	age>=20	0.404	0.071 (0.004)	0.031 (0.003)	0.004 (0.002)	-0.012 (0.002)	-0.011 (0.004)	-0.002 (0.003)	0.004 (0.003)
Earns an F in the course	age<20	0.057	0.015 (0.001)	0.013 (0.001)	0.015 (0.001)	0.033 (0.001)	0.020 (0.002)	0.004 (0.001)	0.011 (0.001)
	age>=20	0.076	0.014 (0.001)	0.011 (0.001)	0.022 (0.001)	0.027 (0.001)	0.020 (0.001)	0.010 (0.001)	0.009 (0.001)
Panel B. Term-level outcomes									
Independent variable: Took at least one course online in the term (overall mean = 0.298)									
Term GPA	age<20	2.97 (0.88)	0.049 (0.003)	0.037 (0.003)	0.020 (0.003)	-	-	0.028 (0.003)	0.022 (0.003)
	age>=20	2.92	0.074	0.022	-0.004	-	-	-0.003	0.011

	(0.94)	(0.006)	(0.005)	(0.004)			(0.005)	(0.004)

Notes. Each cell of columns (2)-(8) shows coefficient estimates and standard errors from a separate regression model. All models include institution and term fixed effects except for column (5) where the institution indicators get subsumed by the course fixed effects. Estimates are weighted by course credit hours (Panel A) or the number of credit hours attempted in the semester (Panel B). Student controls include the total number of credit hours attempted in the semester, student sex, race/ethnicity, age, SAT score, and high school GPA in columns (5)-(7). Sample sizes: course withdrawals N=9,778,847 student-by-courses enrolled for young students and N=3,371,852 student-by-courses enrolled for older students; course grades N=9,600,874 student-by-courses completed for younger students and N=3,301,533 student-by-courses completed for older students; and term GPA N=2,193,724 student-by-terms for younger students and 1,022,535 student-by-terms for older students. Column (6) estimates have roughly half the number of observations as the other columns because the course instructor is not available in the early years of the administrative data. Standard errors are clustered at the declared major-by institution-by-term level.

Appendix Table 4b. Estimates of the relationship between online enrollment and course performance outcomes by student sex

Outcome	Age	(1) Mean (s.d.) in-person outcome	(2) Baseline	(3) Student Xs	(4) Student f.e.	(5) Student Xs + Course f.e.	(6) Student Xs + Professor f.e.	(7) Student Xs and major control function (Z_1)	(8) Student Xs and major control function (Z_1 and Z_2)
Panel A. Course-level outcomes									
Independent variable: Took the course online (overall mean = 0.134)									
Withdraws from the course	female	0.015	0.009 (<0.001)	0.007 (<0.001)	0.008 (<0.001)	0.011 (<0.001)	0.017 (0.001)	0.008 (<0.001)	0.009 (<0.001))
	male	0.020	0.010 (<0.001))	0.008 (<0.001)	0.010 (<0.003)	0.013 (0.001)	0.019 (0.001)	0.009 (0.001)	0.010 (0.001)
Earns an A in the course:	female	0.454	0.047 (0.003)	0.034 (0.003)	0.031 (0.002)	-0.007 (0.001)	-0.018 (0.003)	0.005 (0.003)	0.009 (0.003)
	male	0.358	0.059 (0.002)	0.044 (0.002)	0.031 (0.002)	0.014 (0.002)	-0.0001 (0.002)	0.029 (0.002)	0.022 (0.002)
Earns an F in the course	female	0.051	0.018 (0.001)	0.013 (0.001)	0.015 (0.001)	0.031 (0.001)	0.019 (0.001)	0.007 (0.001)	0.009 (0.001)
	male	0.069	0.013 (0.001)	0.009 (0.001)	0.021 (0.002)	0.024 (0.001)	0.016 (0.002)	0.002 (0.001)	0.006 (0.001)
Panel B. Term-level outcomes									
Independent variable: Took at least one course online in the term (overall mean = 0.298)									
Term GPA	female	3.06 (0.86)	0.029 (0.004)	0.023 (0.003)	0.014 (0.003)	-	-	0.008 (0.004)	0.013 (0.003)
	male		0.074	0.022	-0.004	-	-	0.047	0.039

	(0.006)	(0.005)	(0.004)			(0.003)	(0.003)

Notes. Each cell of columns (2)-(7) shows coefficient estimates and standard errors from a separate regression model. All models include institution and term fixed effects except for column (5) where the institution indicators get subsumed by the course fixed effects. Estimates are weighted by course credit hours (Panel A) or the number of credit hours attempted in the semester (Panel B). Student controls include total credits attempted in the semester, race/ethnicity, age, SAT score, and high school GPA in columns (5)-(7). Sample sizes: course withdrawals N=7,422,862 student-by courses attempted for for female students and N=5,727,837 for male students; course grades N=7,294,152 student-by-courses completed for female students and N=5,608,255 for male students; and term GPA N=1,829,279 student-by-terms for female students and N=1,286,981 for male students. Column (6) estimates have roughly half the number of observations as the other columns because the course instructor is not available in the early years of the administrative data. Standard errors are clustered at the declared major-by institution-by-term level.

Appendix Table 5a. Estimates of the relationship between online enrollment and educational attainment outcomes by student age

Outcome	(1) Mean (s.d.) outcome for students who took no hours online	(2) Baseline	(3) Student Xs	(4) Student Xs and major control function (Z_1)	(5) Student Xs and major control function (Z_1 and Z_2)
Independent variable: Share of credit hours taken online during UNC career (mean = 0.10 hours online)					
Total terms enrolled	5.22 (3.54)	4.365 (1.405)	5.304 (0.922)	5.690 (0.822)	5.487 (0.683)
Interaction I(age>=20)		-5.002 (1.437)	-5.679 (0.938)	-6.108 (0.837)	-5.448 (0.679)
Total credit hour-years attempted	2.22 (1.54)	0.963 (0.542)	1.404 (0.324)	1.567 (0.287)	1.484 (0.222)
Interaction I(age>=20)		-1.614 (0.559)	-1.805 (0.334)	-1.973 (0.296)	-1.711 (0.225)
Attains a degree in 4 years	0.325	0.149 (0.070)	0.167 (0.038)	0.171 (0.036)	0.174 (0.024)
Interaction I(age>=20)		-0.203 (0.075)	-0.206 (0.045)	-0.217 (0.041)	-0.180 (0.027)
Attains a degree in 6 years	0.431	0.249 (0.159)	0.342 (0.086)	0.380 (0.062)	0.360 (0.053)
Interaction I(age>=20)		-0.311 (0.166)	-0.377 (0.093)	-0.435 (0.066)	-0.370 (0.055)

Notes. Credit hour-years are total credits attempted divided by 30 to approximate the equivalent of one full-time year. Student controls include student sex, race/ethnicity, age, SAT score, and high school GPA in columns (3)-(5). All models include institution and cohort fixed effects, an indicator for student age >= 20 years, share of credit hours taken online during UNC career, and an interaction between share of credit hours taken online and student age is >= 20 years. Sample sizes: N=178,913 for the four-year completion sample and N=106,575 for the six-year completion sample. Standard errors are clustered at the declared major-by-institution-by-cohort level.

Appendix Table 5a. Estimates of the relationship between online enrollment and educational attainment outcomes by student sex

	(1)	(2)	(3)	(4)	(5)
Outcome	Mean (s.d.) outcome for students who took no hours online	Baseline	Student Xs	Student Xs and major control function (Z_1)	Student Xs and major control function (Z_1 and Z_2)
Independent variable: Share of credit hours taken online during UNC career (mean = 0.10 hours online)					
Total terms enrolled	5.22 (3.54)	0.690 (0.719)	3.328 (0.631)	3.451 (0.626)	3.501 (0.498)
Interaction female		-0.720 (0.448)	-0.626 (0.363)	-0.689 (0.381)	-0.658 (0.285)
Total credit hour-years attempted	2.22 (1.54)	-0.467 (0.267)	0.844 (0.229)	0.914 (0.232)	0.935 (0.173)
Interaction female		-0.430 (0.182)	-0.363 (0.148)	-0.406 (0.159)	-0.384 (0.120)
Attains a degree in 4 years	0.325	-0.036 (0.040)	0.116 (0.033)	0.121 (0.031)	0.125 (0.021)
Interaction female		-0.088 (0.029)	-0.060 (0.025)	-0.065 (0.024)	-0.046 (0.018)
Attains a degree in 6 years	0.431	-0.085 (0.054)	0.234 (0.045)	0.257 (0.040)	0.248 (0.034)
Interaction female		-0.139 (0.031)	-0.121 (0.027)	-0.142 (0.027)	-0.112 (0.023)

Notes. Credit hour-years are total credits attempted divided by 30 to approximate the equivalent of one full-time year. Student controls include student sex, race/ethnicity, age, SAT score, and high school GPA in columns (3)-(5). All models include institution and cohort fixed effects, an indicator for student sex is female, share of credit hours taken online during UNC career, and an interaction between student is female and share of credit hours taken online. Sample sizes: N=178,913 for the four-year completion sample and N=106,575 for the six-year completion sample. Standard errors are clustered at the declared major-by-institution-by-cohort level.