Analysis of the effects of COVID-19 and school closures on primary and secondary education in Italy

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Dissertation written under the supervision of Professor Hugo Reis.

Dissertation submitted in partial fulfilment of requirements for the MSc in Economics, at the Universidade Católica Portuguesa, 04/01/2022.

ABSTRACT

When the COVID-19 pandemic erupted in Italy, the Italian Government rapidly decided to close all non-essential activities. Schools were therefore promptly closed, and lessons took place online. The sudden and unexpected transition to the online method caused many disruptions to the normal schooling activities. In this paper, we look at their effects on students of primary and secondary education by confronting the Invalsi national tests from 2019 to 2021. At a national level we find that, on average, students from all educational levels decreased their performance. However, non-Italians, females and students with a lower educated mother were more negatively affected.

Italian regions have big differences in terms of wealth, inequality and academic achievements. Moreover, different restrictive measures came into place for each region and grade leading to distinct amounts of days of school closure. We link these characteristics and differences with the percentage difference in test scores between 2019 and 2021. For secondary education we find that one day of full school closure decreases the percentage difference in test scores by 0.15 percentage points.

As we write, the world is facing the rise of the Omicron variant of COVID-19. New variants may develop in the future causing countries to consider new restrictive measures. Our results warn on the immediate negative effects that such policies on school closures may cause on students' performances.

RESUMO

Quando a pandemia do COVID-19 se começou a alastrar por Itália, o governo italiano rapidamente decidiu encerrar todas as atividades não-essenciais. As escolas foram assim encerradas, e as aulas passaram a ser dadas remotamente (*online)*. A repentina e imprevisível transição para métodos *online* causou várias disrupções às atividades escolares normais. Nesta tese olhamos para os seus efeitos nos estudantes do ensino primário e secundário comparando os testes nacionais Invalsi de 2019 a 2021. Em média, todos os níveis de ensino tiveram um declínio no seu desempenho. Contudo, estudantes não-Italianos, do sexo feminino e cuja mãe possuí menos habilitações académicas foram afetadas mais negativamente.

As regiões de Itália apresentam diferenças consideráveis em termos de riqueza, desigualdade e nível educacional. Para além do mais, foram adotadas medidas restritivas diferentes consoante a região e ano de ensino levando ao encerramento das escolas por períodos de tempo diferentes. Ligamos estas características e diferenças com a diferença de percentagem nas pontuações obtidas nos testes entre 2019 e 2021. No ensino secundário, concluímos que um dia de encerramento escolar diminuiu a variação percentual dos testes em cerca de 0.15 pontos percentuais.

Enquanto escrevemos, o mundo enfrenta o aumento da variante Ómicron do COVID-19. Novas variantes poder-se-ão desenvolver no futuro levando países a considerarem novas medidas restritivas. Os nossos resultados realçam os efeitos negativos imediatos que as políticas de encerramento de escolas podem ter no desempenho dos alunos.

I. Introduction

After the first two cases of COVID-19 of tourists coming from China on January 31st, on March 19th Italy surpassed China in terms of most reported deaths[1]. Italy was the first European country to experience a major outbreak of COVID-19 and the first one worldwide to introduce a national lockdown (Saglietto et al. 2020). Schools were completely shut down on March 4th and lessons took place online. COVID-19 was an unexpected shock that forced to rapidly shift to a teaching method that was unknown just a few weeks before. The transition to the online method was not effortless, teaching has always meant to be done in presence. Other difficulties were the lack of personal computers among the students and the difficulty of following daily classes in the same house where siblings would do likewise and parents work (Agasisti, Soncin 2020).

This shock, for its unexpected and unprecedented nature, gives a perfect natural experiment setting. In this paper we focus on its effects on the academic results in mathematics for Italian students in primary and secondary education. We analyzed the results from the national standardized test Invalsi which is performed once a year and compare the results from 2018 and 2019 with the ones in 2021. This thesis aims at analyzing the effects of the disruptions in the school system happened during the COVID-19 pandemic on results for Italian students, at both national and regional levels.

The descriptive statistics presents the magnitude and significance of the decrease in academic performances. We first find that the decrease in performances increases with the grade. We then looked at heterogeneity by computing the average score for each characteristic of the students and by designing an econometric model. Certain characteristics such as being female or being born in a country that is not Italy, are associated with a lower average score. Looking at the general impact of COVID-19, not only we observe that all students were affected but also that the impact is higher for certain characteristics such as being female or not Italian. This is coherent with what ex-ante studies theorized (Baley et at. 2021; Dorn et al. 2020; Grewenig et al. 2020; Goudeau et al. 2021; EED 2020) as well as the first ex-post one suggested (Engzell et al. 2021).

[1] On March 19th 427 people died from COVID-19 in Italy, bringing the total to 3,405 while the number of fatalities in China was 3,245 even though the population of China is more than twenty times higher than Italy's.

By looking at inequality measures and comparing them from 2019 to 2021, with some surprise, we do not see higher dispersion of the grades in 2021. The distribution of the grades shifted to the left, but the shape remained similar.

We then analyze the results at a regional level. There is big heterogeneity in terms of wealth, inequality and academic achievements between Italian regions. Moreover, each region had a different impact of COVID-19 and therefore, different restrictive measures to the school system were implemented. We link the distinctions between regions with percentage difference in the score of the test of mathematics between 2019 and 2021. We find that one day of school closure decreases the percentage difference in test score by 0.15 percentage points for secondary education. One month of school closure (composed by 22 working days) would decrease the average result in mathematics by 3.3 percentage points in grades 8 and 13.

The results and findings are directly relevant for Italy. However, the results can be confronted with the ones from other countries. An international comparison will be important in order to assess the universal effects of COVID-19 on education and this thesis aims at giving a contribution to this.

Our study is not without limitations. The dataset is a representative sample of the population of the students. However, it is not possible to link the same student in different periods since the sample changes every year. Also, schools are given a random identification number making it not possible to link them from one year to the other. We are not able to claim for causality, but we provide suggestive results of what happened to academic performances in the COVID-19 period. The issue of causality can be addressed not only with longitudinal data, but also by being able to control for other not observable characteristics. For example, we are not able to observe measures that schools may have put in place in order to contrast the effects of school closures (for example by giving laptops to the students). If this was the case however, the impact of schooling performances that we find would be even higher.

The paper is organized as follow: section II presents the literature review of this topic; section III describes the background of our analysis, with particular attention regarding the Italian school system and the source of our data: the national standardized test “Invalsi”. Section IV shows the data and the differences in performances from 2019 to 2021 for each grade and characteristic together with an analysis of inequality. Section V describes the econometric models and the results from the estimations. Section VI presents the regional analysis and the

relation between percentage difference in score between 2021 and 2019 and days of school closure. Section VII concludes.

II. Literature review

There is already a vast literature concerning the effects of COVID-19 on education. Most of the research is based on ex-ante analyses and forecasts. There is however a growing number of papers published using newly available data.

In Bailey et al. (2021), the authors ask experts for previsions concerning how much achievement gaps between low- and high-income students in U.S. elementary school will change as a result of COVID-related disruptions to schooling and family life. Dorn et al. (2020) provides forecasts and predictions on the learning losses caused by COVID-19. Both papers conclude that the learning losses will likely be unequal and will last for a long time. Similar findings are observed by Grewenig et al. (2020) in which 1,099 parents in Germany were surveyed.

Other papers such as Goudeau et al. (2021) and Education Endowment Foundation (2020) study the relationship between education and COVID-19 from a theoretical and multidisciplinary point of view. They argue that given that the education of students started relying on families and on technical equipment, school closures will exacerbate inequalities. Our study will provide measures on how the distribution of the grades changed after COVID-19.

The following papers discuss the effects of COVID-19 in Italy. Firstly, Di Tommaso et al. (2021) assesses the impact of schooling closure in Turin. The authors assess the difference in math skills of pupils in primary school by comparing two cohorts: pre-covid and post-covid. They find out that school closure had in general a negative impact on students' performance in mathematics (as expected) and that the effect was larger for the high-achieving pupils and girls with low-educated parents. In order to reach this conclusion, the authors employed a model with a dummy for the Covid cohort and interacted it with other dummies about the characteristics of the students. We used a similar model in order to evaluate how COVID-19 impacted students with different backgrounds. Another paper of interest is Agasisti, Soncin (2020) that revisits the troubles caused by COVID-19 on higher education in Italy, especially in Lombardia.

One of the most interesting ex-post studies is conducted by Engzell et al. (2021). The authors analyze the effect of school closures with a dataset of around 350,000 students in the Netherlands. It is important to notice that the Netherlands underwent a shorter lockdown

compared to Italy (8 weeks). They again find that decreases were larger for students from disadvantage backgrounds.

Another paper of interest is Meeter (2021) which presents results that to some extent, contradict what we have seen so far. The author compares 53,656 performances of students in the Netherlands who used adaptive practicing software for mathematics with similar students in the year before. He finds that the performances not only did not decrease but, in some cases, they were even higher than the year before. This is an important result because contradicts the findings presented until now. We should therefore take into consideration the fact that the learning loss may be different based on the technical teaching method and the software used by students.

Moreover, the three following papers present general findings that are useful in formulating hypotheses on the impact of the pandemic on academic performances. Carlsson et al. (2015) studies the effect of schooling on cognitive skills for a sample of Swedish males taking a test for military service. They find that ten days more of schooling yield approximately a 1% of standard deviation increase in the test. Lavy (2015) evaluates the achievement gaps for students of different countries based on the number of days of schooling using PISA 2006 data for 50 countries. As expected, the author finds a positive and significant relation between instructional time and test scores. Both these papers suggest that school closures given by COVID-19 would negatively impact school grades. Andersen and Nielsen (2019), similarly, finds that students attending a test in Denmark increased the score in a reading test two years later by 9% of a standard deviation compared to students who couldn't take the test because of an IT crash in the testing system. In this case the authors studied the impact of an event on academic performances in the medium term. Our analysis focuses on the immediate impact of COVID-19 on education, but a medium and long-term analysis will be necessary in the future.

During lockdowns, the role of families in students' education has been very important. Students had to share the studying environment with their families and their role in education therefore increased. Literature on this topic suggests that the education of parents is a leading input in the education attainments of their children. This topic is discussed in detail by Bjorklund and Salvanes (2011) who summarize various studies on this topic for developed countries and by Oreopoulos et al. (2006) who examine this matter for the United States. Schuetz et al. (2008) shows that family-background effects are significant in the developed countries attending two international TIMSS tests at a 1% level. This effect is extensively

explained in Hanushek and Woessmann (2011) in which they underline in particular the strong effect of the education of the mother using data from TIMSS international tests. In our analysis we firstly exclude the level of education of the mother because we do not have this data for grade 13. This allows us to compare the findings between all grades. We then estimate another model in which we include it for grades 2,5 and 8 in order to check for changes in the coefficients.

III. Background

Italian school system

In the first six years of their life, Italian children can attend pre-kindergarten and kindergarten. The attendance however is not compulsory.

From six to eleven years of age Italian students attend primary school, they then attend lower secondary school from eleven to fourteen years old. Both academic stages are mandatory. It is also important to notice that both primary and lower secondary education are comprehensive, that means that there is no difference concerning the content between schools.

When the students are fourteen, they already must decide between different academic paths. Normally, given that the students have successfully finished the lower secondary education, they will start upper secondary education. This stage lasts for five years, until students are nineteen years old. Students can choose between three academic paths. More than 50% of the students[2] choose to study in high schools ("Licei"). While basic courses are common to all high schools, the difference lays in the rest of the curriculum. We therefore find "Scientific", "Classical", "Artistic", "Linguistic", "Social Sciences" and some more types of high schools. A smaller percentage of students choose instead to go to Technical Institutes or Professional Institutes. Figure 1 shows a summary of the level of education based on the grades.

The Article 33 of the Italian Constitution states that the Nation has the duty to offer a school system for all. It also grants the option for individuals to establish private schools. Private schools exist for all grades and are legally qualified to issue qualifications of the same level of public schools.

After the upper secondary education, Italian students are ready to apply for universities. We did not cover this step as our analysis focuses on primary and secondary education.

Grade	1	2	3	4	5	6	7	8	9	10	11	12	13
	Primary					Lower secondary			Upper secondary				

Figure 1 Educational stages and grades in Italy.

[2] According to the data from the Italian Ministry of Education, in 2021 57.8% of the students chose "Licei", 30.3% chose "Technical Institutes" and 11.9% chose "Professional Institute".

Invalsi national test

The first national standardized tests were performed in the academic year 2005-06 for the subjects of mathematics and Italian. Since then, the tests have been modified and improved year after year. These developments consisted in modifications of the subjects, the grades tested and in the administration of the test. The current Invalsi system was designed in 2017.

Three subjects are tested in the current format of the Invalsi: Italian, Mathematics and English (divided into Reading and Listening). For our analysis we only focused on the performances of the test of mathematics.

Students are not invited to prepare for the tests. The Invalsi test is supposed to check the progression of the abilities of the student at a given time. It is a photograph of the national status quo of the subjects tested.

Because of the COVID-19 pandemic, in 2020 the Invalsi national tests were not performed at all. It would have been interesting to have data from 2020 since it was the middle of the pandemic. However, we are interested in the difference between before and after the disruptions to schools caused by COVID-19.

The grades tested in primary education are grade 2 and 5. The subjects tested are Italian and Mathematics for both grades and English (listening and reading) for grade 5. The tests are performed in *Pencil Paper Testing* mode which consists in a written test downloaded from the Invalsi website and printed by the schools.

The grade tested in lower secondary school is just one: grade 8. The administration of the test in this case is performed in *Computer Based Testing* mode. This, in theory, makes cheating more difficult as the questions and the answers have random orders. Also, this system makes the collection and correction of the answers easier. The test of Italian is divided in three sections designed to analyze different aspects of the knowledge of the students: comprehension, vocabulary and reflection on the language. Mathematics is also divided in three dimensions: solving, arguing and knowing; and four topics: space and figures, relations and functions, data and previsions, proportionality. The English test is divided in listening and reading, and both parts have questions of A1 and A2 levels. At this point of education students are expected to reach an A2 level.

In upper secondary education the grades tested are normally grades 10 and 13. In 2021 exceptionally, grade 10 was not tested. Again, *Computer Based Testing* is used for the tests.

The test of Italian is divided in two sections: comprehension, reflection on the language. Mathematics is now more focused on the argumentative side. The test is divided in two sections: one is the same for all and one depends on the type of high school. English is again divided in reading and listening, and the questions are from B1 and B2 level since B2 is the level at which students are expected to be at the end of high school.

IV. Data and descriptive statistics

In our analysis we use a representative sample for each test performed for each grade provided by the Invalsi Statistical Department. The dataset contains the results of the national standardized test "Invalsi" for the grades 2, 5, 8, 10 (only for 2018 and 2019) and 13 (only for 2019 and 2021). Since we focus our analysis on the impact of COVID-19 on students' performances, we do not take grade 10 into consideration. This means our data comprises two grades from primary education: grade 2 (the second) and grade 5 (the last); one grade for the lower secondary education: grade 8 (the last one); and one grade for the upper secondary education: grade 13 (the last one). For the purpose of our study, we only looked at the performances in the test of mathematics. We used the test of Italian as a robustness check of our findings in the last section.

A process of merging and cleaning was needed in order to have a unique dataset since the datasets were different from one year to the other. While some basic variables such as age, gender, place of birth, region are common to all datasets, others appear only in some of them. For example, grade 13 never has variables for the education nor the occupational status of the parents.

Our outcome measure is the Weighted Likelihood Estimator (WLE) (Warm 1989) provided by the Statistical Department of the Invalsi.

In the dataset there were already variables for the gender, attendance to pre-kindergarten and kindergarten and whether the student is on time with the studies. We then constructed other variables by, for example, using the string variable describing the birthplaces of the student and his/her parents to construct a dummy for each of them equal to one if the birthplace was Italy. With the description of the parents' occupation, we generated a dummy equal to one if the parent is employed. Finally, we transformed the parents' education description in "years of schooling". In this case "years of schooling" is defined as the number of school years corresponding to the highest academic achievement of the parent.

Data

Concerning the overall dataset, table 1 shows the distribution of observations by grades and years. We observe a decrease in data for the year 2021 especially driven by grade 8. However, this is not a issue since the sample is representative of the population.

The highest amount of available data is found in the student's personal background characteristics. These include gender, place of birth, nationality and whether the student is on time with the studies. Next, there is a high number of information concerning demographic characteristics of the parents.

On the other hand, there are several missing values in the attendance of pre-kindergarten and kindergarten as well as the occupational status and academic background of the parents. Additionally, the dataset completely lacks these variables for grade 13. We took this into consideration when we estimated the model in the next section: we cannot afford to estimate a model that covers only a small percentage of the total observations. Tables 1A, 1B, 1C, and 1D in the Appendix, summarize the number of observations and missing values for each variable.

Given what described above, the following variables were used in our research: gender, place of birth, whether the student is Italian, whether the student is on time with the studies, father's and mother's place of birth, and mother's years of schooling. Other variables important in the literature that we briefly describe are attendance of pre-kindergarten and kindergarten, parents' occupational status, and father's academic career.

	Year of the test		
Grade	**2018**	**2019**	**2021**
2	25,009 31.2%	23,803 20.7%	15,890 25.4%
5	25,827 32.2%	24,781 21.6%	16,631 26.6%
8	29,359 36.6%	29,675 25.8%	9,708 15.5%
13		36,589 31.9%	20,281 32.4%
Total	80,195	114,848	62,510

Table 1 Observations per grade, Mathematics

Descriptive statistics

The descriptive statistics in this chapter provide the first insights about the academic performances before and after COVID-19.

Grades distribution. Figure 2 provides the Kernel density distribution of the test score for grades 2, 5, 8 and 13 and how they changed through the years. These graphs provide an overview of the changes in students' performance in Mathematics from 2019 to 2021. There has been a shift to the left from 2019 to 2021, signaling a decrease in performance. This shift is clearly visible in grade 13. In primary school the difference is still somewhat visible, but to a lesser extent.

The shape of the distribution is quite similar from 2019 and 2021. We address the change of inequality in the appropriate section of the paper. Here however, at a first glance, the fact that the distribution has similar tails through years is visible.

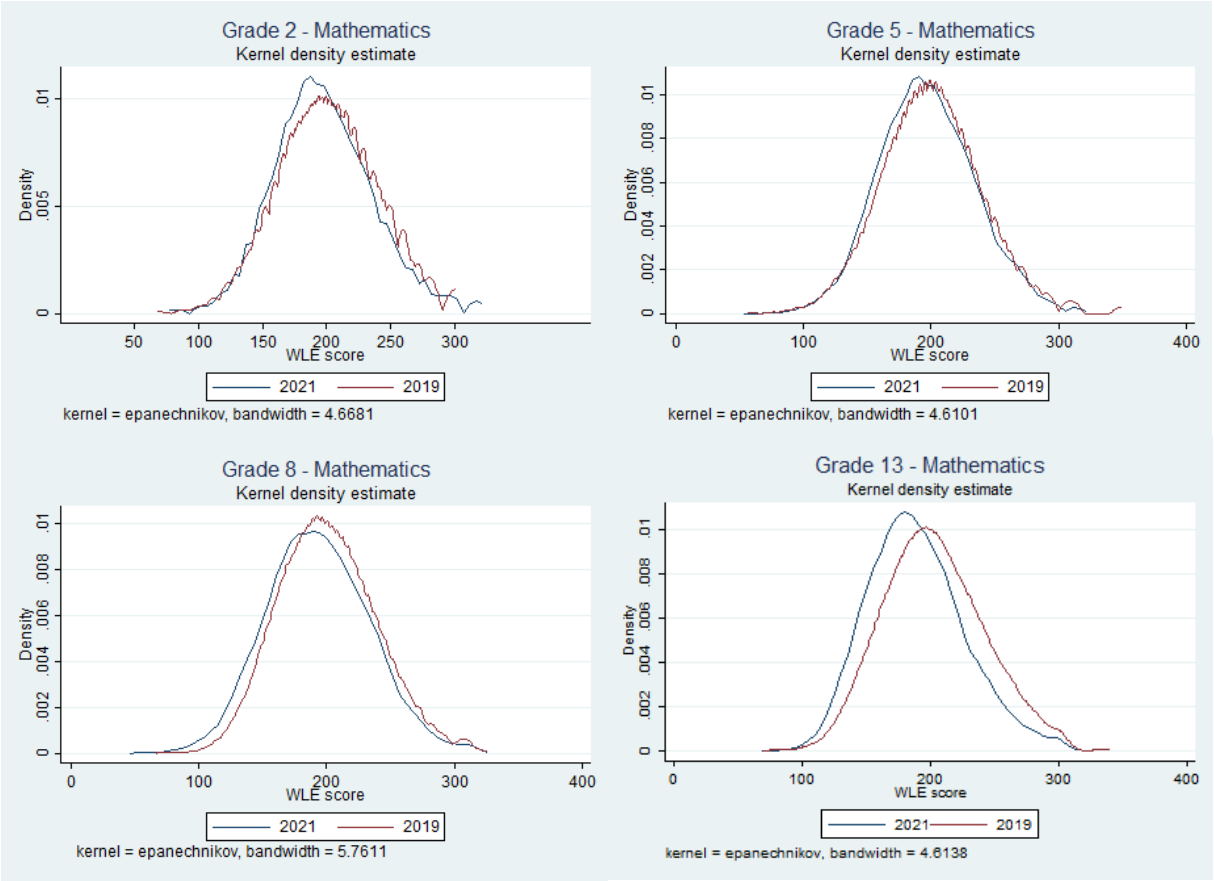

Figure 2 Kernel density distribution of scores in Mathematics by grade.

Scores by grades. Table 2 shows the mean (and standard deviation) of the scores for each grade over the years. The scores stayed stable between 2018 and 2019 followed by a sharp decrease for all the grades in 2021. The differences between 2019 and 2018 are small, this is suggestive that the academic performances have been stable throughout the two years. On the other hand, all the decreases in 2021 compared to 2019 are significantly different from 0 at 99% significance level.

This table confirms the results of the Kernel density distribution. The grade most affected by the COVID-19 related disruption to the school system is grade 13. Also, the grades in the primary education cohort are the ones that were less impacted. This seems to be coherent with the fact that most of the disruptions were concentrated on secondary education. Grade 8 indeed substantially decreased its performance from 2019 to 2021 even though by a much smaller extent than grade 13.

	Year of the test			Differences	
Grade	**2018**	**2019**	**2021**	**2019 - 2018**	**2019 - 2021**
2	200.93 (39.99)	201.31 (39.72)	197.93 (38.89)	0.38	-3.38***
5	201.55 (40.30)	200.77 (39.84)	197.33 (37.59)	-0.78**	-3.44***
8	200.10 (39.67)	200.82 (38.58)	193.42 (40.15)	0.72**	-7.40***
13		202.73 (39.79)	188.76 (37.72)		-13.97***

Standard deviations in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 2 Means and standard deviations of the scores in the test of Mathematics by grades and years. In the last two columns we computed the differences between years and their significance levels.

Heterogeneity analysis. The first finding is that males perform better than females in mathematics. Also, students born in Italy have a starting advantage: in grade 2 in 2019 students born in another country have a much lower average score in the test of mathematics than the students born in Italy. The difference between them however gets smaller as the grade increases, especially between grades 8 and 13. At the end however, even if reduced, the average difference in score is higher than 10 points in 2019 and 2021.

There are little significant differences for grades 2 and 5 when controlling if the student is on time with the studies. This is reasonable since it is very rare for students to be late at this stage of education. In general, the average score for students on time with their studies is, ceteris paribus, higher than the ones who are not.

Students with a higher educated mother have a higher test score than those who do not. This is the first suggestion that the mother's education is indeed relevant for students' performances.

By computing the averages for the characteristics that are not part of the main empirical analysis, we obtain the results in table 3A in the appendix. As expected, the attendance of pre-kindergarten and kindergarten, ceteris paribus, yields a higher average score at the test. Also, having parents employed produces a higher average score. By comparing the means based on the parents' characteristics, we see that in all cohorts having the father born in another country, unemployed or with low academic achievement yields a lower average score in mathematics than the same characteristics just for the mother.

Overall, the performances were relatively stable in all cohorts between 2018 and 2019. They fell for all students after 2020. Most of the decreases in score between 2019 and 2021 are significant at a 99% level.

		Year of the test									
Variable	**Grade**	**2018**	**2019**	**2021**	**2019 - 2018**	**2019 - 2021**	**2018**	**2019**	**2021**	**2019 - 2018**	**2019 - 2021**
		Female					Male				
Gender	2	198.64	199.64	195.53	1.00**	-4.12***	203.13	202.93	200.28	-0.20	-2.65***
		(38.27)	(38.92)	(37.36)			(41.41)	(40.42)	(40.20)		
	5	196.60	197.97	194.28	1.37***	-3.68***	206.44	203.54	200.31	-2.91***	-3.23***
		(37.58)	(37.89)	(35.99)			(42.03)	(41.49)	(38.86)		
	8	198.00	199.35	191.90	1.36***	-7.45***	202.11	202.20	194.86	0.08	-7.33***
		(38.72)	(37.34)	(38.87)			(40.47)	(39.66)	(41.29)		
	13		196.87	185.41		-11.47***		208.93	192.99		-15.95***
			(37.39)	(35.23)				(41.29)	(40.25)		
		Other country					Italy				
Place of birth student	2	186.54	180.64	181.45	-5.90***	0.81	201.37	201.87	198.31	0.50	-3.56
		(38.34)	(40.10)	(37.29)			(39.92)	(39.60)	(38.73)		
	5	184.59	183.00	180.48	-1.60	-2.52	202.27	201.49	197.95	-0.79**	-3.53***
		(41.78)	(41.52)	(40.10)			(39.99)	(39.61)	(37.37)		
	8	181.31	183.42	176.62	2.10	-6.80***	201.10	201.75	194.54	0.65**	-7.21***
		(37.41)	(37.93)	(41.62)			(39.56)	(38.40)	(39.79)		
	13		191.55	178.52		-13.03***		203.45	189.32		-14.13***
			(37.87)	(34.06)				(39.82)	(37.82)		
		No					Yes				
Student is Italian	2	186.75	185.40	183.32	-1.35	-2.08*	203.40	204.05	199.78	0.65	-4.27***
		(36.27)	(38.25)	(36.13)			(39.96)	(39.40)	(38.70)		
	5	189.89	187.27	182.58	-2.62**	-4.69***	203.20	203.03	199.31	-0.17	-3.72***
		(39.59)	(38.50)	(36.00)			(39.95)	(39.63)	(37.37)		
	8	188.90	189.62	182.35	0.72	-7.27***	201.61	202.59	195.26	0.98***	-7.33***
		(37.44)	(36.85)	(39.97)			(39.67)	(38.43)	(39.82)		
	13		197.05	182.17		-14.88***		204.01	189.51		-14.50***
			(37.95)	(34.28)				(39.86)	(37.98)		
		No					Yes				
Student is on time with the studies	2	188.64	187.52	184.99	-1.12	-2.53	201.14	201.53	198.08	0.39	-3.45***
		(42.75)	(39.12)	(40.76)			(39.88)	(39.69)	(38.85)		
	5	180.97	176.77	173.30	-4.19*	-3.47	202.10	201.35	197.79	-0.75**	-3.57***
		(42.28)	(43.33)	(35.04)			(40.02)	(39.56)	(37.48)		
	8	172.19	172.79	164.46	0.61	-8.34***	202.26	203.02	195.20	0.76**	-7.82***
		(32.53)	(33.31)	(35.75)			(39.36)	(38.10)	(39.72)		
	13		184.63	172.73		-11.89***		206.73	192.48		-14.24***
			(35.18)	(32.36)				(39.64)	(37.90)		

Table 3 Means and standard deviations of the scores by grades and years for student's background characteristics and academic history. In the last two columns of the outcomes of each variable we computed the differences between years and their significance levels.

		Year of the test									
Variable	**Grade**	**2018**	**2019**	**2021**	**2019 - 2018**	**2019 - 2021**	**2018**	**2019**	**2021**	**2019 - 2018**	**2019 - 2021**
		High school diploma or less					More than high school diploma				
Mother's academic achievement	2	197.78	197.58	193.06	-0.20	-4.52***	213.01	214.91	208.04	1.90**	-6.86***
		(38.89)	(39.10)	(37.32)			(39.73)	(38.43)	(39.38)		
	5	198.22	196.89	192.54	-1.33***	-4.35***	215.36	216.16	210.99	0.80	-5.17***
		(39.04)	(38.76)	(36.15)			(39.29)	(39.32)	(36.47)		
	8	196.25	197.25	188.53	1.00***	-8.72***	220.88	219.85	213.22	-1.03	-6.63***
		(38.00)	(37.19)	(38.84)			(39.74)	(37.61)	(38.07)		
		Other country					Italy				
Place of birth father	2	189.40	187.41	185.39	-1.99**	-2.02*	203.58	204.39	200.03	0.81**	-4.36***
		(37.46)	(38.59)	(37.00)			(39.90)	(39.32)	(38.77)		
	5	192.21	189.21	185.36	-3.00***	-3.85***	203.30	203.35	199.51	0.05	-3.85***
		(40.37)	(38.71)	(36.89)			(39.88)	(39.69)	(37.31)		
	8	190.91	192.49	184.81	1.58*	-7.68***	201.89	202.80	195.56	0.90**	-7.24***
		(37.94)	(37.65)	(40.61)			(39.73)	(38.44)	(39.74)		
	13		199.70	184.10		-15.60***		204.00	189.84		-14.16***
			(38.51)	(34.99)				(39.85)	(37.99)		
		Other country					Italy				
Place of birth mother	2	190.84	190.65	187.93	-0.18	-2.73***	203.64	204.17	199.97	0.52	-4.20***
		(37.78)	(39.41)	(37.15)			(40.00)	(39.44)	(38.80)		
	5	193.56	191.61	187.92	-1.95**	-3.70***	203.31	203.10	199.42	-0.21	-3.68***
		(39.84)	(38.70)	(36.81)			(39.98)	(39.76)	(37.37)		
	8	193.58	193.22	186.10	-0.36	-7.12***	201.45	202.60	195.36	1.15***	-7.24***
		(38.79)	(37.44)	(39.47)			(39.68)	(38.54)	(39.98)		
	13		199.94	185.56		-14.38***		203.99	189.66		-14.33***
			(38.42)	(35.73)				(39.93)	(38.01)		

Standard deviations in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 4 Means and standard deviations of the scores by grades and years for parents' background characteristics. In the last two columns of the outcomes of each variable we computed the differences between years and their significance levels.

Inequality measures

One of the hypotheses that we are investigating is whether COVID-19 enhanced dispersion in students' performances. This is because the conditions in which lessons took place during the pandemic were more problematic for students who were already less advantaged. In the following paragraphs we present a set of measures that instead does not confirm that COVID-19 enhanced the dispersion of the scores.

The analysis of how inequality developed from 2019 to 2021 is presented using different measures. First, we show the 10th, 50th and 90th percentiles for each grade and for each year. We then computed the ratios between the percentiles. Higher ratios through the years would suggest a higher level of inequality. Finally, we calculated the Gini coefficients by grades through time.

10th, 50th and 90th percentiles by grade and year. As expected, all the percentiles decreased between 2019 and 2021. It is worth mentioning the exception of grade 2 in which we see an increase in the lowest percentile. These results do not suggest that the dispersion increased in 2021.

		Year of the test			Differences	
Grade	**Percentile**	**2018**	**2019**	**2021**	**2019-2018**	**2021-2019**
	10th	152.14	151.85	152.27	-0.29	0.42
2	50th	200.00	202.58	194.78	2.58	-7.80
	90th	251.79	254.53	245.79	2.74	-8.74
	10th	152.34	152.40	149.91	0.06	-2.49
5	50th	199.49	199.29	194.71	-0.20	-4.58
	90th	254.52	250.09	246.82	-4.43	-3.27
	10th	151.56	152.29	143.97	0.73	-8.32
8	50th	196.28	199.82	192.10	3.54	-7.72
	90th	252.33	251.63	245.17	-0.70	-6.46
	10th		152.00	142.54		-9.46
13	50th		200.51	185.95		-14.56
	90th		256.48	239.24		-17.24

Table 5 10th, 50th and 90th percentiles by grades and years with the differences through time of each of them.

Percentile ratios. Table 6 presents the ratios between the 90th and the 10th, the 50th and the 10th, the 90th and the 50th percentiles by grade and year. Higher ratios through the years would suggest a higher level of inequality. In none of the ratios however we observe a significant increase. The ratios stay generally stable and in some cases they even decrease. In grade 13 for example, the ratios for both 90th over 10th and 50th over 10th percentiles decreased. These results suggest that in fact COVID-19 related disruptions to schooling system did not enhance dispersion any grade. This is an important result because it seems to contradict some of the ex-ante research.

	Percentiles ratio								
	90th/10th			50th/10th			90th/50th		
Grade	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**
2	1.655	1.676	1.614	1.315	1.334	1.279	1.259	1.256	1.262
5	1.671	1.641	1.646	1.310	1.308	1.299	1.276	1.255	1.268
8	1.665	1.652	1.703	1.295	1.312	1.334	1.286	1.259	1.276
13		1.687	1.678		1.319	1.305		1.279	1.287

Table 6 Percentile ratios through time by grades.

Gini coefficients. The Gini coefficient is commonly used when comparing the income of different countries. A coefficient close to 1 shows that the income is very unequally distributed among the population while a coefficient close to 0 show a very high level of equality.

In our case we computed the coefficients for each grade and year. They show that the starting point as well as the ending point are very similar. All coefficients are very close to 0.11 in 2018 as well as in the years after. This again supports the finding that COVID-19 shifted the grade distribution to the left as we saw in the Kernel density graphs but did not really increase the dispersion around the mean. The results are in table 7 below.

	Year of the test		
Grade	**2018**	**2019**	**2021**
2	0.112	0.111	0.110
5	0.112	0.111	0.107
8	0.111	0.108	0.117
13		0.111	0.112

Table 7 Gini coefficients through time for each grade.

V. Empirical model and results

We are now going deeper into our analysis of the performance of Italian students before and after COVID-19. This is an introduction to our empirical analysis which will continue with assessing the impact of COVID-19 with the use of a dummy variable for the year 2021. In the last section we explore the differences between regions and to develop more general findings thanks to the addition of other variables to the dataset such as days of lockdowns for schools for each grade and region.

The basic econometric model for the research is based on the education production function (Todd and Wolpin 2003):

$$WLE_{isyg} = \beta_0 + s_{syg} + \beta_1 I_{isyg} + \beta_2 F_{isyg} + \varepsilon_{isyg}$$

Where *WLE* is the result of the test given as the Weighted Likelihood Estimates (WLE). *s* is a vector of school fixed effects. *I* is a vector of student's personal background characteristics such as gender and whether he/she was born in Italy. *F* is a vector of student's family backgrounds' characteristics such as the birthplace of each parent and academic achievements of the mother measured as years of schooling correspondent to her highest academic achievement. All of them are analyzed for years 2018, 2019 and 2021, by grade.

As stated before, the dataset has a high number of missing values for some variables. We therefore decided to perform two regressions. In the first we included variables with a very low number of missing values and that are common to all grades and years. These are gender, student was born in Italy, student is on time with the studies, father and mother were born in Italy. On one hand we are not taking into consideration some important variables, on the other hand however this allows us to have a very large coverage of all the observations (almost always above 90%). Furthermore, since these variables are common to all grades and years, it is possible to do a better comparison of the coefficients. Table 8A in the Appendix summarize the sample used for the estimation.

Regressions for each grade through years

We firstly estimated the model with the variables that were common to all grades. Because of the importance of the mother's level of education in the literature of economics of education we then decided to include the mother's years of schooling. We therefore added the education of the mother among the explanatory variables for all grades except grade 13 for which this dimension was unfortunately not collected. The signs and the magnitude of the coefficients are similar to the ones found excluding mother's years of schooling. As expected, the education of the mother is highly important in the student's score for the test of mathematics for all grades and years.

Overall, we can state that all the significant coefficients have the expected signs based on the literature.

Conditional on the other variables, males perform significantly better in mathematics than female students in all cohorts.

In second grade there is no significance coefficients regarding the student being on time with the studies, probably because it is very rare that the student is not on time with the studies at such an early age. In fifth and eighth grades however, this characteristic becomes more and more important. Being late in fifth grade decreases the score in math by more than 13 points in all year tested. This reaches above 20 points for grade 8 therefore becoming the most impacting characteristic for that grade.

The magnitude of the coefficient associated with the student being born in Italy decreases. This is reasonable: if a child born abroad comes to Italy, then the effects in primary school will be clearly visible. As the child grows up in Italy, he/she will adapt to the language and culture and the effect of being born in another country will therefore fade away.

The R-squared is low for all grades except grade 13. This means that the model only explains around 20% of all regressions, so there is still a large part of our regressions remains unexplained. The inclusion of mother's years of schooling increased the R-squared, but it still remains below 30%.

	Grade 2			Grade 5			Grade 2			Grade 5		
	Math score 2018	Math score 2019	Math score 2021	Math score 2018	Math score 2019	Math score 2021	Math score 2018	Math score 2019	Math score 2021	Math score 2018	Math score 2019	Math score 2021
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Gender = 1 if male	4.908***	3.493***	5.048***	9.902***	5.618***	6.831***	5.168***	3.352***	5.266***	10.067***	5.633***	6.559***
	(0.492)	(0.506)	(0.598)	(0.467)	(0.479)	(0.560)	(0.515)	(0.540)	(0.646)	(0.477)	(0.500)	(0.576)
Student born in Italy	3.468**	6.829***	6.400***	6.242***	5.721***	4.113**	4.987**	8.569***	4.581**	7.287***	6.370***	3.444*
	(1.738)	(1.872)	(1.831)	(1.518)	(1.521)	(1.763)	(1.924)	(2.140)	(2.081)	(1.641)	(1.669)	(1.904)
Student is Italian	8.699***	8.063***	6.291***	5.621***	4.797**	9.978***	6.402***	4.564**	4.051	2.396	0.659	5.380**
	(1.996)	(2.104)	(2.363)	(1.929)	(1.984)	(2.283)	(2.110)	(2.250)	(2.569)	(1.980)	(2.085)	(2.365)
On time with the studies	3.850*	2.288	-0.058	13.756***	13.258***	14.258***	0.190	-2.617	-2.039	9.875***	11.152***	12.133***
	(2.060)	(2.236)	(2.993)	(1.747)	(1.781)	(2.302)	(2.250)	(2.501)	(3.449)	(1.928)	(1.958)	(2.546)
Father was born in Italy	3.958***	7.364***	4.740**	3.422**	6.726***	3.756**	1.829	5.152***	2.526	2.783*	5.375***	3.211*
	(1.489)	(1.609)	(1.831)	(1.412)	(1.479)	(1.765)	(1.559)	(1.698)	(1.960)	(1.430)	(1.536)	(1.820)
Mother was born in Italy	4.146***	1.739	3.626***	2.911***	2.338**	1.477	2.809**	0.739	1.497	1.887*	1.852	-0.198
	(1.102)	(1.144)	(1.262)	(1.051)	(1.092)	(1.197)	(1.156)	(1.221)	(1.379)	(1.078)	(1.157)	(1.224)
Mother's years of schooling							2.398***	2.567***	2.325***	2.646***	2.848***	2.807***
							(0.085)	(0.089)	(0.108)	(0.078)	(0.083)	(0.095)
Constant	186.926***	182.914***	176.487***	194.920***	145.828***	145.008***	179.907***	158.502***	155.519***	156.511***	114.272***	117.950***
	(6.582)	(7.571)	(7.766)	(5.610)	(7.456)	(7.833)	(7.625)	(7.728)	(8.023)	(6.133)	(7.342)	(7.724)
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	22,638	21,271	14,682	24,290	23,210	15,350	19,739	17,820	12,035	21,990	19,971	13,549
R2	0.196	0.188	0.187	0.224	0.208	0.195	0.226	0.226	0.226	0.258	0.261	0.243

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 8 Regressions for grades 2 and 5 through time. In columns 7 to 12, the variable " years of schooling of the mother" was included.

	Grade 8			Grade 13		Grade 8		
	Math score 2018	Math score 2019	Math score 2021	Math score 2019	Math score 2021	Math score 2018	Math score 2019	Math score 2021
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Gender = 1 if male	5.338***	4.082***	4.300***	9.173***	7.081***	4.984***	4.314***	3.514***
	(0.438)	(0.426)	(0.776)	(0.352)	(0.450)	(0.462)	(0.444)	(0.809)
Student born in Italy	3.995***	2.315*	5.078**	0.475	2.566**	6.720***	3.370**	6.774***
	(1.315)	(1.271)	(2.150)	(0.965)	(1.123)	(1.449)	(1.368)	(2.361)
Student is Italian	5.448***	8.026***	6.855**	2.324	4.910***	-0.096	4.579**	2.500
	(1.882)	(1.773)	(3.189)	(1.429)	(1.644)	(2.003)	(1.842)	(3.333)
On time with the studies	25.816***	25.743***	29.060***	11.965***	10.710***	19.956***	19.690***	22.058***
	(0.958)	(0.933)	(1.883)	(0.455)	(0.565)	(1.063)	(1.010)	(2.081)
Father was born in Italy	4.894***	0.673	1.905	0.668	0.348	5.191***	-0.185	-0.396
	(1.314)	(1.264)	(2.374)	80.929)	(1.187)	(1.393)	(1.296)	(2.456)
Mother was born in Italy	0.275	2.015**	3.191*	-1.107	-1.806**	0.533	1.793*	3.076*
	(1.041)	(0.977)	(1.714)	(0.790)	(0.881)	(1.092)	(1.016)	(1.773)
Mother's years of schooling						3.037***	2.917***	3.228***
						(0.076)	(0.074)	(0.133)
Constant	177.031***	166.396***	156.547***	198.521***	200.065***	146.896***	140.109***	127.170***
	(6.729)	(6.179)	(6.082)	(6.636)	(6.584)	(6.719)	(6.037)	(6.113)
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,493	27,820	9,088	34,015	19,604	23,365	24,049	7,700
R2	0.214	0.198	0.198	0.517	0.506	0.260	0.247	0.265

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 9 Regressions for grades 8 and 13 through time. The estimates for grade 13 with mother's years of schooling are not computed because we do not have the description of the level of education of the mother.

Impact of COVID-19 on year 2021

This part of the study is similar to the work done by Di Tommaso et al. (2021) in "The Covid-19 pandemic and school closure: learning loss in mathematics in primary education" in which the authors assess the impact of COVID-19 on pupils comparing scores from grade 2 before the pandemic with the scores one year after in grade 3. They employ a dummy variable for the COVID cohort and find that the estimated loss ranges between -0.23 and -0.19 standard deviations in test scores. Their study is done with longitudinal data from the province of Turin.

In order to study the effect of COVID-19 related disruptions to the school system we employ the following model:

$$WLE_{gir} = \beta_0 + r_{gr} + \beta_1 I_{gir} + \beta_2 F_{gir} + \beta_3 2021_{gir} + \varepsilon_{gir}$$

r is a vector of regional fixed effects in a total of 21 regions. *I* is a vector of student's personal background characteristics such as gender and whether he/she was born in Italy. *F* is a vector of student's family backgrounds' characteristics such as the birthplace of each parent. *2021* is a dummy equal to one if the student was in the 2021 sample. The coefficient of interest is β_3, it expresses the points difference in the score from 2021 to the previous year after controlling for the other variables. The analysis is replicable at every grade in order to compare how much the grades were impacted. As before, in model 2 we added the education of mother in order to make a robustness check and analyze the differences with the previous model.

We estimated our model by Ordinary Least Squares (OLS), implying that we are assuming that *2021* is uncorrelated with the unobservable term ε. One potential effect could arise from different behavior of schools during the pandemic (for example some schools may have decided to give laptops to students). Nevertheless, if that was the case, the effect of COVID-19 would be expected to be even higher.

It is important to notice that this analysis would have been more impactful if it was possible to control for school fixed effects through years as in Di Tommaso et al. (2021). This is unfortunately not possible with our dataset because each school is assigned a new

identification number every year, making it impossible to be tracked through time. We therefore controlled for regional fixed effects.

The results are shown in the tables 10 and 11 below. In both education stages, after controlling for the other variables, COVID-19 has a negative and significant impact on the score for all grades. Grade 2 decreases the score by 4.18 which corresponds to 0.11 standard deviations. Although different from Di Tommaso et al. (2021), the result is still in line with their findings.

Primary education. In general, we observe a null impact of COVID-19 on males since the coefficients are never significantly different from zero. On the other hand, females decrease their score by 4.69 in grade 2 and 4.17 in grade 5. Interestingly in grade 2, the impact of COVID-19 is not smaller for non-Italian students. However, it is not significantly different from zero for grade 5. The findings do not vary when we include mother's years of schooling. The results are in table 10.

Secondary education. The results for secondary education are more extreme than for primary. In this case, in fact, we observe an increase in performances for native students in grade 13 significantly different from zero at a 90% significance level. In general, we find that again females and non-native were more affected by COVID-19.

	Grade 2				Grade 5				Grade 2					Grade 5				
	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score	Math score
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Covid cohort	-4.184***	-4.687***	-2.200*	-2.698**	-3.887***	-4.170***	-5.242***	-5.526***	-5.717***	-6.366***	-3.531***	-1.578	-1.082	-5.088***	-5.212***	-5.002***	-3.801***	-3.996**
	(0.415)	(0.589)	(1.164)	(1.234)	(0.397)	(0.563)	(1.173)	(1.239)	(0.446)	(0.632)	(1.321)	(1.811)	(2.057)	(0.411)	(0.581)	(1.266)	(1.634)	(1.922)
Covid cohort * Male		0.994		1.007		0.563		0.563		1.284			1.317		0.246			0.251
		(0.827)		(0.827)		(0.792)		(0.792)		(0.885)			(0.885)		(0.816)			(0.816)
Covid cohort * Native			-2.269*	-2.281*			1.529	1.529			-2.461*		-1.839			-0.096		0.106
			(1.243)	(1.243)			(1.246)	(1.246)			(1.400)		(1.434)			(1.336)		(1.359)
Covid * Mother's years of schooling												-0.318**	-0.282**				-0.101	-0.103
												(0.135)	(0.138)				(0.124)	(0.126)
Regional fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother's education included	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	35,953	35,953	35,953	35,953	38,560	38,560	38,560	38,560	29,855	29,855	29,855	29,855	29,855	33,520	33,520	33,520	33,520	33,520
R2	0.045	0.045	0.045	0.045	0.048	0.048	0.048	0.048	0.091	0.091	0.091	0.091	0.091	0.110	0.110	0.110	0.110	0.110

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 10 Regressions with dummy variable "Covid cohort". Primary education.

	Grade 8				Grade 13				Grade 8				
Variables	Math score (1)	Math score (2)	Math score (3)	Math score (4)	Math score (5)	Math score (6)	Math score (7)	Math score (8)	Math score (9)	Math score (10)	Math score (11)	Math score (12)	Math score (13)
Covid cohort	-6.504***	-6.529***	-7.538***	-7.567***	-12.798***	-11.287***	-14.779***	-13.235***	-7.391***	-6.878***	-6.858***	-12.721***	-11.197***
	(0.445)	(0.635)	(1.370)	(1.446)	(0.317)	(0.428)	(1.139)	1.176323	(0.461)	(0.656)	(1.473)	(1.760)	(2.154)
Covid cohort * Male		0.048		0.055		-3.330***		-3.323***		-1.011			-1.033
		(0.887)		(0.887)		(0.633)		.63285		(0.917)			(0.917)
Covid cohort * Native			1.155	1.156			2.145*	2.105*			-0.590		-1.376
			(1.447)	(1.447)			(1.185)	(1.185)			(1.550)		(1.568)
Covid * Mother's years of schooling												0.435***	0.455***
												(0.139)	(0.140)
Regional fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother's education included	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Observations	36,908	36,908	36,908	36,908	53,619	53,619	53,619	53,619	31,749	31,749	31,749	31,749	31,749
R2	0.116	0.116	0.116	0.116	0.217	0.218	0.218	0.218	0.192	0.192	0.191	0.192	0.192

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 11 Regressions with dummy variable "Covid cohort". Secondary education.

VI. Regions and days of school closure, a regional perspective

We now analyze the results at a regional level. Italy has big differences in terms of wealth, inequality and academic achievements between regions. Each region had a different level of impact from COVID-19 and different restrictive measures were therefore implemented. We now link these characteristics and differences with the percentage differences in test scores between 2021 and 2019.

Italy was one of the first countries hit by COVID-19 in the Western world. The situation escalated quickly and became very rapidly an emergency. The Government soon understood that the only way to limit the spread of the virus was to keep people home and avoid all non-essential contacts. Schools have been immediately identified as a source of the spread and were therefore completely closed on March 4th, 2020. They remained completely closed until the end of the academic year. The academic year 2020/2021 started at the beginning of September and all lessons returned to a normal "in presence" teaching method. This situation however did not last long and as the spread began to rise new measures were introduced. At this point, for most of the academic year 2020/2021, the restrictions were differentiated between regions and grades. The general goal was to keep the lessons in person as much as possible for the youngest students in primary education and gradually restrict presential classes for older students as the pandemic emergency got worse. The measures for the grades higher than 6 depended on the level of emergency of their regions. From September onward was in fact used a restriction method based on the "color" of the regions. White, yellow, orange and red each meant an increasing level of emergency and, therefore, of restrictions. The teaching method for grades higher than 6 depended on the pandemic situation. The possible outcomes were three: fully "in presence" teaching method, partial school closure for which 50% of students could attend lessons in classes, and complete school closure with online classes for 100% of the students. Additionally, for some weeks during Christmas period, restrictions were increased everywhere in Italy no matter the color of the region.

This high degree of differentiation in the restrictive measures allows us to perform statistics between regions and grades. We have already data about the students' performances for the national test of Mathematics divided by region. We then complemented this dataset with data of the days of partial or complete school closure per grade and region. The following chapter shows in detail sources, cleaning and management of this additional information. We also

checked if the same trend is observable in another test that is part of the Invalsi: Italian. The trends for this test are quite similar.

This section organizes as follows: first we introduce the existing data for regions. This comprises the means and standard deviations for the national Invalsi test of mathematics for each grade and region between the years 2018, 2019 and 2021. We then present our new dataset. After a brief description of the data source and management, we show the summary statistics of the variables of interest, in particular the days of school closure, by grade and region. Finally, we analyze the interactions between days of school closure and the other variables with the percentage difference in results between 2019 and 2021.

Data and descriptive statistics

In the dataset used until now coming from the Statistical Department of the Invalsi, each observation has the corresponding region, without missing values. The sample includes observations from all 21 regions. The most represented region is Lombardia, which is also the most populated region in Italy. The shares of observations per region remains stable through the years and grades. A detailed description of the observations can be found in table 12A, in the Appendix.

Tables 12B and 12C in the Appendix show the means of the score in the test of mathematics throughout the years. In the last two columns for each grade, the difference between the average score in 2019 with respect to 2018 and 2021 with respect to 2019 are highlighted. In order to facilitate the view, the differences between 2021 and 2019 are computed in table 12 below.

A common trend for all grades is the substantial stability of scores between 2018 and 2019. As we have seen before, the grades that decreased their performances the most were from the secondary education. The differences between the averages of the results obtained in 2019 and 2021 is negative, large and significant for almost every region in higher grades. There are some noteworthy exceptions. There are big decreases in grade 2 in 2021 for regions like Basilicata, Umbria, Valle d'Aosta, Marche and Liguria. While for Umbria, Valle d'Aosta, Marche and Liguria there is also an unexpected increase in performances between 2018 and 2019, the reason of the sudden decrease in Basilicata and Friuli Venezia Giulia is of more difficult interpretation. The trend of Molise for grade 5 is also of difficult explanation. We

conclude that there are some anomalies and perhaps a deeper analysis with a larger sample is needed.

For the purpose of this last section, the percentage difference for each regional score between 2019 and 2021 was calculated. We then added the scores for the test of Italian. At his point we are interested in finding the relationship between the above-mentioned academic performances and the days of full or partial closure of schools. Unfortunately, a dataset with the days of school closure divided into regions and grades did not exist so we had to construct a completely new one starting from a dataset from UNESCO which provided the classification of each day as "fully open", "partially opened", "fully closed" at national level. We then used different sources in order to obtain data that we could then merge with the existing dataset. In the Introduction of this section, we briefly explained how at the beginning schools were generally closed and how for the academic year 2020/2021 the measures depended on a variety of variables. We therefore had to go through the measures implemented which we found on the official website of the Chamber of Deputies. We then had to write down all the colors that the regions went through and associate the alternatives of schools fully, partially and completely closed according to the color taking into consideration that one color can mean different rules across grades. Table 13 presents summary of the days of partial and complete school closure. Primary schools have a fixed number of closed days; no partial closure was implemented for primary education. This is different from grades 8 and 13 for which we explained how many different restrictive measures came into place. Grade 13 got the highest number of days of full closure.

Additionally, we added more variables in order to control for other possible effects on school performance. Firstly, we found a measure of COVID-19 harshness in deaths per 100 thousand inhabitants until February 28th, 2021. We got this data from the Istituto Superiore di Sanità which is the institute in charge of following the development of the pandemic and deliver official data. Then we added other variables in order to characterize wealth, inequality, development and academic system of each region. For wealth, we used GDP per capita in 2019. We chose the year 2019 because we are explaining the difference in academic performance happened because of COVID-19 which started spreading at the beginning of 2020. This is the same reason why we used abandon of studies for students between 18 and 24 years old in 2019 as a measure for academic level. For the level of development, we used the Human Development Index (HDI) from 2019. Lastly, for inequality we used the Gini coefficient from 2018. This time, 2018 was used because it was the latest available data. We

assume that nothing happened in 2019 that would severely impact the coefficient. We got all the above-mentioned data from the Italian National Institute of Statistics (ISTAT).

Table 14 shows a summary of these new variables by region. Calabria is the poorest region in terms of GDP per capita in 2019, the least developed in terms of HDI in 2019, one of the most unequal (after Sicilia, Campania and Lazio), and the second for the percentage of students between the age of 18 and 24 years who abandoned studies in 2019 (after Sicilia).

Interestingly for our analysis, Calabria is also the region with the lowest number of deaths by COVID-19 per 100,000 inhabitants (35.72).

	Grade							
Region	2		5		8		13	
Abruzzo	1.31	0.65%	-1.97	-0.98%	-4.77**	-2.37%	-16.93***	-8.60%
Basilicata	-15.71***	-7.32%	-14.05***	-6.55%	-9.85***	-5.02%	-9.07***	-4.70%
Calabria	0.45	0.23%	5.98***	3.21%	-6.73***	-3.71%	-9.50***	-5.24%
Campania	2.96*	1.51%	6.29***	3.26%	-8.95***	-4.76%	-15.81***	-8.56%
Emilia-Romagna	-4.38***	-2.22%	-4.54***	-2.27%	-6.19***	-2.97%	-11.32***	-5.33%
Friuli Venezia Giulia	-8.49***	-4.20%	-2.22	-1.09%	-0.78	-0.37%	-20.52***	-9.25%
Lazio	0.38	0.19%	0.91	0.45%	-3.49**	-1.75%	-12.29***	-6.31%
Liguria	-5.09***	-2.53%	-3.90**	-1.93%	-8.40***	-4.20%	-13.61***	-6.55%
Lombardia	-0.20	-0.10%	-5.94***	-2.91%	-10.64***	-5.09%	-12.27***	-5.65%
Marche	-8.00***	-3.81%	-6.36***	-3.05%	-7.69***	-3.66%	-17.75***	-8.50%
Molise	-3.98*	-1.88%	-12.00***	-5.81%	2.44	1.26%	-3.18	-1.60%
P.A. Bolzano	-3.91*	-2.53%	-2.87	-1.45%	-8.63***	-4.27%	-28.82***	-13.41%
P.A. Trento	-1.29	-1.98%	-3.37*	-1.66%	-2.56	-1.20%	0.21	0.09%
Piemonte	-5.10***	-0.63%	-5.62***	-2.77%	-6.07***	-2.96%	-8.99***	-4.27%
Puglia	-1.78	-0.89%	-7.84***	-3.88%	-9.19***	-4.65%	-25.35***	-12.93%
Sardegna	-1.98	-1.02%	-1.14	-0.60%	-3.09	-1.64%	-13.02***	-7.02%
Sicilia	-3.27**	-1.65%	2.20	1.15%	-5.50***	-2.96%	-10.85***	-5.90%
Toscana	-0.84	-0.42%	-4.50***	-2.22%	-15.88***	-7.58%	-10.30***	-4.96%
Umbria	-12.08***	-5.69%	-9.69***	-4.65%	-0.13	-0.07%	-15.88***	-7.83%
Valle d'Aosta	-10.48***	-5.09%	-7.74***	-3.83%	-1.92	-0.93%	-1.11	-0.53%
Veneto	-6.96***	-3.43%	-5.05***	-2.50%	-5.02***	-2.40%	-14.65***	-6.73%

*** p<0.01, ** p<0.05, * p<0.1.

Table 12 Score differences between 2021 and 2019 for each region by grades and their significance levels.

	Grade 2		Grade 5		Grade 8		Grade 13	
Region	Completely	Partially	Completely	Partially	Completely	Partially	Completely	Partially
Abruzzo	70	0	70	0	76	77	107	46
Basilicata	70	0	70	0	67	86	93	60
Calabria	70	0	70	0	83	70	93	60
Campania	70	0	70	0	81	72	93	60
Emilia-Romagna	70	0	70	0	67	86	93	60
Friuli Venezia Giulia	70	0	70	0	67	86	93	60
Lazio	70	0	70	0	67	86	93	60
Liguria	70	0	70	0	67	86	93	60
Lombardia	70	0	70	0	88	65	98	55
Marche	70	0	70	0	67	86	93	60
Molise	70	0	70	0	67	86	93	60
P.A. Bolzano	70	0	70	0	93	60	103	50
P.A. Trento	70	0	70	0	67	86	93	60
Piemonte	70	0	70	0	83	70	93	60
Puglia	70	0	70	0	67	86	93	60
Sardegna	70	0	70	0	67	86	93	60
Sicilia	70	0	70	0	77	76	103	50
Toscana	70	0	70	0	80	73	93	60
Umbria	70	0	70	0	67	86	93	60
Valle d'Aosta	70	0	70	0	87	66	93	60
Veneto	70	0	70	0	67	86	93	60

Table 13 Summary of the days of full and partial school closure for each region and grade.

Region	COVID deaths 100k	HDI 2019	Study abandon	Gini 2018	GDP per capita 2019
Abruzzo	130.78	0.889	9.8	0.327	25,125
Basilicata	66.42	0.862	11.8	0.296	23,051
Calabria	35.72	0.845	19.0	0.339	17,289
Campania	74.53	0.854	17.3	0.372	18,878
Emilia-Romagna	236.42	0.921	11.3	0.302	36,727
Friuli-Venezia Giulia	234.71	0.903	8.6	0.290	31,923
Lazio	101.90	0.914	12.0	0.354	34,199
Liguria	236.79	0.898	10.1	0.312	32,254
Lombardia	283.30	0.912	11.5	0.315	39,694
Marche	148.13	0.901	8.7	0.295	27,678
Molise	115.54	0.872	11.0	0.310	21,072
Piemonte	216.45	0.920	10.8	0.319	31,724
Prov. Aut. Bolzano	194.41	0.898	11.6	0.338	48,076
Prov. Aut. Trento	221.80	0.910	9.3	0.290	38,777
Puglia	98.68	0.854	17.9	0.330	18,925
Sardegna	71.38	0.868	17.8	0.335	21,344
Sicilia	84.30	0.845	22.4	0.380	17,855
Toscana	126.12	0.907	10.4	0.310	31,928
Umbria	120.17	0.897	9.5	0.290	26,238
Valle d'Aosta	330.27	0.887	14.3	0.282	38,768
Veneto	201.59	0.900	8.4	0.283	33,651

Table 14 Descriptive statistics of the variables that we are going to use in our empirical analysis. The COVID-19 deaths are the total number of fatalities until February 28th, 2021.

The effect of school closure on students' performances

We first analyze the correlations between the percentage difference in the test of mathematics between 2021 and 2019 and the other variables, starting with the days of full closure for primary education (grades 2 and 5) and secondary education (grades 8 and 13). We did not use days of school closure as a variable for the primary education because as we saw before it is constant across both grades and regions. Instead, we used the deaths by COVID-19 per 100,000 inhabitants as a proxy for COVID-19 harshness.

Primary education. Figures 3 below presents the relations between the percentage difference in the test of mathematics from 2019 to 2021 and the variables for primary education. There is slight negative correlation with the number of deaths per 100,000 inhabitants. This is the first time we see that COVID-19 might have had in fact a negative effect on academic performances. The relation with the other variables is mostly unclear even though we observe an unexpected positive correlation between the percentage difference and the study abandon in 2019, and even more clearly with the Gini coefficient in 2018. This would mean that students from unequal regions have been less impacted by COVID-19. The reasons for this unexpected result might be various and, more study would be needed to answer this question.

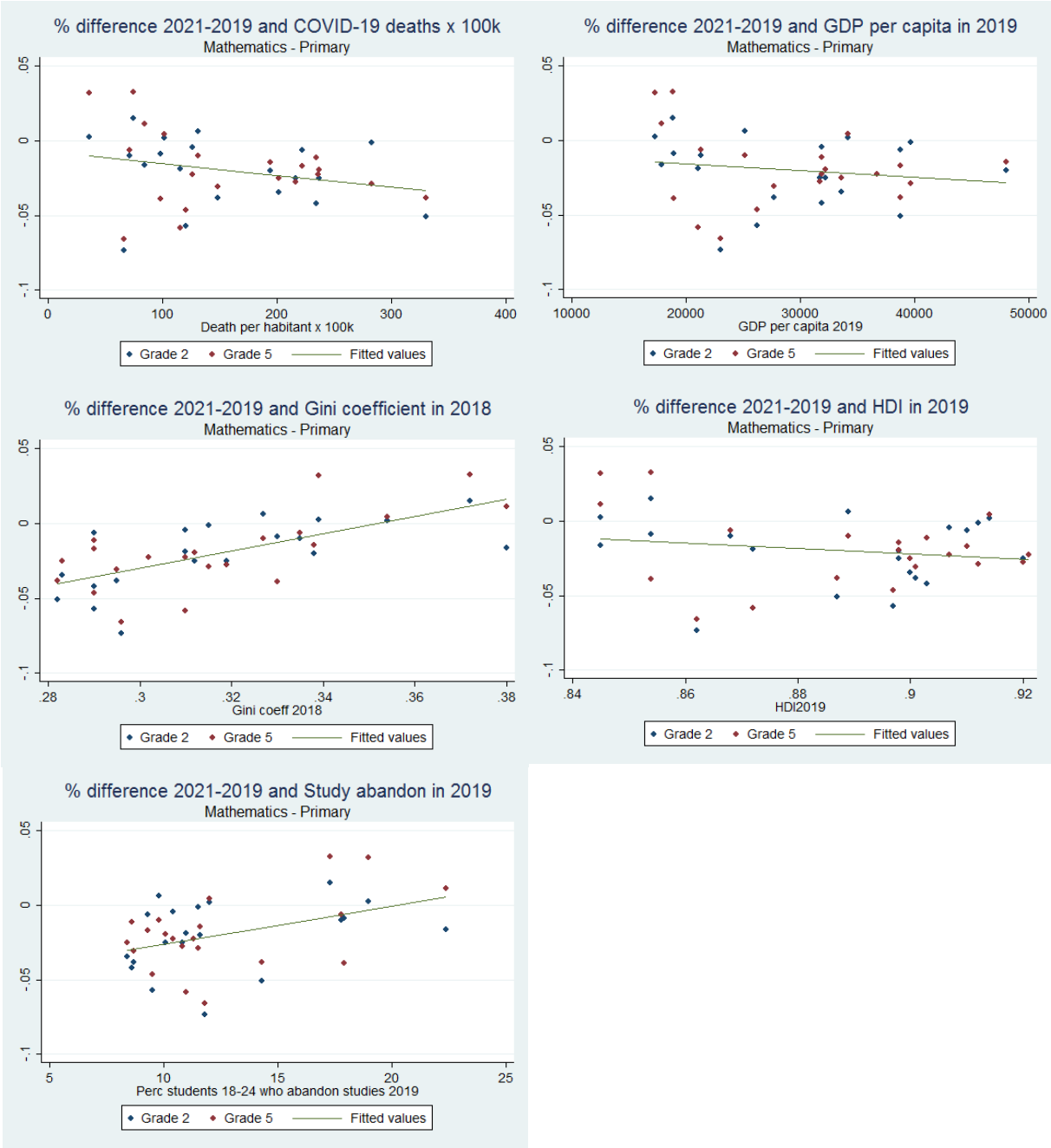

Figure 3 Relations between percentage difference in score of the test of mathematics between 2021 and 2019, and variables of interest. Grades 2 and 5.

Secondary education. Figure 4 below shows the relations between the percentage difference in the test of mathematics from 2019 to 2021 and the variables for secondary education. Days of full school closure were used in this case because, even though some regions share the same number, there is a high variability. We indeed see a clear negative correlation with the academic performances from 2019 to 2021. For the rest there is no further relationship between the academic performances and the other variables.

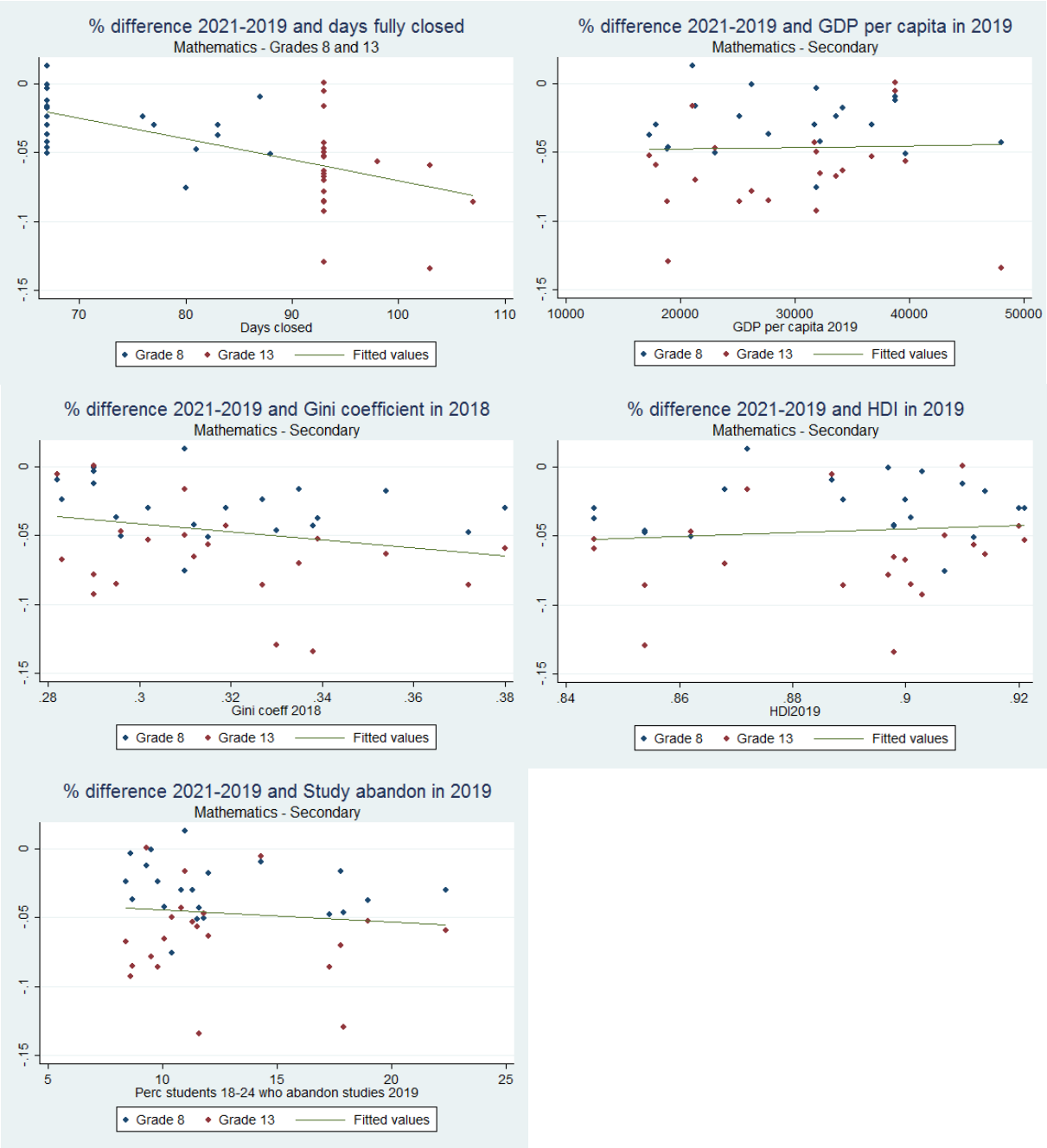

Figure 4 Relations between percentage difference in score of the test of mathematics between 2021 and 2019, and variables of interest. Grades 8 and 13.

Assessing the joint impact of the variables. We then proceeded by assessing the impact of the days of closure after controlling for the variables about wealth, inequality, development and academic that we described before. We did so by estimating the following model by OLS:

$$\%\Delta WLE_{gr} = \beta_0 + \beta_1 DC_{gr} + \beta_2 HDI_{gr} + \beta_3 AS_{gr} + \beta_4 GINI_{gr} + \beta_5 \ln (GDPpc)_{gr} + \varepsilon_{gr}$$

Where $\%\Delta WLE$ is the percentage difference in the test score, *DC* represents the days of full school closure, *HDI* is the Human Development Index in 2019, *AS* is the percentage of students between 18 and 24 years old who abandoned studies in 2019, *GINI* is the Gini coefficient in 2018 and *GDPpc* is the GDP per capita in 2019. The coefficient of interest is β_1 since it represents the effect of one more day of closure on the percentage difference in score of the test of mathematics between 2021 and 2019. We used the death by COVID-19 per 100,000 inhabitants as a proxy for COVID-19 harshness for primary education. Tables 15 and 16 display the results. For primary education the only significant variable is in fact the Gini coefficient for 2018 but not with the sign we would have expected. A positive sign means that the highest the coefficient (and therefore the inequality), the better the students improved their performances in mathematics. This is a result of difficult interpretation and more research on this will be needed. All the other variables fail to explain the percentage difference in score.

Interestingly, in secondary schools the only significant variable is the days of full closure. This suggests that for grades 8 and 13 the days of school closure is the main driver in the decrease in academic performances in Mathematics. All other factors of wealth, inequality and development fail to explain the differences between 2021 and 2019. This result shows that the number of days of closure are more important in the explanation of the academic performances than "traditional" explanatory variables. As the R-squared of the regression is 0.391 we also conclude that a big part of the percentage difference remains unexplained.

As robustness check we performed the same regression for the test of Italian, the results still show a negative and significant impact of the days of full closure, even if with a slightly lower magnitude (tables 15A and 16A in the Appendix).

For the students in grades 8 and 13, we conclude that one more day of school closure decreases the score by 0.15 percentage points. To put this in perspective, the decision of closing schools for one month (considering 22 working days) would decrease the average result in mathematics by 3.3 percentage points in grades 8 and 13.

Variables	Grades 2 and 5 % difference (1)
Deaths per 100k inhabitants	0.0001
	(0.0001)
HDI 2019	0.2821
	(0.2927)
Study abandon 2019	0.0003
	(0.0017)
Gini coefficient 2018	0.6658***
	(0.1803)
Log GDP per capita 2019	-0.0121
	(0.0235)
Intercept	-0.3668
	(0.2360)
Observations	42
R2	0.4915

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 15 Model with "Deaths per 100k inhabitants" as a proxy for COVID-19 harshness estimates for Primary education (grades 2 and 5). Mathematics.

Variables	Grades 8 and 13 % difference (1)
Days completely closed	-0.0015***
	(0.0004)
HDI 2019	0.1931
	(0.4421)
Study abandon 2019	0.0027
	(0.0024)
Gini coefficient 2018	-0.3435
	(0.2382)
Log GDP per capita 2019	0.0066
	(0.0295)
Intercept	-0.0865
	(0.2745)
Observations	42
R2	0.3907

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 16 Model with days of complete school closure estimates for Secondary education (grades 8 and 13). Mathematics.

VII. Conclusion & discussion

There are many ways in which we could look at the effect of COVID-19 on education. In this paper we decided to look at it from two different perspectives. In the first part we looked at individual data and we computed the most basic measures for statistics: means and standard deviations. These measures successfully presented the effects of COVID-19 on Italian students. First, we computed them by grades, and we found that grades 2 and 5 were less affected by COVID-19 than grade 8, and grade 13 was the most affected of all. Then we computed means and standard deviations for each characteristic of the students keeping everything else equal and from here we started to go deeper in the micro effects. We confirmed some expectations such as that students born in other countries get lower grades; we were surprised by other findings such that males perform better than females; and we were intrigued by others, such that employment of the father yields a higher score for the students than employment of the mother. We then analyzed in a methodical way how the shape of the distribution of scores changed from 2019 to 2021. We did this by computing the 10^{th}, 50^{th} and 90^{th} percentiles and their ratios. Unexpectedly we found no big difference of inequality of scores between 2019 and 2021. We confirmed our conclusion with the computation of the Gini coefficient. We then designed an econometric model that could explain the score in the Invalsi test of mathematics while at the same time dealing with a high number of missing values for some variables and missing variables for some grades or years. The results provided interesting insights on how the variables that we analyzed before, jointly work in explaining the academic performances. We were not surprised by the signs of the coefficients, but we found a lot of interesting features such that whether the student is on time with the studies is not important in primary school. Perhaps the most interesting is how the coefficient of the student being born in Italy seems to be less and less important as the student grows up and moves to higher grades. We then added the years of schooling of the mother to our model and we confirmed that the education of the mother is indeed an important explanatory variable.

We then performed another analysis in order to assess the effect of COVID-19 on education while controlling for the other variables. We generated a dummy for year 2021 and we interacted it with the nationality of the student and the gender, then we added the education of the mother. By doing this we confirmed some of the hypotheses that we found in the literature such as that COVID-19 hit advantaged students much less than the others.

In the last part of the paper, we zoomed out in order to see the big picture and get general findings. We therefore looked at the performances of the regions and how they interacted with the days of school closure. We had to create a new dataset with the number of days of school closures by grades and regions looking at the measures implemented in 2020 and the beginning of 2021. We found that grade 13 is the grade that had more days of school closure. We finally designed a model by including other regional variables such as GDP per capita and Gini coefficient and we found that by taking grades 8 and 13, the only significant coefficient was the one associated to the number of days of full closure. This indicated that one more day of school closure decreases the percentage difference between 2021 and 2019 by 0.15 percentage points. As we are writing, countries around the world are facing Omicron variant of COVID-19 and many of them are deciding for new restrictions. New variants are likely to develop in the future. Our result warns policy makers on the negative impacts that each day of school closure would cause on academic performances.

There are some limitations that we have to point out. The first one being the lack of longitudinal data. Although this would not solve the issue of causality, it would be an important step to address it. It was not even possible to follow the same school year after year, this would have made the analysis with the dummy for 2021 much more powerful. There is a high number of missing values and general irregularity in the collection of data. A lot of improvements have been made in the administration of the Invalsi tests in the recent years but many more could be done in order to give ideal tools to researchers to come up with the best analyses and policy advice.

There is much more that could be studied on this topic. In this paper we tried to discuss the effects of COVID-19 on education by using all the newly available data. Data on this topic are however still coming out and the literature on this subject will grow exponentially in the near future. It will be critical to assess the persistence of such learning loss through the years. We are still living in a very challenging time, but we must learn as much as possible from this in order to treat, recover, and designing a better society for the future. Learning about education is crucial for this to happen.

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Appendix

1 Data and descriptive statistics

		Year of the test								
Variable	**Grade**	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**
			Female			Male			Missing	
Gender	2	12,223	11,749	7,855	12,678	12,049	8,035	108	5	0
		48.9%	49.4%	49.4%	50.7%	50.6%	50.6%	0.4%	0.0%	0.0%
	5	12,650	12,334	8,237	13,058	12,446	8,394	119	1	0
		49.0%	49.8%	49.5%	50.6%	50.2%	50.5%	0.5%	0.0%	0.0%
	8	14,138	14,366	4,748	15,016	15,309	4,960	205	0	0
		48.2%	48.4%	48.9%	51.1%	51.6%	51.1%	0.7%	0.0%	0.0%
	13		18,828	11,313		17,761	8,967		0	1
			51.5%	55.8%		48.5%	44.2%		0.0%	0.0%
			Other country			Italy			Missing	
Place of birth student	2	682	558	548	24,159	23,028	14,948	168	217	394
		2.7%	2.3%	3.4%	96.6%	96.7%	94.1%	0.7%	0.9%	2.5%
	5	940	905	570	24,737	23,668	15,744	150	208	317
		3.6%	3.7%	3.4%	95.8%	95.5%	94.7%	0.6%	0.8%	1.9%
	8	1,438	1,460	478	27,674	28,005	9,059	247	210	171
		4.9%	4.9%	4.9%	94.3%	94.4%	93.3%	0.8%	0.7%	1.8%
	13		1,803	943		34,431	19,285		355	53
			4.9%	4.6%		94.1%	95.1%		1.0%	0.3%
			No			Yes			Missing	
Student is Italian	2	2,677	3,047	2,005	20,974	19,333	13,225	1,358	1,423	660
		10.7%	12.8%	12.6%	83.9%	81.2%	83.2%	5.4%	6.0%	4.2%
	5	2,468	3,037	1,921	22,349	21,020	14,084	1,010	724	626
		9.6%	12.3%	11.6%	86.5%	84.8%	84.7%	3.9%	2.9%	3.8%
	8	2,457	2,834	967	25,853	25,838	8,354	1,049	1,003	387
		8.4%	9.6%	10.0%	88.1%	87.1%	86.1%	3.6%	3.4%	4.0%
	13		2,608	1,634		32,421	18,483		1,560	164
			7.1%	8.1%		88.6%	91.1%		4.3%	0.8%

Table 1A Personal background characteristics, summary of data and missing values.

		Year of the test								
Variable	**Grade**	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**
			No			Yes			Missing	
Student attended pre-kindergarten	2	10,773	9,956	6,603	6,591	6,306	4,414	7,645	7,541	4,873
		43.1%	41.8%	41.6%	26.4%	26.5%	27.8%	30.6%	31.7%	30.7%
	5	12,418	11,114	7,680	6,912	6,685	4,747	6,497	6,982	4,204
		48.1%	44.8%	46.2%	26.8%	27.0%	28.5%	25.2%	28.2%	25.3%
	8	13,405	14,023	4,449	6,612	7,618	2,448	9,342	8,034	2,811
		45.7%	47.3%	45.8%	22.5%	25.7%	25.2%	31.8%	27.1%	29.0%
	13		0	0		0	0		36,589	20,281
			0.0%	0.0%		0.0%	0.0%		100.0%	100.0%
			No			Yes			Missing	
Student attended kindergarten	2	1,133	946	853	18,914	17,593	11,936	4,962	5,264	3,101
		4.5%	4.0%	5.4%	75.6%	73.9%	75.1%	19.8%	22.1%	19.5%
	5	1,457	1,363	871	20,355	19,122	13,159	4,015	4,296	2,601
		5.6%	5.5%	5.2%	78.8%	77.2%	79.1%	15.5%	17.3%	15.6%
	8	1,981	1,936	528	21,565	22,990	7,051	5,813	4,749	2,129
		6.7%	6.5%	5.4%	73.5%	77.5%	72.6%	19.8%	16.0%	21.9%
	13		0	0		0	0		36,589	20,281
			0.0%	0.0%		0.0%	0.0%		100.0%	100.0%
			No			Yes			Missing	
Student is on time with the studies	2	419	375	184	24,478	23,423	15,706	112	5	0
		1.7%	1.6%	1.2%	97.9%	98.4%	98.8%	0.4%	0.0%	0.0%
	5	613	594	313	25,093	24,186	16,318	121	1	0
		2.4%	2.4%	1.9%	97.2%	97.6%	98.1%	0.5%	0.0%	0.0%
	8	2,101	2,160	562	27,249	27,515	9,146	9	0	0
		7.2%	7.3%	5.8%	92.8%	92.7%	94.2%	0.0%	0.0%	0.0%
	13		6,622	3,825		29,967	16,455		0	1
			18.1%	18.9%		81.9%	81.1%		0.0%	0.0%

Table 1B Student's academic history, summary of data and missing values.

		Year of the test								
Variable	**Grade**	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**
			Other country			Italy			Missing	
Place of birth father	2	3,256	3,284	2,292	19,823	18,387	12,569	1,930	2,132	1,029
		13.0%	13.8%	14.4%	79.3%	77.2%	79.1%	7.7%	9.0%	6.5%
	5	3,081	3,283	2,175	21,461	20,169	13,365	1,285	1,329	1,091
		11.9%	13.2%	13.1%	83.1%	81.4%	80.4%	5.0%	5.4%	6.6%
	8	3,100	3,505	1,237	24,726	24,655	7,938	1,533	1,515	533
		10.6%	11.8%	12.7%	84.2%	83.1%	81.8%	5.2%	5.1%	5.5%
	13		3,281	2,157		31,523	17,486		1,785	638
			9.0%	10.6%		86.2%	86.2%		4.9%	3.1%
			Unemployed			Employed			Missing	
Father's occupational status	2	1,086	865	553	19,131	17,538	11,506	4,792	5,400	3,831
		4.3%	3.6%	3.5%	76.5%	73.7%	72.4%	19.2%	22.7%	24.1%
	5	1,305	1,071	542	20,779	18,912	12,958	3,743	4,798	3,131
		5.1%	4.3%	3.3%	80.5%	76.3%	77.9%	14.5%	19.4%	18.8%
	8	1,196	1,212	359	22,276	22,819	7,254	5,887	5,644	2,095
		4.1%	4.1%	3.7%	75.9%	76.9%	74.7%	20.1%	19.0%	21.6%
	13		0	0		0	0		36,589	20,281
			0.0%	0.0%		0.0%	0.0%		100.0%	100.0%
		High school diploma or less			More than high school diploma			Missing		
Father's academic achievement	2	16,628	14,754	9,719	3,673	3,528	2,472	4,708	5,521	3,699
		66.5%	62.0%	61.2%	14.7%	14.8%	15.6%	18.8%	23.2%	23.3%
	5	18,467	16,600	10,946	3,905	3,669	2,791	3,455	4,512	2,894
		71.5%	67.0%	65.8%	15.1%	14.8%	16.8%	13.4%	18.2%	17.4%
	8	19,818	20,430	6,404	3,785	3,904	1,372	5,756	5,341	1,932
		67.5%	68.8%	66.0%	12.9%	13.2%	14.1%	19.6%	18.0%	19.9%
	13		0	0		0	0		36,589	20,281
			0.0%	0.0%		0.0%	0.0%		100.0%	100.0%

Table 1C Father's background characteristics, summary of data and missing values.

		Year of the test								
Variable	**Grade**	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**	**2018**	**2019**	**2021**
			Other country			Italy			Missing	
Place of birth mother	2	4,070	4,028	2,880	19,444	17,939	12,174	1,495	1,836	836
		16.3%	16.9%	18.1%	77.7%	75.4%	76.6%	6.0%	7.7%	5.3%
	5	3,914	4,130	2,795	20,910	19,669	13,020	1,003	982	816
		15.2%	16.7%	16.8%	81.0%	79.4%	78.3%	3.9%	4.0%	4.9%
	8	3,932	4,451	1,562	24,393	24,267	7,791	1,034	957	355
		13.4%	15.0%	16.1%	83.1%	81.8%	80.3%	3.5%	3.2%	3.7%
	13		3,789	2,675		30,492	17,075		2,308	531
			10.4%	13.2%		83.3%	84.2%		6.3%	2.6%
			Unemployed			Employed			Missing	
Mother's occupational status	2	1,417	1,276	877	19,185	17,568	11,391	4,407	4,959	3,622
		5.7%	5.4%	5.5%	76.7%	73.8%	71.7%	17.6%	20.8%	22.8%
	5	1,415	1,241	887	21,179	19,231	12,891	3,233	4,309	2,853
		5.5%	5.0%	5.3%	82.0%	77.6%	77.5%	12.5%	17.4%	17.2%
	8	1,202	1,307	427	22,920	23,243	7,331	5,237	5,125	1,950
		4.1%	4.4%	4.4%	78.1%	78.3%	75.5%	17.8%	17.3%	20.1%
	13		0	0		0	0		36,589	20,281
			0.0%	0.0%		0.0%	0.0%		100.0%	100.0%
		High school diploma or less			More than high school diploma			Missing		
Mother's academic achievement	2	15,201	13,242	8,419	5,471	5,410	4,038	4,337	5,151	3,433
		60.8%	55.6%	53.0%	21.9%	22.7%	25.4%	17.3%	21.6%	21.6%
	5	17,390	15,548	9,913	5,353	5,124	4,131	3,084	4,109	2,587
		67.3%	62.7%	59.6%	20.7%	20.7%	24.8%	11.9%	16.6%	15.6%
	8	19,269	19,503	6,122	4,841	5,251	1,800	5,249	4,921	1,786
		65.6%	65.7%	63.1%	16.5%	17.7%	18.5%	17.9%	16.6%	18.4%
	13		0	0		0	0		36,589	20,281
			0.0%	0.0%		0.0%	0.0%		100.0%	100.0%

Table 1D Mother's background characteristics, summary of data and missing values.

		Year of the test									
Variable	**Grade**	**2018**	**2019**	**2021**	**2019 - 2018**	**2019 - 2021**	**2018**	**2019**	**2021**	**2019 - 2018**	**2019 - 2021**
		No					Yes				
Student attended pre-kindergarten	2	199.88	199.97	195.78	0.09	-4.19***	205.06	206.49	200.68	1.44**	-5.82***
		(39.54)	(39.91)	(38.24)			(39.61)	(39.09)	(39.23)		
	5	200.84	199.84	195.02	-1.00*	-4.81***	204.77	204.80	201.75	0.03	-3.05***
		(39.97)	(39.79)	(37.30)			(38.94)	(39.07)	(36.58)		
	8	199.15	199.98	191.26	0.83*	-8.71***	206.04	206.19	199.10	0.15	-7.09***
		839.48)	(38.34)	(39.45)			(39.76)	(38.29)	(41.16)		
		No					Yes				
Student attended kindergarten	2	195.10	196.20	190.23	1.10	-5.97***	201.84	202.44	198.22	0.61	-4.22***
		(41.74)	(39.59)	(38.41)			(39.55)	(39.63)	(38.55)		
	5	197.80	193.50	190.25	-4.30***	-3.25*	202.32	201.75	197.80	-0.57	-3.95***
		(43.56)	(42.11)	(37.18)			(39.55)	(39.25)	(37.07)		
	8	192.73	194.08	182.03	1.35	-12.05***	202.17	202.67	195.05	0.49	-7.62***
		(38.60)	(40.12)	(37.65)			(39.64)	(38.20)	(40.07)		
		High school diploma or less					More than high school diploma				
Father's academic achievement	2	199.53	199.60	194.86	0.07	-4.74***	213.68	215.82	210.12	2.14**	-5.70***
		(39.19)	(39.21)	(37.72)			(39.90)	(38.79)	(40.14)		
	5	199.45	198.60	194.71	-0.85**	-3.89***	216.34	217.52	211.45	1.18	-6.07***
		(39.26)	(38.84)	(36.49)			(39.08)	(40.28)	(37.49)		
	8	197.65	198.89	190.16	1.24***	-8.73***	221.94	221.10	214.18	-0.84	-6.93***
		(38.34)	(37.31)	(39.21)			(39.87)	(38.03)	(38.51)		
		Unemployed					Employed				
Father's occupational status	2	191.34	186.04	185.44	-5.29***	-0.61	202.45	203.41	198.62	0.96**	-4.79***
		(41.67)	(39.43)	(39.11)			(39.54)	(39.53)	(38.59)		
	5	187.42	184.81	185.65	-2.61	0.84	203.28	202.71	198.65	-0.58	-4.06***
		(40.34)	(40.05)	(37.52)			(39.62)	(39.46)	(37.14)		
	8	181.20	181.24	172.59	0.04	-8.65***	202.72	203.52	195.65	0.80**	-7.87***
		(36.53)	(35.31)	(37.88)			(39.52)	(38.17)	(40.02)		
		Unemployed					Employed				
Mother's occupational status	2	197.11	196.70	190.02	-0.41	-6.68***	201.87	202.68	198.18	0.80*	-4.50***
		(40.82)	(39.17)	(37.42)			(39.65)	(39.75)	(38.75)		
	5	196.18	190.88	191.00	-5.30***	0.12	202.36	202.12	198.30	-0.24	-3.82***
		(40.24)	(39.30)	(37.09)			(39.78)	(39.77)	(37.33)		
	8	193.30	193.00	182.33	-0.30	-10.67***	201.30	202.27	194.80	0.97***	-7.46***
		(37.78)	(37.45)	(41.34)			(39.72)	(38.49)	(39.99)		

Standard deviations in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 3A Means and standard deviations of the scores by grades and years for the other variables in the dataset. In the last two columns of the outcomes of each variable we computed the differences between years and their significance levels.

2 Empirical model and results

	Year of the test										
	2018			**2019**				**2021**			
Grade	2	5	8	2	5	8	13	2	5	8	13
Observations per grade	25,009	25,827	29,359	23,803	24,781	29,675	36,589	15,890	16,631	9,708	20,281
Variables	Non-missing values										
Gender	24,901	25,708	29,154	23,798	24,780	29,675	36,589	15,890	16,631	9,708	20,280
Student was born in Italy	24,841	25,677	29,112	23,586	24,573	29,465	36,234	15,496	16,314	9,537	20,228
Student on time with the studies	24,897	25,706	29,350	23,798	24,780	29,675	36,589	15,890	16,631	9,708	20,280
Student is Italian	23,651	24,817	28,310	22,380	24,057	28,672	35,029	15,230	16,005	9,321	20,117
Father was born in Italy	23,079	24,542	27,826	21,671	23,452	28,160	34,804	14,861	15,540	9,175	19,643
Mother was born in Italy	23,514	24,824	28,325	21,967	23,799	28,718	34,281	15,054	15,815	9,353	19,750
Observations in model 1	22,638	24,290	27,493	21,271	23,210	27,820	34,015	14,682	15,350	9,088	19,604
	90.5%	94.0%	93.6%	89.4%	93.7%	93.7%	93.0%	92.4%	92.3%	93.6%	96.7%
Mother is high educated	20,672	22,743	24,110	18,652	20,672	24,754	0	12,457	14,044	7,922	0
Observations in model 2	19,739	21,990	23,365	17,820	19,971	24,049		12,035	13,549	7,700	
	78.9%	85.1%	79.6%	74.9%	80.6%	81.0%		75.7%	81.5%	79.3%	

Table 8A Summary of the model used for the regressions. For each model I computed the number of observations in the sample and compared it with the total number of observations by grades.

3 Regional analysis

	Grade					Year of the test		
Region	**2**	**5**	**8**	**10**	**13**	**2018**	**2019**	**2021**
Abruzzo	2496	2689	2680	3149	2384	4787	6115	2496
	3.9%	4.0%	3.9%	4.1%	4.2%	3.9%	4.1%	4.0%
Basilicata	2185	2485	2495	2701	1967	4455	5239	2139
	3.4%	3.7%	3.6%	3.5%	3.5%	3.7%	3.5%	3.4%
Calabria	3069	3181	3143	3373	2774	5361	6810	3369
	4.7%	4.7%	4.6%	4.4%	4.9%	4.4%	4.5%	5.4%
Campania	5030	5322	5616	5904	4283	10698	10988	4469
	7.8%	7.9%	8.2%	7.6%	7.5%	8.8%	7.3%	7.1%
Emilia-Romagna	3488	3604	3838	4892	3367	6574	9127	3488
	5.4%	5.4%	5.6%	6.3%	5.9%	5.4%	6.1%	5.6%
Friuli-Venezia	2520	2567	2563	3047	2142	4685	5681	2473
Giulia	3.9%	3.8%	3.7%	3.9%	3.8%	3.9%	3.8%	4.0%
Lazio	3972	4236	4509	4823	3853	7299	10026	4068
	6.1%	6.3%	6.6%	6.2%	6.8%	6.0%	6.7%	6.5%
Liguria	2640	2596	2777	3436	2427	4889	6360	2627
	4.1%	3.9%	4.0%	4.5%	4.3%	4.0%	4.2%	4.2%
Lombardia	5021	5230	4967	6692	4476	9142	12595	4649
	7.8%	7.8%	7.2%	8.7%	7.9%	7.5%	8.4%	7.4%
Marche	2712	2682	2961	3727	2510	5216	6724	2652
	4.2%	4.0%	4.3%	4.8%	4.4%	4.3%	4.5%	4.2%
Molise	2251	2406	1937	1752	1333	3660	3934	2085
	3.5%	3.6%	2.8%	2.3%	2.3%	3.0%	2.6%	3.3%
Piemonte	3540	3703	3653	4250	3246	6601	8440	3351
	5.5%	5.5%	5.3%	5.5%	5.7%	5.4%	5.6%	5.4%
Prov. Aut.	2550	2682	1619	1118	792	3686	3652	1423
Bolzano	3.9%	4.0%	2.4%	1.4%	1.4%	3.0%	2.4%	2.3%
Prov. Aut.	2429	2499	2558	1850	1290	4109	4422	2095
Trento	3.8%	3.7%	3.7%	2.4%	2.3%	3.4%	2.9%	3.4%
Puglia	4003	4081	4569	5048	3297	8802	9117	3079
	6.2%	6.1%	6.6%	6.5%	5.8%	7.2%	6.1%	4.9%
Sardegna	1818	1839	2560	2795	2467	3889	5200	2390
	2.8%	2.7%	3.7%	3.6%	4.3%	3.2%	3.5%	3.8%
Sicilia	4210	4333	5099	4892	3432	8377	9334	4255
	6.5%	6.4%	7.4%	6.3%	6.0%	6.9%	6.2%	6.8%
Toscana	3460	3616	3602	4614	4065	6189	9297	3871
	5.3%	5.4%	5.2%	6.0%	7.1%	5.1%	6.2%	6.2%
Umbria	2358	2465	2643	2920	2082	4672	5375	2421
	3.6%	3.7%	3.8%	3.8%	3.7%	3.8%	3.6%	3.9%
Valle d'Aosta	1491	1483	1417	914	907	1991	2698	1523
	2.3%	2.2%	2.1%	1.2%	1.6%	1.6%	1.8%	2.4%
Veneto	3459	3540	3536	5310	3776	6518	9516	3587
	5.3%	5.3%	5.1%	6.9%	6.6%	5.4%	6.3%	5.7%
Total	64702	67239	68742	77207	56870	121600	150650	62510

Table 12A Observations for each region divided first by grades and then by years. Lombardia is the most represented region in the sample.

	Grade 2					Grade 5				
	Year of the test			Differences		Year of the test			Differences	
Region	**2018**	**2019**	**2021**	**2019 - 2018**	**2021 - 2019**	**2018**	**2019**	**2021**	**2019 - 2018**	**2021 - 2019**
Abruzzo	201.39 (39.37)	201.85 (41.44)	203.17 (40.35)	0.46	1.31	201.04 (40.26)	201.06 (42.46)	199.10 (38.06)	0.03	-1.97
Basilicata	218.21 (41.63)	214.62 (37.58)	198.91 (42.64)	-3.59*	-15.71***	210.98 (39.59)	214.43 (38.62)	200.38 (39.27)	3.45*	-14.05***
Calabria	192.56 (38.37)	191.93 (40.75)	192.38 (39.66)	-0.63	0.45	192.18 (40.84)	186.46 (37.64)	192.44 (39.53)	-5.72***	5.98***
Campania	196.36 (41.61)	195.69 (41.61)	198.65 (42.21)	-0.68	2.96*	193.18 (40.25)	193.02 (38.97)	199.31 (42.14)	-0.16	6.29***
Emilia-Romagna	198.02 (38.83)	197.05 (39.66)	192.67 (37.05)	-0.97	-4.38***	202.12 (40.17)	200.19 (41.03)	195.65 (36.93)	-1.93	-4.54***
Friuli-Venezia Giulia	202.57 (38.77)	202.19 (39.49)	193.71 (38.98)	-0.38	-8.49***	207.95 (41.04)	203.20 (39.02)	200.98 (34.84)	-4.76***	-2.22
Lazio	202.01 (40.21)	200.27 (39.24)	200.65 (40.34)	-1.74	0.38	202.04 (38.30)	202.23 (38.53)	203.14 (38.58)	0.19	0.91
Liguria	196.35 (39.66)	201.35 (38.53)	196.26 (37.26)	5.00***	-5.09***	200.37 (38.79)	201.94 (39.26)	198.04 (38.02)	1.58	-3.90**
Lombardia	201.78 (39.49)	200.48 (39.68)	200.28 (38.08)	-1.30	-0.20	201.47 (39.98)	204.10 (38.83)	198.15 (36.40)	2.63**	-5.94***
Marche	204.04 (39.65)	209.75 (38.58)	201.75 (37.81)	5.71***	-8.00***	207.54 (38.89)	208.31 (37.72)	201.96 (36.29)	0.77	-6.36***
Molise	211.21 (41.38)	211.54 (41.06)	207.56 (42.80)	0.33	-3.98*	220.24 (45.48)	206.62 (37.90)	194.62 (36.92)	-13.62***	-12.00***
Piemonte	201.86 (39.60)	201.18 (39.57)	196.09 (38.19)	-0.68	-5.10***	203.83 (40.98)	202.76 (40.09)	197.15 (36.31)	-1.06	-5.62***
Prov. Aut. Bolzano	198.60 (37.20)	196.86 (38.29)	192.95 (35.73)	-1.74	-3.91*	199.12 (37.52)	197.87 (38.71)	195.00 (35.42)	-1.25	-2.87
Prov. Aut. Trento	204.32 (40.99)	206.00 (39.68)	204.71 (37.33)	1.68	-1.29	207.76 (38.88)	202.70 (36.12)	199.32 (33.54)	-5.07***	-3.37*
Puglia	201.85 (39.12)	200.64 (38.39)	198.86 (38.12)	-1.21	-1.78	202.61 (40.19)	201.96 (42.94)	194.13 (39.81)	-0.64	-7.84***
Sardegna	192.77 (35.64)	194.81 (36.02)	192.82 (38.95)	2.04	-1.98	187.55 (37.43)	189.72 (38.06)	188.58 (36.08)	2.17	-1.14
Sicilia	196.10 (41.94)	198.13 (40.83)	194.86 (37.26)	2.03	-3.27**	189.74 (38.75)	191.72 (41.03)	193.91 (39.41)	1.98	2.20
Toscana	203.79 (39.99)	199.17 (38.40)	198.33 (38.15)	-4.62***	-0.84	207.68 (38.47)	202.40 (40.22)	197.90 (36.03)	-5.28***	-4.50***
Umbria	204.22 (37.81)	212.35 (38.11)	200.27 (37.86)	8.13***	-12.08***	207.07 (39.60)	208.42 (39.41)	198.73 (39.29)	1.35	-9.69***
Valle d'Aosta	196.78 (37.55)	206.02 (36.64)	195.54 (36.93)	9.24***	-10.48***	198.03 (38.49)	202.17 (37.88)	194.43 (36.35)	4.14*	-7.74***
Veneto	202.75 (39.11)	202.51 (38.48)	195.56 (35.96)	-0.24	-6.96***	203.30 (38.53)	202.29 (38.83)	197.24 (33.71)	-1.00	-5.05***

Standard deviations in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 13B Means and standard deviations of the test in mathematics per region in 2018, 2019 ans 2021. Grades 2 and 5. In the last two columns for each grade we computed the differences through time and their significance levels.

	Grade 8					Grade 13		
	Year of the test			Differences		Years of the test		Difference
Region	**2018**	**2019**	**2021**	**2019 - 2018**	**2021 - 2019**	**2019**	**2021**	**2021 - 2019**
Abruzzo	200.48 (38.32)	201.38 (36.55)	196.62 (35.00)	0.91	-4.77**	196.76 (37.83)	179.83 (35.43)	-16.93***
Basilicata	189.13 (36.58)	196.09 (37.65)	186.25 (37.60)	6.96***	-9.85***	193.13 (41.64)	184.06 (36.77)	-9.07***
Calabria	182.78 (36.51)	181.36 (35.25)	174.63 (41.26)	-1.42	-6.73***	181.45 (33.82)	171.95 (34.16)	-9.50***
Campania	184.02 (38.22)	187.88 (38.09)	178.93 (38.49)	3.86***	-8.95***	184.83 (35.49)	169.02 (31.96)	-15.81***
Emilia-Romagna	211.88 (41.18)	208.48 (38.67)	202.29 (41.41)	-3.40**	-6.19***	212.46 (39.69)	201.14 (36.38)	-11.32***
Friuli-Venezia Giulia	213.19 (38.92)	212.11 (37.83)	211.34 (40.72)	-1.08	-0.78	221.87 (40.02)	201.35 (33.05)	-20.52***
Lazio	201.56 (38.22)	198.64 (37.48)	195.15 (39.27)	-2.93**	-3.49**	194.94 (39.02)	182.65 (34.84)	-12.29***
Liguria	203.55 (37.80)	199.88 (37.23)	191.48 (40.91)	-3.68**	-8.40***	207.94 (34.46)	194.33 (37.47)	-13.61***
Lombardia	210.17 (39.95)	208.98 (38.53)	198.34 (37.50)	-1.19	-10.64***	217.31 (37.82)	205.04 (36.00)	-12.27***
Marche	209.16 (40.29)	209.96 (39.16)	202.26 (37.32)	0.79	-7.69***	208.75 (41.28)	191.00 (36.66)	-17.75***
Molise	199.96 (40.19)	194.44 (35.36)	196.88 (37.68)	-5.52***	2.44	198.96 (38.46)	195.78 (38.12)	-3.18
Piemonte	204.03 (39.65)	205.02 (37.82)	198.96 (38.85)	1,00	-6.07***	210.60 (37.80)	201.61 (34.37)	-8.99***
Prov. Aut. Bolzano	204.03 (38.25)	202.20 (37.69)	193.58 (37.94)	-1.82	-8.63***	214.92 (36.81)	186.10 (34.82)	-28.82***
Prov. Aut. Trento	212.95 (38.41)	213.66 (37.19)	211.10 (35.28)	0.71	-2.56	227.04 (41.24)	227.25 (37.00)	0.21
Puglia	192.68 (37.69)	197.74 (37.53)	188.55 (40.44)	5.06***	-9.19***	196.00 (36.58)	170.65 (32.20)	-25.35***
Sardegna	192.08 (35.47)	188.68 (35.37)	185.59 (38.84)	-3.40**	-3.09	185.47 (34.65)	172.45 (32.15)	-13.02***
Sicilia	186.42 (35.90)	185.58 (37.06)	180.08 (38.38)	-0.84	-5.50***	183.92 (35.15)	173.07 (32.65)	-10.85***
Toscana	206.65 (37.92)	209.39 (38.09)	193.51 (39.04)	2.74**	-15.88***	207.73 (39.70)	197.43 (37.54)	-10.30***
Umbria	209.94 (38.21)	204.09 (38.83)	203.95 (40.32)	-5.86***	-0.13	202.91 (37.60)	187.03 (34.06)	-15.88***
Valle d'Aosta	207.95 (36.45)	206.79 (34.84)	204.87 (38.03)	-1.16	-1.92	210.08 (34.10)	208.97 (34.77)	-1.11
Veneto	211.20 (39.82)	209.61 (35.77)	204.59 (38.44)	-1.59	-5.02***	217.56 (36.72)	202.91 (34.96)	-14.65***

Standard deviations in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 12C Means and standard deviations of the test in mathematics per region in 2018, 2019 ans 2021. Grades 8 and 13. In the last two columns for each grade we computed the differences through time and their significance levels.

Variables	Grades 2 and 5 % difference (1)
Deaths per 100k inhabitants	0.0001
	(0.0001)
HDI 2019	0.4000
	(0.3096)
Study abandon 2019	0.0004
	(0.0018)
Gini coefficient 2018	0.5226**
	(0.1907)
Log GDP per capita 2019	-0.0182
	(0.0248)
Intercept	-0.3289
	(0.2497)
Observations	42
R2	0.358

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 15A Model with "Deaths per 100k inhabitants" as a proxy for COVID-19 harshness estimates for Primary education (grades 2 and 5). Italian.

Variables	Grades 8 and 13 % difference (1)
Days completely closed	-0.0013***
	(0.0003)
HDI 2019	-0.1332
	(0.3980)
Study abandon 2019	-0.0004
	(0.0021)
Gini coefficient 2018	0.2102
	(.2145)
Log GDP per capita 2019	0.0248
	(0.0266)
Intercept	-0.1198
	(0.2471)
Observations	42
R2	0.301

Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table 16A Model with days of complete school closure estimates for Secondary education (grades 8 and 13). Italian.