Adopting Online Learning in College Developmental Education Coursework:

Impact on Student course Persistence, Completion, and Subsequent Success

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Abstract

Developmental education is the most widespread strategies used by colleges to provide academically weak students with additional training in key subject areas. To reduce costs and also to address the large volume of enrollment in these courses, many institutions have replaced traditional face-to-face instruction with online instruction in developmental coursework. This paper examines the impact of fully online instruction, compared with traditional face-to-face instruction, on both concurrent developmental course outcomes, and on downstream outcomes, using a unique administrative dataset from a state community college system that includes longitudinal student-unit record data from more than 40,000 students enrolled in developmental education courses. Results from a two-way fixed effects model that controls for selection both at the course- and student-level indicate that taking one's first developmental course through the online format reduces developmental course completion rate by 13 percentage points and subsequent enrollment in the gatekeeper course by 7 percentage points.

Keyword: community college, developmental education, online course, two-way fixed effects, student outcomes

1. Introduction

Developmental education has been one of the most widespread and costly strategies used by colleges, especially open-access institutions, to provide academically weak students with additional training in key subject areas (Chen, 2016). At community colleges, for example, 10% of all credits earned are from developmental coursework, which lead to a cost of almost $4 billion annually (Scott-Clayton & Rodriguez, 2015). Due to the huge cost associated with developmental education and the large volume of enrollment in these courses, many institutions have replaced or are considering replacing traditional face-to-face instruction with online instruction to save on costs and to address demand.

Would students enrolled in developmental coursework achieve similar learning outcomes when the course content is delivered fully online rather than through traditional face-to-face lectures? Answers to this question have important policy implications for higher education success as well as for educational equality: first, timely completion of developmental courses plays a critical role in a student's college career; students required to take but failing to pass developmental education face academic hurdles in enrolling in other college-level courses and subsequent progression toward the degree (Calcagno, Crosta, Bailey, & Jenkins, 2007). As a result, colleges tend to be particularly concerned with success rates in these courses. Additionally, developmental education is more prevalent at community colleges than four-year institutions; disproportionately enrolling students from low-income and racial-minority groups, community colleges assume a critical role in addressing the national equity agenda by providing a key point of access to postsecondary education for these students (National Center for Public

Policy and Higher Education, 2011). Supporting students to progress through developmental coursework thus becomes fundamental to reducing inequality between subgroups of students.

Yet, whether students benefit from or are subject to performance decrement from fully online format in developmental coursework remains unclear. On one hand, advocates for online learning are optimistic about the potential of technology to better address individual needs through self-paced learning (Choy, 2002; Kleinman & Entin, 2002). On the other hand, the literature in education psychology converges to suggest that learner-centered online learning requires students to assume greater responsibility during their learning process than do traditional learning contexts (Azevedo, Cromley, & Seibert, 2004; Corbeil, 2003; Guglielmino & Guglielmino, 2003; Hannafin & Land, 1997). Since students enrolled in developmental courses are often academically underprepared and lack self-directed learning skills, fully online learning environment may impose additional challenges to these students (Xu & Jaggars, 2014; Xu & Xu, 2019).

This paper extends the existing literature on distance learning in higher education by examining the impact of delivery format in developmental coursework — online versus face-to-face — on concurrent course outcomes in developmental coursework, as well as on important downstream outcomes, such as students' subsequent persistence into and performance in gatekeeper courses. Gatekeeper courses are first college-level courses in English and math that are typically required for a college degree, and therefore represent critical milestones in a student's college career. We use a unique administrative dataset from an anonymous state community college system that includes longitudinal student-unit record data from four cohorts of students enrolled in developmental education courses. To address student nonrandom sorting by course delivery format, we exploit the fact that many students are assigned to developmental

courses in multiple subjects, which allows us to conduct within-individual comparisons by using an individual fixed effects model. We further include college-course fixed effects into our model, therefore comparing students enrolled in exactly the same developmental education course at a specific college. Additionally, our dataset includes a rich set of instructor characteristics and we include them in some of our models to address the possibility that instructors teaching online sections of a course are different from instructors teaching face-to-face sections.

Our results, discussed in more detail below, show robust estimates of negative impact of taking one's developmental course through the online delivery format on course completion rate by more than 13 percentage points. This effect is driven by both decreased probability of course persistence and lower course grade among those who persist to the end of the course. In terms of downstream outcomes, our analyses indicate that taking one's first developmental course online in a subject area reduces the student's probability of ever enrolling in the gatekeeper course in that subject by 7 percentage points. Yet, among students who do enroll in the gatekeeper course, we do not find any significant difference in their gatekeeper course grade. These results indicate that academically underprepared students enrolled in developmental coursework may face additional challenges in completing the developmental education requirement successfully in an online learning environment, compared with on-campus face-to-face versions of these courses, therefore cautioning the expansion of online learning in developmental courses.

2. Background and Relevant Literature

2.1 Developmental Education at Community Colleges

As low-cost open-access institutions, community colleges provide a key point of access to postsecondary education for millions of low-income and ethnic minority students. According to the data from the Beginning Postsecondary Longitudinal Survey, more than 60% of first-time

community college students in the academic year of 2011-2012 were first-generation college students, compared with approximately 40% at four-year institutions. Yet, as a result of the open-access policy, many community college students are not academically ready for college-level coursework upon initial college enrollment.

The most common approach that colleges use to address this problem has been to provide students the opportunity to strengthen their skills and bring them up to an adequate level for further college-level coursework through "developmental" or "remedial" education. Based on data from the 2004/09 Beginning Postsecondary Students Longitudinal Study (BPS: 04/09) that followed a nationally representative sample of students who entered college during the academic year of 2003-04, Chen (2016) found that more than two thirds of those starting at a public two-year institution and 40% of those starting at a public four-year institution took at least one developmental course. Developmental education is particularly intensive at community colleges, where almost half of incoming students took multiple developmental courses.

It should be noted that while developmental education is common among all community college students, the participation rate is particularly high among racial minority students and students from low-income backgrounds. Among 2003- 2004 first-time community college entrants, 75% of Hispanics students and 78% of black students took developmental education, compared with 64% of white students; in a similar vein, 76% of students from the lowest quartile of income took developmental education, compared with 59% of students from the highest quartile. These striking contrasts indicate that the effectiveness of developmental education coursework is not only fundamental to the postsecondary success among millions of college students enrolled at community colleges, but will also have important implications for educational equality between students from disadvantaged and more affluent backgrounds.

Although developmental coursework is provided in multiple fields of study, it is most prevalent in English and math; for the subject of English, it is typical practice for colleges to assess and prepare students in reading and writing separately. In the state community college system examined in the current study, for example, almost one third of the students have taken at least one developmental course in reading, writing, or math. The traditional developmental program typically consists of a sequence of multiple courses across several semesters, and students are assigned to different combinations of course requirements based on their initial assessment test scores in the corresponding subject area upon initial college enrollment (Grubb, 2013). For example, in a three-course math sequence, the lowest level of developmental math usually covers arithmetic, the middle level covers beginning algebra concepts, and the highest level prepares students for college algebra. Therefore, a student with the least preparation for math (and therefore assigned to the lowest level in math) would need to complete all the three developmental courses before they are allowed to embark on college-level math courses or courses that have college math prerequisites.

The large enrollment and intensity of developmental education imposes huge costs to institutions, which has been estimated at more than $1 billion each year (Noble, Schiel, & Sawyer, 2003). To meet the high demand of developmental education, and in the face of tight state budgets, many colleges have been seeking possible cost-saving strategies to deliver developmental education programs. Without the class size constraints associated with physical classrooms and with the potential to increase the number of sections faculty teach, online learning has been arguably one of the most popular approaches. For example, Bettinger, Doss, Loeb, Rogers, & Taylor (2017) found that a 10% increase in online class size did not reduce

current course grade or subsequent course enrollment, potentially addressing demand and reducing costs at the same time.

The most promising and direct evidence for using online learning to reduce cost in delivering developmental coursework comes from a recent report by the National Center for Academic Transformation (2013). Based on expenditure data from 28 community colleges that switched to a blended model which modularized course materials and replaced class time with computer lab (among other content-related changes), the report found that blended format reduced the per-student cost by 20% for math developmental education on average. It should be noted though that the online expansion at community colleges is not unique to developmental coursework. In section 2.2, we provide an overview of the rapid growth of online learning at the particular setting of community colleges in recent years.

2.2 Rapid Growth of Online Learning at Community Colleges

While community colleges open up postsecondary education opportunities to students from all backgrounds, these institutions face many challenges, including limited space, faculty shortages, and large proportions of working adults (Carnevale, Jayasundera, Repnikov, & Gulish, 2015). These circumstances provide a context in which online learning can thrive (Harasim, 2000; Xu & Jaggars, 2011). Advocates are also particularly optimistic about the potential of fully online coursework to address capacity constraints in lower-division courses with large enrollments (Choy, 2002; Kleinman & Entin, 2002). As a result, online learning enrollments at two-year colleges have increased more quickly than at 4-year colleges. Based on the Integrated Postsecondary Education Data, Xu & Xu (2019) estimated that almost one third of degree-seeking students enrolled at community colleges took at least one fully online course in the 2016-2017 academic year, and among these students, one third were enrolled online exclusively.

In fact, distance learning through fully online coursework is now viewed as one of the most promising ways to alleviate barriers by allowing these colleges to offer additional courses or course sections to their students and increase access to (and presumably progression through) required courses (Allen & Seaman, 2014; Allen, Seaman, Hill, & Poulin, 2015; Parsad & Lewis, 2008).

Due to the flexibility of online learning, online courses seem to be particularly appealing to students who assume working and family responsibilities. For example, based on data from California's Community College System, Johnson and Mejia (2014) found that online courses were more popular among students aged 25 or older; the report also reveals racial and ethnic differences in online enrollment, where Latino students were less likely to attempt online courses than White, African American, or Asian students. This disparity may partially reflect the broadband internet access divide, as research suggests that Latinos are typically less likely to have internet access at home (Baldassare, Bonner, Petek, & Shrestha, 2013).

2.3 Potential Challenges of Online Learning at Community Colleges

With the rapid growth of online education and its potential benefits to address the needs of diverse student populations, questions remain regarding its effectiveness at community colleges (Aragon & Johnson, 2008). Skeptics of online learning point out two additional challenges associated with online teaching and learning compared with traditional face-to-face delivery -- increased need for student self-regulation in the absence of the structure of regular in-person class meetings, and the reduction in personal interaction generally found in online classes.

First, drawing on the education psychology literature, researchers argue that student-centered online learning requires learners to assume greater responsibility to engage in the learning process, relative to traditional learning contexts. Unlike face-to-face courses in which

students attend course lectures at a fixed time, students working in a fully virtual environment are required to plan out when they will watch the course lectures and work on corresponding assignments, learn course materials independently, manage time wisely, keep track of progress on course assignments, overcome technical difficulties and the feeling of isolation, and take the initiative to communicate with instructors and peers for questions and group assignments. Granted, these self-directed learning skills -- such as time management skills, the ability to manage learning tasks independently and strategically, and the capability of setting one's own learning goals, and being self-motivated and self-disciplined -- are important in any learning environment, but they are more crucial to effective online education.

Yet, many community college students, especially those from disadvantaged backgrounds and those who are less prepared academically, enter college without adequate self-directed skills. These students therefore may struggle particularly in a fully online learning environment (Corbeil, 2003; Xu & Jaggars, 2014). Indeed, using data from the California Community College System, Hart, Friedmann, & Hill (2018) found that while all students were subject to online performance decrement, students with lower academic preparedness were associated with the strongest declines. Similar patterns are also identified in Xu & Jaggars (2014) using data from the Washington Community College System.

Based on these findings, researchers have highlighted the importance of providing additional support and scaffolding to prepare students toward successful online learning (e.g. Xu & Jaggars, 2014). The effectiveness of such skill scaffolding activities pivots on effective student-teacher communications and interactions. Yet, computer-mediated communications are often criticized for imposing greater challenges to achieve effective interpersonal connections, since nonverbal and relational cues—common in face-to-face communication—are generally

missing. Existing research consistently points out that student-teacher and student-student interactions are often limited to written text in online coursework at community colleges, which may lead students to feel isolated and unsupported (e.g. Bambara, Harbour, Davies, & Athey, 2009).

The higher demand for student self-regulation and greater difficulties of achieving effective interpersonal interactions associated with online learning imply that academically underprepared students, such as those enrolled in developmental education coursework, may encounter greater barriers to success when the developmental education course content is delivered online. Would students enrolled in developmental coursework achieve similar learning outcomes when the course content is delivered fully online rather than through traditional face-to-face lectures? While not directly answering this question, two existing studies provide some suggestive evidence on this issue. Using data from a large public four-year university, Cung, Xu, Eichhorn, & Warschauer (2019) assessed the impacts of an instructional change in developmental math from the blended format to fully online format. The authors found that students in fully online format achieved significantly worse final exam scores and final grades. In a similar vein, based on college administrative data from the Kentucky Community and Technical College System, Kozakowski (2019) examined the effect of adopting a blended model in developmental math that replaced the in-class lecture with on-campus computer lab. The author found that the blended model reduced math developmental course pass rates, college persistence, and degree attainment. Although these two studies did not directly compare between online and traditional in-class format in delivering developmental education, they both provide suggestive evidence that developmental students may struggle more when greater amount of course content is delivered online rather than through the traditional in-class interactions. We

build on the two studies and further extend them by directly examining the extent of performance decrement (or gain) when a traditional developmental face-to-face course is replaced by a fully online delivery format.

2.4 Potential Affordances of Online Learning at Community Colleges

Despite the additional challenges associated with online learning, some researchers argue that it could also offer important affordances compared with traditional face-to-face learning context, which may potentially improve the learning experiences. One such affordance is providing personalized learning experience to students, delivering instruction in which the pace of learning and the instructional approach can be optimized for the needs of each learner (US Department of Education, 2014). Technology can also help instructors meet students where they are and advance them to mastery, accounting for their different strengths, levels of prior knowledge, and interests, along with immediate personalized feedback, which might be more difficult to achieve in the traditional face-to-face setting. For example, many content providers have built intelligent tutoring systems for delivering personalized instruction and feedback across many domains, such as Carnegie Learning and ALEKS.

Additionally, one great advantage of the virtual learning environment lies in its potential to identify at-risk learners in a timely way, based on individual online learning behaviors that might otherwise go unnoticed in face-to-face lectures with large class sizes (Romero & Ventura, 2010). Student click-stream and learning analytics data on the platform that closely record when and how a student accesses online materials and completes assignments allow the tracking of student access to study materials and their practice within the system in a timely and efficient manner. Such information can be provided back to the student as a form of personalized feedback; it can also provide instructors with an efficient way to identify struggling students

early on and provide suggestions or interventions to better support at-risk students (Romero & Ventura, 2010). For example, Arnold and Pistilli (2012) used local course data to build predictive models that correlate disparate types of measures (such as online learning patterns, student surveys, and online learning diagnostics) with student course performance to identify students who are at risk of negative academic outcomes.

However, it is worth noting that despite the potential of advanced technologies to achieve personalized learning experiences, they do not provide instructors with the ability to personalize their instructional content automatically. Skeptics of online learning point to the quality of online courses currently offered at community colleges, where the majority of instructors simply transfer their in-class pedagogy to the online format, rather than finding ways to take advantage of the capabilities of computer-mediated distance education to facilitate active and personalized learning (Bambara et al., 2009; Cox, 2006; Philip, 2011; Jaggars & Xu, 2016). As a result, the extent to which online developmental coursework can indeed provide personalized learning experiences to students at community colleges and eventually enable them to progress through the developmental sequence more effectively remains largely unknown.

3. Present Study and Contribution

This paper contributes to the existing literature on online education at community colleges by providing the first causal estimate regarding whether delivering developmental education through online versus face-to-face format influences student learning outcomes at this particular setting. Due to the large volume of enrollment in developmental coursework, many institutions have replaced or are considering replacing traditional face-to-face instruction with online course delivery to address resource constraints in space and faculty. Findings from this

study would therefore directly inform the design and expansion of distance learning at community colleges.

In addition, we look beyond student performance in the current developmental coursework and further examine whether taking developmental education online may affect students' subsequent enrollment and performance in the corresponding gatekeeper courses. The majority of the existing studies on distance learning focuses on current course outcomes. To our knowledge, in addition to the Kentucky study mentioned above (Kozakowski, 2019), only two other studies (Hart et al., 2018; Krieg & Henson, 2016) have examined downstream outcomes of distance learning. Based on a fixed effects model, Hart et al. (2018) found that online course-taking was positively associated with course repetition and negatively associated with subject persistence at the California community colleges. Similarly, using student transcript data from a large comprehensive university, Krieg & Henson (2016) found that students taking online prerequisites earned lower grades in subsequent courses compared with students who took the prerequisite face-to-face. Our study builds on these studies and adds to the current literature by directly comparing between online versus face-to-face format in delivering developmental coursework in terms of both concurrent developmental course outcomes and subsequent progression through the gatekeeper requirement.

4. Data and Research Background

4.1 Data and Research Context

Data and State Context. Our data include four cohorts of first-time college students, a total of 79,725 students, in an anonymous state community college system (referred to as ASCCS hereafter). These students were initially enrolled in ASCCS between fall 2005 and summer 2009, and were tracked until summer 2012, or at least four years since initial enrollment.

The dataset contains information on student demographics, institutions attended, each student's intended major at college entry, and students' placement test scores in reading, writing, and math. It also includes detailed transcript data on each college course taken, grades received, course section number, course subject, whether it is a developmental or college-level course, the characteristics of the instructor teaching a specific class, and whether the course is delivered online or through traditional face-to-face mode.

Compared with the characteristics of typical two-year institutions nationwide based on data from the Integrated Postsecondary Education Data Systems (IPEDS), ASCCS institutions are more likely to be located in rural areas, smaller in enrollment size, more concentrated with white students, and are subject to lower graduation rates. The graduation rates are particularly low among students assigned to developmental education programs, where only 9.4% earn an associate degree in three years. In view of the low graduation rates, the state has implemented a series of initiatives aiming at improving postsecondary attainment and reducing the percentage of students assigned to college remediation. Yet, still about one third of the first-time college enrollees take developmental education courses during the period of the current study. In the meantime, similar to other community colleges, ASCCS has also expanded online learning in developmental coursework, partly to address the large demand for developmental education and partly to reduce the costs associated with it.

State Developmental Education Placement Tests. Since 1988, ASCCS has required competency-based testing for students enrolling in college for the first time. This policy requires all first-year students seeking an associate degree or higher to meet the assessment and placement standards in the disciplines of reading, writing, and mathematics. Students who score below the state established minimum threshold are then required to enroll in remedial

coursework before they are allowed to take college-level courses in the corresponding subject area.

During the period of the present study, first-time entering freshmen may be exempted from taking the placement tests if they submit an SAT or ACT score that has met the state standard; otherwise, the students would be required to take the ACCUPLACER or COMPASS placement exams mandated by the state. First-time entering freshman who scores above the state-established minimum score of the test in a subject is categorized as "college-ready" and placed in college-level courses in English and mathematics respectively; otherwise, they are placed in developmental courses in English writing, reading, or mathematics. It should be noted that although the system sets minimum standards on placement exams, institutions may establish higher standards on cutoff scores for each subject. Students whose scores dictate placement in developmental programs are required to enroll in the developmental courses they are assigned to during their first academic year.

Developmental Sequence and Course Content. During the period of this study, ASCCS follows the traditional developmental sequence that consists of three courses for each subject area. In developmental math, the lowest level, such as "Basic Math Skills" or "Fundamental Math", teaches the fundamental operations of arithmetic and introductory elements of computations and statistics. The next level is elementary algebra, which incorporates the basic topics in arithmetic and algebra. The highest level is intermediate algebra, which prepares students for college algebra. In developmental writing and reading, the lowest level covers basic writing and reading skills, such as building vocabulary and constructing sentences. The middle level focuses on reading and writing a coherent essay. The highest level writing covers the

methods of paragraph development while the highest level reading develops word-attack skills, context clues, and skills of skimming and scanning college-level essays.

Students assigned to any level of the developmental sequence were required to complete all the developmental education requirement within two semesters of full-time enrollment. A Minimum grade of 2.00 (i.e. "C") was required in all developmental courses before advancing to the next course level.

4.2 Outcome Measures

Our study examines the impact of taking developmental education coursework online versus face-to-face, on both the current course outcomes and subsequent enrollment and performance in the college-level gatekeeper course in the corresponding subject area. Our primary analyses of current course outcomes focus on the impact of course delivery format on whether a student successfully complete the developmental education course, where the outcome measure is equal to 1 if a student successfully passes the course and equal to 0 if the student either fails the course or withdraws from the course after the course census date.

Such effect may be driven by either or both of two specific mechanisms: by influencing whether a student persists to the end of the course, and by increasing or decreasing learning outcomes as measured by course grade. To shed light on the specific venue through which online learning format may influence students, we further include two measures into our analysis of current course outcomes: a) the impact of course delivery format on persisting to the end of the course (versus early course withdrawal), and b) the impact on course grade among students who persist to the end of the course. It should be noted that the transcript data available to us already excludes courses that are dropped early in the semester (prior to the course census date). As a

result, "withdrawing from a course" in our analysis means that a student pays full tuition for the course without earning any credit from it.

Considering that the goal of the developmental program is to prepare students for subsequent learning in college-level coursework, we further examine the impact of delivering developmental courses online on three subsequent outcome measures that are beyond the developmental education stage: a) whether a student subsequently enrolls in the gatekeeper course of the subject area; b) whether a student passes the gatekeeper course of the corresponding subject, as opposed to either failure to enroll in the gatekeeper course or enrolling in it but failing it; and c) grade in the gatekeeper course conditional on enrollment in gatekeeper course in the corresponding subject, where the grade ranges from 0 (a failing grade of F) to 4 (a full grade of A), including decimals such as 3.8.

4.3 Sample Description

We limit our sample to students who have taken at least one developmental education course and focus on the first developmental course taken in each subject area. Approximately one third of the student body has attempted at least one developmental course (referred to as developmental students hereafter) and the analytical sample includes 41,781 developmental students with a total of 61,831 course enrollments, where approximately 10% (N=3,557) of the students attempt at least one developmental course online. Of the 41,781 students in our analytical sample, 48% take developmental writing, 39% take developmental reading, and 83% take developmental math. About one fifth of the developmental students take both writing and reading. Since these students only have one downstream outcome in the subject of English, we randomly choose a course as the student's initial English developmental course. We also conduct a separate robustness check where we collapse the sample at the student-subject level and define

the key explanatory variables as the proportion of credits taken through online in each subject area. The results are fairly consistent.

Table 1 provides summary statistics for students who take all of their first developmental courses face-to-face versus those who attempt at least one online. Compared with students who take a complete face-to-face course spectrum, the ever-online students are more likely to be older, female, black students, part-time students, and students with lower math placement test scores but higher reading and writing scores.

One unique feature of our dataset is that it includes a rich set of instructor characteristics that are often missing from the existing literature on distance learning. Table 2 presents the average demographic characteristics, degree attainment, and employment information of instructors in our analytical sample. To provide insight on possible differences between instructors teaching online versus face-to-face sections of developmental courses, we present summary statistics separately for instructors who only teach face-to-face sections of developmental coursework and instructors who teach at least one section online. Consistent with the student enrollment by course delivery format, the majority of the instructors teach a fully face-to-face spectrum, where only about 15% of the developmental teaching force offers courses online during the period of this study. These "ever-online" instructors are fairly comparable to face-to-face-only instructors in demographic composition, except for that ever-online instructors are slightly more likely to be Black and Asian.

In terms of highest degree attained, however, ever-online instructors on average receive higher degree attainment. Specifically, ever-online instructors are twice as likely to have received a doctorate and more than one third less likely to hold a Baccalaureate as the highest degree. In terms of employment features, ever-online instructors are noticeably more likely to be

employed in full-time positions (56% versus 43%) and on average teach more credit each term compared to instructors who only teach face-to-face sections. The divergence in teaching load and full-time employment, accordingly to ASCCS administrators, is mainly due to the professional development required before an instructor is assigned to an online course. Since part-time adjunct faculty has less professional development opportunities, they are less likely to complete the online teaching training requirement compared to their full-time counterparts.

To sum up, these descriptive patterns suggest that online instructors tend to receive higher degree attainment and are more likely to be employed with full-time contract with an institution. Considering that these individual differences may also contribute to instructors' effectiveness, we control for available instructor characteristics in our preferred model specifications.

5. Methodology

5.1 Addressing Ability Sorting for Current Course Outcomes

The major challenge in exploring the impact of course delivery formats on student learning outcomes is that some unobserved individual characteristics, such as motivation and ability, may influence both learning outcomes and choice of course delivery format. We might be concerned, for example, that the same student who takes a course online rather than face-to-face is likely to have other family or work responsibilities that may negatively influence her course learning outcomes. The descriptive statistics shown in Table 1 suggest that ever-online students are indeed different from students who only take face-to-face courses in a number of ways. To further shed light on student sorting by course delivery format, we run a simple regression at the student-by-subject level that uses a student's demographic and pre-college academic

characteristics to predict whether the student takes her first developmental course in a specific subject online controlling for college-fixed effects.

The results presented in column 1 of Table 3 indicate that online takers are less likely to be racial minority students. Once we control for college-by-course fixed effects in column 2--therefore comparing students who take exactly the same developmental course at the same college -- more distinctions between online takers and face-to-face takers emerge. Specifically, online takers are more likely to be females, white students, and students who enroll part time during first term in college. In terms of prior academic preparedness, online takers receive significantly higher placement test scores in writing, but comparable scores in the other two subjects. Finally, it seems that online sections also on average have slightly smaller class size compared to face-to-face sections. To sum up, it seems that online takers are older students with slightly better academic preparedness upon college enrollment. This implies that the negative impact of distance learning might be underestimated without controlling for key individual characteristics.

That said, to address potential problems of student systematic sorting into distance learning, we take advantage of the fact that half of the students in our analytical sample are required to take math, reading, and writing developmental coursework, which allows us to employ an individual fixed effects model to control for any unobserved individual characteristics that are constant within a student. We further combine the individual fixed effects model with college-by-course fixed effects, therefore comparing students enrolled in exactly the same course at a college. More formally, our two-way fixed effects model relates student outcomes i, in section s of course c in subject k at campus j during term t to the delivery format that the student has in her first developmental course in a subject area. It should be noted that "course" is

different from "section". Specifically, we use "course" or "college-course" to refer to a particular course taught at a specific college, such as Calculus I taught at college A. we use "class" or "section" to refer to a specific section of a course that is uniquely identified by a combination of college, course title, section, and term, such as Calculus I-100 taught by Professor A between 9am and 11am on Thursday in the fall term of 2007.

$$Y_{icstkj} = \alpha + \beta\ online_{icstkj} + \rho_{ckj} + X_{cstk} + \pi_t + \sigma_i + \mu_{icstkj} \tag{1}$$

The key explanatory variable is the course delivery format of the first developmental course a student takes in a specific subject area ($online_{icstkj}$). ρ_{ckj} represents college-course fixed effects for the developmental course examined, therefore only comparing students who take exactly the same developmental course at a college (such as intermediate algebra at college 101) but enroll in different sections; X_{cstk} includes information at the course-section level (e.g., number of total enrollments in the course section and the available characteristics of the course instructor).The full list of instructor covariates include individual-level indicators for gender and race, as well as individual-by-term indicators for age at the beginning of a given term, highest degree attained, whether full time employed during that term, whether having other job responsibilities in addition to instruction, whether having K-12 work experience, and number of developmental courses taught prior to a given term. It should be noted that while our analytical sample only covers student transcript records between 2005 and 2012, the instructor file tracks the instructor-by-term information (such as classes taught in each term) back to 1994, which provides a more accurate estimate of teaching experiences. In all of our regression analyses, we use the instructor file to create an indicator for an instructor's teaching experiences in developmental education

coursework at the beginning of a given term, measured as the total number of developmental courses taught by the instructor since 1994 and prior to that term. π_t and σ_i represent fixed effects for the semester of course enrollment and student individual fixed effects respectively.

5.2 Addressing Ability Sorting for Gatekeeper Course Performance

Learning experience in a student's developmental coursework may influence her subsequent gatekeeper course outcomes in at least two ways: whether a student enrolls in a gatekeeper course in the corresponding subject, and the student's grade in the gatekeeper course. One potential threat to estimating the impact on gatekeeper course performance is that a student' developmental course learning experience may also influence students' subsequent choice of the gatekeeper class. Therefore, in quantifying the impact of delivery format of developmental courses on gatekeeper course performance, we use a separate model that further controls for next-class fixed effects:

$$Y_{icskjt+1} = \alpha + \beta \text{ Online}_{icskjt} + S_{cskjt+1} + \rho_{ckj} + X_{cskjt} + \sigma_i + \mu_{icskjt+1} \qquad (2)$$

where student i's outcomes in the next class section s in course c in subject k at campus j in time $t+1$ to the course delivery format of the first developmental course a student takes in a specific subject area (Online $_{icskjt}$). Since the next course-section fixed effect $S_{cskjt+1}$ is a combination of college, course, time and specific section, this model specification compares student performance in exactly the same next course section taught by the same course instructor. It is worth noting that for gatekeeper enrollment and performance outcomes, we still keep the college-by-developmental-course fixed effects (ρ_{ckj}) in the model. This is intended to take care of potential variations in course difficulty between developmental courses within a subject.

5.3 Validity of the Fixed Effects Approach

The remaining source of selection after controlling for college-course, student, and term fixed effects is students' differential sorting by delivery format by course subject. We would be concerned, for example, that a student is more likely to take a more challenging subject through online format and a less challenging one face-to-face. If that is the case, a negative estimate of distance learning may be partly driven by a student's differential ability across subjects. In a similar vein, students may be more likely to take a class through the face-to-face format in a subject which they attach more value to and also spend more time in that class.

To shed light on the possibility of differential sorting of course delivery format by subject areas, we compare students' relative ranking in math and writing placement tests respectively and code for the "better subject" where the student has a higher standing among all the students. Column 3 of Table 3 includes an indicator for whether a particular developmental course falls under the subject which a student is better at, controlling for individual fixed effects. The estimate is small in size and is not significant, indicating that while students have general preferences for online versus face-to-face delivery format, such preference is likely to be constant within an individual.

6. Results

6.1 Impact of Online Learning on Developmental Course Outcomes

Table 4 presents the estimated impact of online delivery format on three developmental course outcomes: (i) whether a student successfully passes a course (versus either failing the course or withdrawing from the course); (ii) whether a student persists to the end of the course (versus withdrawing after the course add/drop period but before the end of the course); and (iii)

course grade among students who persist until the end of the course. For each outcome measure, we use three different model specifications: a baseline regression that includes available student characteristics presented in Table 1, course-section characteristics (i.e. section enrollment size and credit hours), and term fixed effects; a second model that further includes student fixed effects and college-by-course fixed effects; and finally, our preferred model specification that also controls for available instructor characteristics.

The estimates indicate that taking one's first developmental course online has a negative impact on all three outcome measures and the estimates are robust across all model specifications. Focusing on the estimates based on the preferred specification (column 3, 6, and 9), online delivery format reduces course completion rate by more than 13 percentage points. This effect is driven by both reduced probability of persisting to the end of the course and performance decrement in course grades. Specifically, students who take the same developmental course online are more likely to withdraw early from the course by 9 percentage points; among students who persist to the end of the course, they are subject to a performance decrement by almost 0.3 of a grade point on a 0 to 4 grading scale, which is equivalent to approximately one letter grade down (such as from B+ to B).

6.2 Impact on Gatekeeper Course Enrollment and Performance

Table 5 presents the estimated impact of online delivery format on subsequent gatekeeper course enrollment and performance, again based on three model specifications. Given the sizable negative impact of online format on developmental course completion, it is unsurprising that students who take their first developmental course online in a subject area are also significantly less likely to successfully enroll and pass the gatekeeper course in that subject. Specifically,

taking developmental coursework online is associated with reduced probability of enrolling and passing the corresponding gatekeeper course by 4 percentage points.

Additional analyses on course enrollment and performance separately indicate that the negative impact of distance learning on gatekeeper course completion is primarily driven by reduced probability of every embarking on the gatekeeper course: students taking their first developmental course in a subject online are associated with lower probabilities of enrolling in the gatekeeper course in that subject by 7 percentage points. Considering that the average probability of gatekeeper enrollment among students assigned to developmental programs is 57% in English and 31% in math, the 7 percentage-point average decrease in gatekeeper enrollment represents approximately a 12% to 23% lower probability for gatekeeper enrollment, which is fairly sizable in magnitude.

6.3 Does the Effectiveness of Online Learning Improve Over Time?

With the advancement in technology and system-wide policy changes, the effectiveness of the online delivery format may improve over time relative to face-to-face delivery. To examine this possibility, Appendix Figure 1 estimates the relative impact of different course delivery formats on two outcomes -- passing developmental courses and enrolling in gatekeeper course -- separately by cohorts. While the estimates are consistently negative and vary over time, we do not identify any noticeable trend in improvement of online format over time. We also formally test the possibility of over-time improvement by including time trend into the model and an interaction between the time trend and course mode. The interaction terms are weak and non-significant for both outcome measures.

6. Discussion and Conclusion

Addressing high demand for developmental education and low rates of successful completion with space constraints has been an ongoing challenge for postsecondary institutions. With advances in online instructional technology, online instruction is increasingly considered as a way to alleviate developmental education burdens. Based on a large administrative data from all the public two-year institutions in a state, our study is the first that quantifies the impact of fully online versus traditional face-to-face delivery formats in developmental coursework on developmental education outcomes, as well as on subsequent enrollment and performance in gatekeeper coursework.

Based on a two-way fixed effects model that controls for both student-level and course-level fixed effects, our results indicate that the learning outcomes of developmental education students are substantially compromised when the developmental coursework is delivered online: taking one's developmental coursework online not only negatively influences successful completion of the contemporaneous developmental course, but also results in reduced probability of ever enrolling in gatekeeper courses, which would fundamentally impede students' academic progress. The estimates are fairly robust to the inclusion of a rich set of instructor characteristics.

These results therefore have several important implications for online course offering and teaching at community colleges. First, our results are in line with a number of recent studies on distance learning at community colleges that have all identified noticeable online performance decrement (e.g. Hart et al., 2018; Johnson & Mejia, 2014; Kozakowski, 2019; Xu & Jaggars, 2011, 2013). The consistent and sizable negative estimates associated with online delivery format indicates that online courses at community colleges, at least as currently practiced, do not support students as effectively as traditional face-to-face lectures. Among these studies, Kozakowski (2019) focused on the impact of course delivery format on developmental students'

academic outcomes and is therefore most relevant to our study. Kozakowski found that students who took developmental math through the blended learning format were less likely to pass the course by 10 percentage points compared with students taking the same course through traditional face-to-face format, which is somewhat similar to the 13 percentage decrease in course completion we find. While the performance decrement in online courses is worrisome overall, its negative impact on developmental coursework warrants special attention, as completion of the developmental sequence is critical to students' academic progression.

Additionally, our results also highlight the importance of assisting students in managing their online learning experiences. A consistent finding across studies of online learning is that the virtual environment requires students to possess strong self-directed learning skills. However, based on interviews with 38 online instructors and 47 students enrolled in online courses at two community colleges, Bork and Rucks-Ahidiana (2013) found that while instructors and students generally agreed on the importance of self-directed learning management skills in successful online learning, they disagreed on how to best meet those expectations: many faculty expected their online students to begin courses already equipped with self-directed learning skills, and did not believe that faculty should be responsible for helping students develop those skills. In contrast, students anticipated that instructors help students develop management skills and guide students through the learning process. In view of the misalignment between online instructors and students, colleges therefore may consider informing and preparing both students and faculty for online teaching and learning. For students, colleges may provide distance readiness assessments, online learning orientation, and skill scaffolding modules to help students meet the requirements of the role as an online learner. At the same time, college may offer faculty

professional development opportunities that inform online instructors of the importance of and specific approaches to scaffolding self-directed learning skills among students in online courses.

Finally, given the potential of online learning to provide flexibility to individual students and to address resource constraints faced by institutions, the current online expansion at community colleges is likely to continue. For example, based on a national survey of college administrators in all degree-granting postsecondary institutions, Allen and Seaman (2016) found that almost two thirds of the institutions indicated that the expansion of fully online coursework is critical for their long term strategy. Due to the unstoppable trend of online expansion, it is therefore important for institutions to identify instructional practices and college-provided student and instructor support that can be adopted at large to facilitate teaching and learning in a virtual environment. For example, when students struggle in courses, it might be useful for them to access academic support and services provided by the college, such as academic counseling and tutoring services. However, since online students often choose the format in order to accommodate work and family responsibilities (Jaggars, 2014), they may face challenges accessing these supports if they are delivered exclusively on campus. Colleges may therefore consider providing comprehensive counseling and tutoring also through the online format. Identifying promising practices that are malleable and are within the control of the institutions and course instructors -- rather than demanding more self-directed efforts from students -- will allow colleges to implement policies and programs that have the potential to improve the effectiveness of online delivery at scale.

Acknowledgment

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Tables

Table 1. Student Characteristics by Course Delivery Format

	Took at least one online course	Took only face-to-face course
Age upon initial enrollment	24.6	22.8
	(8.22)	(7.26)
Female	65.7%	59.5%
Race		
White	45.7%	60.6%
Asian	0.5%	1.4%
Black	48.5%	31.5%
Hispanic	2.6%	3.8%
Other race	2.7%	2.7%
Non-resident	1.1%	1.1%
High School GPA	2.51	2.49
	(0.59)	(0.72)
High School Graduate	81.6%	82.0%
Full-time	68.8%	76.7%
Placement test score (standardized)[a]		
Math	-0.43	-0.54
	(0.82)	(0.79)
Reading	0.48	-0.41
	(0.98)	(0.94)
Writing	0.44	-0.44
	(0.99)	(0.94)
N	3,557	38,224

Note: Standard deviation in parentheses.

a. The placement test scores are standardized within each college with mean of zero and standard deviation of 1.

Table 2. Instructor Characteristics by Course Delivery Format

	Taught at least one course online	Taught only face-to-face courses
Female	70.2%	70.3%
Age in 2012	49.0	50.9
	(12.40)	(13.48)
Race		
White	81.3%	86.6%
Black	15.3%	11.2%
Hispanic	0.0%	0.2%
Asian	3.5%	1.1%
Other	0.0%	1.0%
Highest degree attainment		
Bachelor's degree	18.5%	25.1%
Master's degree	66.2%	67.2%
Doctorate	15.2%	7.7%
Full-time employed[a]	56.3%	43.2%
Have other job responsibilities in addition to instruction	47.0%	55.2%
Average credit hours/Term	13.1	9.5
	(7.77)	(6.94)
Ever worked in K12 sector	35.8%	48.8%
Total number of dev ed courses taught between 1994 and 2012[b]	15.6	7.5
	(10.9)	(9.0)
1-3	13.2%	38.8%
4-10	19.2%	32.8%
> 10	67.5%	28.5%
Course section characteristics		
Enrollment size	19.4	18.6
	(8.7)	(9.0)
Average credit hours of the section	3.0	3.0
	(0.24)	(0.36)
N	151	1,046

Note: Standard deviation in parentheses.

a. Full-time employed defined as worked as full-time instructor during at least half of the terms employed in the institution between 2005 and 2012.

b. While our analytical sample only covers student transcript records between 2005 and 2012, the instructor file tracks the instructor-by-term information (such as classes taught in each term) back to 1994, which provides a more accurate estimate of teaching experiences. In all of our regression analyses, we used the instructor file to create an indicator for an instructor's teaching experiences in developmental education course work at the beginning of a given term, measured as the total number of developmental courses taught by the instructor since 1994 and prior to that term.

Table 3. Student Sorting into Online Delivery Format

	Sorting among students		Sorting within students
Better Subject[a]			-0.0030
			(0.0017)
Age upon initial enrollment	-0.0013	-0.0013**	
	(0.0006)	(0.0003)	
Female	0.0021	0.0045**	
	(0.0016)	(0.0015)	
Race (reference group – White)			
Black	-0.0112*	-0.0082**	
	(0.0042)	(0.0030)	
Hispanic	-0.0201**	-0.0184**	
	(0.0067)	(0.0056)	
Asian	-0.0129*	-0.0122	
	(0.0055)	(0.0070)	
Other	0.0227	0.0029	
	(0.0163)	(0.0043)	
High school GPA	0.0027	-0.0009	
	(0.0027)	(0.0015)	
Earned high school diploma	0.0014	0.0043	
	(0.0059)	(0.0029)	
Fulltime during first term	-0.0090	-0.0115**	
	(0.0069)	(0.0027)	

Table 3. Student Sorting into Online Delivery Format (continued)

	Sorting among students		Sorting within students
Placement test score (standardized)			
Math	0.0039	0.0016	
	(0.0029)	(0.0013)	
Writing	0.0052	0.0046**	
	(0.0031)	(0.0015)	
Reading	-0.0007	0.0005	
	(0.0037)	(0.0014)	
Class size	-0.0013	-0.0018*	-0.0012**
	(0.0008)	(0.0008)	(0.0004)
Course credit hours attempted	0.0002	-0.0381	-0.0112
	(0.0165)	(0.0536)	(0.0247)
Spring term[b]	-0.0055	-0.0055	-0.0236**
	(0.0045)	(0.0046)	(0.0076)
Summer term	0.0156	0.0167	0.0004
	(0.0144)	(0.0129)	(0.0110)
College FE	Yes	Yes	Yes
Student FE			Yes
College-by-course FE		Yes	Yes
Observations	61,831	61,831	61,831
R-squared	0.2603	0.5101	0.8455

Note: Robust standard errors in parentheses: ** $p<0.01$, * $p<0.05$.
a. Better subject defined as the subject where a student had relatively higher ranking among peers at a college compared with the student's relative ranking in other subjects.
b. Reference category is fall term.

Table 4. Impact of Delivery Format on First Developmental Course Performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Pass the Course			Persist to the end of the Course			Course grade		
Online	-0.1130**	-0.1512**	-0.1349**	-0.0425**	-0.0939**	-0.0880**	-0.3603**	-0.3356**	-0.2840**
	(0.0284)	(0.0283)	(0.0285)	(0.0149)	(0.0213)	(0.0216)	(0.1012)	(0.0879)	(0.0889)
N	61,831	61,831	61,831	61,831	61,831	61,831	51,559	51,559	51,559
R-squared	0.1423	0.7425	0.7435	0.0899	0.7134	0.7135	0.2015	0.7945	0.7951
Term FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student FE		Yes	Yes		Yes	Yes		Yes	Yes
College-by-course FE		Yes	Yes		Yes	Yes		Yes	Yes
Student Covariates	Yes			Yes			Yes		
Instructor Covariates			Yes			Yes			Yes
Course Section Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses: ** $p<0.01$, * $p<0.05$. Student covariates include all the variables listed in Table 1. Instructor covariates include individual-level indicators for gender and race, as well as individual-by-term indicators for age at the beginning of a given term, highest degree attained, whether fulltime employed during that term, whether having other job responsibilities in addition to instruction, whether having K-12 work experience, and number of developmental courses taught prior to a given term. Course section covariates include enrollment size and credit hours.

Table 5. Impact of Delivery Format in Developmental Coursework on Gatekeeper Course Enrollment and Performance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Enroll in and pass gatekeeper course			Enroll in gatekeeper course			Grade of gatekeeper course		
Take developmental course online	-0.0415**	-0.0420*	-0.0395*	-0.0654**	-0.0735**	-0.0698**	0.0258	-0.0675	-0.0169
	(0.0116)	(0.0181)	(0.0182)	(0.0191)	(0.0194)	(0.0200)	(0.0586)	(0.1703)	(0.1739)
N	61,831	61,831	61,831	61,831	61,831	61,831	26,291	26,291	26,291
R-squared	0.1540	0.6975	0.6984	0.2128	0.7507	0.7510	0.1112	0.6914	0.6917
Term FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student FE		Yes	Yes		Yes	Yes		Yes	Yes
College-by-course FE		Yes	Yes		Yes	Yes		Yes	Yes
Student Covariates	Yes			Yes			Yes		
Instructor Covariates			Yes			Yes			Yes
Course Section Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Next-class Section FE								Yes	Yes

Note: Robust standard errors in parentheses: ** $p<0.01$, * $p<0.05$. Student covariates include all the variables listed in Table 1. Instructor covariates include individual-level indicators for gender and race, as well as individual-by-term indicators for age at the beginning of a given term, highest degree attained, whether fulltime employed during that term, whether having other job responsibilities in addition to instruction, whether having K-12 work experience, and number of developmental courses taught prior to a given term. Course section covariates include enrollment size and credit hours.

Appendix

Appendix Figure 1a. Estimated Effect of Course Delivery Format by Cohort (Outcome: Pass the Developmental Course)
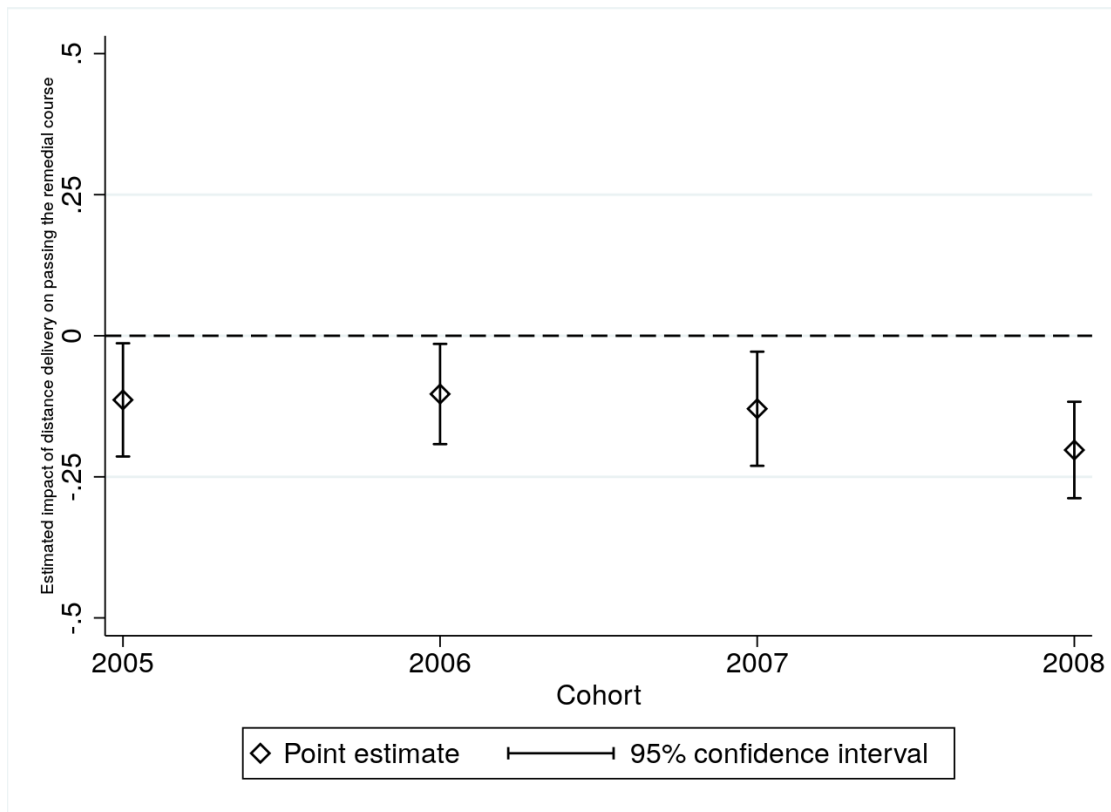
Appendix Figure 1b. Estimated Effect of Course Delivery Format by Cohort (Outcome: Enroll in Gatekeeper Course in the Corresponding Subject Area)