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Hard times for girls in STEM. The heterogeneous effects of distance learning on student achievement during the Covid pandemic.

By Piera Bello, Annalisa Cristini, Anna Maria Falzoni, and Federica Origo,

Department of Economics, Università degli studi di Bergamo

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Abstract:

In this paper, we study the impact of distance learning on student achievement in higher education by exploiting the outbreak of the COVID-19 pandemic and the consequent shift from in-person to online teaching during the second semester of the 2019/2020 academic year in Italy. We estimate a diff-in-diff model using administrative data for different cohorts of students from a large university located in Bergamo in Northern Italy. Our results show that online teaching is associated with a lower number of credits and passed exams and with an increase in the average grade. Additional analyses provide evidence for significant heterogeneity by field of study and gender, with women in engineering being those who suffered the most from the shift to online teaching. Survey evidence points to gender differences in study-life balance and reduced relations with both peers and teachers in explaining the results.

Keywords: distance learning, student achievement, Covid, Diff-in-diff, gender, STEM
JEL codes: I21, I23, D9, J16, J24

1.Introduction

Online teaching outperforms in-person teaching along several dimensions, such as student base from other geographic areas, costs of teaching, and access to education for more disadvantaged and working students (Deming et al, 2015; Cowen and Tabarrok, 2014; Deming et al., 2020). Moreover, during lockdowns, implemented for pandemic control, online teaching may be the only way to keep providing education.

Yet, its educational benefits are still unclear. The main challenge associated with the evaluation of online teaching is self-selection bias. Students more likely to enrol in online courses compared to those in face-to-face courses are usually part-time students, of higher age and living farther away. Moreover, those enrolling in online courses might differ from the other ones along some unobservable characteristics, such as motivation and commitment.

In this paper, we address these identification challenges and identify the causal effect of online education on students' performance by exploiting the outbreak of the COVID-19 pandemic in Italy. The introduction of a national lockdown on 9 March 2020 in Italy forced universities to provide distance education via online-learning platforms.

We collect administrative data on the population of four cohorts of students enrolled in Master's programs at the University of Bergamo. By using a Difference-in-Differences approach, we evaluate the impact of online teaching on students' achievement by comparing the difference in students' performance between the second and the first semester of the 2019-2020 academic year with the average difference in the performance between the second and the first semester in the three previous academic years.

Our results document that, among Master's students, distance learning during the first wave of the Covid pandemic has significantly reduced the number of credits earned (-1.7 credits) and increased the average grade (0.28 points on a 30-point scale). The result is due to a reduction in both the number of credits per exam and the number of exams taken. In addition, online teaching was associated with an increase of 2.8% in the probability of being an "inactive" student (i.e. students that have obtained less than 10 credits per semester). Additional analyses provide interesting evidence for significant heterogeneity in the effect across fields of study and gender. While the loss in credits is concentrated among students enrolled in engineering, the positive effect on grades is driven by those studying humanities or economics. Moreover, women in engineering are those who suffered the most from the shift from face-to-face lectures to online teaching, while no effect is found for their male counterparts.

For our analysis, we could also access ad-hoc survey data collected in the Fall of 2020 to monitor students' health and behaviours, especially related to distance learning, during the first wave of Covid. The survey was sent to all the enrolled students at the University and asked detailed questions on how

they were dealing with the exceptional circumstance. We exploit this information to shed light on potential channels behind these results; descriptive evidence suggests that women in engineering struggled more than their male counterparts in combining their studies with family life (because of their higher responsibilities at home) and suffered the most from the lack of interactions with teachers and peers. This points to the role of differences in family responsibilities and in self-confidence in competitive environments in explaining the differential effect of online teaching across fields of study and gender (Del Boca et al. 2020; Federicova et al. 2018).

Our paper contributes to the literature on the effect of online teaching on student performance. Due to the difficulty of addressing selection bias when comparing students attending in-person courses and those choosing online courses, most of the empirical evidence on the education effect of online teaching comes from randomized experiments (Alpert et al. 2016) or an instrumental variables approach (Bettinger et al., 2017 and Xu and Jaggars, 2013). These studies document a negative effect of online teaching on student performance. However, Cacault et al. (2021), who analyse the effects of offering access to a live streaming platform to a randomized pool of students at a Swiss university, show that the effect is heterogeneous across students – a negative impact is found for low-ability students, while high-ability students benefit from the use of this type of online technology.

The COVID-19 pandemic and the subsequent lockdowns have enabled researchers to study the causal effect of online teaching on a larger scale. By exploiting the implementation of national lockdowns, several papers have shed new light on this topic (Ayllón, 2022; Rodríguez-Planas, N., 2022; De Paola et al., 2023; Hardt, 2023).

The closest papers to our work are Bonaccolto-Topfer et al. (2022), De Paola et al. (2022) and Bratti and Lippi (2022), which exploit the shift from in-person to online teaching during the second semester of the 2019/2020 academic year in Italy. Their results provide interesting and partly contrasting evidence on the effect of distance learning. While Bonaccolto-Topfer et al. (2022) use administrative data from a university in Northern Italy and find evidence for a null effect of online teaching on student achievement, De Paola et al. (2023) focus on students at a university located in Southern Italy and find that online teaching reduced student performance of 1.4 credits per semester. The effect in the latter is fully driven by bachelor students, while master students are not affected. Moreover, they investigate the role played by procrastination and document that the effect is even worse for those students with present bias. Finally, Bratti and Lippi (2023), for another large university in the North of Italy, and by focusing on master students, document a negative effect of the pandemic on the number of credits, but a positive effect on the average grade. The focus of the paper is the

investigation of a differential effect of online teaching between genders, but they do not find supporting evidence for this hypothesis.

Outside the Italian context, most of the existing evidence exploiting the outbreak of the COVID-19 pandemic documents a negative effect on education associated with distance learning. For instance, for the Netherlands, Engzell et al. (2022) provide evidence for a learning loss in 2020 compared to the previous years for students in primary schools, which is driven by students coming from more disadvantaged groups. Moreover, Casalone et al. (2021) show that COVID has impacted the probability of passing an exam in Turkey and Sweden. Finally, Núria Rodríguez-Planas (2022) documents a differential effect by students' pre-COVID-19 academic performance and income groups, with lower income students outperforming their high-income counterparts.

Our paper makes several contributions to this literature. Firstly, we interpret our results with respect to different study strategies that students might adopt in order to respond to the change in the teaching modality. Secondly, we provide the first evidence for significant differences in the effect of online teaching across fields of study in higher education, which sheds light on the channel through which distance learning affects education. While the adoption of technologies and online platforms might help the learning process for economics or humanities, the loss of interactions among students might overcome the benefits of technology in contexts in which concepts are more difficult to understand and interaction among students is more important, such as in engineering. Finally, we contribute to the literature on gender in education, especially that related to gender differences in STEM (Justman and Mendez, 2018), by showing that teaching practices play a role in shaping gender differences in achievement: the performance of women in a STEM field such as engineering is negatively affected by distance learning, while the same is not true for their male counterparts.

The remainder of the paper is structured as follows. Section 2 illustrates the institutional context. Section 3 describes the empirical strategy and the data. Section 4 presents our main results and robustness checks. Section 5 discusses the possible explanations for our results. Finally, Section 6 concludes.

2. Institutional context

The Italian University system is organized into three main cycles. The First Level Degree (Bachelor's Degree) lasts three years and is awarded to students who have gained 180 credits. This gives access to a Master's Degree, which formally lasts two years and allows to acquire 120 more credits. Some fields of study, such as medicine and law, also offer a Degree lasting 5 years ("*Laurea a Ciclo Unico*"). Students who have acquired a Master's Degree (or a 5-year degree) can apply to a PhD program.

Students who enrol on a certain Bachelor's or Master's degree program have to follow a study plan that sets the specific courses and credit requirements per year. Usually, the total amount of credits (that is 180 for a Bachelor's degree, and 120 for a Master's program) is evenly distributed across years, resulting in roughly 60 credits per year. Each course can cover from 6 to 12 credits. Each credit corresponds to 25 hours of student workload. The study plan is usually rather rigid, except for a few elective exams in the last year. In each academic year, courses are distributed in two semesters (i.e., the fall and spring semester), but 12-credit courses can last more than one semester.

Most university degrees do not require that students attend a minimum number of lectures. However, formal attendance is defined by the year in which the course is scheduled. Once students earn formal attendance, they can take the exam on specific dates, either at the end of the semester in which the course is offered or in other exam sessions in the same academic year. Each course has a fixed number of exam sessions throughout the year (at the university of Bergamo, they range from 5 to 8, depending on the degree), but students can take or retake the exam whenever they want; they can also refuse the proposed mark and retake the exam in case they believe they can improve their performance. In the Italian University system exams are graded on a 30-point scale (the highest score is 30 cum laude) and a minimum score of 18 is required to pass the exam. Unfortunately, professors are not required to register grades below 18, hence it is not possible from official registers to disentangle students who do not show up from those who fail the exam.

Given this peculiarity of the Italian university system, it is very likely that students who truly attend a certain course will take the exam right after the end of the course, and in any case within the end of the academic year in which the course is offered in the study plan of his/her cohort of enrolment.

Concerning teaching practices, until the fall semester of the 2019-20 academic year, all the courses offered by traditional Universities were taught in presence. Although e-learning tools were available, their use was rather limited and mainly devoted to sharing teaching material with students.

The unexpected outburst of the Covid pandemic at the beginning of 2020 forced all Italian Universities to abruptly switch all teaching activities from face–to-face to online lectures. The University of Bergamo, being in one of the areas that were first and harshly hit by the unknown virus, was among the first Italian Universities to do so: all activities at the University premises, including lectures, were suspended on 22nd February 2020, a few days before the beginning of the spring semester (17th February), and by mid-March, all the courses offered in that semester were taught remotely.

3.Empirical strategy and Data

3.1 Empirical Strategy

Our empirical strategy exploits the fact that at the beginning of the second semester of the academic year 2019-2020, universities in Italy were forced to switch to online teaching because of the COVID-19 emergency. Whereas in the first semester of the academic year 2019/2020 and in all previous years, teaching was only in person.

By using a Diff-in-Diff estimator, we compare the difference in the performance of students between the first and the second semester in the 2019/2020 academic year with the average difference between the two semesters in the previous academic years (2016/2017-2018/2019). We use the average grade obtained and the total number of credits acquired in a semester as two proxies for the performance of the student.

Formally, we estimate the following model:

$$y_{isy} = \alpha_0 + \beta_1 IISem_s + \beta_2 ay19/20_y + \beta_2 IISem_s * ay19/20_y + \delta_1 X_i + \gamma_i + m_i + n_i + \varepsilon_{isy}$$

Where y_{isy} is the number of credits or alternatively the average grade obtained by student *i* in the semester *s* and academic year *y*. $IISem_s$ and $ay19/20_y$ are, respectively, a dummy for the second semester of the year (March-May) and a dummy for the 2019/2020 academic year.

$IISem_s * ay19/20_y$is the interaction term between the dummy for the second semester and that of the academic year 2019-20. In a Diff-in-Diff framework, this is our variable of interest since it measures the effect of online teaching on the performance of the students.

We also control for a vector of individual characteristics such as gender, age and residence (the full list of controls is provided in Table 1), which might affect the performance of the students. We also include dummies for the cohort (γ_i), for the degree course (m_i) and for the year of the Master's program (n_i). Finally, $\varepsilon_{isy}$is an error term. Standard errors are clustered at the student level.

This specification allows us to control for differences in the composition of students across years and disentangle the causal effect of online teaching on education outcomes from other confounding factors.

To explore potential differences in the effect of online teaching on male and female students, in a further specification, we also interact our variable of interest with a dummy variable for girls ($Female_i$). We estimate the model for the entire sample of students in our sample and then separately by field of study.

Our Diff-in-Diff estimation is based on the parallel trend assumption, and hence we assume that, in the absence of the switch from face-to-face to distance learning forced by the pandemic, the difference in student performance between the first and the second semester would have been constant over time. In other words, we assume that the difference in the performance between the second and the first semester for the academic years 2016, 2017 and 2018 can be used as a proxy for the difference in the performance for the academic year 2019 in the absence of the change in the teaching mode. We check the validity of this assumption in the following section.

3.2. Data

Our study uses administrative data from the University of Bergamo, located in the Lombardy region of Italy. The dataset covers four cohorts of students from 2016 to 2019 and includes detailed information on their demographic characteristics (such as gender, age, municipality of residence, type of High School, and High School grade), and academic careers (such as the field of study, the date of enrolment, the year of course, the specific exams passed, the number of credits earned per exam and exams grades). Additionally, we collect information at the municipal level on mortality rates, which we link to students using their municipality of residence. Finally, we obtained data from the survey "Distance Teaching and COVID-19 Emergency", which was conducted at the same university during the pandemic, to analyse how students coped with the changes caused by the pandemic, especially related to distance learning.

Our dataset is structured at the individual level and contains information on each passed exam. We aggregate our data at the student-semester level. We initially considered all the students enrolled in both Bachelor' and Master's degree, but for the first group of students we could not detect a pre-treatment parallel trend. For this reason, we focus our analysis on students enrolled in Master's Degrees. Furthermore, since we are interested in understanding the effect of a switch in teaching from face-to-face to online lectures, we need to focus on students who actually attend lectures. As we discussed in the Institutional Setting Section, In Italy, this is not usually required, but truly attending students are more likely to take the exam within the academic year in which the course is offered in their study plan. For this reason, we focus only on the sample of exams taken in the same academic year of formal attendance.

Table 1: Descriptive Statistics

Academic Variables:		
	Mean	Sd
II Semester	0.679	0.467
Credits per Semester	33.475	14.771
Credits per Year	55.511	16.955
Grade (30-point scale)	27.286	2.796
Demographic Variables:		
Female	0.625	0.484
Age	25.600	4.457
High School Final G.	73.494	18.280
Lyceum	0.564	0.496
Immigrant	0.076	0.264
Same Province	0.531	0.499
Different Region	0.144	0.350
Obs	71596	

Notes: The table provides summary statistics for our variables of interests and control variables. Academic Years: 2016-2019

Table 1 presents some descriptive statistics. Our sample includes 8680 students, for a total of 71,596 observations (student-exam). According to the table, students acquire, on average, 55 credits per year and 33 per semester. The average grade is 27 (on a 30-point scale). Females are the majority of the population of students.

The key identifying assumption in our analysis is the existence of parallel trends prior to the pandemic. We check our assumption by estimating a model similar to Equation 1 in which we interact our dummy variable for the second semester $IISem_s$ with two dummies for the 2017 and 2018 academic year $(ay17/18_t), (ay18/19_t)$. The 2016 academic year is used as the reference category. Table 2 provides the results. None of our interaction terms is statistically significant at 5 percent level. This evidence validates our assumption.

Table 2: Parallel Trend

	(1) Credits per Semester	(2) Average Grade
2017/2018	-0.612	0.242**
	(1.052)	(0.117)
2018/2019	-0.284	0.304*
	(1.367)	(0.158)
II Semester*2017/2018	-1.791*	-0.154
	(1.059)	(0.0996)
II Semester*2018/2019	-1.071	-0.130
	(1.078)	(0.0957)
Observations	31,272	31,102
R-squared	0.207	0.105
Controls	Yes	Yes

Notes: OLS estimates. The dependent variable is the total number of credits per semester in column 1 and the average grade in column 2. Standard errors are clustered at the individual level. The regression also includes the II Semester dummy variable and the vector of control variables. Academic years: 2016-2018.

4. Results

Baseline estimates

We report our Diff-in-Diff estimates in Table 3. The table shows that distance learning during the first wave of the COVID pandemic has significantly reduced the number of credits earned (-1.7 credits), but the average grade has slightly increased (0.27 points on a 30-point scale). The first effect is not negligible, since it corresponds to around 5% of the mean credits earned in one semester, but the gain in terms of grades is much less pronounced (around 1% of the average grade), even if comparable to the gain associated to coming from academics oriented upper secondary school (such as a Lyceum)

Regarding the other controls, as expected a better performance in terms of credits is registered for higher ability students (as it is proxied by the high school final grade), while the opposite is found for

immigrants. No significant differences emerge by gender, except for a slightly higher grade for females (whose size is much smaller than the effect of distance learning discussed above).

Table 3: The effect of online teaching

VARIABLES	(1) Credits per Semester	(1) Average Grade
Final Grade High School	0.0135**	0.000672
	(0.00583)	(0.00127)
Lyceum	0.467**	0.262***
	(0.224)	(0.0500)
Immigrant	-1.934***	-0.808***
	(0.698)	(0.176)
Same province	1.139***	0.400***
	(0.239)	(0.0535)
Diff region	-0.200	-0.0408
	(0.360)	(0.0793)
Female	0.317	0.275***
	(0.244)	(0.0541)
II Semester	14.94***	-0.388***
	(0.281)	(0.0409)
2019/2020	-5.687***	0.161
	(0.875)	(0.139)
II Semester*2019/2020	-1.716***	0.268***
	(0.452)	(0.0619)
Observations	12,854	12,206
R-squared	0.273	0.075
Other controls	Yes	Yes

Notes: OLS estimates. The dependent variable is the total number of credits per semester in column 1 and the Average grade in column 2. Standard errors are clustered at the individual level. Academic years: 2016-2019.

Our results are coherent with quite different studying strategies: for example, in the new learning environment, especially when it was not clear how long it had to be in place, students may have simply reduced the number of exams taken, or they may have chosen to focus only on shorter exams to maximize grades. Furthermore, the decline in credits earned may be due to an increase in the

number of students who did not successfully pass any exam (a sort of extensive margin) or the number of credits earned by students taking exams (intensive margin).

In order to get a better insight into the relevance of alternative explanations, we decompose the effect on credits into three main components: the average number of credits per exam, the number of exams and the share of students who acquire less than 10 credits per semester (No Exam).

Estimates in Table 4 show that the overall effect on credits is due to both a reduction in the number of credits per exam (column 1) rather than the number of exams taken (column 2). This evidence is coherent with the strategy of taking first exams of relatively shorter courses. Furthermore, distance learning during the first strict lockdown has caused an increase of 2.7% in the probability of being an "inactive" student.

Table 4: Decomposition of the effects on Credits: Average Number of Credits per exam, Number Exams, No exams

	(1)	(2)	(3)
	Av. N.		
VARIABLES	Credits	N. Exams	No Exam
II Semester	0.553***	1.881***	-0.146***
	(0.0418)	(0.0320)	(0.00657)
2019/2020	-0.515***	-1.082***	0.165***
	(0.118)	(0.0929)	(0.0212)
II Semester*2019/2020	-0.158**	-0.262***	0.0279***
	(0.0678)	(0.0510)	(0.00973)
Observations	12,297	12,854	12,854
R-squared	0.213	0.343	0.090
Controls	Yes	Yes	Yes

Notes: OLS estimates. The dependent variable is the average number of credits per exam in column 1, the number of exams per semester in column 2, and a dichotomous variable for those who have acquired less than 10 credits per semester in column 3. Standard errors are clustered at the individual level. Academic years: 2016-2019.

Heterogeneous effects

The sudden shift from face-to-face lectures to distance learning could have impacted students' performance in quite different ways, depending also on the nature of the course. Such change could have been less relevant for subjects whose lectures were mainly based on oral presentations or in-class discussions. This is more frequent in law and humanities, while it is less common in quantitative courses, such as engineering ones, where learning is more based on solving written exercises. We then test the existence of heterogeneous effects by field of study, distinguishing between Humanities

and Law, Engineering, and Economics & Management (assuming that the latter may be a sort of blend of the first two groups in terms of the nature of subjects).

Diff-in-Diff estimates in Table 5 highlight that students enrolled in humanities or law degrees experience the largest benefit in terms of grades, with no significant decline in credits; on the contrary, students enrolled in engineering courses register the largest reduction in credits, with no significant gains in grades. Economics and management students lay between these two groups and display similar results to those estimated for the whole population of students. In relative terms, the credit decline in engineering is much larger than the average grade increase in humanities and law: the coefficient estimated for credits in engineering is almost twice as high as that reported in Table 3 for the whole population of students, while the estimated coefficient for grades in Humanities and law is around 22% larger than the corresponding Diff-in-Diff effect in the whole sample. We obtain similar estimates also when we control for student fixed effects (see Table A1).

Table 5: Heterogeneous effects by field of study

	(1)	(2)	(3)	(4)	(5)	(6)
	Credits per Sem	Grade	Credits per Sem	Grade	Credits per Sem	Grade
VARIABLES	Humanities	Humanities	Engineering	Engineering	Econ&Man	Econ&Man
II Semester	14.42***	-0.457***	8.902***	-0.0637	12.52***	-0.449***
	(0.392)	(0.0590)	(0.685)	(0.0974)	(0.467)	(0.0692)
2019/2020	-4.225***	0.00310	2.677	0.375	-4.432***	0.0663
	(1.295)	(0.197)	(2.480)	(0.355)	(1.569)	(0.236)
II Semest*2019/2020	-0.265	0.331***	-2.977***	0.174	-1.870**	0.254**
	(0.600)	(0.0866)	(1.108)	(0.152)	(0.818)	(0.109)
Observations	6,343	6,272	2,304	2,297	3,650	3,637
R-squared	0.269	0.089	0.156	0.107	0.240	0.069
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: OLS estimates. The dependent variable is the total number of credits per semester in column 1,3,5 and the average grade in column 2,4,6. Standard errors are clustered at the individual level. Academic years: 2016-2019.

As for the baseline estimates, we try to decompose the effects in terms of number of exams taken, number of credits per exam and share of inactive students. The decomposition analysis reported in Figure 1 reveals interesting differences between engineering students and the remaining ones: while the first have taken exams in fewer but longer courses, i.e. exams with more credits, students in

humanities and social sciences have experienced a significant decline in the number of credits per exam, with no significant change in the number of exams taken.

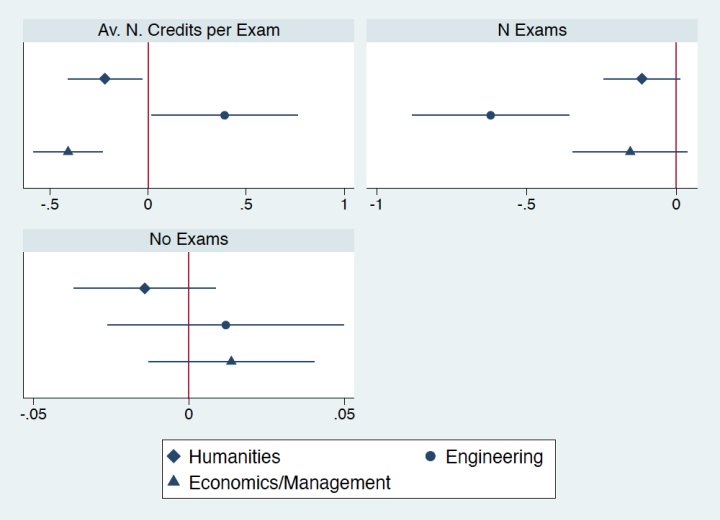
Estimates that consider heterogeneous effects by gender within field of study show that the negative effect on credits in engineering degrees is mainly driven by girls, who also registered a slight (although only weakly statistically significant) increase in grades compared to boys. On the contrary, no statistically significant gender differences emerge in the other fields of study (see Figure 2).

The decomposition analysis reveals that the larger reduction in credits for women in engineering courses is mainly driven by a reduction in the number of exams taken: compared to boys, girls in this field of study took on average one exam less (see Figure 3). They also register a relatively higher number of credits per exam, but the estimated difference is not statistically significant.

Overall, the estimated gender differences suggest that women enrolled in engineering degrees seem to choose more challenging study strategies than their male counterparts. However, the lower number of exams taken may also be due to other factors, such as gender differences in housework during the lockdown, which could have halted girls' learning mainly in those fields of study that require more exercise. We further investigate this channel in the following Section.

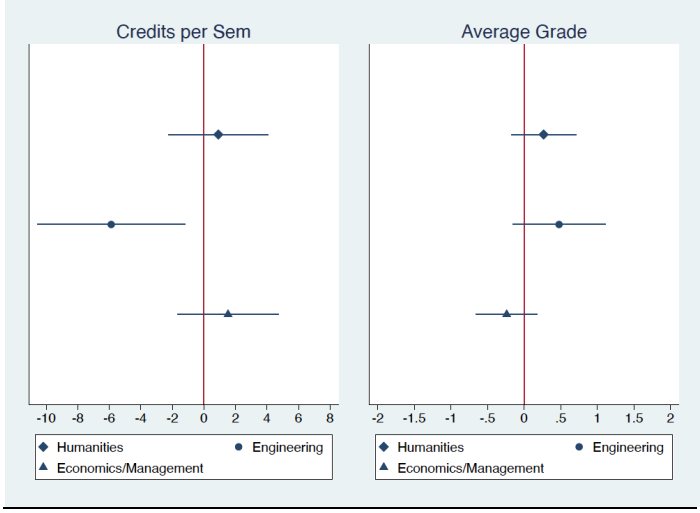
Figure 1: Decomposition of the effects on Credits:

Average Number of Credits per exam, Number Exams, No exams by Field of Study



Notes: Plots of the coefficient of the interaction variable of Equation 1 (OLS estimates) by field of study. The dependent variable is the average number of credits per semester in the first graph, the total number of exams in the second graph, and a dummy variable for those who obtain less than 10 credits per semester in the third graph. Academic years: 2016-2019.

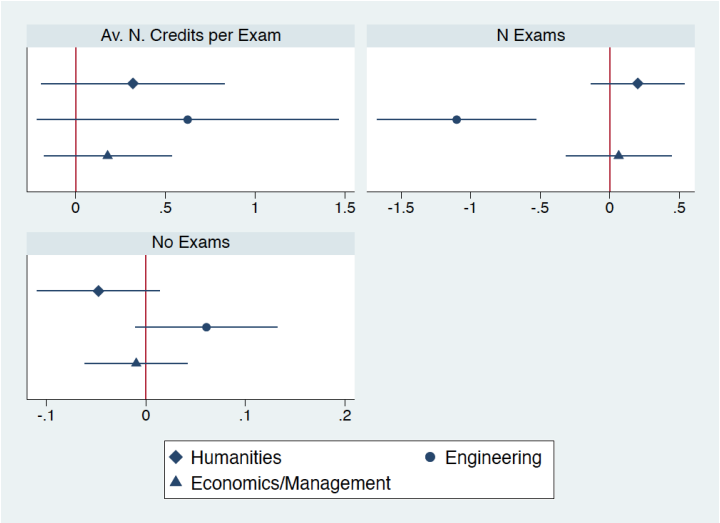
Figure 2: The role of gender by field of study



Notes: The figure shows the coefficient of the interaction term II Semester*2019/2020*Female in an Equation similar to Equation 1 by field of study. The dependent variable is the total number of credits per semester in the first graph, and the average grade in the second graph.

Figure 3: Decomposition of the gender effect on Credits:

Average Number of Credits per Exam, Number Exams, No exams by Field of Study



Notes: The figure shows the coefficient of the interaction term II Semester*2019/2020*Female in an Equation similar to Equation 1 by field of study. The dependent variable is the average number of credits per semester in the first graph, the total number of exams in the second graph, and a dummy variable for those who obtain less than 10 credits per semester in the third graph. Academic years: 2016-2018.

Robustness checks

We run several robustness checks to check the validity of our results. First, we replicate our analysis by including student FE. Table A1 reports the results, which appear quite similar in magnitude and in significance to those reported in the previous section.

Second, we investigate whether our results are more driven by the overall disruptive effect of the pandemic rather than by the abrupt change in the teaching mode. To do so, we exploit the large variation in excess mortality across municipalities and distinguish between students living in municipalities that were severely hit by the pandemic from the other ones. If we find significant effects also for students in municipalities that were only mildly hit by the pandemic, this should confirm that our main results are not entirely driven by the pandemic, but they may be attributable to the switch in the teaching mode. In Table A2, we report the results of a regression in which we interact our variable of interest with a dummy equal to 1 for those students coming from municipalities that have been more severely affected by the pandemic during the first wave (namely, those with an excess mortality rate larger than 1.8, which corresponds to the 2nd tertile of the excess mortality distribution in the Lombardy region). Table A2 shows that the level of the excess mortality only influences the effect of online teaching on the average grade, for students in humanities, while no effect is found for the total number of credits.

Finally, it may be argued that the switch from face-to-face to distance learning was followed by significant changes also in the type of exams that students had to take at the end of the course. More precisely, whenever possible, final written tests were converted into oral exams, which could be carried out more easily remotely. In order to investigate and disentangle the effect of the modality of the exam on the education outcomes from that of online teaching we proceed in two steps. First, we analyse whether the increase in the probability of taking an oral exam increased with the pandemic, and whether this increase was different across the fields of study. Then, we computed the share of oral exams taken by each student in each semester and added this additional control to our baseline estimates. Table A3 in the Appendix shows that the probability of taking an oral exam increases during the pandemic but differently across the fields of study. The increase was largely lower for engineering and slightly lower for humanities compared to economics and management. In light of these differences, we check that our results are robust to including the share of oral exams among our controls. The results in Table A4 show that an increase in the share of oral exams increases both the number of credits and the average grade, but our main Diff-in-Diff results persist also once we control for the exam modality. While the magnitude of effect on grade for humanities is lower than in the previous analysis (Table 5), the effect on credits for engineering becomes even larger.

5. Channels

Different underlying factors can explain the heterogeneous effects of distance learning by field of study and gender. For example, girls may have more difficulties than boys in attending lectures for many hours at home, especially when they have to reconcile it with family duties, such as taking care

of younger siblings. This may be particularly relevant in countries, like Italy, where there are large asymmetries and stereotypes in gender division of domestic work (Cutillo and Centra, 2017; Del Boca et al., 2020). The study-life balance can be more challenging for girls in degrees requiring to solve long or technical written exercises, where continuous interruptions may hamper the learning process. The literature actually shows that, while females have stronger self-regulation than males in online learning contexts (Alghamdi et al., 2020), males can use more learning strategies and have better technical skills than females (Yu, 2021). These gender differences can also reflect into different perceptions of the workload required by a certain online course. In this perspective, girls could have suffered more than boys the inability to access University on-site facilities (such as labs or libraries) that could help them in their learning process.

A third potential mechanism may stem from the lack of personal relationships with both teachers and peers caused by distance learning. Evidence from psychological literature shows that, compared to men, women are on average more extraverted and agreeable, they participate in more interconnected social groups and are more active in maintaining social and emotional bonds (Costa et al, 2001; Weisberg et al, 2011). Furthermore, the ability to benefit from social support can be crucial to face difficulties in the university environment (Wilcox et al, 2005; Elmer et al., 2020). Girls may suffer more than boys from reduced social interactions especially in degrees requiring more problem solving and teamwork skills.

Finally, distance learning in the COVID context could have exacerbated mental health problems, with negative effects on both attending online courses and the probability to pass an exam. Recent research on undergraduate students in Italy shows that higher levels of stress, anxiety, loneliness and other depressive measures are primarily associated with limited social interactions and sparser co-studying networks caused by distance learning during the first wave of COVID (Giusti el al, 2021). Newly arising stressors during the pandemic can have exacerbated mental health problems, but negative effects of distance learning on students' mental health were reported in the literature also before the COVID crisis (Know et al, 2010; see also the literature review in Dabrovski and Michell, 2022).

To investigate these potential underlying factors, we utilized data from the ad-hoc survey carried out at the University of Bergamo in Fall 2020 to collect information on behaviours and opinion of students regarding distance learning. The survey was sent to all students enrolled in any Bachelor or Master's program in the academic year 2019-2020. Around 3160 students responded to the survey, of whom 690 enrolled in a Master's program. For the latter, we used some questions from the survey to create measures of difficulties related to study-life balance, perceived workload of online courses, the impact of distance learning on relations with teachers and peers and mental health.

In terms of study-life balance, we focused on the following questions: Q1) Did your siblings experience any difficulties related to the COVID-19 emergency? Q2) Was it challenging to balance the home environment with your distance learning program? To assess the impact on workload, we analysed the students' responses to the following questions: Q3) Did the inability to access libraries, archives, or study rooms negatively impact your ability to find useful information? Q4) Was the workload required for each course proportionate, taking into account the extraordinary circumstances? With regard to relations with teachers and peers, we examined the following: Q5) Did the new modes of communication make it more difficult to communicate with teachers? Q6) Did the lack of direct contact with teachers negatively affect your overall preparedness? Q7) Did the absence of direct contact with classmates adversely affect your social and relational experiences related to university life?

Finally, for the mental health, we analyse the students' answer to the following questions: Q1) Have you had any difficulty sleeping regularly lately? Q2) Have you recently felt happy? Q3) Have you recently had the impression that you cannot cope with the difficulties?

Using this information, we create a set of variables that we use as dependent variables in regression models in which the regressors of interest are gender, field of study and the interaction between gender and field of study.

The results are shown in Table 6 and 7.

Table 6: Channels (1)

	Study-life balance		Work-load		Relations with teachers and peers		
	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Female	-0.040	-0.467**	0.435**	0.075	0.029	-0.212***	-0.196***
	(0.072)	(0.226)	(0.177)	(0.068)	(0.069)	(0.068)	(0.072)
Humanities	-0.233**	-0.053	-0.372	0.005	0.157	0.023	-0.053
	(0.102)	(0.318)	(0.298)	(0.092)	(0.102)	(0.102)	(0.102)
Engineering	-0.173**	-0.067	0.103	0.032	0.014	-0.060	-0.173**
	(0.076)	(0.240)	(0.195)	(0.070)	(0.073)	(0.075)	(0.076)
Fem*Eng	0.193*	0.754**	-0.622**	0.094	-0.030	0.211*	0.268**
	(0.115)	(0.355)	(0.300)	(0.111)	(0.111)	(0.110)	(0.114)
Fem*Hum	0.158	0.635*	0.087	-0.103	-0.220*	-0.026	0.082
	(0.114)	(0.352)	(0.317)	(0.104)	(0.113)	(0.109)	(0.112)
Observations	679	656	655	679	679	679	679
R-squared	0.020	0.028	0.038	0.029	0.017	0.050	0.031

Notes: Academic year 2019/ 2020. Survey data. Controls include age and nationality.

Table 7: Channels II

VARIABLES	(1) Issues Sleep	(2) Happiness	(3) Difficulties
Female	-0.035	0.036	0.054
	(0.071)	(0.073)	(0.070)
Humanities	-0.081	-0.094	0.199**
	(0.097)	(0.097)	(0.101)
Engineering	-0.037	-0.071	0.066
	(0.074)	(0.075)	(0.074)
Fem*Eng	0.110	0.064	-0.020
	(0.113)	(0.117)	(0.114)
Fem*Hum	0.136	0.015	-0.015
	(0.109)	(0.109)	(0.113)
Observations	679	679	679
R-squared	0.007	0.015	0.045

Notes: Academic year 2019/2020. Survey data. Controls include age and nationality.

According to the evidence, female engineering students were the most affected by the absence of contact with peers and limited access to universities during the pandemic, resulting in poorer work-life balance. This finding may account for the variations observed in the preceding section's outcomes. No evidence suggesting a role played by mental health in explaining our results is found.

6. Conclusions

In this paper, we investigate the effects of distance learning on student achievement by exploiting the sudden switch from traditional face-to-face to online lectures at the University of Bergamo during the first wave of the Covid pandemic. Diff-in-diff estimates based on detailed administrative data for the population of Master's students enrolled from the academic year 2015-16 to the academic year 2019-20 show that distance learning has caused a slight increase in the average grade (+1%) but this came at a cost of a significantly reduction in the number of credits earned (-5% per semester). Further analysis reveals that the overall effect on credits is driven by both a lower number of credits per exam and a lower number of exams passed.

Estimates by field of study highlight that those students enrolled in humanities or law degrees experienced the largest benefit in terms of grades, with no significant decline in credits; on the contrary, students enrolled in engineering programs registered the largest reduction in credits, with no significant gains in grades, while students in economics and management saw both some reduction of credits and some increase in grades. Estimates by gender within field of study show that the

negative effect on credits in engineering degrees is mainly driven by girls, who passed a lower number of exams but registered a slight increase in average grades compared to boys in the same field. On the contrary, no statistically significant gender differences emerge in the other fields of study. Overall, the estimated gender differences in a STEM field of study like engineering suggest that women seem to choose more challenging study strategies than their male counterparts (that is, take fewer but longer courses). However, the lower number of exams successfully taken by girls is also coherent with gender differences in time dedicated to housework, during the lockdown. This could have halted girls' learning mainly in those fields of study that require more time to understand complex concepts and solve lengthy exercises. Further evidence based on an ad-hoc survey carried out on a sample of students enrolled in Fall 2020 confirms that girls were indeed more likely to take care of younger siblings during school closure or to help with housework (Zabaniotou, 2021).

This evidence suggests that the difficulty to reconcile work and family life – the so called "double burden" - may start well before women enter the labour market and may be relevant also for young and single girls. Most importantly, such double burden seems crucial, especially in fields (such as engineering) where girls are a minority, with the risk of causing negative effects on both current students' performances and future labour market career.

It is important to mention that although our study has the limitation of not fully differentiating the impact of the pandemic from that of online teaching, our heterogeneity analysis and robustness checks highlight factors that are more closely associated with online teaching in general, rather than being specific to the pandemic.

From a policy perspective, our results call for interventions aimed not only to attract girls in STEM degrees, but also to support them during their studies, monitoring their progress to prevent drop-out or delays in time to degree.

Appendix:

Table A1: The effect of online teaching (Individual FE)

	(1) Credits per sem	(2) Grade	(3) Credits per sem	(4) Grade	(5) Credits per sem	(6) Grade
	Humanities	Humanities	Engineering	Engineering	Econ&Man	Ec&Man
II Semester	14.85***	-0.434***	9.397***	0.0927	12.63***	-0.474***
	(0.414)	(0.0567)	(0.722)	(0.0925)	(0.538)	(0.0704)
2019/2020	-1.401	0.227	1.355	-0.300	-3.677**	0.0620
	(1.565)	(0.214)	(2.571)	(0.331)	(1.807)	(0.237)
II Semest.*2019/2020	-0.177	0.449***	-2.545**	0.164	-1.870**	0.375***
	(0.625)	(0.0858)	(1.104)	(0.142)	(0.804)	(0.105)
Observations	6,343	6,272	2,304	2,297	3,650	3,637
R-squared	0.621	0.686	0.540	0.723	0.526	0.690
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Student FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: OLS estimates. The dependent variable is the total number of credits per semester in columns 1,3,5 and the average grade in columns 2,4,6. Standard errors are clustered at the individual level. Academic years: 2016-2019.

Table A2: The effect of online teaching and the effect of the pandemic

	(1) Credits per sem	(2) Grade	(3) Credits per sem	(4) Grade	(5) Credits per sem	(6) Grade
	Humanities	Humanities	Enginee.	Engineer.	Econ.&Man	Econ.&Man
	(1.345)	(0.188)	(2.553)	(0.372)	(1.608)	(0.244)
High Excess M	-0.716	0.213**	-0.0115	-0.125	0.851	0.154
	(0.510)	(0.101)	(0.922)	(0.193)	(0.617)	(0.136)
II Sem.*2019/2020	-0.477	-0.367***	-2.294	-0.0328	-1.173	0.228
	(0.744)	(0.115)	(1.539)	(0.214)	(1.028)	(0.139)
II Sem.*2019/2020 *High Excess M	0.668	0.442**	-1.395	0.412	-1.863	0.0657
	(1.253)	(0.208)	(2.224)	(0.299)	(1.692)	(0.217)
Observations	6,343	6,343	2,304	2,297	3,650	3,637
R-squared	0.270	0.241	0.156	0.109	0.242	0.069

Notes: OLS estimates. The dependent variable is the total number of credits per semester in columns 1,3,5 and the average grade in columns 2,4,6. Standard errors are clustered at the individual level. Academic years: 2016-2019.

Table A3: Probability of an online exam. Differences across Field of Study.

	(1) Oral Exam
II Semester	-0.00203
	(0.0112)
2019/2020	0.0500**
	(0.0225)
II Semester*2019/2020	0.182***
	(0.0172)
II Semester*2019/2020*Engineering	-0.102***
	(0.0319)
II Semester*2019/2020*Humanities	-0.0686***
	(0.0221)
Observations	12,854
R-squared	0.494
Controls	Yes

Notes: OLS estimates. The dependent variable is the probability of taking an oral exam. Standard errors are clustered at the individual level. Academic years: 2016-2019.

Table A4: The effect of online teaching (Controlling for the modality of the exam)

	(1) Credits per sem	(2) Grade	(3) Credits per sem	(4) Grade	(5) Credits per sem	(6) Grade
	Humanities	Humanities	Engineering	Engineering	Econ&Man	Ec&Man
Oral Exam	1.881***	1.126***	3.501***	0.923***	3.095***	0.921***
	(0.615)	(0.114)	(0.945)	(0.161)	(0.802)	(0.131)
II Semester	14.27***	-0.540***	7.896***	-0.332***	12.66***	-0.404***
	(0.397)	(0.0582)	(0.744)	(0.106)	(0.469)	(0.0700)
2019/2020	-4.523***	-0.166	2.236	0.249	-4.436***	0.0680
	(1.299)	(0.198)	(2.484)	(0.350)	(1.558)	(0.232)
II Semester*2019/2020	-0.477	0.201**	-3.246***	0.108	-2.533***	0.0618
	(0.601)	(0.0863)	(1.099)	(0.151)	(0.829)	(0.111)
Observations	6,343	6,272	2,304	2,297	3,650	3,637
R-squared	0.270	0.108	0.162	0.122	0.245	0.084
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: OLS estimates. The dependent variable is the total number of credits per semester in columns 1,3,5 and the average grade in columns 2,4,6. Standard errors are clustered at the individual level. Academic years: 2016-2019.

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